ENVIRONMENTAL ASSESSMENT

POST-IRENE RENOURISHMENT PROJECT
BOGUE BANKS, NORTH CAROLINA

July 2012

Prepared for:
Division of Environmental Assessment
Bureau of Ocean Energy Management
381 Elden Street
Herndon, VA 20170-4817

Prepared by:
Dial Cordy and Associates Inc.
201 North Front Street, Suite 307
Wilmington, NC 28401

EXECUTIVE SUMMARY

This Environmental Assessment presents an evaluation of potential environmental, cultural, and anthropogenic effects associated with Carteret County's Post-Irene Renourishment Project (Project). The Project potentially includes sand placement in three discrete locations of Carteret County's Bogue Banks shoreline: (1) western Emerald Isle (EI) between transects 9 - 16; (2) eastern EI between survey transects 35 - 46; and (3) Pine Knoll Shores (PKS) between survey transects 61 - 70. The borrow source would be previously dredged sand from an operational Ocean Dredged Material Disposal Site (ODMDS) located on the Outer Continental Shelf (OCS) approximately three miles (mi) south of Beaufort Inlet, North Carolina (NC). The ODMDS is a functioning element of NC's federal deep-draft navigation project at the Port of Morehead City. Carteret County, as represented by the County's Shore Protection Office (SPO), proposes entering into a negotiated non-competitive lease agreement with the Bureau of Ocean Energy Management (BOEM) authorizing a maximum reclamation of up to one million cubic yards (cy) of previously dredged sand. The sand would be extracted by hopper dredge, transported, and placed via pipeline along approximately 7.1 mi of "Irene" affected oceanfront shoreline.

Following Hurricane Irene, the Federal Emergency Management Agency (FEMA) evaluated and confirmed sand losses as documented by Carteret County's monitoring and maintenance plan for their locally engineered beaches. The eligible sand volumes determined through the Bogue Banks Beach and Nearshore Mapping Program (BBBNMP) totals 1,344,123 cy. The sand volume estimated for this Project totals up to 1,000,000 cy (992,000 cy); including a base volume eligible for FEMA reimbursement in addition to supplemental sand desired by EI, PKS, and the County. The total proposed volume is based on federal, state, and local economic viability while facilitating FEMA participation. The recipient beaches and the ODMDS have been included in previous post storm renourishment events without significant natural or anthropogenic effects. Agency consultation has been initiated by BOEM and the United States Army Corps of Engineers South Atlantic Wilmington District with the National Marine Fisheries Service and the United States Fish and Wildlife Service. This Post-Irene EA has found that no significant long-term environmental effects are anticipated from implementing the Proposed Action Alternative, i.e., using OCS resources from the ODMDS, located approximately three mi offshore of Beaufort Inlet, NC. With implementation of the Proposed Avoidance and Minimization Measures (Section 8), the potential effects of the ODMDS dredging reclamation and beach placement would be localized and temporary.

TABLE OF CONTENTS

Page

*All appendices are on enclosed CD

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

μg/M^3	Microgram Per Cubic Meter
AIWW	Atlantic Intracoastal Waterway
ALPINE	Alpine Ocean Seismic Survey Inc.
BA	Biological Assessment
BBBNMP	Bogue Banks Beach and Nearshore Mapping Program
BBBRP	Bogue Banks Beach Restoration Project
BOEM	Bureau of Ocean Energy Management
°C	Degree Centigrade
CAA	Clean Air Act
CAMA	Coastal Area Management Act
CFR	Code of Federal Regulations
CLNS	Cape Lookout National Seashore
CO	Carbon Monoxide
CPE	Coastal Planning & Engineering
CSA	Coastal Science Associates
CSE	Coastal Science & Engineering
cy	Cubic Yards
dB	Decibel
dBa	A-Weighted Decibels
dB re 1 μPa	decibel referenced to 1 micropascal
DC&A	Dial Cordy and Associates Inc.
DIR	Prevailing Wind Directions
DMMP	Dredge Material Management Plan
EA	Environmental Assessment
EFH	Essential Fish Habitat
EI	Emerald Isle
EIS	Environmental Impact Statement
EO	Executive Order
ESA	Endangered Species Act
°F	Degree Fahrenheit
FR	Federal Register
FT	Feet/Foot
FEMA	Federal Emergency Management Agency
FMC	Fishery Management Councils
FMP	Fishery Management Plans
FONSI	Finding of No Significant Impact
GRR	General Reevaluation Report
HAPC	Habitat Areas of Particular Concern
HP	Horsepower
Hs	Peak Wave Height
Hz	Hertz
M	Million
MAFMC	Mid-Atlantic Fishery Management Council

LIST OF ACRONYMS (continued)

M-AT	Mid-Atlantic Technology and Environmental Research, Inc.
MBNP	Master Beach Nourishment Plan
MCAS	Cherry Point Marine Corps Air Station
Mg/L	Milligrams Per Liter
Mg/M^3	Milligram Per Cubic Meter
MHW	Mean High Water
MLW	Mean Low Water
Mi	Mile(s)
MiSA	Micropolitan Statistical Area
MMPA	Marine Mammal Protection Act
mm	Millimeter
mph	Miles Per Hour
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NAAQS	National Ambient Air Quality Standards
NAVD	North American Vertical Datum
NC	North Carolina
NCDAQ	North Carolina Division of Air Quality
NCDC	National Climatic Data Center
NCDCM	North Carolina Division of Coastal Management
NCDENR	North Carolina Department of Environment and Natural Resources
NCDMF	North Carolina Division of Marine Fisheries
NCDWQ	North Carolina Division of Water Quality
NCSPA	North Carolina State Ports Authority
NCWRC	North Carolina Wildlife Resources Commission
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
NM	Nautical Miles
NMFS	National Marine Fisheries Service
NO_2	Nitrogen Dioxide
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NO_x	Nitrogen Oxides
NPC	Noise Pollution Clearinghouse
NRHP	National Register of Historic Places
NTU	Nephelometric Turbidity Units
O_3	Ozone
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
ODMDS	Ocean Dredged Material Disposal Site
OSHA	Occupational Safety and Health Administration
Pb	Lead
PEIS	Programmatic Environmental Impact Statement
PGU	Peak Gusts
PKS	Pine Knoll Shores
$PM_{25,}$ PM_{10}	Particulate Matter
PNA	Primary Nursery Area
POR	Period of Record
ppb	Parts Per Billion

LIST OF ACRONYMS (concluded)

ppm	Parts Per Million
ppt	Parts Per Thousand
RBO	Regional Biological Opinion
SAB	South Atlantic Bight
SAFMC	South Atlantic Fishery Management Council
SAV	Submerged Aquatic Vegetation
SAW	South Atlantic Wilmington District
SEAMAP	Southeast Area Monitoring and Assessment Program
SHPO	State Historic Preservation Office
SO_2	Sulfur Dioxide
SPD	Mean Wind Speeds
SPO	Shore Protection Office
SPP	Species
STD	Standard
T&E	Threatened and Endangered
TP	Peak Wave Time Period
UAB	Underwater Archaeology Branch
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USEPA	United States Environmental Protection Agency
USDOI	United States Department of the Interior
USFWS	United States Fish and Wildlife Service
VOC	Volatile Organic Compound
WIS	Wave Information Study

1.0 INTRODUCTION

Hurricane Irene made landfall at Cape Lookout, North Carolina (NC) on 27 August 2011, approximately nine miles (mi) east of Bogue Banks (Figure 1). One of the storm's major impacts was oceanfront beach erosion within Carteret County's engineered beaches of Pine Knoll Shores (PKS), Indian Beach/Salter Path, and Emerald Isle (EI) (Figure 2). Incipient and primary dunes and other subaerial and subaqueous environments sustained erosion through the -12-foot (ft) North American Vertical Datum (NAVD) contour. The volumetric sand losses within the engineered beaches were quantified through the Bogue Banks Beach and Nearshore Mapping Program (BBBNMP) and confirmed by the Federal Emergency Management Agency (FEMA) following the federal government's declaration of Hurricane Irene as a federal disaster in Carteret County.

Renourishment triggers established for the publicly engineered beaches include: (1) sand losses of 50% or greater of initial construction volumes placed or (2) if average sand volumes from the top of dune to -12 ft NAVD88 fall below 225 cubic yards (cy)/ft (typical cross-sections are provided in Section 4.2). Criterion (1) was used by FEMA to assess Post-Irene sand volume losses. To fully utilize FEMA's settlement, the State, County, EI, and PKS are proposing to place up to one million (M) cy (992,000 cy) of the 1.34 M cy eligible for FEMA reimbursement. FEMA's participation covers a dredge plant's mobilization and demobilization (estimated at $4,000,000) plus approximately 300,000 cy of beach renourishment. In an effort to fully maximize FEMA's participation, the State; County; and local municipalities are supplementing volumes as local budgets allow. Maximum potential replacement volumes are delineated in Table 1.

Similar post hurricane FEMA renourishment projects have been implemented along reaches of EI and PKS. Hurricane Isabel occurred in 2003 with renourishment in 2004 and Hurricane Ophelia occurred in 2005 with renourishment in 2007. The County would target Post-Irene renourishment efforts to occur during the 2012 - 2013 winter dredging window.

Carteret County's Shore Protection Office (SPO) previously managed the development of the NEPA compliant *Environmental Impact Statement (EIS), Bogue Banks Restoration – Phase I and Phase II* [Coastal Science & Engineering (CSE) 2001 (Appendix A); CSE 2002 (Appendix B)]. Phases I and II of this project covered beach restoration projects along portions of EI and PKS. The United States Army Corps of Engineers (USACE) South Atlantic Wilmington District (SAW) prepared: (1) *Evaluation Report and Environmental Assessment/Finding of No Significant Impact for Morehead City Harbor Section 933 Carteret County, North Carolina,* (*August 2003*) (USACE 2003; Appendix C). The 2003 document addresses a two phase effort (2004 and 2007) by the USACE and SPO to beneficially use active maintenance and upland stockpiled dredge material for shoreline renourishment purposes. These shoreline protection actions took place within and adjacent to the proposed Project areas. In conjunction with the above efforts and as a result of shoreline losses from previously named storm events, Isabel and Ophelia, NEPA compliant documents were prepared supporting permits placing additional Ocean Dredged Material Disposal Site (ODMDS) material within and adjacent to the proposed Project areas (2004 and 2007). Subsequent to the EIS and the two USACE Environmental Assessments (EA), the SPO was issued sand placement authorizations in 2004 and 2007 for the FEMA Post-Isabel

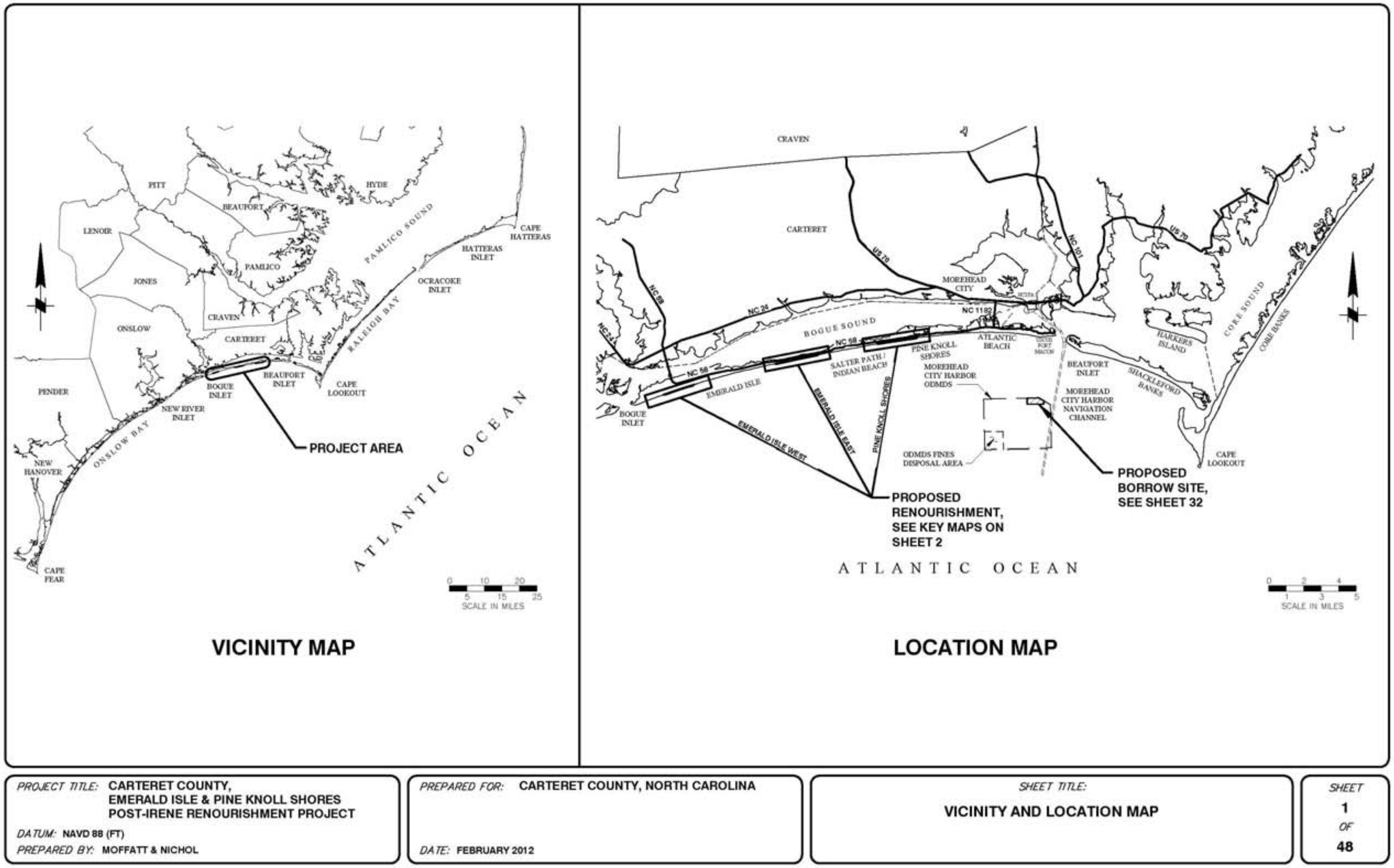


Figure 1. Vicinity and Location Map

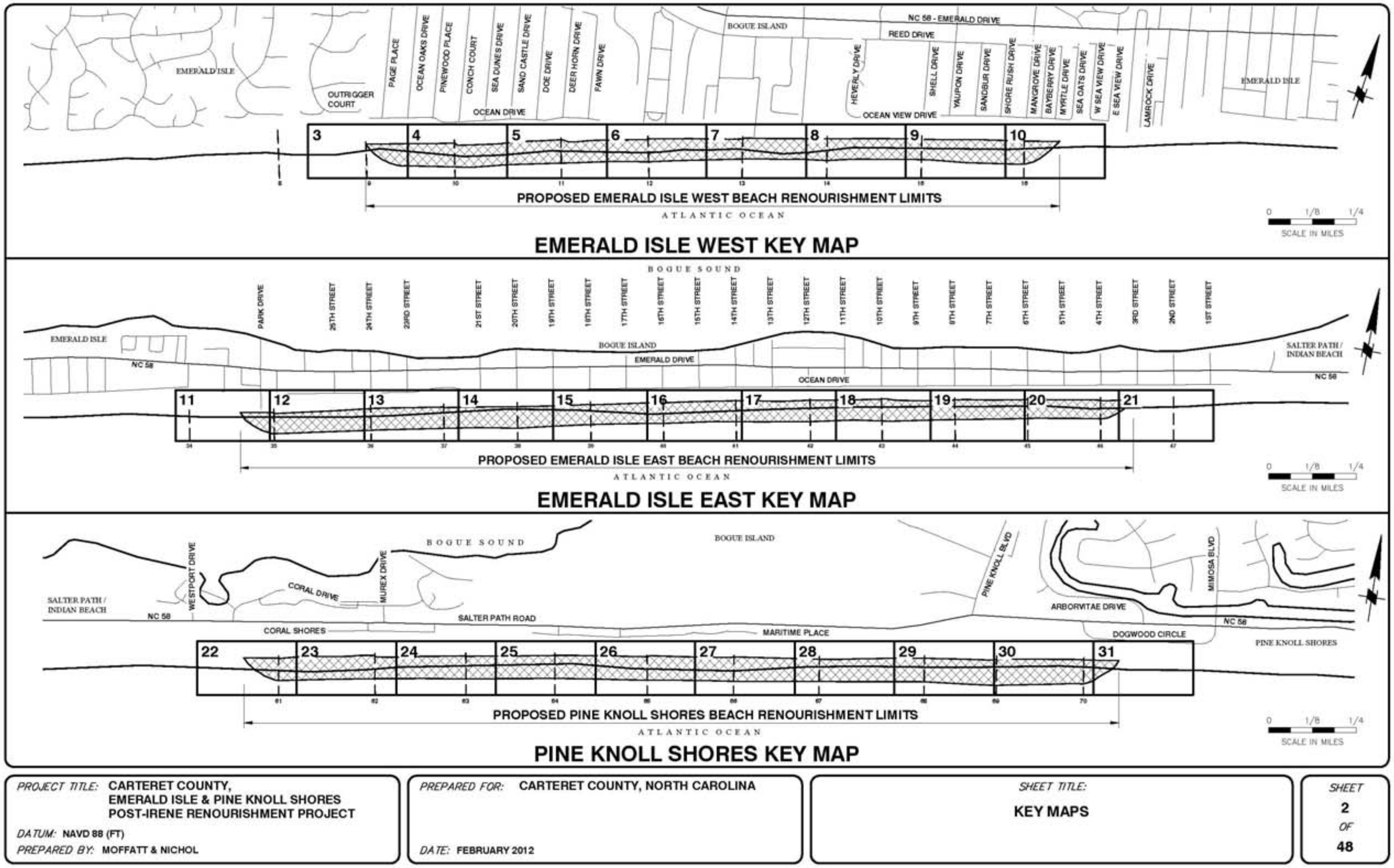


Figure 2. Map of the Three Reaches in Emerald Isle and Pine Knoll Shores

Table 1. Maximum potential replacement volumes.

	Transect Survey Stations	FEMA (cy)	County (cy)	Municipality (cy)	Total (cy)
Emerald Isle	9-16, 35-46	157,000	259,000	259,000	675,000
PKS	61-70	113,000	102,000	102,000	317,000
Totals		**270,000**	**361,000**	**361,000**	**992,000**

Restoration and FEMA Post-Ophelia Restoration, respectively (USACE 2004a, 2007; Appendices D and E). These post-storm authorizations allowed the SPO to utilize ODMDS sands for beach renourishment within and adjacent to the proposed Project areas. Figure 3 and Table 2 describe past projects resulting in supplemental shoreline placements along all of Bogue Banks for the last 30 years.

This EA will assist the Bureau of Ocean Energy Management (BOEM) in determining if the Proposed Action Alternative would significantly affect the environmental, cultural, or anthropogenic resources within the proposed Project area (Figure 1). This EA incorporates by reference existing analyses and provides supplemental analysis of potential environmental effects resulting from the Proposed Project Alternative.

This EA is supplemented by:

- Essential Fish Habitat Assessment (EFH) compliant with the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA);
- Biological Assessment (BA) meeting specifications of the Endangered Species Act (ESA);
- concurrence from the NC State Historic Preservation Office (SHPO);
- NC Division of Coastal Management (NCDCM) Major Permit;
- NC Division of Water Quality (NCDWQ) 401 Water Quality Certification; and a
- Clean Water Act Section 404 authorization via General Permit 291 (Personal communication, David L. Timpy, USACE SAW, February 6, 2012).

This project meets BOEM's project criteria for accessing Outer Continental Shelf (OCS) sand resources because of local government sponsorship, local funding, and public accessibility. BOEM's negotiated non-competitive lease agreement would allow reclamation, transport, and placement of beach compatible sand along the recipient project shorelines.

1.1 Authorization

Public Law 103-426 enacted 31 October 1994 gave BOEM the authority to convey, on a noncompetitive basis, the rights to OCS sand, gravel, or shell resources for shore protection; beach or wetlands restoration projects; or for use in construction projects funded in whole or part or authorized by the federal government. In implementing this authority, BOEM may issue a negotiated non-competitive lease agreement for the use of OCS sand to a qualifying entity.

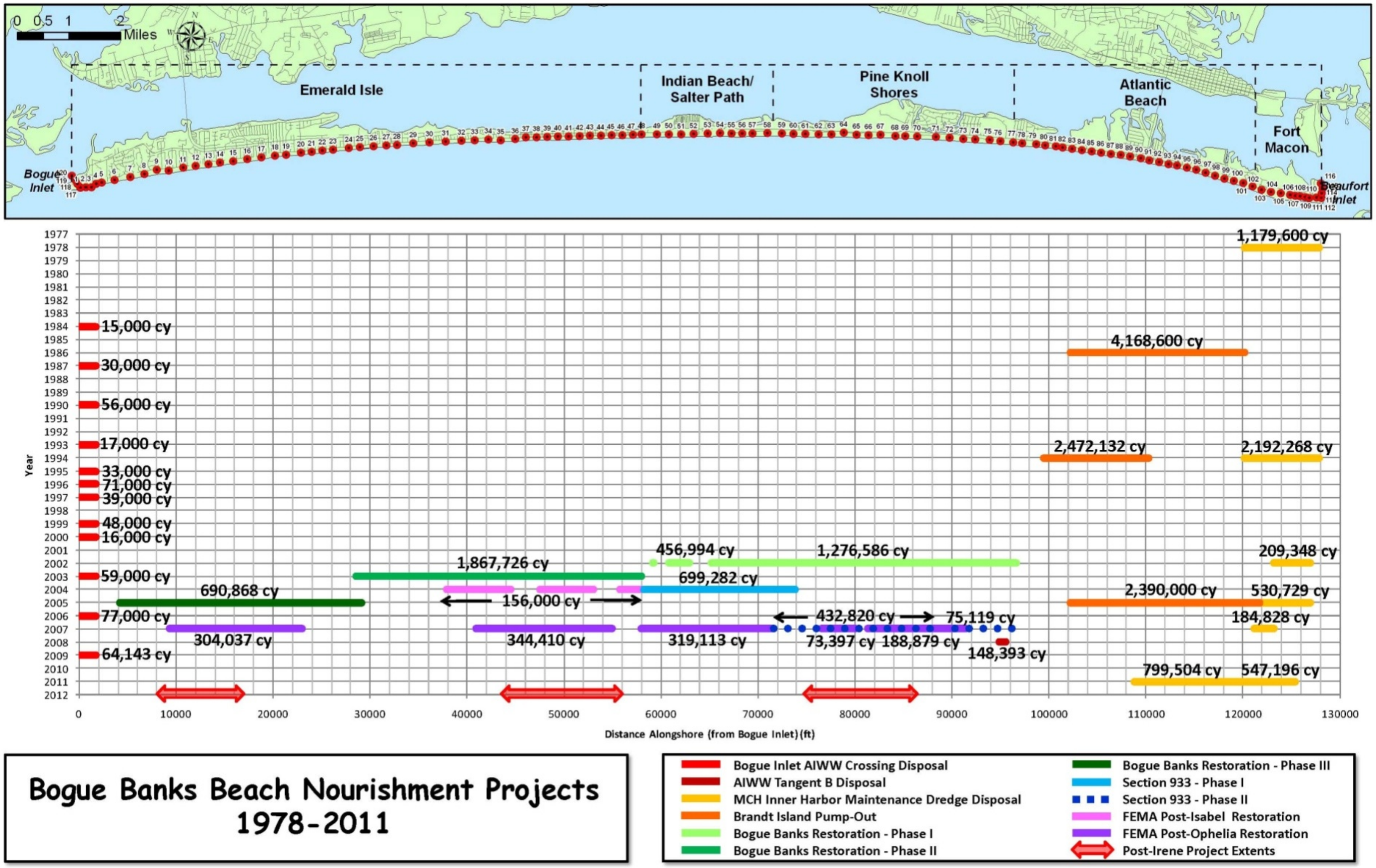


Figure 3. Bogue Banks Nourishment History

Table 2. Bogue Banks historic shoreline placements.

Project Name	Date	Sand Volumes (cy)	Author[1]	Documentation[2]
USACE Disposal – Fort Macon	2011	547,196	USACE	EA
USACE Disposal – Atlantic Beach	2011	799,504	USACE	EA
AIWW - Tangent B, Sec. 1	2008	148,393	USACE	NA
Section 933 - Phase II	2007	507,939	USACE	EA, FONSI
FEMA Post-Ophelia Sand Replacement	2007	1,229,836	CSE	EA
Inner Harbor Maintenance	2007	184,828	USACE	DMMP
Bogue Banks Restoration - Phase III	2005	690,868	CPE	EIS
Brandt Island Pump-Out	2005	2,390,000	USACE	DMMP
Inner Harbor Maintenance	2005	530,729	USACE	DMMP
Section 933 - Phase I	2004	699,282	USACE	EA
FEMA Post-Isabel Sand Replacement	2004	156,000	CSE	EA
Bogue Banks Restoration - Phase II	2003	1,867,726	CSE	EA
Bogue Banks Restoration - Phase I	2002	1,733,580	CSE	EIS
Inner Harbor Maintenance	2002	209,348	USACE	DMMP
Brandt Island Pump-Out	1993-1994	2,472,132	USACE	EA, FONSI
Inner Harbor Maintenance	1993-1994	2,192,268	USACE	EA, FONSI
Brandt Island Pump-Out	1986	3,918,484	USACE	EA
Inner Harbor Maintenance	1986	250,116	USACE	EA
Inner Harbor Maintenance	1978	1,179,600	USACE	EA

[1] Authors include USACE, CSE, and Coastal Planning & Engineering (CPE).
[2] Documentation includes EA/Finding of No Significant Impact (FONSI), EISs, and Dredged Material Management Plans (DMMP).

NEPA and Title 40 of the Code of Federal Regulations (CFR), Parts 1500-1508 (40 CFR 1500-1508) require federal agencies to consider the potential environmental consequences of proposed actions and alternatives. Executive Order (EO) 11514, Protection and Enhancement of Environmental Quality (amended by EO 11991), provides a policy directing the federal government to take leadership in protecting and enhancing the environment.

BOEM and the USACE are cooperating agencies having jurisdiction over different project facets and locations. OCS resources (beyond three mi) fall under BOEM's jurisdiction, as found in the OCS Land Act. Beach nourishment permitting is a federal action requiring review through the Rivers and Harbors Act Section 10 and the Clean Water Act Section 404. These federal permitting actions, including BOEM issuance of a negotiated non-competitive lease for OCS sand use and the USACE's Section 404 authorization, trigger the preparation of this EA. This EA will be used by BOEM and the USACE for evaluation of potential project effects, guidance in developing a permit decision, and consideration of a negotiated non-competitive lease agreement.

2.0 PROJECT HISTORY

The project area beaches have received supplemental sand under three previous renourishment projects as well as previous post-hurricane events. As listed in Tables 3 and 4, over 8M cy of material have been placed on EI and PKS since 1984.

Table 3. Dredge and fill operations for Emerald Isle.

Year	Borrow Source	Dredge Type	Sand Volume (cy)
1984	Bogue Inlet AIWW Crossing	Pipeline	15,000
1987	Bogue Inlet AIWW Crossing	Pipeline	30,000
1990	Bogue Inlet AIWW Crossing	Pipeline	56,000
1993	Bogue Inlet AIWW Crossing	Pipeline	17,000
1995	Bogue Inlet AIWW Crossing	Pipeline	33,000
1996	Bogue Inlet AIWW Crossing	Pipeline	71,000
1997	Bogue Inlet AIWW Crossing	Pipeline	39,000
1999	Bogue Inlet AIWW Crossing	Pipeline	48,000
2000	Bogue Inlet AIWW Crossing	Pipeline	16,000
2003	Bogue Inlet AIWW Crossing	Pipeline	59,000
2003	Borrow Site A & B2 (offshore)	Hopper/Pipeline	1,867,726
2004	ODMDS	Hopper	156,000
2005	Bogue Inlet	Pipeline	690,868
2006	Bogue Inlet AIWW Crossing	Pipeline	77,000
2007	ODMDS	Hopper	648,447
2009	Bogue Inlet AIWW Crossing	Pipeline	64,143

Carteret County SPO, unpublished data

Table 4. Dredge and fill operations for Pine Knoll Shores.

Year	Borrow Source	Dredge Type	Sand Volume (cy)
2002	Borrow Site A, B1 & B2 (offshore)	Hopper	1,276,586
2007	Morehead City Outer Harbor	Hopper	507,939
2007	ODMDS	Hopper	239,796
2008	AIWW Tangent B	Pipeline	148,393

Carteret County SPO, unpublished data.

The target reaches were first nourished in 2002 - 2005 during Phases I, II, and III of the BBBRP, which placed approximately 4.3 M cy of sand on an approximate 16.7 mi section of EI, Indian Beach, and PKS. Sand sources for the BBBRP included two nearshore ocean borrow sites off EI and Indian Beach; and sand beneficially used from the realignment of Bogue Inlet. The project area beaches received additional sand in 2004 during the Post-Isabel Sand Replacement Project, which placed 156,000 cy of sand from the ODMDS within EI. Project area beaches were last renourished in 2007 during the Post-Ophelia Sand Replacement Project, which placed approximately 1M cy sand from the ODMDS on approximately 10.4 mi of beach. Two Section 933 projects were also completed (2004 & 2007) along the recipient beaches and the adjacent reach of Indian Beach/Salter Path with total nourishment volumes approaching 0.7M cy and 0.5M cy, respectively. The Carteret County SPO is currently developing a Master Beach Nourishment Plan (MBNP) and Programmatic Environmental Impact Statement (PEIS) that will provide for long-term maintenance of the entire Bogue Banks.

Existing information for the proposed project reaches is contained within the NCDCM Major Permit #124-01 and USACE Permit #200000362 (Appendices D and E). These permits outline the original formulation and data sources for the Bogue Banks renourishment projects (Phases 1 and 2 accomplished between December 2001 and April 2003) and previous FEMA projects. Since the last 2007 FEMA placement, the project area has continued to lose sand at an accelerated pace and the protection trigger of 225 cy/ft above -12' NAVD may be reached within the next year or two without the proposed project. A recent beach survey in 2010 indicated that the profile volume above -12 feet NAVD along portions of the target beaches had fallen to 48 percent of the baseline volume. The Post-Irene survey has shown that some portions of these reaches are now down to 35 percent of the original engineered volumes (Moffatt and Nichol 2010). Given the overall health of the beach along Bogue Banks, the project team anticipates this could be the last individual project required until the Bogue Banks MBNP is implemented (barring another major storm event).

3.0 PURPOSE AND NEED

The Project's purpose is to restore sand volumes and elevations providing future storm protection and reducing future potential storm damage to the subaerial beach, protective berm, adjacent infrastructure, and coastal structures along the approximate seven miles of Project shoreline. Since the last shore protection effort in 2007 and with the recent sand volume losses resulting from Hurricane Irene; erosion has been exacerbated, detrimentally affecting the shorelines of EI and PKS.

The SPO's proposed Project would provide:

- existing public and private infrastructure improved storm protection,
- minimization of potential structural storm damage,
- improved continued public access and use,
- further support of NC and Bogue Banks' tourism industry, and
- restoration of pre-storm shoreline sand volumes for continued natural resource usage.

While providing the above, the proposed Project would retain compliance with FEMA's criteria for publicly engineered and managed beaches and fulfill NC's static line exception stipulations. The static vegetation line is defined by the NCDCM in Section .0300 - Ocean Hazard Areas 15A NCAC 7H .0305: A static vegetation line shall be established in coordination with the NCDCM using on-ground observation and survey or aerial imagery for all areas of oceanfront that undergo a large-scale beach fill project. Once a static vegetation line is established, and after the onset of project construction, this line shall be used as the reference point for measuring oceanfront setbacks in all locations where it is landward of the vegetation line.

The purpose of this BOEM proposed action is to respond to an OCS sand use request under the authority granted to the United States Department of the Interior (USDOI) by the Outer Continental Shelf Lands Act (OCSLA). The proposed action is necessary because the Secretary of the Interior delegates the authority granted in the OCSLA to BOEM for authorizing the use of OCS sand resources for the purpose of shore protection and beach restoration.

The proposed project is located in an area affected by Hurricane Irene with higher erosion losses compared to adjacent shorelines. The sand volumes per linear foot are quickly approaching the minimum volume historically targeted by the SPO as a nominally accepted healthy shoreline (225 cy/ft). FEMA representatives agreed that, based on a site visit on 8 November 2011, some portions of the project areas have experienced sand volume losses beyond the 50% locally placed for managing an engineered beach. Initially, efforts were made to coordinate beneficial use of USACE dredged material removed during annual maintenance (2012) from the Port of Morehead City's federal deep-draft navigation project. This proposed option was unavailable to the USACE as the SPO's proposed project area is beyond the USACE's authorized disposal area. The USACE validated the decision based upon the fact that the Proposed Action Alternative was beyond the area of inlet influence; thereby removing the material from the coastal system as affected by the USACE's channel maintenance efforts. As indicated above, the SPO is also managing the development of a MBNP encompassing the entirety of Bogue Banks (approximately 26 mi). The MBNP's tasks and ensuing schedules plus resulting effects of Hurricane Irene resulted in a timeline risk potentially jeopardizing the Project's immediate needs; a risk that Carteret County, the SPO, and the Towns of EI and PKS are uncomfortable taking. As such, the SPO is initiating the proposed Project as a response to Hurricane Irene and as an interim step toward the MBNP. The proposed Project will expedite a course of action addressing the Project area's imminent needs and leveraging FEMA participation towards maximizing proposed sand volumes.

4.0 ALTERNATIVE EVALUATION

4.1 Alternative to the Proposed Action (No Action)

The following was considered as an alternative to the proposed action: Do Not Authorize Use of OCS Sands. Under this alternative, BOEM would not authorize a negotiated non-competitive lease agreement for use of OCS material. Project proponents, the SPO, and the Towns of EI and PKS, could either:

Option (a) Re-evaluate the project, choosing another alternative borrow location or offshore sand source to restore the three reaches, or
Option (b) Locate onshore sources of comparable sand quantity and quality.

Option (a) would not minimize overall environmental effects because of the imminent need to protect the shorelines associated with the Project by either constructing new or augmenting existing protection mechanisms for the beaches. Carteret County has previously considered a range of non-structural alternatives to beach fill (USACE 2004a). Beach fill using an offshore borrow area was chosen as the preferred alternative. In addition, the ODMDS borrow material includes highly compatible sand based on recent investigations (Alpine 2012). Option (b) is not considered to be viable, as upland sources of needed quality and quantity are limited in the Project vicinity.

The No Action alternative would not meet the Project's purpose and need and; therefore, was not carried forward for further evaluation.

4.2 Borrow from the ODMDS (Proposed Action)

The Carteret County SPO proposes to renourish approximately 7.1 mi of oceanfront shoreline (within the Towns of EI and PKS) that was affected by Hurricane Irene (Figure 2). As determined through the BBBNMP, 1,344,123 cy of sand were eroded from the top of the dune out to -12 ft NAVD and were considered eligible for FEMA reimbursement as the engineered beach volume losses. The sand volume estimated for this proposed Project totals up to approximately 1,000,000 cy (992,000 cy); including a base volume approved by FEMA for reimbursement; in addition to supplemental sand volumes desired by the Towns of EI, PKS, and the County. The total proposed volume is based on federal, state, and local economic viability while facilitating FEMA participation. Based on previous post-storm renourishment events involving the recipient beaches and ODMDS, the fill material would consist of beach-quality sand. The material to be dredged from the ODMDS was confirmed by recent sediment analyses (Figures 4 and 5) (Appendix F). Specific sediment characteristics are discussed in further detail in Section 4.2.

The Morehead City ODMDS is a United States Environmental Protection Agency (USEPA) designated ocean dredged material disposal site. The site is utilized by the USACE as a disposal area for material dredged during maintenance of the Morehead City Harbor navigation channels. Disposal is limited to dredged materials that have been evaluated and approved in accordance with USEPA Ocean Dumping Regulations and Criteria. The ODMDS occupies an area of approximately eight square nautical miles (nm) offshore of eastern Bogue Banks. The

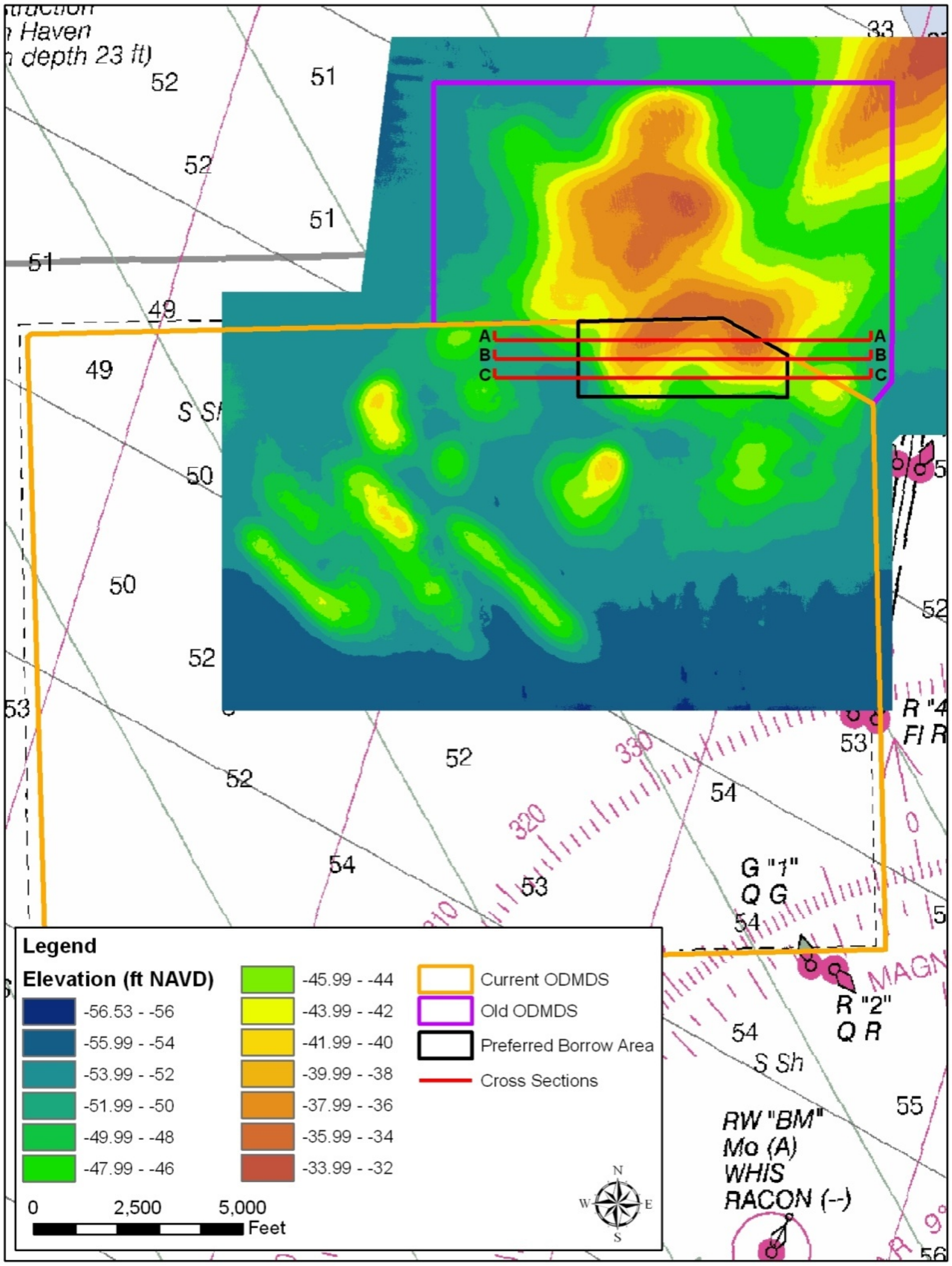


Figure 4. Borrow Area Site Plan

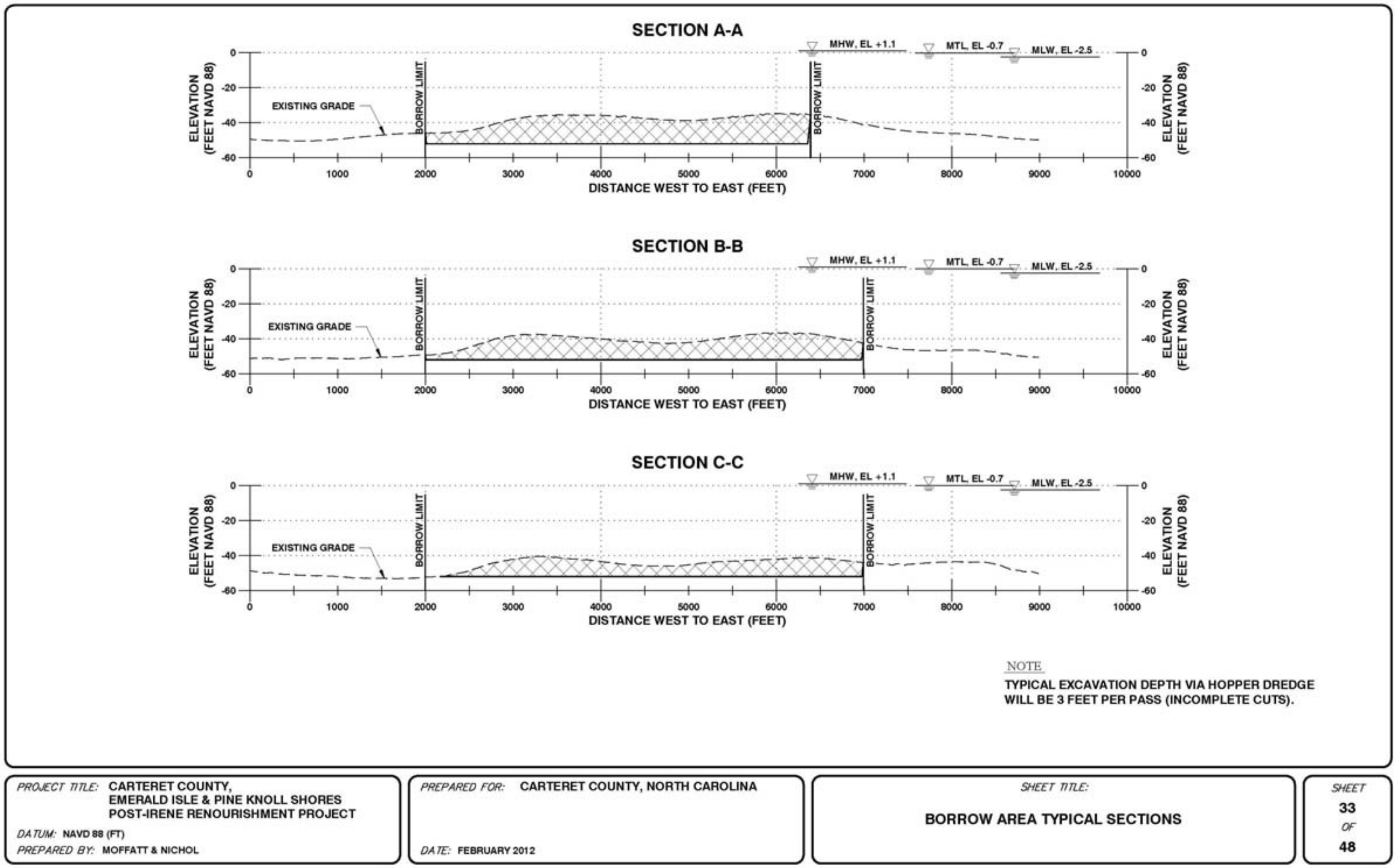


Figure 5. Borrow Area Typical Sections

inner boundary of the ODMDS is just over three nm from shore, and the outer boundary is approximately 11 nm from shore. Depths range from approximately -31 to -55 ft mean low water (MLW). Sand from the ODMDS has been used during previous renourishment projects on Bogue Banks, including the 2004 Post-Isabel and the 2007 Post-Ophelia sand replenishment projects that placed sand on or adjacent to the proposed Project beaches.

The proposed Project includes sand placement of up to 1M cy along 7.1 mi in three discrete oceanfront shoreline locations of Bogue Banks shoreline: (1) western EI between survey transects 9-16 (approximately 265,000 cy along 2 mi); (2) eastern EI between survey transects 35-46 (approximately 410,000 cy along 2.6 mi); and (3) PKS between survey transects 61-70 (approximately 317,000 cy along 2.5 mi) (Figure 2, 6 – 11). The western boundary of the Project is approximately two miles east of Bogue Inlet, and the eastern boundary of the Project is approximately eight miles west of Beaufort Inlet (Figure 1).

4.2.1 Methods of Construction

The proposed Project would involve use of a hopper dredge to excavate sand from the ODMDS. Hopper dredges are self-propelled vessels that employ a trailing suction draghead to remove sediment from the seafloor. The draghead is equipped with various types of steel cutting teeth or blades and/or high pressure water nozzles that dislodge thin layers (approximately two to five feet deep) of sediment from the seafloor. A mixture of loose sediment and water is pumped through a suction pipe into a hopper onboard the dredge. Sediment settles in the hopper and excess water is discharged via an overflow system (i.e., scuppers). Once fully loaded, the hopper dredge would travel from the ODMDS to a nearshore pump-out station along the target beach. As specifically described by Hales (1995) the proposed methodology includes removing dredged material from the hopper dredge, where the dredge moors to an anchored floating structure, buoy, or multiple buoy berths. An underwater pipeline, situated in approximately 30 ft of water, then extends from the buoy to shore. A hose is connected from the buoy to the hopper-dredge discharge manifold. The dredge then mixes the dredged material with water to form a slurry and pumps the slurry from its discharge manifold through the floating hose to the anchored floating buoy and on through the underwater pipeline toward shore where it would be pumped onto the recipient beach (Hales 1995). The dredge would then return to the ODMDS and the cycle of dredging and discharging would be repeated. Equipment refueling would occur as needed at the Port of Morehead City. The position of the nearshore pump-out station and discharge pipeline would shift incrementally as construction progresses along the beach. Potential effects as they related to construction methodology are described in Section 6.0.

Placement and grading activities on the beach would involve the use of bulldozers to redistribute and grade the beach fill material to the proposed beach profile. Bulldozers would access the beach via existing public access points. Bulldozer operations would be restricted to areas seaward of the existing dune toe. Dunes and vegetation would be avoided and protected during construction. Dredging and grading would occur around the clock, thus requiring nighttime lighting on the beach and onboard the dredge. All construction activities would take place within the 16 November through 31 March hopper dredging environmental window. Based on previous renourishment projects, the project team expects the dredge will excavate and discharge 10,000 to 15,000 cy of sediment per 24-hour period. Sand placement and grading will progress along the beach at a rate of 400 to 700 linear ft per 24-

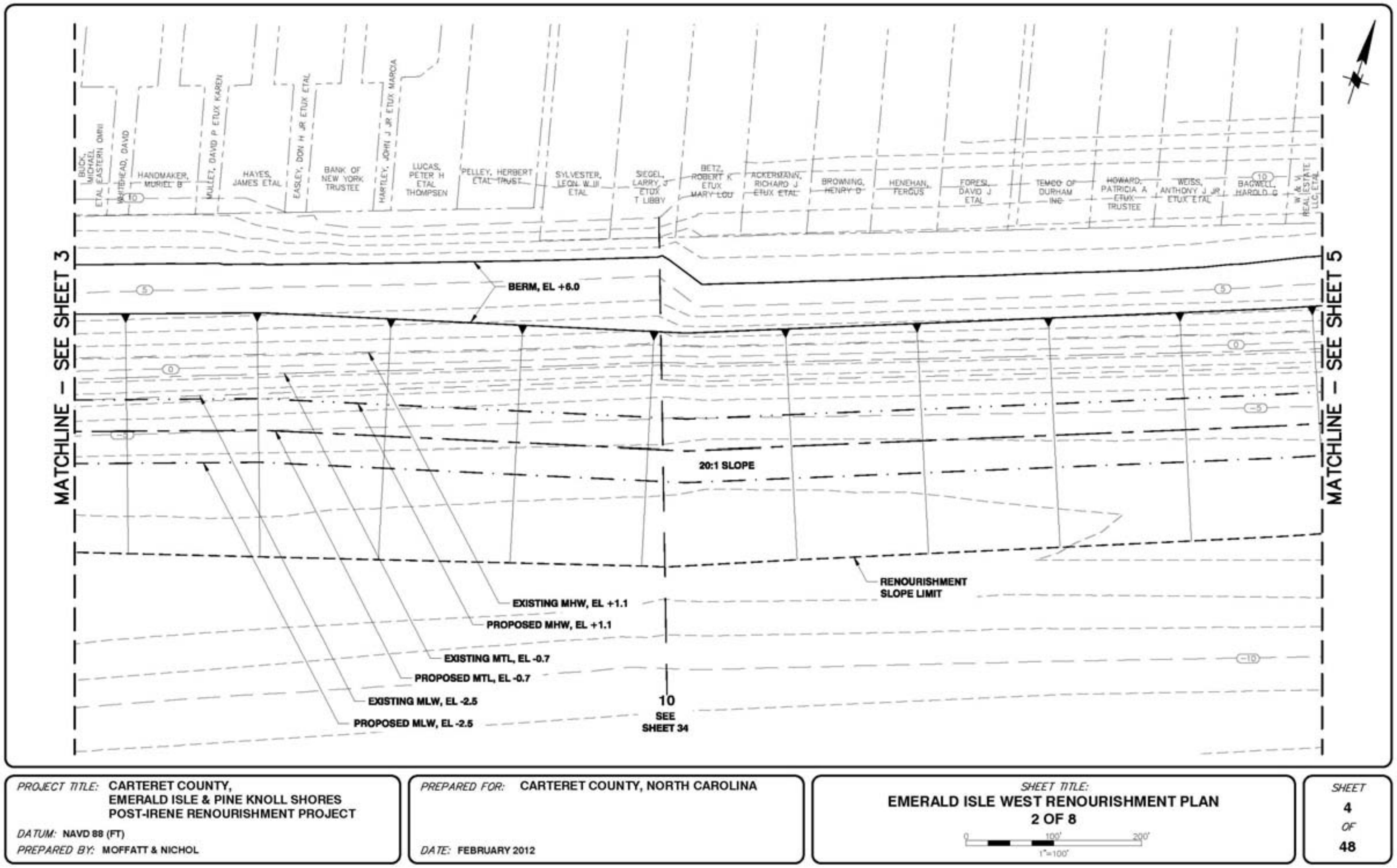


Figure 6. Emerald Isle West Renourishment Plan (Typical)

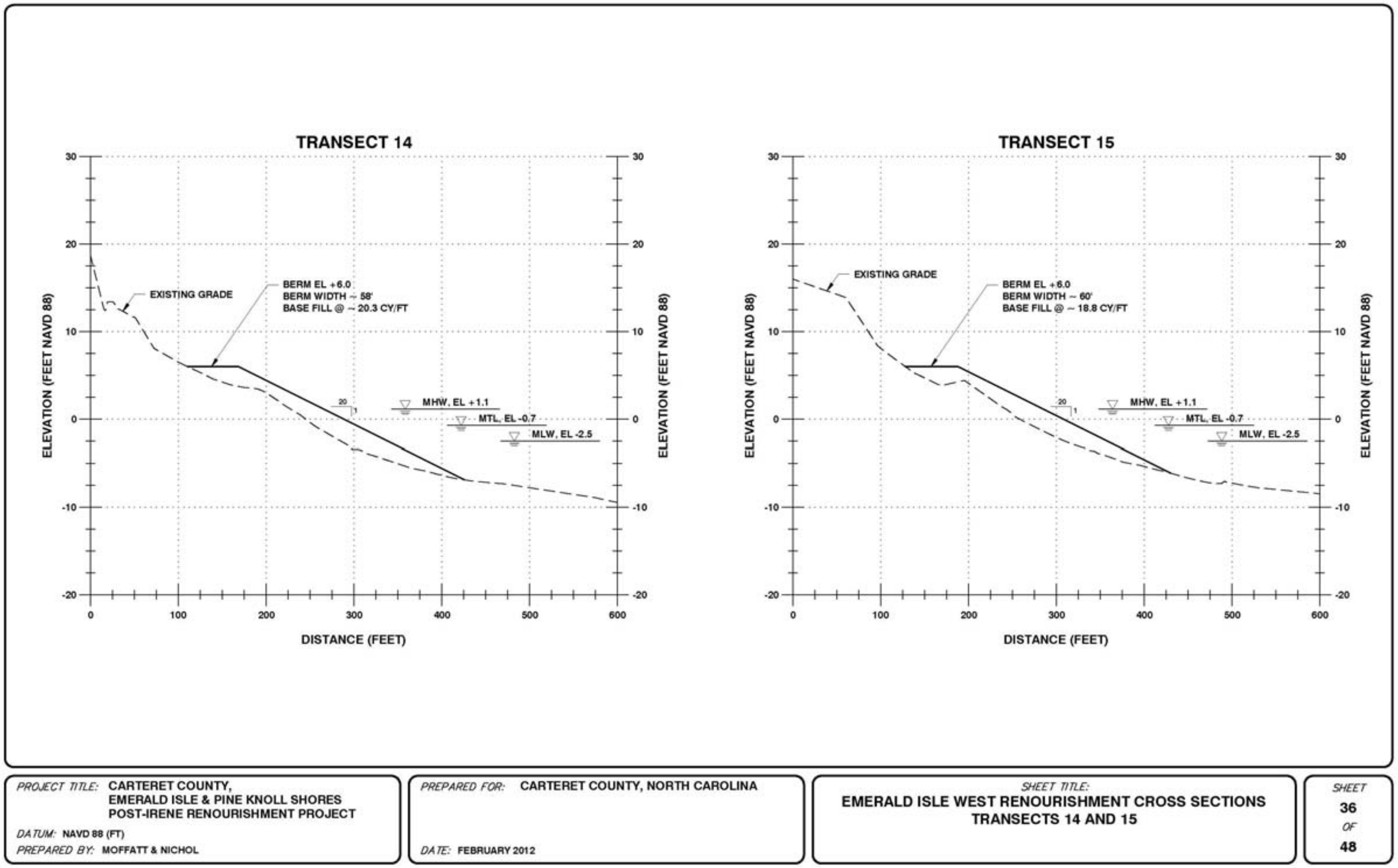


Figure 7. Emerald Isle West Fill Template (Typical)

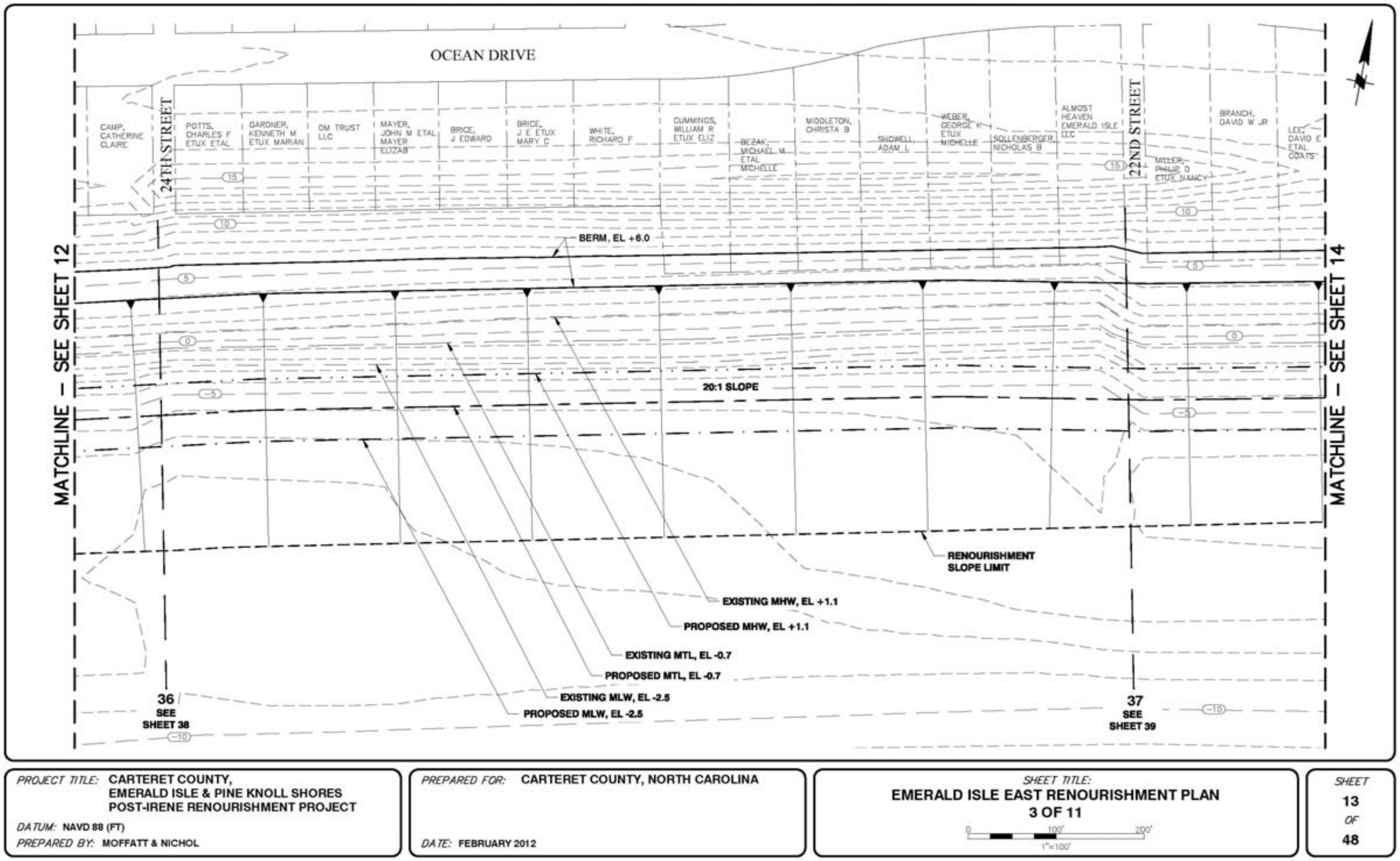


Figure 8. Emerald Island East Renourishment Plan (Typical)

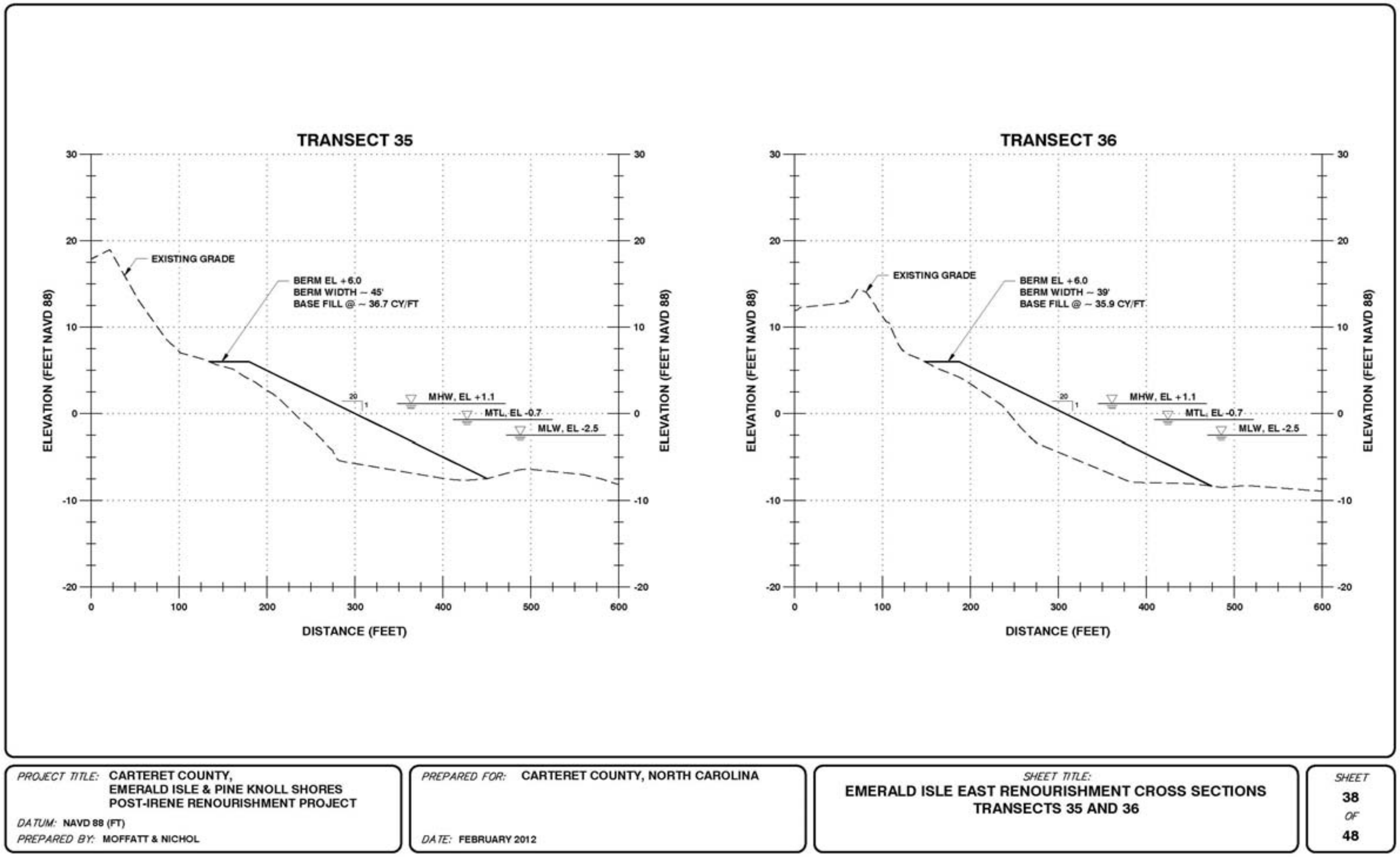


Figure 9. Emerald Isle East Fill Template (Typical)

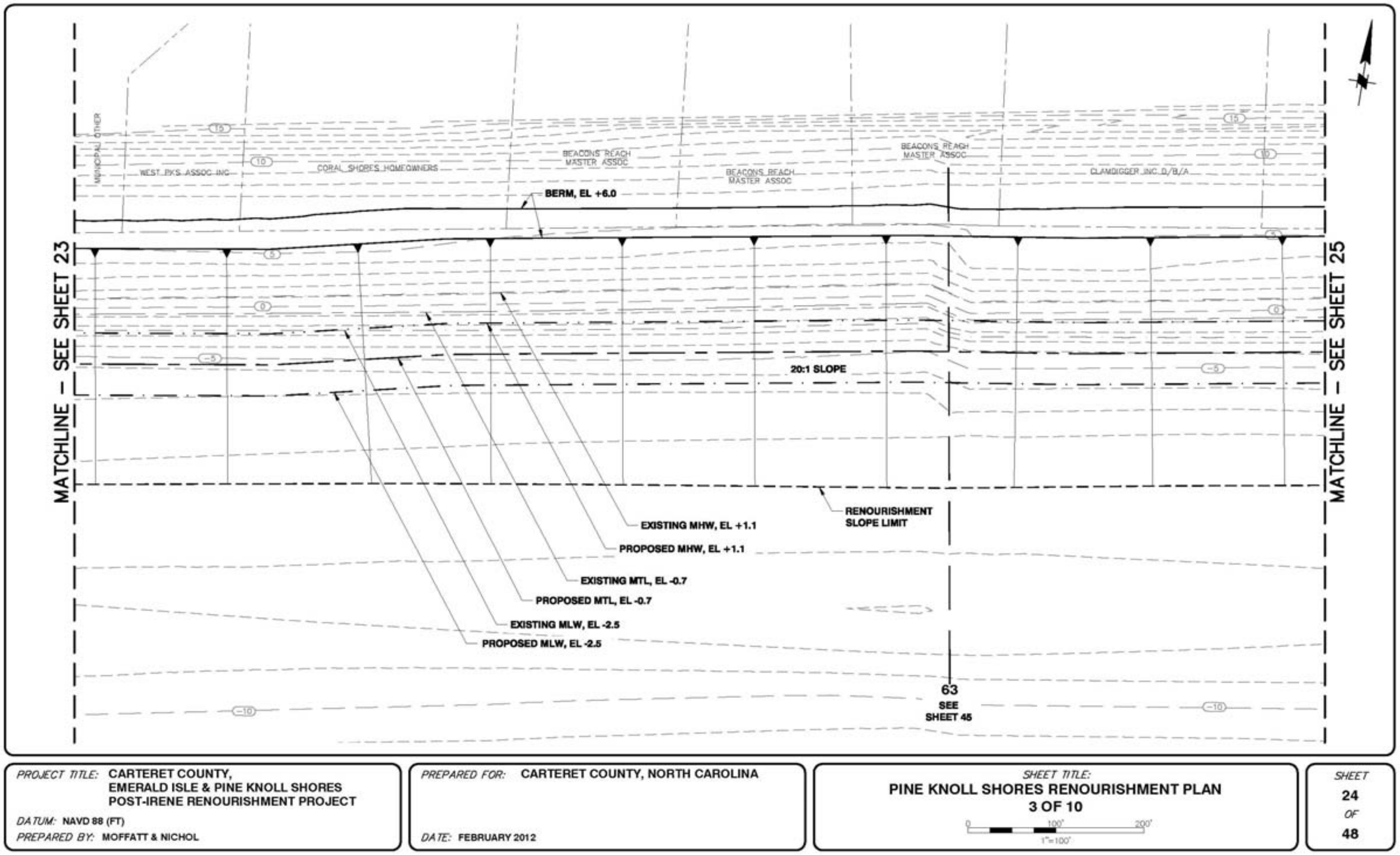


Figure 10. Pine Knoll Shores Renourishment Plan (Typical)

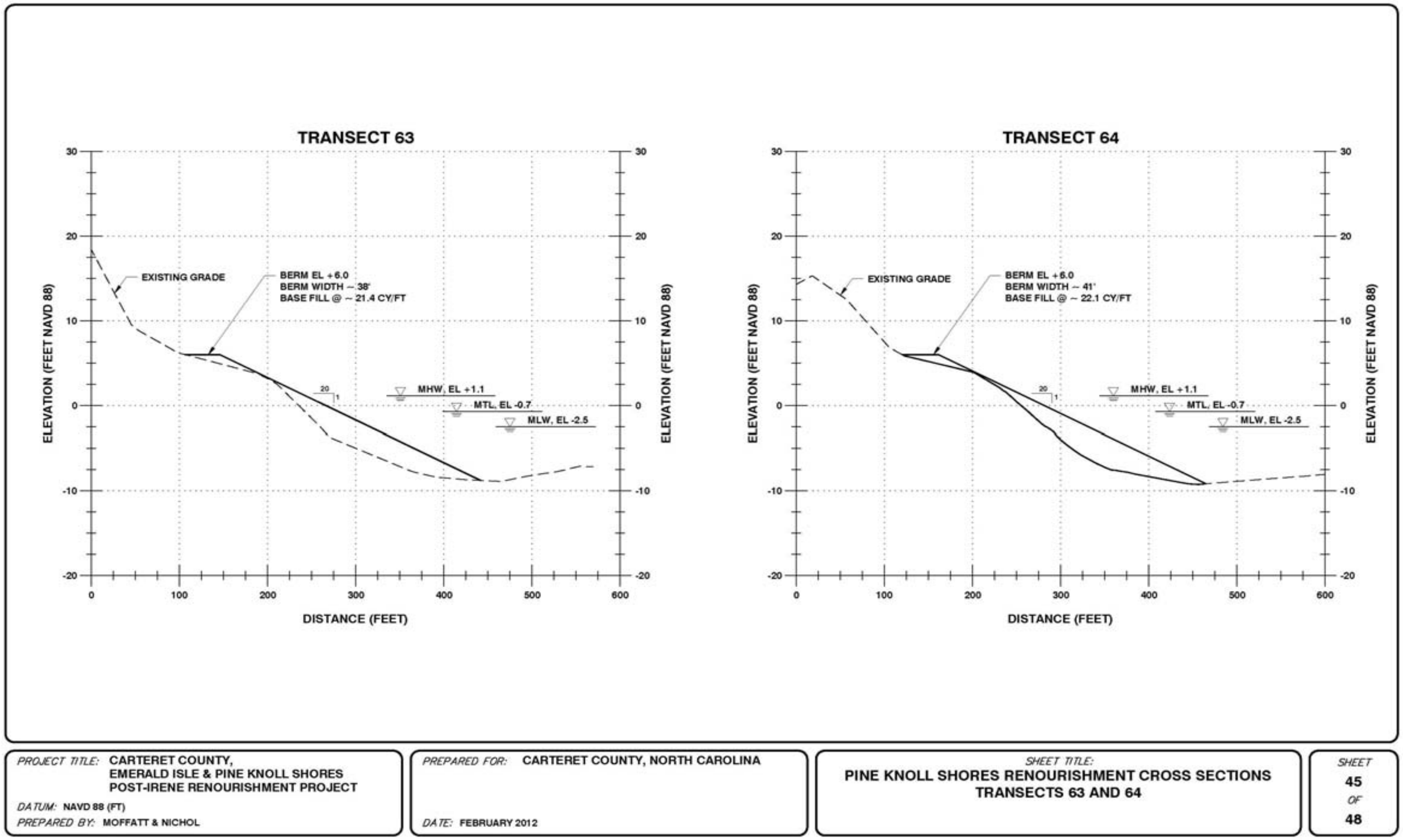


Figure 11. Pine Knoll Shores Fill Template (Typical)

hour period. Based on these estimated production rates, the project would require approximately two to three months for completion.

Consistent with previous permits for hopper dredge nourishment projects (NCDCM Permits #124-01, #181-06 and USACE Permit #200000362), construction would take place within the routinely approved environmental window (November 16 through March 31) (Appendices D and E).

4.2.2 Sediment Compatibility

Suitable sand sources within the ODMDS have been identified in accordance with State of North Carolina Technical Standards for Beach Fill Projects [15A North Carolina Administrative Code (NCAC) 07H .0312]. Sediment data summarizing the sand source and native beach characterization are provided in Section 5.2. The North Carolina Technical Standards require analysis and comparison of sediments from the recipient beach and the proposed borrow site. Sediment properties that are considered include percent weight of fine-grained sediment, percent weight of granular sediment, percent weight of gravel, and percent weight of calcium carbonate.

4.2.3 Rationale for Selection

The Proposed Action Alternative would achieve project objectives described in Section 3.0 and minimize potential environmental effects. The Proposed Action Alternative would allow the beneficial re-use of high quality dredged sand, minimize overall project costs, provide for sediment compatibility, and allow for a timely completion of the approximate seven miles of oceanfront shoreline renourishment.

5.0 AFFECTED ENVIRONMENT

The Cape Lookout area is more diverse than most marine areas along the United States Atlantic Coast due to the mixing of the Gulf Stream from the south with the Labrador Current from the north [United States Fish and Wildlife Service (USFWS) 2002]. As a result of this oceanographic mixing, the marine flora and fauna are a mixture of cold-water and warm-water species. Highly migratory aquatic species such as whales and recreationally important finfish are common. With the unique east-west orientation of Bogue and Shackleford Banks often providing the first or last landfall for north-south migrating birds, seabirds from the Arctic and the tropics co-mingle.

Bogue Banks is an east-west trending barrier island with a length of approximately 26 miles and an average width of approximately 2,000 ft. The island has an extensive beach ridge system with isolated elevations in excess of 39 ft (Cleary and Pilkey 1996). The southern shoreline of Bogue Banks fronts open waters of the Atlantic Ocean. The northern shoreline fronts Bogue Sound a shallow, open-water lagoon that separates the island from the mainland. Bogue Inlet separates the island from Bear Island to the west, and Beaufort Inlet separates the island from Shackleford Banks to the east. The major landforms that make up Bogue Banks include the intertidal and upper dry ocean beach, a system of active primary and secondary sand dunes, a series of interior forested relict dune ridges, and narrow intertidal marsh flats along the margins of Bogue Sound. Vegetation zones from the ocean to the sound include dune grass, maritime shrub, maritime forest, and salt marsh communities (Taggart 1980). The majority of the interior portion of Bogue Banks is heavily developed; and consequently, most of the remaining natural vegetation between the frontal dunes and the back barrier salt marshes is highly fragmented.

The Town of EI occupies the western end of Bogue Banks between Bogue Inlet and the Town of Indian Beach. The Town of PKS is east of the Town of Indian Beach and west of the Town of Atlantic Beach. As defined previously, the western boundary of the proposed Project is approximately two miles east of Bogue Inlet, and the eastern boundary of the Project is approximately eight miles west of Beaufort Inlet. The eastern EI target beach lies along a relatively narrow section of Bogue Banks where the width of the island ranges from approximately 900 to 1,150 ft. In contrast to the majority of Bogue Banks, this narrow section of the island is subject to rare overwash events during storms. Residential beachfront development is continuous along the entire project oceanfront. The total beach fill area would include portions of the upper supratidal beach, intertidal beach, and adjacent subtidal bottom. Project fill volumes would average approximately 27 cy per linear foot of beach, depending on reach-specific losses. The proposed beach profiles would average 45 ft in width seaward of the dune toe as a 6-ft-high NAVD level berm, and then continue seaward on a 1:20 slope to a depth of -8 ft NAVD. Since only the portion of the profile above high water is controllable during renourishment, intertidal and subtidal portions of the profile will be subject to natural adjustment by waves following placement of the beach fill. The existing condition of significant resources, found within the vicinity of the project area, in both the marine and terrestrial environment is described below. Physical resources, socioeconomic resources, recreation and aesthetic resources, cultural resources, and water quality conditions are also discussed below.

5.1 Coastal Processes

As described in Section 1, the study area is in Carteret County, NC centrally positioned on NC's coast south of Cape Lookout. Bogue Banks is an approximately 26-mile long barrier island located on the low-energy limb of the Cape Lookout foreland with a relatively unique east-west orientation. Beaufort Inlet borders the island to the east, separating Bogue Banks from Shackleford Banks. Bogue Inlet borders Bogue Banks to the west, separating the island from Bear Island. Shackleford Banks is part of the Cape Lookout National Seashore (CLNS), and Bear Island is part of the Hammocks Beach State Park. Bogue Sound, a relatively shallow embayment system encompassing reaches of the Atlantic Intracoastal Waterway (AIWW), separates Bogue Banks from the mainland and Onslow Bay (Atlantic Ocean). The island's width [land above mean high water (MHW)] varies from approximately 4,000 ft at the widest point to approximately 800 ft at the narrowest point; both dimensions are found on western EI and eastern EI respectively. Bogue Banks' geographical features and locations portend tropical storms, hurricanes, and erosional effects (USACE 2003).

The Morehead City ODMDS is located on the inner continental shelf of Onslow Bay at depths of -31 to -55 feet MLW. Physical oceanographic processes on the inner shelf of Onslow Bay are primarily driven by synoptic scale (2-14 days) wind events. In contrast to the middle and outer shelf regions, inner shelf processes are little affected by synoptic scale Gulf Stream events and seasonal forcing mechanisms (Pietrafesa et al. 1985). Studies have shown that significant sediment mobilization events on the inner and middle shelf of Onslow Bay are primarily driven by high-energy storms and associated increases in wave orbital velocities (Marshall 2004, Wren 2004). Marshall (2004) reported that fine-grained sediments (<0.2041 mm) were frequently suspended (even under average fair-weather conditions); however, full suspension conditions accounted for less than one percent of the total sediment suspension time over a period of 19 months. Furthermore, a single storm (Hurricane Irene) accounted for 72 percent of the full suspension conditions. During Hurricane Isabel, near-bottom wave orbital velocities were more than six times higher than the fair-weather average, and full sediment suspension conditions occurred for more than forty eight consecutive hours (Marshall 2004).

5.1.1 Tidal Conditions

Tide gauges at Atlantic Beach (ocean side on Triple S Pier); Morehead City; Duke Marine Lab (Beaufort); and Shell Point (Harkers Island) were used for succinct tidal studies during the 1960s and 1970s. However, the Duke Marine Lab has continuously measured soundside tide cycles since 1973 (USACE 2001a). Bogue Banks' ocean tides are semidiurnal with high and low tides approximately equal through consecutive cycle periods. The National Oceanic and Atmospheric Administration's (NOAA), National Ocean Service (NOS) has measured (at Atlantic Beach's Triple S Pier) the mean tide range as approximately 3.7 ft and a mean spring tide range as approximately 4.3 ft. The mean tide range inside the Beaufort Inlet at the Duke University Marine Laboratory and the NC State Port Authority, Port of Morehead City is approximately 3.0 ft (USACE 2001b). Within the Bogue Inlet system as measured at the United States Coast Guard Station, the semidiurnal mean tidal range is approximately 2.2 ft with a mean spring tide range of approximately 2.6 ft [United States Coast Guard (USCG) 2008].

5.1.2 Wave Climate

In general terms, the ocean waters in Bogue Banks' proximity are considered somewhat a mild-energy environment. Small waves less than three ft in height make up approximately two-thirds of the characteristic offshore wave climate with short period wind waves transferring the majority of the energy to Bogue Banks' shoreline. Important wave sheltering effects result from the Cape Lookout Shoal Complex and barrier island landforms (Shackleford Banks) proximal to Bogue Banks; primarily the east end near Fort Macon and Beaufort Inlet. Bogue Banks' sheltered effects wane as one moves east to west along the island toward Bogue Inlet. These geographic factors play a role in minimizing potential nor'easter wave generating effects. The dominant short-period southwest waves normally represent summer time wave conditions; however, occasional long-period waves originate from nor'easters formed south of NC primarily during the spring and winter months (CPE 2004).

Wave height estimations inferred from observations or calculated from offshore wind speeds and directions can have ranging accuracies as compared to wave measurements. A 1956-1975 data set of modeled waves from the USACE Wave Information Study (WIS) showed mean wave heights in the Project area of approximately 4.3 ft in approximately 30-foot water depths. Approximate depths between 60 ft and 90 ft at locations seven nm southeast of Cape Lookout and 25 nm south of EI respectively, indicated mean wave heights of 3.9 ft. However, the study did see a sheltering effect on the eastern end of Bogue Banks related to navigation maintenance (USACE 2001a). Additional WIS data (1980 - 1999) indicated approximately 50% of wave heights near the Beaufort Inlet area were 1.6 - 3.2 ft in height and typically from the south-southwest. However, waves during August to November were primarily from the east-southeast with the largest waves occurring in December-March [North Carolina Coastal Resource Commission (NCCRC) 2010].

Similarly, WIS data (1976-1995) for the Bogue Inlet area, based on the general shoreline alignment, indicated that onshore wave patterns develop from the north-northeast clockwise around to the west-southwest. Nearly 37% of the waves developed from the east-southeast through the south-southeast directions with an average wave height of 3.8 ft (CPE 2004).

As discussed in Section 1.0, Hurricane Irene was a Category 1 storm making landfall on the morning of August 27, 2011. Although Bogue Banks was located on the storm's "weak side" it was still considered a significant event. Based on preliminary review, wave conditions during Hurricane Irene [significant wave height (Hs)=28.4', peak wave time period (Tp)=16 sec] were considered more severe than those that occurred during Hurricane Ophelia (Hs=19', Tp= 11 sec). The duration of elevated wave conditions were similar for both storms (36 - 48 hours).

5.1.3 Shoreline Currents

An increasing gradient, or an increase in transport potential along a shoreline, is an indication of erosion potential; whereas a decrease in transport potential infers potential beach stability or accretion [North Carolina Department of Environment and Natural Resources (NCDENR) 2009]. Many versions of the USACE WIS data bases have been used in portending Bogue Banks' longshore transport. Based on the WIS data set used, sediment transport currents along Bogue Banks differ in magnitude and direction. Another approach describing sediment current movement and accumulation along Bogue Banks facilitates geological indicators. Such an approach infers Bogue Banks' net longshore transport rate as low supported by beach profiles and aerial photographic comparisons; the cycling of accretion and erosion on Emerald Isle's western end; and using USACE placed material (texture and color) on Atlantic Beach, as an indicator of a low net transport (USACE 2001a). However, storm events can exacerbate shoreline currents inducing severe erosion. These storm current induced effects can be temporary or can move sand considerable distances offshore. Storm wave induced currents can also act as a natural bypassing system moving sediment from one side of an inlet to another. Previous analyses indicate primarily a westerly-directed littoral drift with a reversal (nodal) point occurring near Triple S Pier on Atlantic Beach (USACE 2001a). Generally speaking, the scales of east and west transport are relatively similar and likely responsive to seasonal deviation and storm events.

Shoreline current transport in the vicinity of both Beaufort and Bogue Inlets is directed toward the inlets. A westerly current transport continues from western EI to Bogue Inlet (CPE 2004). Studies associated with the Bogue Inlet area's wave energy indicate a predominantly westward littoral current transport; yet, the analyses suggested a nearly balanced sediment transport during March through July. Shoreline studies along PKS and Salter Path/Indian Beach indicate several minor transport gradients and reversals within these shoreline areas (CPE 2004).

5.1.4 Wind/Climate

The National Climatic Data Center (NCDC) provides monthly climate summary data for the region, including Carteret County, North Carolina. Table 5 provides the monthly average wind speeds and directions from the Cherry Point Marine Corps Air Station (MCAS) and Cape Hatteras, North Carolina reporting stations. The period of record (POR) for this data is

Table 5. Monthly average wind directions and speeds.

Cherry Point MCAS, North Carolina	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Prevailing Direction (DIR)	N	N	S	SSW	SSW	SSW	SSW	SSW	NNE	NNE	N	N	SSW
Mean Wind Speed (SPD)	6	7	7	7	6	6	5	5	5	6	6	6	6
Peak Gusts (PGU)	58	66	68	81	64	81	66	104	107	86	59	68	107
Cape Hatteras, North Carolina	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Prevailing Direction (DIR)	N	N	N	NNE	NNE	NNE	NNE	NNE	NNE	SW	SW	SW	NNE
Mean Wind Speed (SPD)	12	12	12	12	11	11	10	10	11	11	12	11	11
Peak Gusts (PGU)	59	58	63	60	46	55	45	98	87	66	78	60	98

1930 to 1996. In the following table, prevailing wind directions (DIR) are stated in compass points; mean wind speeds (SPD) and peak gusts (PGU) are in miles per hour (NCDC 1998).

Recent wave hindcast studies (Jensen 2010) indicate that the wave climate along Bogue Banks is dominated by small (height <3 feet), short period (<8 second) wind waves out of the southeast to southwest sector. During the spring and summer, prevailing winds are out of the southwest and the predominant direction of wave approach is from the south. As the prevailing winds shift to the northeast in the fall, the predominant direction of wave approach shifts towards the east to southeast sector. As the prevailing winds shift to the north-northwest during the winter, the predominant direction of wave approach pattern shifts back towards the southeast to south sector. The wave climate along Bogue Banks is influenced by Cape Lookout, which shelters the area from the high energy northeast winds and waves that dominate the region (Heron et al. 1984). The sheltering effect results in a relatively low energy wave regime dominated by small, short-period, southerly waves. Although protected against northeast winds and storm waves, the area is highly exposed to tropical storms and hurricanes approaching from the south.

5.1.4.1 Hurricanes and Tropical Storms

Tropical cyclones are classified as tropical depressions, tropical storms, or hurricanes based on maximum sustained wind speeds of <39 miles per hour (mph), 39 to 73 mph, or ≥74 mph; respectively. The Saffir-Simpson Hurricane Scale, also based on maximum sustained wind speeds, is used to classify hurricanes on a scale ranging from one to five (Table 6). During the period 1900 through 2011, Carteret County received direct or indirect hits from 25 hurricanes (Zervas 2009) (Table 7). Direct hits are recorded when the innermost core of the hurricane passes over the County. Indirect hits are recorded when the County experiences hurricane force winds or when tides are 4 to 5 feet above normal. Hurricanes that hit Carteret County between 1900 through 2011 included ten Category 1 storms, six Category 2 storms, and eight Category 3 storms. During this same period, 32 tropical storms passed within 75 miles of Bogue Banks (State Climate Office of North Carolina 2010). The hurricane history of Carteret County is marked by periods of relatively intense hurricane activity. The County was hit by six hurricanes during the period 1953 through 1960, and five hurricanes hit the County during the period 1996 through 1999. In addition, the County experienced successive hurricane hits during 2003, 2004, 2005, 2008, 2010, and 2011. The hurricanes that hit the County during these relatively short time periods account for 64 percent of the total hits.

Knutson et al. (2010) summarized recent efforts to model the effects of climate change on the frequency and intensity of tropical cyclones. Models consistently indicate that the global frequency of tropical cyclones will either decrease or remain the same as the climate warms during the 21st century. However, storm intensity and precipitation levels are expected to increase. A recent modeling study conducted by the NOAA Geophysical Fluid Dynamics Laboratory suggests that the frequency of the most intense (Category 4 and 5) hurricanes in the Atlantic basin will nearly double by the end of the 21st century (Bender et al. 2010). This study estimates that the increase in intensity will outweigh the overall reduction in tropical cyclone frequency, resulting in a 30 percent increase in potential hurricane damage by 2100.

Table 6. Saffir-Simpson hurricane wind scale.

CATEGORY	MAXIMUM SUSTAINED WIND SPEED
1	74-95
2	96-110
3	111-130
4	131-155
5	>155

Table 7. Carteret County hurricane strikes 1900-2009.

YEAR	CATEGORY[1, 2]
1908	1
1913	1
1918	1
1933	3
1944	(3)
1953	1
1954	(2)
1955	(3),(3)
1958	(3)
1960	3
1971	1
1985	(3)
1986	1
1996	(2),(3)
1998	(2)
1999	(2),2
2003	2
2004	1
2005	1
2008	(1)
2010	(1)
2011	1

[1]Plain numbers represent direct hits. Numbers in parentheses represent indirect hits. Multiple numbers for the same year indicate more than one hurricane strike.

[2]Source: NOAA. 2010. County Hurricane Strikes by Saffir-Simpson Category. Available on-line at: http://www.nhc.noaa.gov/ms-excel/HurricaneStrikes_20100204.xls.

5.2 Geology and Sediment Characteristics

Bogue Banks is a relatively high elevation barrier island with characteristic large oceanfront dunes and extensive interior forested dune ridges that reach heights of over 39 feet. Portions of the island are also very wide, with maximum widths along PKS and western EI reaching 4,000 feet. These wide sections of the island contain multiple shore-parallel forested dune ridges. The island narrows to a minimum width of 800 to 1,000 feet along eastern EI. Although the central portion of Atlantic Beach reaches a width of over 5,000 feet, most of the width was created by filling tidal marshes on the back side of the island. The natural vegetation on Bogue Banks is characterized by the typical barrier island ocean-to-sound sequence of plant communities.

The large frontal dunes and forested dune ridges were formed during a period of seaward island migration that began approximately 4,000 years ago (Riggs et. al. 1996). During this period, an abundant supply of sand on the adjacent continental shelf fueled the formation of new oceanfront dunes. Eventually, the supply of sand on the adjacent continental shelf was exhausted, and the island ceased its seaward progression. Bogue Banks has since shifted to an erosional state and is currently experiencing active erosion along both the oceanfront and soundside shorelines. The average annual erosion rate along most of the oceanfront shoreline is approximately two - three feet per year. Due to the island's east-west orientation and the sheltering effect of Cape Lookout, Bogue Banks is protected against the high energy northeast wind and wave pattern that dominates the majority of the coast. However, the island is highly exposed to tropical storms and hurricanes approaching from the south, which can cause severe short-term erosion.

The affected marine environment, as defined for this EA, encompasses the subtidal seafloor and overlying ocean water column seaward of the mean low water line out to a depth of approximately 20 meters. As described by Hine and Snyder (1985), the mean low water line separates the intermittently exposed intertidal beach from the permanently submerged (subtidal) lower beach. The shoreface along Bogue Banks extends seaward out to a depth of approximately 12 meters (distance of 500 to 800 m from shore) where it flattens and matches the gentle slope of the inner continental shelf. Seaward of the shoreface on the inner shelf of Onslow Bay, a thin (1-2 meters) and discontinuous layer of modern sand is superimposed on ancient hard geological strata (rocks and cemented sediments). The ancient hard strata are frequently exposed on the inner shelf, forming structural habitats known as hard bottoms.

The Morehead City ODMDS occupies an area of eight nm^2 at depths of -31 to -55 feet MLW. Depths are generally shallowest in the northern inshore portion of the ODMDS and gradually deepen towards the southern offshore portion. Sediments are predominantly sands with varying amounts of silts and clays. The quantity of shell material varies from a trace to 25 percent. The seafloor is essentially flat, with the exception of dredged material mounds in the northeastern third and central portion of the ODMDS due to navigation maintenance dredging disposal events. Remote sensing surveys have not identified any potential hard bottom features or cultural resources at the ODMDS. Bathymetric surveys indicate that sandy and coarse dredged materials have the potential to mound appreciably when specific areas are repeatedly used for disposal (USACE and USEPA 2009).

5.2.1 Borrow Area Sediments

Vibracores were obtained in the ODMDS by Alpine Ocean Seismic Survey Inc. (Alpine) in December 2011, supporting sand source investigations for the MBNP. A portion of these vibracores were collected at the state-mandated 1,000 ft spacing and this area is being denoted as the borrow site for the proposed Post-Irene project (Figure 4). Shallow excavations (2-5 ft deep, typical) would be made by a hopper dredge and pumped via submerged pipe to the beach. Utilizing the portion of the ODMDS which has vibracore data at the state-mandated 1,000 ft spacing and assuming a potential cut depth down to elevation -52 ft NAVD (equal to the original offshore floor elevation), an area of approximately (~) 197 acres of the total ODMDS area of ~6,900 acres would meet the renourishment requirement of 1,000,000 cy (Appendix F). Appendix G (Permit Drawings) includes all engineering plan drawings of the entire project area as well as the ODMDS borrow source.
Detailed information regarding recent vibracore investigations and characteristics of the proposed ODMDS borrow sediment is provided in Appendix F. Moffatt & Nichol identified 27 samples from ten ODMDS vibracores representative of the proposed borrow area and material to be placed on the beach.

Sediment data summarizing the sand source are provided below in Table 8. Sand placed on the beach will meet NCDCM's sediment compatibility standards as detailed in Sediment Criteria Rule, contained in the Technical Standards for Beach Fill Projects (15A NCAC 07H .0312).

Table 8. Sand characterization comparisons.

Sand Characterization	Native Beach	ODMDS Borrow Site	NCDCM Standards	Compliance
Silt Percentage	1%	0.5%	+ 5% of Native	Within Standards
Sand Percentage	94%	98%	+ 5% of Native	Within Standards
Gravel Fraction	5%	1.5%	+ 5% of Native	Within Standards
Calcium Carbonate Fraction	15-20%	9-21%	+15% of Native	Within Standards

Sources: CSE, USACE, Alpine and NCDCM 15A NCAC 07H .0312 Technical Standards for Beach Fill Projects (3) (a through h).

The typical sediment type in the ODMDS borrow site is medium sand (average mean sediment size = 0.31 mm), moderately to poorly sorted (average standard deviation = 1.09 phi), and strongly coarse-skewed (coefficient of skewness < - 0.3). Less than 2% of the material is >2 mm in diameter. The native beach (composite 1999 - 2001) was also characterized as medium sand (mean size = 0.30 mm), moderately well sorted, and coarse-skewed. The comparison, depicted in Table 8, shows the proposed borrow area sediments to be similar to native (1999 - 2001 composite). Using the James 1975 overfill factor (RA), the borrow sediment has an RA = 1.14.

These ODMDS borrow area results compare more positively to the native beach than the previous sand used for the Post-Ophelia renourishment. Visual observations of the present borings indicate mud content is very low with only trace amounts seen in nearly every core. Only one sample tested contained greater than 5% fine grained sediment (vibracore O24 sample 1; 5.1% passing 200 sieve); all other samples were comprised of less than 1% fine grained material. Samples consisted of 9 - 21% calcium carbonate. The typical colors of ODMDS sediments are light-to-medium to dark gray-to-brown as described in the geological logs in Appendix F. The photos within Appendix F also show the sands to be gray to brown in color, which is very similar to the colors reported for the sand used in the Post-Ophelia project.

The Proposed Action Alternative (issuance of a non-competitive lease by BOEM) would authorize use of up to 1M cy of OCS material. The sand would be removed from the ODMDS (Figure 4) by a hopper dredge and transported to the three reaches for placement as fill (Figure 2). Given the distance from the ODMDS to the recipient beaches (ranging 7-21 mi), the borrow sand would be delivered via a hopper dredge facilitating offshore pump out stations. These stations would direct the sand slurry on the three reaches. The dredging footprint and ODMDS bottom-disturbing activities would be confined to the ODMDS as delineated through geotechnical testing (Appendix F), cultural investigation, and hardbottom confirmation.

5.2.2 Native Beach Sediments

Native beach sediments were sampled by CSE between 1999 and 2001 to establish native grain size distribution for purposes of a compatibility analyses. Details are described in the EA for Phases 1 and 2 (CSE-Stroud 2001) and in NCDCM Permit #124-01. Mean grain size of baseline samples (composites) was 0.302 millimeter (mm), standard deviation (sorting parameter) was 0.585 mm, and samples were coarse-skewed as a result of moderately high percentages of coarse material. The primary coarse fraction consists of shell fragments, most of which would be termed “shell hash” because grain sizes of the shell material are typically greater than 2 mm mean diameter. Native samples from 1999 to 2001 averaged approximately 15-20 percent shell and were classified as medium sand, moderately well-sorted, and coarse-skewed. This native size distribution has been approved and adopted for the proposed project.

Sediment data summarizing the native beach characterizations are provided above in Table 8. Sand placed on the beach will meet NCDCM’s sediment compatibility standards as detailed in Sediment Criteria Rule, contained in the Technical Standards for Beach Fill Projects (15A NCAC 07H .0312).

5.3 Water Quality

In NC, water quality is assessed primarily at the watershed or river basin (i.e., basinwide) level due to the watersheds’ interconnectedness. Basinwide water quality plans are prepared by the NCDWQ for each of the seventeen major river basins in the State and are updated at five-year intervals. The Proposed Action Alternative is contained within the White Oak River Basin; water quality plans were developed by NCDWQ in February 1997 and updated in November 2001. The Atlantic Ocean south of the proposed project reaches is also rated by NCDWQ, and has been designated “SB” for water quality classification. This means that ocean surface waters are used and suitable for recreation, including frequent or organized swimming. More limited stormwater controls are required under the Coastal Area

Management Act (CAMA) than the stormwater controls required under higher water quality designations. There are no categorical restrictions on wastewater discharges (NCDWQ 2003a).

Based on the above classification, water quality standards include: (1) turbidity in the receiving water shall not exceed 25 Nephelometric Turbidity Units (NTU), (2) changes in salinity due to hydrological modifications shall not result in the removal of the functions of a Primary Nursery Area (PNA), (3) temperature shall not be increased above the natural water temperature by more than 0.8 degrees centigrade (ºC) during the months of June, July, or August nor more than 2.2ºC during other months, and in no cases to exceed 32ºC due to the discharge of heated liquids, (4) dissolved oxygen cannot decrease below 5.0 milligrams per liter (mg/l), except in "poorly flushed tidally influenced streams or embayments, or estuarine bottom waters" which may have decreased values from natural causes, and (5) pH levels "shall be normal for the waters in the area, which generally range between 6.8 and 8.5 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions" (NCDWQ 2003b).

Historically, infrequent water sampling has been conducted in the vicinity of the project area. Data collected by Searcy (2003) off the Highway 24 Bridge in Swansboro, from November 2002 through January 2003, reported a range of salinities from 24.0 to 28.6 ppt, with an average of 26.7 ppt in the area. During the same period, water temperatures ranged from 4.0ºC (39.2ºF) to 17.1ºC (62.8ºF), with an average of 9.8ºC (49.6ºF).

NCDENR Basinwide Assessment Report (2000) states turbidity levels taken adjacent to Swansboro from 1994 through 1999 ranged from 1.0 to 13.0 NTUs, with an average measurement of approximately 5.2 NTU. Elevated levels of turbidity are expected in the surf zone at the effluent discharge point on the beach. Schubel et al (1978) discovered that 97–99 percent of discharged slurry settled to the bottom within a few tens of meters from the discharge point. Other studies have found that the distribution of turbidity was confined to the discharge point (Nichols et al 1978; USACE 2001a).

In April 2002, Phase 1 of the Bogue Banks restoration project involved pumping 1.73 million cy of sand to renourish PKS and Indian Beach. During operations, turbidity was measured along two cross-shore transects (4,000 ft) – one inside the pumping zone and one away from the pumping zone. Turbidity was also measured along shore in the surf zone (3.8 miles) within the project area before pumping started and during sand pumping (CSE, unpublished data, April 2002).

The longshore turbidity measured before pumping provides background data with which to compare changes in turbidity. Background nearshore turbidity levels measured between 13.0 and 94.0 NTU with an average turbidity of ~50.0 NTU. After pumping started, turbidity in the surf zone showed a slight overall increase in the longshore direction (measurements averaged ~65 NTU) with a sharp increase at the point of sand discharge (>400 NTU). The sharp increase was seen only locally at the point of discharge and was drastically reduced within several hundred feet alongshore (CSE, unpublished data, April 2002). No offshore turbidity monitoring was required or conducted (Personal communication, Mickey Sugg, USACE SAW, 27 June 2012).

5.4 Air Quality

The Clean Air Act (CAA) of 1990 delineates the USEPA's responsibilities for improving and protecting the nation's air quality. The last significant amendments occurred in 1990 substantially enhancing the responsibility and authority of the federal government. The authority enhancements were through expanded regulatory authorizations, emphasizing implementation and enforcement while also considering a benefit-cost approach. USEPA is authorized to set air pollutant limits ensuring environmental and basic health protection standards for the United States; however, individual states have the option to enforce more stringent air pollution laws, if desired (USEPA 2010a).

The CAA's 1990 amendments basically included (USEPA 2010a):

- Acid Deposition Control Programs
- Control of an Additional 189 Air Toxics under National Emission Standards for Hazardous Air Pollutants
- Permit Program Requirements (Title V)
- Modified and Expanded Enforcement Authority
- Enhanced Attainment Provisions with the National Ambient Air Quality Standards (NAAQS)

The USEPA has set national ambient air quality standards for six common or "criteria pollutants" (Table 9). Ambient air is that portion of the atmosphere, external to buildings, which the general public has access. USEPA uses the term criteria because the allowable concentration levels of these six pollutants are human health-based and/or environmentally based limits. The human health-based limits are the primary standards and the environmental or property damage limits are the secondary standards. Currently, the six criteria air pollutants are: Ozone (O_3), Particulate Matter (PM_{25}), and (PM_{10}) particles with aerodynamic diameters of 2.5 or 10 microns or less, Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), and Lead (Pb) (USEPA 2010b).

The NC Division of Air Quality (NCDAQ) maintains an ambient air monitoring network for those criteria pollutants requiring monitoring by USEPA. Areas that exceed USEPA's national ambient air quality standards, based on regional ambient air monitoring, are designated as non-attainment areas. Carteret County is included in the non-metropolitan statistical area of NC's southern coastal plain. Carteret County is also included within New Bern's micropolitan statistical area (MiSA) (NCDAQ 2010).

The NCDAQ operates two ambient air monitoring stations within this MiSA; one station in Kenansville and the other in Kinston at Lenoir Community College. The Kenansville, Duplin County site operates a fine particulate monitor (sampled each third day) and a high-volume particulate PM_{10} monitor (sampled each sixth day). The Kenansville site is considered a general/background ambient air monitoring site. The Lenoir Community College site operates a seasonal continuous ozone monitor and a fine particulate monitor (sampled each third day). The ozone monitor at Lenoir Community College is considered a rural ozone monitor in a MiSA (NCDAQ 2010).

Carteret County is designated as within attainment for all criteria pollutants (Personal communication, B. Newland, NCDAQ, March 2012). State Implementation Plans are not triggered for areas in attainment with the NAAQS.

Table 9. National ambient air quality standards.

Primary Standards				
Pollutant	**Level**	**Averaging Time**	**Level**	**Averaging Time**
Carbon Monoxide	9 parts per million (ppm) [10 milligram per cubic meter (mg/m^3)]	8-hour (1)	None	
	35 ppm ($40\ mg/m^3$)	1-hour (1)		
Lead	0.15 microgram per cubic meter ($\mu g/m^3$) (2)	Rolling 3-Month Average	Same as Primary	
	$1.5\ \mu g/m^3$	Quarterly Average	Same as Primary	
Nitrogen Dioxide	53 parts per billion (ppb) (3)	Annual (Arithmetic Average)	Same as Primary	
	100 ppb	1-hour (4)	None	
Particulate Matter (PM10)	150 µg/m3	24-hour (5)	Same as Primary	
Particulate Matter (PM2.5)	15.0 µg/m3	Annual (6) (Arithmetic Average)	Same as Primary	
	35 µg/m3	24-hour (7)	Same as Primary	
Ozone	0.075 ppm [2008 standard (std)]	8-hour (8)	Same as Primary	
	0.08 ppm (1997 std)	8-hour (9)	Same as Primary	
	0.12 ppm	1-hour (10)	Same as Primary	
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Average)	0.5 ppm	3-hour (1)
	0.14 ppm	24-hour (1)		

Source: USEPA 2010b

(1) Not to be exceeded more than once per year.
(2) Final rule signed October 15, 2008.
(3) The official level of the annual NO2 standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the 1-hour standard
(4) To attain this standard, the 3-year average of the 98th percentile of the daily maximum 1-hour average at each monitor within an area must not exceed 0.100 ppm (effective January 22, 2010).
(5) Not to be exceeded more than once per year on average over 3 years.
(6) To attain this standard, the 3-year average of the weighted annual mean PM2.5 concentrations from single or multiple community-oriented monitors must not exceed $15.0\ \mu g/m^3$.
(7) To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed $35\ \mu g/m^3$ (effective December 17, 2006).
(8) To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm. (effective May 27, 2008)
(9) (a) To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.
(b) The 1997 standard—and the implementation rules for that standard—will remain in place for implementation purposes as EPA undertakes rulemaking to address the transition from the 1997 ozone standard to the 2008 ozone standard.
(c) EPA is in the process of reconsidering these standards (set in March 2008).
(10) (a) EPA revoked the 1-hour ozone standard in all areas, although some areas have continuing obligations under that standard ("anti-backsliding").
(b) The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is < 1.

5.5 Noise

The beachfront's naturally occurring noise sources are similar along the entire 26-mile oceanfront shoreline. Naturally occurring noise sources are ocean waves, wind, and birds. Anthropogenic noise emission sources and receptors vary along Bogue Banks primarily by shoreline use, access, proximity, and season. Anthropogenic noise emission sources occurring on or near the beach would vary seasonally with the influx of the summer tourist, their transportation, and their shoreline use. These anthropogenic noise levels intensify in locations planned and developed for public use and shoreline access. Indirectly, landward infrastructure supporting the tourism industry and local municipalities would result in additional noise sources as well as receptors. Along the inlet shorelines, recreational and commercial vessels are additional anthropogenic noise sources.

Ambient sound in the ocean consists of the normally prevailing underwater sound emanating from natural and man-made sources. Hildebrand (2009) described the major natural and anthropogenic components of ambient ocean noise. Natural sources of noise include processes such as earthquakes, wind-driven waves, rainfall, bio-acoustic sound generation, and thermal agitation of seawater. Anthropogenic noise is generated by a variety of activities, including commercial shipping, oil and gas exploration, naval operations (e.g. sonar, communications, and explosions), fishing (e.g. sonar, acoustic deterrent and harassment devices), research (e.g. air-guns, sonar, telemetry, communication, and navigation) and other activities such as construction, icebreaking, and recreational boating. Ambient low-frequency ocean noise (10-500 Hz) is dominated primarily by commercial shipping and secondarily by seismic exploration. Ambient mid-frequency noise (500 Hz-25 kHz) is dominated by sea-surface agitation; including breaking waves, spray, bubble formation and collapse, and rainfall. Sonar (e.g. military and mapping) and small vessels also contribute to mid-frequency ambient noise. Due to rapid attenuation, high frequency noise (>25 kHz) is confined to an area close to the receiver. At frequencies greater than 60 kHz, thermal agitation of water molecules is the dominant source of ambient noise.

In a previous air noise assessment conducted on Radio Island, noise levels were documented for background and ambient levels. One sampling location was approximately 130 ft south of US 70 on the Morehead City to Beaufort causeway and another sampling location was the middle of Radio Island proper. The sampling period was April mid-morning; and the results were 61.9 and 44.9 a-weighted decibels (dBa), respectively [North Carolina State Ports Authority (NCSPA) 2001].

5.6 Archaeology/Cultural Resources

On 26 April 2010, the North Carolina Department of Cultural Resources, SHPO was requested to identify any known historical or archaeological sites that have been recorded along Bogue Banks. Pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106 codified at 36 CFR Part 800, comments and the last known positions of six archaeological sites were provided by SHPO. These are described in Table 10, depicted in Figure 12, and documented in Appendix H.

Table 10. Bogue Banks' known historical or archaeological sites.

SHPO ID	Site Name	Site Description
0001BBB	Iron Steamer Pier Wreck	Civil War, Blockade Runner, Pevensey
0002BBB	Gun Emplacement	World War II, Shore Battery
0003BBB	Salter Path	Ship Timbers with Iron Fasteners
0004BBB	Cupola	Ship Hull Portions with Planking
0005BBB	El Pier Wreck	Ship Timber with Iron Fasteners
0006BBB	Ocean Reef	Ship Wreckage with Extensive Remains

SHPO approves sand deposition as additional resource protection; however, if resources are exposed and construction is in close proximity, inspections by the Underwater Archaeology Branch would be required. Extensive borrow source assessments have been conducted along Bogue Banks and the assessments' findings and recommendations were considered during project alternative evaluation. Proposed borrow sources were assessed via remote-sensing and target identification techniques, identifying potential presence and significance of submerged archaeological remains (Hall 2011; Appendix J).

5.6.1 Known Archaeological and Historical Resources in the Project Area's Vicinity

A survey of historical and archaeological literature and archival background research confirmed considerable evidence of maritime activity along the southeastern NC coast. Historic maritime activity associated with the Beaufort Inlet area continues today in the form of commercial fishing and international shipping. Documented maritime activity dates from the sixteenth century when Spanish and English explorers visited the NC coast. As a consequence of nearly 300 years of navigation in the Cape Lookout coastal region, there is a high probability that historically submerged cultural resources are located in the area. That evidence suggests a high probability for submerged cultural resources in the waters around Beaufort and possibly Bogue Inlet.

The high probability of historical shipwrecks in the Beaufort Inlet vicinity is confirmed by location and identification of the remains of several historically significant vessels. The most significant Beaufort Inlet area shipwreck is Blackbeard's flagship the *Queen Anne's Revenge* (31CR314). A decade of investigation of the *Queen Anne's Revenge* has been carried out by the Underwater Archaeology Branch (UAB) and the shipwreck has been listed on the National Register of Historic Places (NRHP) (Lawrence 2007). Remains of the transport steamer *Quinnebaug* (0001BUI), a Civil War steamer lost off Shackleford Banks on 20 July 1865 (Berman 1972), were discovered by Tidewater Atlantic Research in 1992 (Watts 1992). While that wreck is not currently on the NRHP, the vessel meets criteria for inclusion. Remains of the schooner *L. A. Bailey* (0004BUI) and its cargo of railroad iron also lie near Beaufort Inlet. Like *Quinnebaug*, the L. A. Bailey is not on the NRHP, but meets several eligibility criteria. The 20th century remains of the trawler Parkins can also be considered potentially eligible. Parkins, a fishing trawler built in Pocomoke City, Maryland, in 1923 and owned by the Beaufort Fish-Scrap & Oil Company was lost during a storm on 21 December 1942 (Berman 1972).

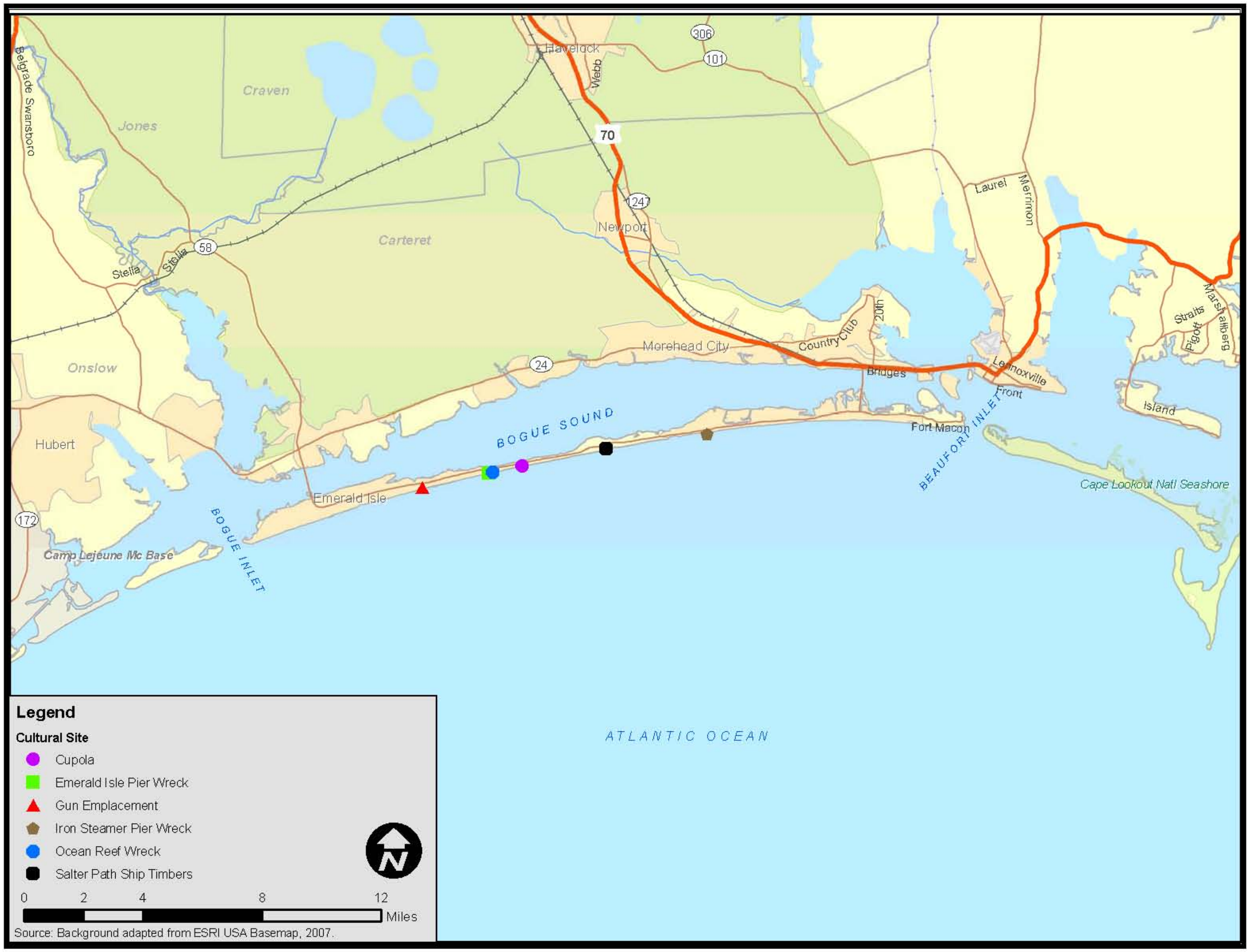


Figure 12. Known Cultural Resource Sites and Shipwrecks

A number of unidentified shipwrecks in the immediate project vicinity are listed with the UAB. These include a late nineteenth century site which produced copper sheathing and brick (0005BUI), a site containing a brass shoe buckle and pewter spoon dating to the first half of the eighteenth century (0006BUI), and a site comprised of seven eighteenth-century cannons (0007BUI). There are at least 144 shipwrecks recorded in coastal waters in the vicinity of Beaufort Inlet. Because of their association with the broad patterns of NC history, the remains of sunken vessels preserve important information about the maritime heritage of the NC coast.

The *Queen Anne's Revenge*, was declared a protected site by the NC Department of Cultural Resources. She is currently protected by additional sediment that has migrated into the area and a 300-yard perimeter established to restrict activities in the vicinity of the site. Access to the site, even for dredged material disposal, is not permitted unless separately coordinated between the NC Department of Cultural Resources and the USACE.

BOEM considers the area of potential effect to consist of the Morehead City ODMDS area (see Figure 1), which is an U.S. Environmental Protection Agency (USEPA) designated dredged material disposal site. While it is unlikely that significant submerged cultural resources would be contained within the previously dredged material of the ODMDS, Moffatt and Nichol Engineers contracted with Mid-Atlantic Technology and Environmental Research, Inc. to conduct an archaeological remote sensing survey in the Morehead City ODMDS dated September 08, 2011 (Hall 2011). The conclusions of the report are as follows:

- All of the targets identified during this project were found to be associated with modern debris that is either related to the present day ODMDS or past artificial reef systems such as the tire reefs created in the 1970s.

- Given the nature of re-deposited dredge material, the results of the 2011 archaeological survey indicating that no historic properties are present, and the fact that no original seafloor under the disposal site will be disturbed, BOEM has reached a determination of No Historic Properties Affected, pursuant to 36 CFR 800.4(d)(1).

The SHPO did not object within 30 days of receipt of BOEM's letter in reference to the ODMDS. Therefore, BOEM's Section 106 responsibilities have been fulfilled and there is a determination of no impact to historic or cultural resources at the proposed borrow site.

5.7 Benthic Resources

Benthic resources described in this section include macroinvertebrates associated with soft/sand bottom habitat located within the intertidal/surf zone and the subtidal/nearshore region located off Bogue Banks and the nearby Beaufort ebb shoal. No hardbottom habitat has been documented to occur in the nearshore areas off the recipient beaches or within the ODMDS (Hall 2011).

5.7.1 Intertidal/Surf Zone Benthic Communities

In NC, the dominant benthic macrofauna of the intertidal beach are mole crabs (*Emerita talpoida*), coquina clams (*Donax variablis, D. parvula*), several species of haustoriid amphipods, and the spionid polychaete *Scolelepis squamata* (Deaton et al. 2010). Leber (1982) documented seasonal changes in the intertidal macroinvertebrate community at Bogue Banks. Mole crabs and coquina clams dominated the macroinvertebrate community for most of the year. Mole crab densities were highest from April through October, and densities of the coquina clam *D. variabilis* were highest from May through November. Densities of both species declined sharply in the late fall and were completely absent between mid-January and mid-February. Recolonization by juveniles and adults of both species was evident by late February. Densities of the coquina clam *D. parvula* were highest from May through August. *D. parvula* disappeared from the intertidal zone in late August, and remained absent from the intertidal zone until the following March. Haustoriid amphipods (*Haustorius* sp. and *Amphiporeia virginiana*) dominated the benthic community for a brief period during early winter, but were present in low numbers throughout the remainder of the year. Peterson et al. (2006) detected seasonal changes in polychaete abundance at Bogue Banks. Densities of intertidal polychaetes (primarily *Scolelepis squamata*) increased after March, peaked during the warmer months, and declined in the fall.

More recent studies of the intertidal/shallow subtidal benthic community include those associated with a series of beach fill projects conducted between winter 2001-2005 (Peterson et al 2006, CSA 2002-2006). Peterson et al (2006) took advantage of the winter 2001-2002 beach nourishment project on Bogue Banks to evaluate the ecological impacts and recovery from large-scale sedimentation during the subsequent warm season as a function of the month of filling. He also utilized previous quantitative sampling data from 1998 (Manning 2003) at several localities along Bogue Banks, including areas to be filled and a control area outside but near the fill zone. Use of the temporal data before the project as well as sampling following the project allowed for a rigorous design that could use a "beyond BACI" (Underwood 1994) approach to control for natural temporal and spatial variation. Prior to the 2001-2002 beach nourishment, the Bogue Banks' beaches had not been modified by filling except for five smaller beach fill projects at Fort Macon and Atlantic Beach from 1973–1994 (Valverde et al. 1999) and dredge material disposal in spring 1990 along two small stretches of beach in PKS (Peterson et al. 2000). The 2001-2002 project dredged materials from offshore to place 100–176 m^3 of sediment per linear m along 10.8 km of shoreline from the western edge of Atlantic Beach to near the western boundary of Indian Beach. Nourishment of the beach began in November 2001, moving east to west until completed in April 2002. The temporal progression of fill allowed for a comparison of study sites that were filled in December, February, and early April to test for differences in impacts and rate of recovery as a function of date of disturbance (Peterson et al 2006). It should be noted that no biological sampling took place in January because of the dramatic seasonal depression of macrobenthic invertebrate abundances known to occur during the winter on Bogue Banks (Diaz 1980, Leber 1982).

Filling of the beach with much coarser sediments than occurred on the native beach caused dramatic suppression of beach macroinvertebrates for at least one warm season (Peterson et al 2006). As a result of the beach fill disturbance, invertebrate densities were depressed on filled beaches during the March-November time frame, with abundances of Donax spp. and haustoriid amphipods averaging less than 10% of control levels. Recovery on filled beaches was not initiated by either taxon during the March–November sampling. *Emerita talpoida*, an order of magnitude less abundant than Donax spp. on control beaches, showed a pattern of initial depression on filled beaches followed by recovery in mid-summer. Polychaetes, in particular *Scolelepis squamata*, experienced a warm-season increase in abundance of equal magnitude on filled and control beaches. Recruitment of ghost crabs appeared inhibited on filled beaches, likely due to the persistent shell hash. Intertidal shell cover on filled beaches averaged 25 – 50% in mid-summer as compared to 6 – 8% on control beaches. The author concluded that, despite adaptations of the benthic fauna to natural sediment dynamics, a high degree of sediment deposition, cumulative spatial disturbances along 10.8 km of beach, and the change in the coarse shelly character of the beach; beach fill resulted in a disturbance that exceeded biotic resilience of the benthic community for at least one warm season.

The Towns of Atlantic Beach, PKS, Indian Beach, and EI placed approximately 8.55 million cy of sand over approximately 21 miles of ocean shoreline along Bogue Banks in Carteret County from 2001 through 2005. The work was completed in several phases over a five-year period. Phases One and Two , which were completed during the winters of 2001/2002, 2002/2003, and 2003/2004 respectively, included nourishment of 12.5 miles of beach along PKS, Indian Beach, and EI with ~3.6 million cy of sand. Phase Three was completed between December 2004 and March 2005, including placement of ~700,000 cy from Bogue Inlet along about four miles of EI. Other smaller localized beach fill efforts also occurred during this period (see Section 2.0).

The biological monitoring plan for Phases One through Three of the Bogue Banks Renourishment Project (2001-2005) fulfilled the permit requirements set forth by federal and state resource agencies. The benthic sampling schedule performed over this period is summarized in Table 11. Monitoring was implemented to document the impact on invertebrates, fish, and endangered plants. The offshore borrow areas were left to adjust naturally and recolonize while other areas were being excavated. Fill sections were left to adjust naturally as soon as the required volumes were pumped into place and confirmed by surveys. Reports generated over the five year period were submitted as annual reports to the state and federal agencies (CSA 2002-2006). The monitoring plan scope (2001–2005) for benthic resources included the following goals:

Quantify the changes in benthic populations in the borrow areas.

Quantify the changes in benthic populations along the beach.

Compare impacted areas of the beach with unrestored areas.

Monitor the recovery and population of ghost crabs in the project area.

While the benthic sampling from 2001-2005 included all of Bogue Banks (CSA 2001-2006), the following summary is provided for only beaches affected by the proposed action alternative. Sampling was conducted twice annually (every June and November) for five years following the end of the Phase Two project on EI beach, or until organisms recovered to near or above baseline conditions. Two monitoring events were conducted in 2001 (June and November) to set baseline conditions for post-dredge monitoring comparison.

The seventh and final biological monitoring event for Phases One - Three took place in June 2005 (CSA 2006). For this monitoring event, spatial comparisons were made between dominant benthic invertebrates (mole crabs, coquina clams, and bristle worms). Baseline pre-dredge results from November 2001 were compared with the 2005 data in order to evaluate if the benthic community had returned to pre-dredge conditions.

Table 11. Summary on benthic monitoring events for Bogue Banks (2001-2005).

Date	Sample	Status
June 2001	Pre-Dredging, Spring Sample	Complete
November 2001	Pre-Dredging, Fall Sample	Complete
November 2001-April 2002	**Beach Nourishment, Phase 1**	Complete
June 2002	Post Dredging, Spring Sample	Complete
November 2002	Post Dredging, Fall Sample	Complete
November 2002-April 2003	**Beach Nourishment, Phase 2**	Complete
June 2003	Post Dredging, Spring Sample	Complete
November 2003	Post Dredging, Fall Sample	Complete
December 2004-March 2005	**Beach Nourishment, Phase 3**	Complete
June 2004	Post Dredging, Spring Sample	Complete
November 2004	Post Dredging, Fall Sample	Complete
June 2005	Post Dredging, Spring Sample	Complete
November 2005	Post Dredging, Spring Sample	Complete

Results of biological monitoring through June 2005 are summarized as follows:

PKS Beach – Four years after the beach fill events described above, species diversity and evenness returned to or above pre-dredge (baseline) levels. The numbers of mole crabs and bristle worms recovered to near or above baseline levels. Data showed that coquina clams and *A. virginiana* were still below baseline, but were recovering well.

Indian Beach – Species diversity and evenness decreased slightly since the previous annual post dredging monitoring event, but increased to near baseline levels. Species abundance was approaching baseline conditions.

EI Beach – Compared to previous pre-nourishment surveys, species diversity and evenness increased close to baseline levels. *A. virginiana* and mole crabs were below pre-dredge levels; however, abundance continued to increase. The numbers for coquina clams and bristle worms surpassed the baseline abundance values.

Control Sites – There were six control sites for Bogue Banks. Three control sites were located in EI (Stations 1–3). The other three control stations were located in Atlantic Beach (Stations 1–3). Three control sites were monitored for the final monitoring event, two from EI (Fairfax & Ocean, control Station 4), and one from Atlantic Beach (control Station 3). At Station 3, data revealed a decrease in species diversity and evenness since the previous annual sampling event. Total number of organisms increased since the last sampling event due to a spike in the bristle worm population. The abundance values for other species remained fairly constant throughout the study.

Both EI control stations showed a decrease in species diversity and evenness since the previous survey. There was an increase in number of organisms at the three stations due to spikes in populations from all four dominant species. Although species diversity, evenness, and abundance values were below baseline levels; data suggests that recovery of organisms were moving in a positive direction. The finalized biological monitoring (2005) for Phases One and Two confirmed that species present before nourishment had repopulated the nourished beaches by varying degrees, depending on the species (CSA 2006).

It is important to note, while the permit required benthic monitoring described above did qualitatively assess changes in abundance, species richness, and in species diversity and evenness over a 4-5 year period associated with three phases on beach construction, no quantitative analysis of temporal or spatial changes in the benthic community was performed. Due to all the pulsed cumulative disturbances across the 10.8 km area of beach fills over five years, accounting for observed temporal and spatial differences over time was not possible, nor was sorting out the effects of natural seasonal changes and spatial differences in sediment texture possible given the qualitative nature of the sampling design.

5.7.2 Nearshore and ODMDS Benthic Communities

Nearshore benthic communities between Morehead City and North Topsail Beach have been studied by Peterson et al. (1999), Coastal Science Associates Inc. (2006), the USACE (Hague and Massa 2010), CP&E (2004) and Dial Cordy (2012a). Although sampling sites and protocols varied, taxa in order of abundance remained relatively consistent including polychaetes, annelids, bivalve mollusks, amphipod crustaceans, echinoderms, and nematodes. The community of invertebrates sampled in each study is thought to be representative of those occupying this environment over a broad geographic area.

In association with the Bogue Banks 2001-2005 dredging and beach fill events (Section 2.0), CSA conducted a benthic study to assess effects of dredging benthic macroinvertebrates within borrow area B-2, located two miles south of Salter Path, Indian Beach offshore in an average depth of 35-42 ft. (CSA 2006). The three stations sampled within the borrow area and two outside controls were selected from those sampled by Peterson and Wells (2000). Sampling performed included a pre-dredging baseline study (November 2001) and annually for three years following dredging (CSA 2006). Summary results for borrow area B-2 are presented in Table 8 of the report and Tables 19-23 of Appendix 7.2. The dominant phyla found in this borrow area and the outside controls were polychaetes, crustaceans (amphipods), gastropods and bivalves. The benthic communities within the three borrow area stations showed a variable temporal and spatial response to dredging. Recovery in terms of species richness occurred within one year of dredging at two of the three stations, and in two-three years at the third station. Temporal changes in species richness were quite variable between dredged stations and between control stations, showing no definitive pattern. In terms of abundance, the population one year after dredging exceeded pre-dredge values within one year at two of the three stations. For the third dredged station, values never reached the baseline value but did increase each year. Abundance values on average were higher prior to dredging at the control stations than at the dredged stations. Species diversity and evenness showed similar trends with values exceeding baseline within one year of dredging at two of the three stations and in two-three years at the third station. Species richness and evenness values at the control stations were similar to those observed at the dredged stations. In summary, based on interpretation of the data contained in the report, the benthic community generally recovered within one year of dredging based on the metrics assessed.

In conjunction with the development of the Morehead City Harbor DMMP, the USACE Wilmington District investigated opportunities to expand the existing nearshore ODMDS off Bogue Banks (west of Beaufort Inlet) and create a new nearshore ODMDS off Shackleford Banks (east of Beaufort Inlet), in Carteret County, NC. To aid in the siting of the above locations, the benthic community was characterized over a broad area inshore of the existing Morehead ODMDS on the Beaufort Inlet ebb shoal (Hague and Massa 2010). This report included a description of macroinvertebrate and sediment sampling methods at 96 sample locations offshore of Beaufort; a summary of the laboratory analyses; a compilation of sediment and macroinvertebrate sampling results; and a determination of potentially least affected area(s). Using these results and associated index values, the stations were grouped based on similarity for low, medium, and high silt/clay content and corresponding fine sand content occurring within those groups. Stations with low species density (<627 number of species/m^2), diversity (<9.7), and/or richness (<2.8) were confirmed and presented within the groupings.

The faunal abundance of the major taxa is summarized below in Table 12. Dominant taxa based on percent composition included polychaetes (43%), crustaceans (25.7%), gastropods and bivalves (20.5 %), and echinoderms (1.6%). Based on single samples taken at the 96 stations, the total taxa collected was 260 species with 7,053 total individuals. The total number of individuals, total number of species, and density from the 96 stations ranged from 1-183 individuals, 1-57 total species, and 27.3-4,609 individuals/m^2, respectively. Simpson Diversity and Margelef's Richness ranged from 1-33.62 and 1.44-11.18, respectively.

Table 12. Summary of overall abundance of major benthic macroinfaunal taxonomic groups from the September 2009 sampling event.

Taxa	Total No. Taxa	% Total	Total No. Individuals	% Total
Annelida				
Oligochaeta	1	0.4	45	0.6
Polychaeta	88	33.8	3,098	43.9
Mollusca				
Bivalvia	38	14.6	744	10.5
Gastropoda	39	15.0	704	10.0
Scaphopoda	2	0.8	5	0.1
Arthropoda				
Malacostraca	66	25.4	1,814	25.7
Ostracoda	1	0.4	8	0.1
Echinodermata				
Asteroidea	1	0.4	1	0.0
Echinoidea	4	1.5	70	1.0
Holothuroidea	3	1.2	17	0.2
Ophiuroidea	2	0.8	29	0.4
Other Taxa	15	5.8	518	7.3
Total	**260**		**7,053**	

Source: Hague and Massa 2010

5.7.3 Hardbottom Benthic Resources

In January 2009, as part of an ongoing USACE shoreline analysis, nearshore groundtruthing investigations for potential hardbottom resources were undertaken along Bogue Banks from Beaufort Inlet to Bogue Inlet. A USACE designed protocol was implemented inshore of -25 ft NGVD and offshore beyond depth of closure. The groundtruthing locations were determined from previous side-scan back-scatter anomalies denoted in earlier geophysical surveys (Figure 13). Each geophysical survey irregularity was investigated as potential hardbottom resources. Based on groundtruth corroboration, each target was classified as varying

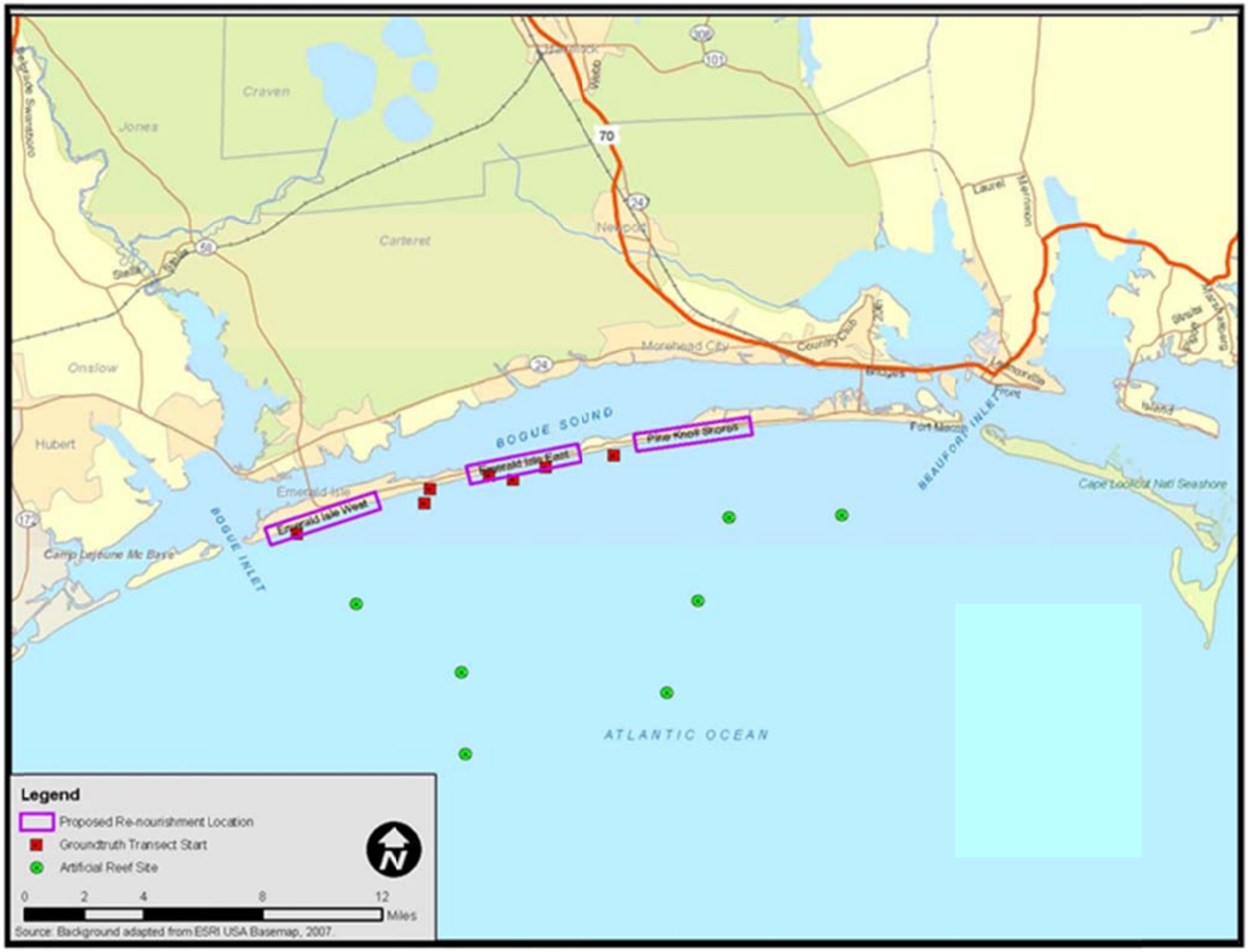


Figure 13. Hardbottom Groundtruthing and North Carolina Division of Marine Fisheries Artificial Reef Sites

textured sediments ranging from coarse shell-hash to fine dense clay and not as hardbottom resources (Anamar and CPE 2009). In addition, as part of a Carteret County 2011 archaeological remote sensing and target identification effort, the ODMDS was surveyed for cultural resources. This remote sensing effort confirmed no hardbottom resources are located within the ODMDS (Hall 2011). Based on the two studies discussed above (Anamar and CPE 2009, Hall 2011) no hardbottom benthic resources are located within the proposed Project area.

5.8 Fish and Wildlife Resources

5.8.1 Terrestrial

5.8.1.1 Maritime Shrub Thickets

The maritime shrub thicket community normally occurs landward of the dune where it is protected from salt spray and the full force of ocean winds. The maritime shrub thicket occurs sporadically along the backside of Bogue Banks; along the inlet spits, within upland disposal areas, and interspersed with marsh areas bordering the sound. However, a large portion of the maritime shrub thicket historically found within this barrier island community has been heavily impacted by development. Dominant shrubs and trees in the community are wax myrtle (*Myrica cerifera*), yaupon (*Ilex vomitoria*), red cedar (*Juniperus virginica*), live oak (*Quercus virginiana*), and loblolly pine (*Pinus taeda*). Vines are also common with greenbriar (*Smilax bonanox*), pepper-vine (*Ampelopsis arbore*a), and grape (*Vitus rotundifolia*) being particularly abundant. The community type offers excellent cover for neotropical migrating songbirds. Other important species that may be found in the maritime thicket include the seaside sparrow (*Ammodramus maritimus*), painted bunting (*Passerina ciris*), saltmarsh sharp-tailed sparrow (*A. caudacutus*), Nelson's sharp-tailed sparrow (*A. nelsoni*), as well as marsh wrens (*Cistothorus palustris*) and sedge wrens (*C. platensis*). Raptors may also be found during migration [e.g., American kestrel (*Falco sparverius*), merlin (*F. columbarius*), peregrine falcon (*F. peregrines*), bald eagle (*Haliaeetus leucocephalus*), and northern harrier (*Circus cyaneus*)].

5.8.1.2 Beach and Dune

Beach and dune communities that may be impacted occur adjacent to and within the beach placement areas of EI and PKS (approximately 78 acres). Terrestrial habitat types within these areas include sandy or sparsely vegetated beaches and vegetated dune communities. The first line of stable vegetation is outside or landward of the proposed project limits.

Mammals occurring in this environment are opossums (*Didelphis virginiana*), cottontails (*Sylvilagus* spp.), red foxes (*Vulpes vulpes*), gray foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), feral house cats (*Felis catus*), shrews (*Soricidae* spp.), moles (Talpidae), voles (*Microtus arvalis*), and house mice (Mysticeti).

The beach and dune community could be considered depauperate in both plants and animals. The beach environment is severe because of constant exposure to salt spray, shifting sands, wind, and sterile soils with low water retention capacity. Therefore, plant and animal species diversity within the beach and dune community is low. Common vegetation of the upper beach includes beach spurge (*Euphorbia polygonifolia*), sea rocket (*Cakile edentula*), and pennywort (*Hydrocotyle bonariensis*). The dunes are more heavily vegetated and common species are American beach grass (*Ammophila breviligulata*), panic grass (*Panicum amarum*), sea oats (*Uniola paniculata*), broom straw (*Andropogon virginicus*), seashore elder (*Iva imbricata*), and salt meadow hay (*Spartina patens*) (Nash 2003). Seabeach amaranth has been documented on Bogue Banks and is addressed in the BA [Dial Cordy and Associates Inc. (DC&A) 2012a]. Important macroinvertebrates of the beach/dune community are the mole crabs, coquina clams, and ghost crabs (*Ocypode quadrata*) (see Section 6.7)

Ghost crabs occupy the upper zone of the beach environment and function as an important predator in the beach community. Up to 60 percent of their diet consists of mole crabs and up to 25 percent consists of coquina clams (Wolcott 1978). During the sea turtle nesting season, ghost crabs are also known to prey on incubating sea turtle eggs and newly hatched sea turtle hatchlings. *O. quadrata* is the only ghost crab occurring in the southeastern United States and, though little is known regarding its life history, its reproductive and larval components most likely reflect that of other decapods. Although timing of recruitment is poorly understood, recruitment most likely occurs between late spring and early fall (Hackney et al. 1996).

5.8.2 Marine

Habitats within the Proposed Action Alternative borrow area (ODMDS) consist of both open-ocean water and bottom sediments; the latter includes coarse marls, sand, and silty sands deposited inside the ODMDS by previous and ongoing navigation maintenance disposal projects. Habitats along the transport pathway from the ODMDS to the placement area consist of nearshore water column and bottom habitat that ranges from soft muds to firm sands. The nearshore water column supports zooplankton and phytoplankton assemblages that serve as food for juvenile fish and commercially important invertebrates. Demersal and pelagic fish inhabit the water column (Section 5.9), including a number of federally managed species. Several species of marine mammals and sea turtles are seasonal residents (Section 5.10).

Marine waters in the vicinity of the beach nourishment placement areas and offshore borrow site provide habitat for a variety of commercial and recreational fish. Kingfish (Sciaenidae), spot (*Leiostomus xanthurus*), bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), spotted sea trout (*Cynoscion nebulosus*), southern flounder (*Paralichthys lethostigma*), red drum (*Sciaenops ocellatus*), king mackerel (*Scomberomorus cavalla*), and Spanish mackerel (*S. maculates*) are actively fished from boats, the beach, and local piers. According to the NCDMF commercial and recreational harvest statistics, the species noted above compose an average of approximately 28 percent of the total pounds of fish landed in NC in 2007 (http://www.ncfisheries.net/statistics/index.html). The surf zone typically exhibits a high diversity of fish fauna. According to data collected from surf zone seine sampling along the SAB, 130 fish species are known from the surf zone between NC and southern Georgia; of which, 47 species have been recorded from NC beaches. The major recruitment period for juvenile fishes to surf zone nurseries is late spring through early summer. The waters also accumulate juvenile, ocean spawning, and estuarine-dependent fish and invertebrates in the late winter and early spring before their transport through the inlets (Hackney et al. 1996).

As discussed in the above sections, the total placement includes 267 acres of which 78 acres is the dry sand beach and the intertidal zone area (approximately 189 acres below MHW, approximately 147 acres below MLW) serves as the primary habitat for invertebrates. These invertebrates, which are adapted to the high-energy, sandy-beach environment include: ghost crabs, mole crabs, coquina clams, amphipods, isopods, and polychaetes. The species are not commercially important; however, they provide an important food source for surf-feeding fish and shore birds. Offshore bottoms also provide habitat for benthic-oriented organisms as described in Section 5.7 Habitat Areas of Particular Concern (HAPCs) include hardbottom areas which generally support a diversity of soft corals, anemones, and sponges; providing habitat for reef fish such as black sea bass (*Centropristis striata*), red porgy (*Pagrus pagrus*), and groupers (*Epinephelus* spp.). Hardbottoms are also attractive to pelagic species such as king mackerel, Spanish mackerel, amberjack (*Seriola dumerili*), and cobia (*Rachycentron canadum*).

5.8.2.1 Non-ESA-Listed Marine Mammals

A total of 38 marine mammal species have been reported from coastal waters between Cape Hatteras and New River Inlet (Department of the Navy 2008). These species include 33 cetaceans (whales, dolphins, and porpoises), four pennipeds (seals, sea lions, and fur seals), and one sirenian (West Indian manatee) (Table 13). All marine mammals are protected under the Marine Mammal Protection Act (MMPA) of 1972, which prohibits the take (harassment or injury) of marine mammals in United States waters. A number of these 38 species are federally listed as threatened or endangered, including the North Atlantic right whale, humpback whale, sei whale, fin whale, blue whale, sperm whale, and West Indian manatee. These federally listed species are addressed in-depth in Section 5.10 and in the BA (DC&A 2012a). The vast majority of the remaining 26 non-listed species are not expected to occur in nearshore waters. Many of these species are typically found in offshore waters near the continental shelf break or beyond. A number of other species are known only from stranding records or rare sightings considered extralimital to their normal distribution. Marine mammal occurrence data compiled by the Department of the Navy (2003, 2008) indicate that the only non-listed species that are expected to occur regularly in the project area are the bottlenose dolphin and Atlantic spotted dolphin.

Bottlenose dolphins may be present in both estuarine and nearshore marine waters throughout the year, although estuarine occurrences peak during summer and most winter sightings are from the nearshore ocean (Department of the Navy 2003, 2008). Bottlenose dolphins along the South Atlantic coast include both resident and migratory populations. Studies indicate the presence of a year-round resident bottlenose dolphin population in the vicinity of Beaufort, North Carolina. This resident Beaufort population is the northernmost documented site of year-round bottlenose dolphin residency in the western North Atlantic (Koster et al. 2000). Atlantic spotted dolphins regularly occur in inshore waters south of Chesapeake Bay (Mullin and Fulling 2003). Nearshore sightings of Atlantic spotted dolphins have been recorded in the vicinity of the project area during winter, spring, and summer (Department of the Navy 2008).

Table 13. Marine mammals reported from coastal waters between Cape Hatteras and New River Inlet.

Common Name	Species Name	Status
North Atlantic right whale	*Eubalaena glacialis*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
Minke whale	*Balaenoptera acutorostrata*	
Bryde's whale	*Balaenoptera edeni*	
Sei whale	*Balaenoptera borealis*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Blue whale	*Balaenoptera musculus*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Pygmy sperm whale	*Kogia breviceps*	
Dwarf sperm whale	*Kogia sima*	
Cuvier's beaked whale	*Ziphius cavirostris*	
True's beaked whale	*Mesoplodon mirus*	
Gervais' beaked whale	*Mesoplodon europaeus*	
Blainville's beaked whale	*Mesoplodon densirostris*	
Sowerby's beaked whale	*Mesoplodon bidens*	
Northern bottlenose whale	*Hyperoodon ampullatus*	
Rough-toothed dolphin	*Steno bredanensis*	
Bottlenose dolphin	*Tursiops truncatus*	
Pantropical spotted dolphin	*Stenella attenuata*	
Atlantic spotted dolphin	*Stenella frontalis*	
Spinner dolphin	*Stenella longirostris*	
Striped dolphin	*Stenella coeruleoalba*	
Clymene dolphin	*Stenella clymene*	
Short-beaked common dolphin	*Delphinus delphis*	
Fraser's dolphin	*Lagenodelphis hosei*	
Risso's dolphin	*Grampus griseus*	
Melon-headed whale	*Peponocephala electra*	
Pygmy killer whale	*Feresa attenuate*	
False killer whale	*Pseudorca crassidens*	
Killer whale	*Orcinus orca*	
Long-finned pilot whale	*Globicephala melas*	
Short-finned pilot whale	*Globicephala macrorhynchus*	
Harbor porpoise	*Phocoena phocoena*	
Harbor seal	*Phoca vitulina*	
Gray seal	*Halichoerus grypus*	
Harp seal	*Pagophilus groenlandicus*	
Hooded seal	*Cystophora cristata*	
West Indian manatee	*Trichechus manatus*	Endangered

Source: Geo-Marine 2008
Note: Those species identified as endangered under the ESA are addressed in the BA (DC&A 2012a).

5.8.3 Avian

Birds common to the project areas' nearshore ocean are loons (*Gavia* spp.), grebes (*Podilymbus* spp.), northern gannets (*Morus bassanus*), cormorants (*Phalacrocorax* spp.), scoters (*Melanitta* spp.), red-breasted mergansers (*Mergus serrator*), gulls (*Larus* spp.), and terns (*Sterna* spp.) (LeGrand 1983, USACE 2007, Sauer et al. 2008). The habitats and food sources of such seabirds are within the marine environment; whether nearshore, offshore, or pelagic. The species can be divided into four groups by their feeding strategies which are reflected in their anatomy, physiology, and habitat niche: surface feeders; surface swimmers/pursuit divers; plunge-divers; and scavengers/pirates (i.e., steal from other birds). The waters in proximity of the proposed action area are very important to migrating and wintering northern gannets, loons, and grebes because of the abundant resources associated with inlet shoal features and Cape Lookout/Shackelford Banks. These inlet areas and associated shoals are considered EFH for several managed fish and shrimp (Caridea) species and are also considered HAPCs [South Atlantic Fishery Management Council (SAFMC) 1998, South Atlantic Region 2008a and 2008b]. These diverse marine and estuarine communities support a variety of fish species that provide a forage base for migrating and wintering sea birds. Terns feed by diving on insects and small fish and the black skimmer (*Rynchops niger*) feeds on shrimp or small fish by flying just above the water with the tip of its long lower mandible shearing the surface. The USFWS indicates that sea ducks raft in large numbers in the nearshore ocean waters of the project area during spring and fall migrations. Ducks, geese, and many kinds of shorebirds may also be found here during the spring and fall (Sauer et al. 2008).

The beaches and inlets of the project vicinity are heavily used by migrating shorebirds. However, dense development and high public use of project area oceanfront beaches may reduce the beachfront value to shorebirds. Though most of the project area is heavily developed, the spits at each end of the island provide important habitat adjacent to the inlets and associated intertidal shoals. These areas offer high value habitat for breeding birds including terns, black skimmers, piping plovers (*Charadrius melodus*), Wilson's plovers (*C. wilsonia*), and American oystercatchers (*Haematopus palliatus*). Additionally along the ocean beach, black-bellied plovers (*Pluvialis squatarola*), ruddy turnstones (*Arenaria interpres*), whimbrels (*Numenius phaeopus*), willets (*Tringa semipalmata*), red knots (*Calidris canutus*), semi-palmated sandpipers (*C. pusilla*), and sanderlings (*C. alba*) may be found (LeGrand 1983, USACE 2007, and Sauer et al. 2008). Table 15 provides a more complete list of waterbirds found in the project vicinity. The project area dunes support fewer numbers of birds, but can be very important habitats for resident species and migratory songbirds. The maritime forest nearby the project area is important for painted buntings; in the herbaceous dune areas, the American kestrel, merlin, bald eagle, peregrine falcon, northern harrier, and other raptors may be found during migration. Other birds occurring in the area are mourning doves (*Zenaida macroura*), swallows (Hirundinidae), fish crows (*Corvus ossifragus*), starlings (Sturnidae), meadowlarks (*Sturnella magna*), red-winged blackbirds (*Agelaius phoeniceus*), boat-tailed grackles (*Quiscalus major*), and savannah sparrows (*Passerculus sandwichensis*) (Johnson and Dechant-Shaffer 2002, Sauer et al. 2008).

The piping plover is federally listed as threatened under the ESA. Additional information regarding piping plover occurrences in the project area is provided in Section 5.10.3 and in the BA (DC&A 2012a). The red knot is currently a candidate for federal listing, and a number of additional shorebirds and waterbirds are listed by the State of NC as endangered threatened, special concern, or significantly rare (Table 14). These species may be found year-round in the study area during the breeding, migration, and wintering seasons with peak abundance occurring in the summer months. All these bird species may use the project area for roosting, foraging, breeding, and nesting (Potter et al. 1980).

Table 14. List of waterbirds that occur in the project area and their status.

Common name	Scientific name	Season[a]	Fed status[b]	NC status[c]
Red-throated loon	*Gavia stellata*	M, W		
Common loon	*Gavia immer*	M,W		
Horned grebe	*Podiceps auritus*	M,W		
Brown pelican	*Pelecanus occidentalis*	B,M,W		SR
Double-crested cormorant	*Phalacrocorax auritus*	B,M,W		
Northern gannet	*Morus bassanus*	M,W		
Great blue heron	*Ardea herodias*	B,M,W		
Great egret	*Ardea alba*	B,M,W		
Snowy egret	*Egretta thula*	B,M		SC
Reddish egret	*Egretta rufescens*	M		
Tricolored heron	*Egretta tricolor*	B,M		SC
Little blue heron	*Egretta caerulea*	B,M,W		SC
Black-crowned night heron	*Nycticorax nycticorax*	B,M,W		
White ibis	*Eudocimus albus*	B,M,W		
Glossy ibis	*Plegadis falcinellus*	B,M		SC
Osprey	*Pandion haliaetus*	B,M		
Clapper rail	*Rallus longirostris*	B,M,W		
Black-bellied plover	*Pluvialis squatarola*	M,W		
Wilsons plover	*Charadrius wilsonia*	B,M		SR
Semipalmated plover	*Charadrius semipalmatus*	M		
Piping plover	*Charadrius melodus*	B,M,W	T (E*)	T
Killdeer	*Charadrius vociferus*	B,M,W		
American oystercatcher	*Haematopus palliatus*	B,M,W		SC
American avocet	*Recurvirostra americana*	M		
Black-necked stilt	*Himantopus mexicanus*	B,M		SR
Greater yellowlegs	*Tringa melanoleuca*	M,W		
Lesser yellowlegs	*Tringa flavipes*	M,W		
Willet	*Tringa semipalmata*	B,M,W		
Spotted sandpiper	*Actitis macularius*	M		
Whimbrel	*Numenius phaeopus*	M		
Marbled godwit	*Limosa fedoa*	M,W		
Ruddy turnstone	*Arenaria interpres*	M,W		
Sanderling	*Calidris alba*	M,W		
Semipalmated sandpiper	*Calidris pusilla*	M		
Western sandpiper	*Calidris mauri*	M,W		
Least sandpiper	*Calidris minutilla*	M,W		
Red knot	*Calidris canutus* ssp. *rufa*	M,W	C	
Dunlin	*Calidris alpina*	M,W		
Short-billed dowitcher	*Limnodromus griseus*	M,W		
Bonaparte's gull	*Chroicocephalus philadelphia*	M,W		
Laughing gull	*Leucophaeus atricilla*	B,M		
Ring-billed gull	*Larus delawarensis*	M,W		
Herring gull	*Larus argentatus*	B,M,W		
Great black-backed gull	*Larus marinus*	B,M,W		
Gull-billed tern	*Gelochelidon nilotica*	B,M		T

Table 14. (concluded)

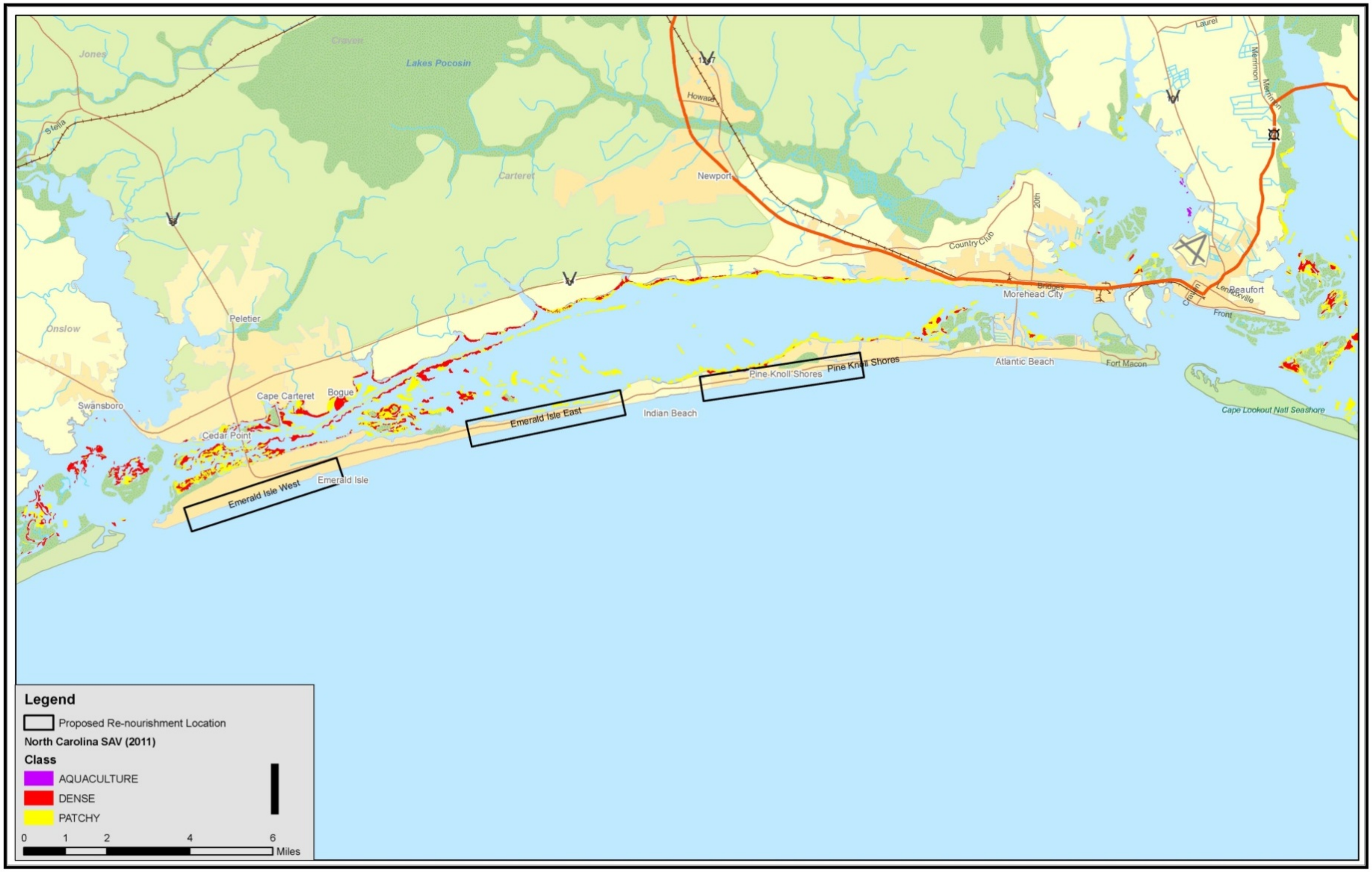
Common name	Scientific name	Season[a]	Fed status[b]	NC status[c]
Caspian tern	*Hydroprogne caspia*	B,M,W		SR
Royal tern	*Thalasseus maximus*	B,M,W		
Sandwich tern	*Thalasseus sandvicensis*	B,M		
Common tern	*Sterna hirundo*	B,M		SC
Forster's tern	*Sterna forsteri*	B,M,W		
Least tern	*Sternula antillarum*	B,M		SC
Black tern	*Chlidonias niger*	M		
Black skimmer	*Rynchops niger*	B		SC

Sources: LeGrand, 1983, http://www.aou.org/checklist/north/, North Carolina Wildlife Resources Commission (NCWRC) (Sara Schweitzer).
[a]. Season: B = Breeding, M = Migrating, W = Wintering
[b]. Federal status: Endangered (E), Threatened (T), Candidate (C) (http://www.fws.gov/endangered/).
*Two distinct piping plover populations are recognized under the ESA. The piping plover in the Great Lakes is an endangered species and the Northern Great Plains and Atlantic Coast piping plovers are threatened. Both populations are found on the North Carolina coast.
[c]. North Carolina Status: Endangered (E), Threatened (T), Special Concern (SC), Significantly Rare (SR).
E, T, and SC status species are given legal protection status by the NCWRC. SR status is defined as any species which has not been listed by the NCWRC as E, T, or SC species; but which exists in the state in small numbers and has been determined by the North Carolina Natural Heritage Program to need monitoring (http://www.ncnhp.org/Pages/heritagedata.html).

5.9 Essential Fish Habitat and Managed Species

As amended, the MSFCMA (P.L. 94-265) set forth new requirements for the NMFS, regional fishery management councils (FMC), and other federal agencies to identify and protect important marine and anadromous fish habitat. Those amendments established procedures for identifying EFH and a requirement for interagency coordination to further the conservation of federally managed fisheries. As mandated in the Magnuson-Stevens Act and in coordination with NMFS, several fishery management councils the SAFMC, Mid-Atlantic Fishery Management Council (MAFMC), and the Atlantic States Marine Fishery Commission oversee and manage species and EFHs found within the Project area.

The SAFMC manages marine areas including live/hardbottoms, coral and coral reefs, artificial/manmade reefs, *Sargassum*, and the marine water column as well as many estuarine features. Similarly, the MAFMC manages the marine water column as well as estuarine areas (SAR 2008a, MAFMC 2011). The ASMFC coordinates conservation and management between states sharing near shore fishery resources while working cooperatively with the United States East Coast Fishery Management Councils (ASMFC 2011). As discussed in DC&A 2012b, the estuarine marshes are essential habitat to many managed species and serve multiple functions to various finfish life-stages (Street et.al. 2005). Considered HAPCs, the nearest North Carolina Division of Marine Fisheries (NCDMF) designated primary nursery areas (PNA) are approximately three miles from Bogue and Beaufort Inlets; Hawkins and Dicks Creek, Calico and Turner Creek, respectively. Archer Creek is approximately 0.5 miles from a recipient beach location, but separated by EI proper and the nearest SAV's are approximately 0.5 miles from both Bogue and Beaufort Inlets (NCDMF 2011) (Figure 14).



Source: NCDMF 2011

Figure 14. Existing SAV areas within the vicinity of Bogue Banks

The Project Action Alternative proposes no efforts within Beaufort or Bogue Inlets, offshore relief areas, or within Bogue or Back Sounds where the above EFH locations would or could exist. The EFH areas within the Project area include the marine water column and unvegetated sandy bottoms.

Table 15 lists the federally managed fish species potentially found in the Project area for which Fishery Management Plans (FMP) have been developed by the SAFMC, MAFMC, and NMFS. In addition, Table 8 lists the species' life stages and area locations that have designated EFH. The categories of EFH and HAPC as well as a description of specific HAPC resources (i.e., hardbottom, coral, artificial reef, and *Sargassum*) in the Project area are provided in the March 2012 EFH Assessment prepared by DC&A. The fish species and habitats shown require special consideration to promote their viability and sustainability. This section briefly summarizes what can be found in more detail in the EFH Assessment (DC&A 2012b).

Table 15. Federally managed fish species.

Species		Life Stage(s) Found at			
Common Name	**Scientific Name**	**Bogue Inlet**	**Bogue Sound**	**Beaufort Inlet**	**Back Sound**
INVERTEBRATES					
Brown shrimp	*Farfantepenaeus aztecus*	ELJA	LJA	ELJA	LJA
White shrimp	*Litopenaeus setiferus*	ELJA	LJA	ELJA	LJA
Pink shrimp	*Farfantepenaeus duorarum*	ELJA	LJA	ELJA	LJA
Spiny lobster	*Panulirus argus*	JA	JA	JA	JA
COASTAL DEMERSALS					
Red drum	*Sciaenops ocellatus*	ELJA	ELJA	ELJA	ELJA
Bluefish	*Pomatomus saltatrix*	JA	JA	JA	JA
Summer flounder	*Paralichthys dentatus*	LJA	LJA	LJA	LJA
COASTAL PELAGICS					
Spanish mackerel	*Scomberomorus maculatus*	LJA	LJA	LJA	LJA
King mackerel	*Scomberomorus cavalla*	JA	JA	JA	JA
Cobia	*Rachycentron canadum*	LJA	JA	LJA	JA
Dolphinfish	*Coryphaena hippurus*	JA	N/A	JA	N/A
SNAPPER/GROUPER					
Black sea bass	*Centropristis striata*	LJA	LJA	LJA	LJA
Rock sea bass	*Centropristis philadelphica*	J	J	J	J
Gag grouper	*Mycteroperca microlepis*	JA	J	JA	J
Black grouper	*Mycteroperca bonaci*	J	J	J	J
Gray snapper	*Lutjanus griseus*	J	J	J	J
Yellow jack	*Carangoides bartholomaei*	J	J	J	J
Blue runner	*Caranx crysos*	J	J	J	J
Crevalle jack	*Caranx hippos*	J	J	J	J
Bar jack	*Caranx ruber*	J	J	J	J
Sheepshead	*Archosargus probatocephalus*	JA	JA	JA	JA

Table 15. (concluded)

Species		Life Stage(s) Found at			
Common Name	Scientific Name	Bogue Inlet	Bogue Sound	Beaufort Inlet	Back Sound
HIGHLY MIGRATORY					
Bluefin tuna	*Thunnus thynnus*	N/A	N/A	A	N/A
SHARKS					
Spiny dogfish	*Squalus acanthias*	JA	N/A	JA	N/A
Smooth dogfish	*Mustelus canis*	JA	J	JA	J
SMALL COASTAL SHARKS					
Bonnethead	*Sphyrna tiburo*	JA	JA	JA	JA
Atlantic sharpnose	*Rhizoprionodon terraenovae*	JA	JA	JA	JA
Blacknose shark	*Carcharhinus acronotus*	JA	JA	JA	JA
Finetooth shark	*Carcharhinus isodon*	JA	JA	JA	JA
LARGE COASTAL SHARKS					
Great hammerhead	*Sphyrna mokarran*	JA	N/A	JA	N/A
Scalloped hammerhead	*Sphyrna lewini*	JA	N/A	JA	N/A
Smooth hammerhead	*Sphyrna zygaena*	JA	N/A	JA	N/A
Nurse shark	*Ginglymostoma cirratum*	JA	N/A	JA	N/A
Blacktip shark	*Carcharhinus limbatus*	JA	N/A	JA	N/A

Legend: E, Egg; L, Larval; J, Juvenile; A, Adult; N/A, Not Applicable [National Oceanic and Atmospheric Administration, Fisheries Service 2011a and 2011b, and DC&A 2012b]

5.9.1 State Managed Fish Species

The state has prepared FMPs for several fish species that utilize resources within the study area. These species include striped mullet (*Mugil cephalus*), spotted sea trout, southern flounder, three species of sea mullet or southern kingfish (*Menticirrhus americanus*), gulf kingfish (*M. littoralis*), and northern kingfish (*M. saxatilis*), striped bass (*Morone saxatilis*), and red drum. Of these species, the red drum and southern flounder are also federally managed by the SAFMC. All of these species use the project area during a portion of their life cycle. The following subsections contain a summary of excerpts contained in the state FMPs (http://www.ncdmf.net/fmps/index.html) and provide detail pertaining to life cycle requirements and habitat use of each species within the study area.

5.9.1.1 Striped Mullet

The striped mullet fishery has played a significant role in the history of the NC commercial and recreational fishing industry and was ranked as the most abundant and important saltwater fish of NC in the early 1900's (NCDMF 2006a). Currently, the NC striped mullet commercial fishery is the largest along the United States Atlantic seaboard. However, recognizing the increased fishing pressure, the NC stock has been designated a species of concern since 1999.

Striped mullet are found in almost all shallow marine and estuarine habitats including beaches, tidal flats, lagoons, bays, rivers, channels, marshes, and grass beds. Habitat use varies greatly based on life history stages, seasons, and location (NCDMF 2006a).

Adult spawning migration occurs in fall and winter months in the southeastern United States, with larvae mostly found within the offshore surface waters during the winter and spring months. Larval shoreward migration is likely facilitated by onshore, wind-driven, (Ekman) drift; characteristic of southeastern United States winter wind patterns.

5.9.1.2 Spotted Sea Trout

Spotted sea trout, also known as speckled trout, is a highly sought after commercial and recreational fish in NC (NCDMF 2010). They are harvested throughout the year with a large peak in the fall/winter (October – February) and a small peak in the spring (April – May). The spawning season for spotted seatrout varies depending on location. In NC, spawning occurs from April to October, with a peak in May through June. Spawning takes place on or near seagrass beds, sandy banks, shell reefs, near the mouths of inlets, and off the beach (NCDMF 2010). Larvae utilize the passive transport of tidal flow to migrate into and within estuaries for settlement. Spotted seatrout have distinct seasonal migrations and migrate to deeper, warmer water in the estuaries and ocean during winter months and return to oyster beds and shallow bays and flats as the water warms.

The diet of seatrout varies and consists of copepods, mysids, amphipods, polychaetes, and shrimp within the small size class (<5.5 inches) and a variety of fishes [i.e. menhaden (*Brevoortia* spp.), spot, striped mullet] and shrimp as they get larger (>5.5. inches). Spotted seatrout use the water column habitat for spawning, egg and larval transport, foraging, and movement throughout the estuary and nearshore coastal areas. Of the available habitats, marine soft bottom has been noted to function as important habitat for spotted seatrout, especially during summer and winter estuarine temperature extremes. The complex structure of shell bottom also functions as an important nursery, foraging area, and refuge for this species. The invertebrates and small resident finfish living on and among shell bottom provide juvenile and adult spotted seatrout with an important forage base.

5.9.1.3 Southern Flounder

NCDMF (2005) considers the southern flounder the most economically important commercial finfish species in NC and it is a significant component of the recreational fishery. Summer flounder was historically the primary flounder species landed in the State until the decline in the fishery in the mid-1980s, at which point the harvest of southern flounder began to increase. Summer Flounder are currently federally managed by the MAFMC. The majority of the landings of southern flounder in NC have historically come from Pamlico, Albemarle, and Core sounds.

Habitat use patterns of southern flounder vary among riverine, estuarine, and coastal waters depending on life stage. In NC, adult southern flounder inhabit estuarine waters during the spring and summer; preferring the lower salinity portions of the sounds, rivers, and bays. Adults typically migrate out of the rivers and estuaries in the fall in order to spawn over soft bottom shoals in the ocean during the winter months. Following the spawning period, adult flounder return through the inlets to the estuaries and rivers. Planktonic larvae remain in the offshore waters for between 30 to 60 days before they are carried through ocean inlets into estuaries through passive transport in late winter. The southern flounder's diet consists of mainly fish [including mullet, menhaden, shad (*Alosa sapidissima*), anchovies (*Engraulis* spp.), pinfish (*Lagodon rhomboides*), mojarra (*Eucinostomus gula*), and Atlantic croaker (*Micropogonias undulatus*)], crabs [including blue (*Callinectes sapidus*), mud (*Scylla serrata*), and stone crabs (*Menippe mercenaria*)], mysids, mollusks, penaeid shrimp (*Penaeus* spp.), and amphipods - depending on life stage.

5.9.1.4 Sea Mullet

Three species of kingfish occur in NC: southern kingfish, gulf kingfish, and northern kingfish. Kingfish are demersal members of the drum family (Sciaenidae). Southern kingfish is the most abundant kingfish in the SAB, including the project area, and Gulf of Mexico. These species support significant recreational and commercial fisheries (NCDMF 2007).

All three species are short-lived demersal fish that inhabit nearshore ocean and estuarine habitats ranging from nearly fresh [2.0 parts per thousand (ppt)] to hypersaline (36.6 ppt) waters depending on the species. Kingfish spawn during early spring to early fall, and as temperatures cool; southern kingfish move to deeper, warmer water or migrate south. Spawning locations are unknown off NC; however, anecdotal evidence suggests spawning occurs in soft bottom habitat of the nearshore ocean and possibly inshore (NCDMF 2007). Juvenile kingfish are spring-summer residents of the surf zone with abundances peaking in the spring.

The kingfish are opportunistic epi-benthic or planktonic feeders; feeding predominantly on polychaetes, crustaceans, copepods, and small fishes as adults. The re-suspension and retention of inorganic nutrients in the surf zone, an important nursery area for kingfish, creates a food rich environment for larvae and juveniles. Additionally; intertidal flats, ocean beaches, and inlets are dynamic soft bottom features comprised of shifting sands; which also serve as a highly valuable foraging area.

5.9.1.5 Striped Bass

Striped bass which inhabit coastal rivers and estuaries in NC exhibit two differing life history strategies (NCDMF 2004a). Some portion of the stock is migratory; with mature adults residing in the Atlantic Ocean, returning to the river to spawn in the spring, and migrating back to the ocean for the summer and fall months. Both migratory and resident life history strategies necessitate use of river segments with sufficiently flowing waters for spawning, riverine and estuarine nursery habitat for egg; larval; and early juvenile stages. Estuarine as well as oceanic habitats are used by sub-adults and mature adult fish.

Migratory striped bass use the water column of inland and coastal rivers for spawning. They migrate to and from the spawning grounds of rivers and adjacent estuaries and inlets to the Atlantic Ocean, where they spend much of the spring, summer, and fall. Striped bass adults are reported to remain relatively close (4-5 mi) to shore when in the ocean.

5.9.1.6 Red Drum

As described by NCDMF (2008), red drum is common along the Atlantic coast over a wide range of habitats from Chesapeake Bay to Key West, Florida. Red drum spawning occurs at night in or around major estuaries and inlets within a salinity range of 25-35 ppt and temperatures between 22-30 °C. In NC, larvae are found over a wide range of salinities (0-33 ppt). Fertilized eggs and larvae are passively transported through the water column from the spawning sites to shallow bays and estuaries via wind and tidal currents. The majority are transported to the upper reaches of the estuary where they settle out in shallow, low-salinity nursery areas with abundant food supplies, such as coastal creeks, protected bays with sandy or muddy bottoms, and grass beds.

Red drum are eurythermal and in NC they have been collected over a wide range of habitat types and associated temperature and salinity ranges. During extreme cold conditions in the winter, small juvenile red drum leave the shallow water habitats for channels and other deep water areas and then return to shallow water areas the following spring as water temperatures rise. Once mature, red drum tend to spend more time in the ocean; but are still estuarine dependent as they come inshore to feed, develop, and spawn. Red drum forage on a variety of prey items, depending on their life stage and associated habitat preference.

In the fall, a portion of the sub-adult fish residing in the rivers move toward higher salinity areas such as the barrier islands' grass flats and shoals, inlets, and the surf. Sub-adults residing near coastal inlets and barrier islands during the summer likely enter the surf in the fall. During the spring, adult red drum occur along the beaches and inlets for one to two months as they move from offshore wintering grounds. By late September, most adult drum are found around the coastal inlets, outer bars, shoals, and along the beaches where they remain through November before moving offshore for winter. The EFH prepared for this project describes habitats for this species in detail (DC&A 2012b).

5.9.1.7 Shellfish

The commercial fishing industry is a very important economic component to NC. According to Burgess and Bianchi (2004), shellfish (i.e., bivalves, crustaceans, and others) as a whole are more economically important than finfish in NC. The commercial shell fishing industry in NC consists of Eastern oysters (*Crassostrea virginica*), hard clams (*Mercenaria mercenaria*), bay scallops (*Argopecten irradians*), blue crabs, and shrimp. Between 1972 and 2002, the total shellfish composition of NC commercial landings has varied. Total shellfish landings have exhibited an overall increase, and the value for shellfish landed exhibited an overall increase. From 1994 to 2002, the majority of shellfish landings and revenue was attributable to hard blue crabs and shrimp (Burgess and Bianchi 2004). Although important resources in and around Bogue Banks, the Proposed Action Alternative does not include estuarine habitats associated with shellfish species other than blue crabs and shrimp. Therefore, other species such as hard clams and eastern oysters are not further discussed or evaluated within this document.

5.9.1.8 Blue Crabs

Blue crabs are managed under the NC blue crab FMP dated December 2004 (NCDMF 2004b). With increasing concerns over fluctuating blue crab landings and increasing fishing effort, numerous requests have been made to further protect the spawning stock of blue crabs in NC. The blue crab life cycle consists of an offshore phase and an estuarine phase. Blue crabs use a wide range of habitats depending on their life stage, sex, maturity, and associated salinity preferences (NCDMF 2004b). After mating, females migrate to high-salinity waters in lower estuaries, sounds, and nearshore spawning areas. Most females spawn for the first time two to nine months after mating, usually from May through August the following season. Juveniles (i.e., typically 2.5 millimeters [mm] wide) gradually migrate into shallower, less-saline waters in upper estuaries and rivers where they grow and mature. When air temperatures drop below 50 °F, adult crabs leave shallow, inshore waters and seek deeper areas where they bury themselves in mud and remain in a state of torpor throughout the winter (Zinski 2006).

5.9.1.9 Shrimp

Shrimp are managed under the NC shrimp FMP dated April 2006 (NCDMF 2006b). The most common commercially important species in NC are the Penaeid shrimp: white shrimp (*Litopenaues setiferus*), pink shrimp (*Farfantepenaeus duorarum*), and brown shrimp (*F. aztecus*). Penaeid shrimp are spawned in the ocean and carried by tides and wind driven currents into the estuaries. By late summer and fall, they return to the ocean to spawn (NCDMF 2009). The most significant threat to shrimp stocks is loss or degradation of habitat from pollution or physical alteration. Critical habitat types that support juvenile shrimp nursery areas include salt marsh and inshore seagrass habitat (NCDMF 2006b). The EFH prepared for this project described in detail habitats for this species (DC&A 2012b).

5.10 Threatened and Endangered Species

The ESA of 1973, as amended (16 U.S.C. 1531–1543), provides a program for the conservation of threatened and endangered (T&E) plants and animals and the habitats in which they are found. The lead federal agencies for implementing the ESA are the U.S. Fish and Wildlife Service (USFWS) (http://www.fws.gov/) and the National Marine Fisheries Service (NMFS) (http://www.nmfs.noaa.gov/). The USFWS has primary responsibility for terrestrial organisms (including sea turtles on land) as well as some marine species such as manatees, while the responsibilities of NMFS are mainly marine wildlife such as whales, dolphins, pinnipeds, sea turtles and anadromous fish [i.e., shortnose (*Acipenser brevirostrum*) and Atlantic sturgeons (A. oxyrhynchus)]. Section 7 of the ESA requires federal agencies to use their legal authorities to promote the conservation purposes of the ESA and to consult with the USFWS and NMFS, as appropriate, to ensure that effects of actions they authorize, fund, or carry out will not jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat of such species.

In accordance with Section 7 (a)(2) of the ESA, BOEM and the USACE have been in consultation with the USFWS and NMFS to ensure that effects of the proposed Post-Irene Renourishment Project would not jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat of such species.

Updated lists of T&E species for the project area (Carteret County, NC) were obtained from the NMFS (Southeast Regional Office, St. Petersburg, FL) (http://sero.nmfs.noaa.gov/pr/endangered%20species/specieslist/PDF2010/South%20Atlantic.pdf) and the USFWS (Field Office, Raleigh, NC) (http://www.fws.gov/raleigh/es_tes.html) websites. These lists were combined to develop a composite list of T&E species that could be present in the project area based upon their geographic range. However, an actual species occurrence in the area would depend upon the availability of suitable habitat, the season of the year relative to a species' temperature tolerance, and migratory habits. A summary of the likelihood of occurrence for protected species is provided below. Additional information is provided in the BA (DC&A 2012a).

5.10.1 Whales

5.10.1.1 North Atlantic Right Whale (Endangered)

The North Atlantic right whale (*Eubalaena glacialis*) population is divided into a western North Atlantic population, which numbers approximately 300 animals, and an eastern North Atlantic population that is nearly extinct (these whales would not be present in the proposed action area). Western North Atlantic right whales range from wintering and calving areas off the coast of the southeastern United States to summer feeding and nursery areas that extend northward from New England to Nova Scotia. Important summer feeding and nursery areas are located in Massachusetts Bay, Cape Cod Bay, the Great South Channel (east of Cape Cod), as well as the Bay of Fundy and the Scotian Shelf in Canada. In the fall, a portion of the western North Atlantic population (consisting primarily of pregnant females, females with young calves, and some juveniles) migrate southward to nearshore continental shelf waters off the coast of southern Georgia and northern Florida. Calving takes place from December through March, and the peak migration periods are November/December and March/April. Recent surveys along the mid-Atlantic coast indicate that some mother-calf pairs may also use the area from Cape Fear, NC, to South Carolina as a wintering/calving area (NMFS 2005). Designated critical habitat units for the right whale include the Great South Channel (east of Cape Cod), Massachusetts Bay, Cape Cod Bay, and near shore ocean waters from the Altamaha River in Georgia, south to central Florida [59 Federal Register (FR) 28793].

In an effort to better define the geographic and temporal extent of the right whale mid-Atlantic migratory corridor, Knowlton et. al (2002) analyzed 489 right whale sightings that occurred between 1974 and 2002. The largest number of sightings (34.4 percent) occurred within 0 to 5 nm of land, and well over half of the sightings (63.8 percent) occurred within 0 to 10 nm of land. Nearly all of the sightings (94.1 percent) were within 0 to 30 nautical miles (nm) of land. A total of 17 sightings were within a 35 nm radius of the Port of Morehead City, and 15 of these sightings were within a 20 nm radius of the port. Sightings in the vicinity of the Port of Morehead City occurred from October through April, with a peak during February and March. This same pattern also occurred in the vicinity of the Port of Wilmington. It is assumed that migrating right whales may be present in the vicinity of the ODMDS from October through April as they move back and forth between the summer feeding/nursery areas and winter calving sites.

5.10.1.2 Humpback Whale (Endangered)

Humpback whales (*Megaptera novaeangliae*) have a worldwide distribution that encompasses all oceans in both hemispheres (NMFS 1991a). The western North Atlantic population ranges from summer feeding grounds in the northeastern United States, Canada, and Greenland to winter mating and calving grounds in the West Indies. In the western North Atlantic, humpback whales spend the spring, summer, and fall within foraging grounds in the Gulf of Maine, the Gulf of St. Lawrence, Newfoundland/Labrador, and western Greenland. During the winter, most whales from the North Atlantic foraging grounds migrate to the West Indies where mating and calving occur (Waring et al. 2011). Significant numbers of whales are also sighted along the mid-Atlantic coast from New Jersey to NC during the winter, and it has been suggested that the mid-Atlantic areas represent supplemental foraging habitat for juvenile as well as mature humpback whales (Barco et al. 2002). No critical habitat has been designated for the humpback whale

Humpback whales occur in nearshore and offshore waters of North Carolina during the fall, winter, and spring as they migrate between the northern feeding grounds and the southern calving areas. As described above, there is also evidence that some humpbacks may overwinter along the mid-Atlantic coast between North Carolina and New Jersey (Barco et al. 2002). In North Carolina, humpback whale sightings are concentrated in the waters off of Cape Hatteras, primarily during the winter. An analysis of historical sighting and stranding data from the project area revealed two sightings in the nearshore ocean off of Bogue Banks, several sightings in the nearshore ocean off of Cape Lookout, and ten strandings between Cape Lookout and Bogue Inlet (Department of the Navy 2008). It is assumed that humpback whales may be present in the vicinity of the ODMDS during periods of winter migration.

5.10.2 West Indian Manatee (Endangered)

West Indian manatees (*Trichechus manatus*) are intolerant of cold water temperatures; and consequently, are generally restricted to inland and coastal waters of peninsular Florida during the winter. In the fall as water temperatures fall below 68°F, manatees aggregate at natural thermal refugia in the southern two-thirds of Florida or take up residence at power plants, paper mills, or other warm water industrial outfalls in Florida. In the spring, as water temperatures reach 68°F, manatees disperse from winter aggregation sites. Some remain near their thermal refuges, while others undertake extensive movements along the coast and up rivers and canals. Warm weather sightings are most common in Florida and Georgia. Summer sightings drop off rapidly north of Georgia, and sightings north of Cape Hatteras are rare (USFWS 2001). The current best estimate of population size is 3,807 animals based on aerial surveys of warm water refugia in 2009 (USFWS 2009a). Numerous coastal water bodies in Florida have been designated as critical habitat for the manatee. Critical habitat has been designated as far north as Nassau County on the east coast of Florida and as far north as Citrus County on the west coast of Florida (42 FR 47840-47845).

Manatee occurrences in NC are primarily restricted to the months of June through October. Sightings in the vicinity of Bogue Banks have been reported from the AIWW north of State Highway 101 (July 2000), Calico Creek (August 1999), the Beaufort waterfront (August 1999), Hammocks Beach State Park (June 1998), the Sportsman Pier in Atlantic Beach (August 1994), the United States Coast Guard Station at Fort Macon (August 1994), Barden Inlet (November 1992), Peletier Creek (October 1990), and the western end of Shackleford Banks (August 1983) (USFWS 2002).

Manatees inhabit marine, brackish, and freshwater environments where they are found in seagrass beds, salt marshes, freshwater bottom areas, and many other habitat types. Manatees feed on a wide variety of submerged, floating, and emergent vegetation. Seagrasses are a staple in coastal habitats and preferred foraging habitat consists of shallow seagrass beds with access to deep water. Manatees, in the vicinity of the Florida-Georgia border, feed on salt marsh vegetation [i.e., smooth cordgrass (*Spartina alterniflora*)] which they access at high tide. Although manatees tolerate a wide range of salinities; they prefer areas where osmotic stress is minimal, or areas that have a natural or artificial source of fresh water (USFWS 2001).

5.10.3 Piping Plover (Threatened)

Piping plovers are divided into three distinct breeding populations: the Atlantic Coast population (NC to Canada), the Great Lakes population, and the Northern Great Plains population. The Great Lakes breeding population is currently listed as endangered; whereas, the Northern Great Plains and Atlantic Coast breeding populations are currently listed as threatened. The estimated number of Atlantic Coast breeding pairs has increased steadily from 790 pairs in 1986 to 1,849 pairs in 2009 (USFWS 2011). The number of Great Lakes breeding pairs increased slightly from 51 pairs in 2003 to 63 pairs in 2008, while the United States Northern Great Plains breeding population increased from 586 pairs in 1996 to 1,212 pairs in 2006 (USFWS 2009b). The breeding range of the Atlantic Coast population extends from NC to Newfoundland, Canada. Piping plovers arrive on the Atlantic Coast breeding grounds and initiate courtship in late March or early April. Along the Atlantic Coast, most chicks fledge by the end of July, although flightless chicks may be present through late August (USFWS 1996a).

Southward migration to the wintering grounds occurs during late July, August, and September. The wintering ranges of the three breeding populations overlap, including coastal areas from NC to Texas, as well as northern Mexico and the Caribbean (USFWS 1996a). All piping plovers on the wintering grounds are considered threatened under the

ESA, regardless of breeding origin. The breeding, migratory, and wintering ranges overlap in NC; and consequently, piping plovers can be found in the state during every month of the year (Cameron et al. 2006). In NC, breeding sites are confined to undeveloped and unstabilized portions of barrier islands, most notably within the CLNS, Cape Hatteras National Seashore, Pea Island National Wildlife Refuge, and on Lea and Hutaff Islands (USFWS 2009b). Since 1986, the estimated number of breeding pairs in NC has ranged from 20 to 64 pairs (USFWS 2011). NC's barrier islands serve as important migratory stop over and wintering sites. Piping plovers from all three breeding populations utilize the NC coastline during the non-breeding season. Important stop over and wintering sites in NC include undeveloped beaches along Cape Hatteras National Seashore, CLNS, Bear Island, Bird Shoals, and Lea/Hutaff Island; as well as some sites on developed islands, such as the west end of Bogue Banks and the south end of Topsail Island (Cameron et al. 2006).

5.10.3.1 Breeding Habitat

Atlantic Coast nest sites are located above the high tide line on coastal beaches, sandflats at the end of sand spits, gently sloping foredunes, blowout areas behind primary dunes, and washover areas between dunes. Suitable dredge material deposits may also be used as nest sites (USFWS 1996a). Breeding piping plovers within the southern recovery unit are almost completely restricted to undeveloped, unstabilized, low lying barrier island flats and spits. Important nesting habitats include wide, flat, sparsely vegetated beaches with access to abundant moist substrate habitats for foraging. Nesting habitats at CLNS include the highly dynamic ends of barrier islands, recently closed and sparsely vegetated old inlets, expansive barrier mudflats, and newly created ocean-to-sound overwash sites (USFWS 2009b).

Foraging habitats include the intertidal zone of ocean beaches, overwash sites, mud flats, sand flats, wrack lines, and the shorelines of coastal ponds, lagoons, and salt marshes (USFWS 1996a). Of particular importance are moist substrate foraging habitats associated with blowouts, washover areas, spits, unstabilized and recently closed inlets, ephemeral pools, and sparsely vegetated dunes (USFWS 2009b). Broods exhibit a preference for mud flats, sand flats, ephemeral pools, and wrack (Cohen et al. 2010). Primary prey includes polychaete marine worms, insects, crustaceans, and bivalve mollusks (USFWS 1996a).

5.10.3.2 Wintering Habitat

Generally, wintering plovers on the Atlantic Coast are found at accreting ends of barrier islands; along sandy peninsulas, and near coastal inlets. Preferred foraging habitats include sandflats adjacent to inlets or passes, sandy mudflats along prograding spits, and overwash areas. Roosting sites generally include inlet and adjacent ocean and estuarine shorelines and nearby exposed tidal flats (USFWS 1996a). Piping plovers on the wintering grounds spend the majority of their time foraging. Their primary prey includes polychaete marine worms, crustaceans, insects, and bivalve mollusks. Adjacent habitats consisting of sand flats, mud flats, and algal mats above the high tide line are also important, especially for roosting plovers. Debris, detritus, and/or microtopographic relief provide refuge from high winds and cold weather. Important components of beach/dune habitats include surf-cast algae for foraging, sparsely vegetated backbeach habitats above high tide and seaward of the dune line for roosting, and spits and overwash sites for feeding and roosting. Plovers may also use flat, sparsely vegetated dredge disposal islands that mimic natural habitats. Piping plover habitats are constantly changing in response to dynamic coastal processes (erosion, accretion, succession, and sea level change) with habitats disappearing and being proximally reformed. The availability of suitable habitat is dependent on natural sediment transport processes and major storm events that control the formation and movement of barrier islands, inlets, and other coastal landforms (USFWS 2003).

5.10.3.3 Critical Habitat

Critical habitat has not been designated for the Atlantic Coast breeding population; however, critical habitat units for the wintering population have been designated along the Atlantic and Gulf coasts from NC to Texas (66 FR 36038 36143). In NC, a total of 18 critical habitat units have been designated from Dare County south to Brunswick County. Constituent elements of critical wintering habitat are those habitat components that are essential for the primary biological needs of foraging, sheltering, and roosting plovers. The primary constituent elements are associated with intertidal beaches and flats (mud flats, sand flats, algal flats, and washover passes) and associated dune systems and flats above high tide. Important components of intertidal flats include sand and/or mudflats with little or no emergent vegetation. Adjacent exposed or sparsely vegetated sand, mud, and algal flats above high tide are also important, especially for roosting plovers. Important components of the beach/dune ecosystem include surf cast algae, sparsely vegetated back beach habitats, salterns, spits, and washover areas. Only areas containing these primary constituent elements within the designated boundaries are considered critical habitat.

5.10.4 Sea Turtles

5.10.4.1 Loggerhead Sea Turtle (Threatened)

Loggerhead sea turtles (*Caretta caretta*) occur throughout temperate and tropical waters of the Atlantic, Pacific, and Indian Oceans. In the United States, loggerheads nest from Texas to Virginia; however, most nesting occurs from Alabama to NC. Loggerheads are commonly found throughout the North Atlantic, the northern Caribbean, the Bahamas; and east to the west coast of Africa, the western Mediterranean, and the west coast of Europe. During non-nesting years, adult females from United States nesting beaches occupy waters off the eastern coast of the United States, the Bahamas, the Greater Antilles, Yucatán, and the Gulf of Mexico. Adult loggerheads undertake extensive migrations between foraging grounds and nesting beaches (NMFS and USFWS 2007a, 2008).

Loggerheads are found in a wide variety of habitats that include nesting beaches, neritic waters (nearshore waters with depths < 600 ft), and oceanic waters (depths >600 ft). Loggerheads nest on ocean beaches, with nests typically positioned between the high tide line and the dune front. Relatively narrow, steeply sloped, coarse-grained beaches are the preferred nesting habitat. Estuarine waters represent important inshore habitat during the juvenile neritic stage. During this stage, loggerheads inhabit essentially all continental shelf waters off the coast of the eastern United States and in the Gulf of Mexico. Adults also inhabit nearshore waters, but are less likely to utilize enclosed, shallow estuarine waters. Shallow water habitats with expansive ocean access represent important foraging habitat for adults. Adults also inhabit offshore continental shelf waters from New York south throughout Florida and the Gulf of Mexico (NMFS and USFWS 2008). No critical habitat has been designated for the loggerhead sea turtle.

5.10.4.2 Green Sea Turtle (Threatened)

Green sea turtles (*Chelonia mydas*) are distributed circum-globally in tropical, subtropical, and to a lesser extent, temperate waters. In the United States, green sea turtles are distributed from Massachusetts to Texas. Nesting in the United States is limited primarily to the east coast of Florida, although green turtles nest in small numbers in Georgia, South Carolina, and NC. Habitats include ocean beaches, convergence zones in the open ocean, and foraging grounds in shallow protected waters (NMFS and USFWS 1991). Generally, adults remain in the nearshore environment, but may enter the oceanic zone when migrating between foraging grounds and nesting beaches. Recent studies indicate that some adults may also reside in the oceanic zone (NMFS and USFWS 2007b). Coastal waters that surround Culebra Island, Puerto Rico have been designated as critical habitat for the green sea turtle (63 FR 46693).

5.10.4.3 Kemp's Ridley Sea Turtle (Endangered)

Kemp's ridley sea turtles (*Lepidochelys kempii*) occur primarily in coastal waters of the Gulf of Mexico and the western North Atlantic Ocean. Data indicate that adults utilize coastal habitats of the Gulf of Mexico and the southeastern United States. Adults inhabit nearshore waters and are commonly found over crab-rich sandy or muddy bottoms. Nesting is limited primarily to the northeastern coast of Mexico, although rare nesting events have been recorded from the southeastern United States. Juveniles utilize a wide range of bottom substrates, but apparently depend on an abundance of crabs and other invertebrates (NMFS and USFWS 2007c). No critical habitat has been designated for the Kemp's ridley sea turtle.

5.10.4.4 Hawksbill Sea Turtle (Endangered)

Hawksbill sea turtles (*Eretmochelys imbricate*) are distributed circum-globally in tropical, and to a lesser extent, subtropical waters of the Atlantic; Indian; and Pacific Oceans. Nesting occurs on ocean beaches throughout the tropics and subtropics. In the continental United States, hawksbill sea turtles have been reported from all of the Gulf States and along the east coast as far north as Massachusetts; however, sightings north of Florida are rare. Hawksbill sea turtles are regularly sighted in the Florida Keys and on reefs off the coast of Palm Beach County. Major nesting areas in the western North Atlantic Ocean include the insular Caribbean, the Yucatan Peninsula in Mexico, and Panama. Nesting in the continental United States is restricted to the southeastern coast of Florida and the Florida Keys (NMFS and USFWS 1993). Juveniles and adults are most commonly associated with coral reef habitats; however, additional habitats may include other hardbottom habitats, seagrass beds, algal beds, mangrove bays and creeks, or mud flats. Post pelagic juveniles and adults utilize a variety of food items that include sponges and other invertebrates, as well as marine macroalgae. Adults undertake extensive migrations up to hundreds or thousands of miles between foraging grounds and nesting beaches (NMFS and USFWS 2007d). Critical habitat for the hawksbill sea turtle includes coastal waters that surround Mona and Monito Islands, Puerto Rico (63 FR 46693).

5.10.4.5 Leatherback Sea Turtle (Endangered)

The leatherback sea turtle (*Dermochelys coriacea*) occurs in all oceans of the world and has the largest geographic range of any sea turtle. Nesting occurs on beaches throughout tropical and subtropical regions; foraging turtles are distributed north and south into sub-polar regions. Major nesting areas in the western North Atlantic Ocean and Caribbean Sea include Florida, St. Croix, the United States Virgin Islands, Puerto Rico, Costa Rica, Panama, Columbia, Trinidad and Tobago, Guyana, Surinam, and French Guiana. Adults and sub-adults migrate seasonally to foraging areas in the northern latitudes. During the summer and fall, the highest densities of leatherbacks in the north Atlantic are located in Canadian waters (NMFS and USFWS 2007e). Although leatherback sea turtles are commonly known as highly pelagic animals, recent telemetry studies have documented high use foraging sites in continental shelf and slope waters (James et al. 2005). Leatherback sea turtles undertake extensive migrations between northern foraging grounds and tropical and subtropical nesting beaches (NMFS and USFWS 2007e). Coastal waters along the southwest coast of St. Croix, U.S. Virgin Islands have designated as critical habitat for the leatherback sea turtle (63 FR 46693).

5.10.4.6 Occurrence within the Project Area

NC's sounds and estuaries provide important developmental and foraging habitats for post-pelagic juvenile loggerhead, green, and Kemp's ridley sea turtles. Most of the information regarding the inshore distribution of sea turtles in NC has been generated by studies in the Pamlico-Albemarle estuarine complex. Large numbers of loggerhead, green, and Kemp's ridley sea turtles are incidentally captured each year during commercial fishing operations in the Pamlico-Albemarle estuarine complex. All three species are represented primarily by juveniles, with few reported captures of older juveniles and adults (Epperly et al. 2007). All three species move inshore during the spring, disperse throughout the sounds during the summer, then leave the sounds and move offshore during the late fall and early winter. Epperly et al. (1995a) reported the presence of sea turtles in inshore waters from April through December. Goodman et al. (2007) reported inshore and nearshore ocean occurrences from April through November.

Leatherback sea turtles are primarily a pelagic species preferring deep, offshore waters. Leatherbacks may be present in nearshore ocean waters during certain times of the year; however, they rarely enter inshore waters. Epperly (1995b) reported the appearance of significant numbers of leatherback turtles in nearshore ocean waters during May, coincident with the appearance of jellyfish prey. Sightings declined sharply after four weeks and only a few sightings were reported after late June. Leatherbacks were infrequently observed in inshore waters during this period. The surveys conducted by Goodman et al. (2007) recorded only one leatherback observation which occurred during the summer in the nearshore ocean south of Cape Hatteras. Epperly et al. (1995a) reported the occurrence of three leatherbacks in Core and Pamlico Sounds during December 1989.

Hawksbill sea turtles are very rare in NC waters and they rarely enter inshore waters (Epperly et al. 1995a). A total of nine hawksbill stranding incidents were reported along NC beaches between 1998 and 2009 (Seaturtle.org 2011). Strandings were reported during the months of January, March, April, and November. Epperly et al. (1995b) reported the incidental capture of one hawksbill in Pamlico Sound.

Several studies have reported a strong relationship between sea turtle distribution and sea surface temperature. Goodman et al. (2007) conducted aerial sea turtle surveys and sea surface temperature monitoring in Core Sound, Pamlico Sound, and adjacent nearshore ocean waters from July 2004 to April 2006. All but one of the 92 sea turtle observations occurred in waters where sea surface temperatures were above 11°C. All sightings in the sounds occurred between 16 April and 20 November; all sightings in the nearshore ocean occurred between 23 April and 27 November. The winter distribution of sea turtles offshore of Cape Hatteras was also correlated with sea surface temperatures above 11°C (Epperly et al. 1995c). In a similar study by Coles and Musick (2000), sea turtle distribution offshore of Cape Hatteras was restricted to sea surface temperatures ≥13.3°C.

In NC, the sea turtle nesting and hatching season extends from May 1 through November 15 (Holloman and Godfrey 2008). Loggerheads account for the majority of the sea turtle nests in NC. Green sea turtles nest consistently in low numbers along the NC coast; while leatherback sea turtle nesting is rare in NC. NC nesting records for the period of 2000 through 2009 included 6,575 loggerhead sea turtle nests, 116 green sea turtle nests, and 33 leatherback sea turtle nests. Kemp's ridley sea turtle nesting is extremely rare in NC, with only five nesting records for the state. There are no records of hawksbill sea turtle nesting in NC. Sea turtles nest along the entire Bogue Banks ocean-facing beach. Since 1996, annual surveys have documented an average of 30 nests on Bogue Banks. Nearly all of the records are loggerhead nests; although two leatherback sea turtle nests and one green sea turtle nest were recorded in 2005 (Holloman and Godfrey 2008).

Permit stipulations for the three-phased Bogue Banks Restoration Project constructed in the mid-2000s included its own distinct sea turtle nesting monitoring program that was administered by the NC Wildlife Resources Commission. The complete suite of reports for this six-year effort (2002-07) were reviewed and a summary sheet for the 1996-2010 nesting seasons is available below (Table 16).

Table 16. Summary of turtle nestings and false crawls Bogue Banks, NC. 1996-2010.

Turtle Nestings

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Ft. Macon	0	5	3	3	2	NR[(a)]	NR	NR	0	3	NR	NR	6	6	5
Atlantic Beach	NR	NR	1	NR	NR	NR	NR	2	3	3	2[(k)]	1	7	4	4
Pine Knoll Shores	1[(f)]	11	3[(c)]	4	1	NR	5	9	5	15[(h)]	5	3	7	4	11
Salter Path/Indian Beach	1	NR	2[(d)]	NR	NR	NR	1	5	4	4[(i)]	6[(l)]	2	5	5	5
Emerald Isle	15[(g)]	18	16[(e)]	31[(b)]	14	21	13	22	9	14[(j)]	20[(m)]	16	8	16	29
Totals	17	34	25	38	17	21	19	38	21	39	33	22	33	35	54

False Crawls

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Ft. Macon	3	2	12	0	0	NR	NR	NR	0	0	NR	NR	1	3	1
Atlantic Beach	NR	NR	0	NR	NR	NR	NR	21	7	2	0	4	0	2	4
Pine Knoll Shores	0	1	25	0	0	NR	7	26	5	4	1	2	6	3	6
Salter Path/Indian Beach	0	NR	6	NR	NR	NR	0	10	6	2	1	1	1	0	1
Emerald Isle	0	1	1	30	6	19	12	23	2	15	11	20	6	4	14
Totals	3	4	44	30	6	19	19	80	20	23	13	27	14	12	26
False Crawl/Nest Ratio	0.2	0.1	1.8	0.8	0.4	0.9	1.0	2.1	1.0	0.6	0.4	1.2	0.4	0.3	0.5

Notes:
(a) NR = No Report.
(b) ~Twenty-two nests lost because of Hurricanes Dennis & Floyd, erosion.
(c) Two nests lost because of Hurricane Bonnie.
(d) Two nest lost because of Hurricane Bonnie.
(e) ~Nine nests lost because of Hurricane Bonnie and erosion.
(f) One nest lost because of Hurricane Fran.
(g) Fifteen nests lost because of Hurricanes Bertha and Fran.
(h) Two nests lost because of Hurricane Ophelia.
(i) One nest lost because of Hurricane Ophelia.
(j) Six nests lost because of Hurricane Ophelia.
(k) One nest lost because of Tropical Storm Ernesto.
(l) One nest lost because of Tropical Storm Ernesto.
(m) Four nests lost because of Tropical Storm Ernesto.

5.10.5 Shortnose Sturgeon and Atlantic Sturgeon

5.10.5.1 Shortnose Sturgeon (Endangered)

The shortnose sturgeon inhabits large Atlantic Coast rivers from the St. Johns River in northeastern Florida to the Saint John River in New Brunswick, Canada. Shortnose sturgeon occur primarily in slower moving rivers or nearshore estuaries associated with large river systems. Adults in southern rivers are estuarine anadromous, foraging at the freshwater-saltwater interface and moving upstream to spawn in the early spring. Shortnose sturgeons spend most of their life in their natal river systems and rarely migrate to marine environments. Spawning habitats include river channels with gravel, gravel/boulder, rubble/boulder, and gravel/sand/log substrates. Spawning in southern rivers begins in later winter or early spring and lasts from a few days to several weeks. Shortnose sturgeons are benthic omnivores, feeding on crustaceans, insect larvae, worms, and mollusks. Juveniles randomly vacuum the bottom and consume mostly insect larvae and small crustaceans. Adults are more selective feeders, feeding primarily on small mollusks (NMFS 1998).

Hall et al. (1991) and Collins et al. (2001) used telemetry studies to characterize the movements and habitats of the shortnose sturgeon in the Savannah River. According to Hall et al. (1991), spawning migrations began in late January and continued through March. Spawning areas were characterized by submerged timber with scoured sand, clay, and gravel substrate. After spawning, fish moved downstream and returned to brackish water within two weeks of spawning. Data indicated that most or all sturgeon left the freshwater reaches of the river by early May. The freshwater-saltwater interface was identified as an apparent feeding ground for sturgeon. Depths in the feeding areas ranged from 20 to 35 ft, and salinities ranged from zero to six ppt, depending on tidal stage. Foraging habitat substrate consisted of coarse sand and small gravel with some mud.

5.10.5.2 Atlantic Sturgeon (Endangered)

On 6 February 2012, NFMS published the Final Listing Rules for five distinct Atlantic sturgeon population segments along the Atlantic Coast (77 FR 5914, 77 FR 5880). The New York Bight, Chesapeake Bay, Carolina, and South Atlantic distinct population segments were listed as endangered; and the Gulf of Maine distinct population segment was listed as threatened. The historic range of the Atlantic sturgeon included estuarine and riverine systems from Labrador, Canada to the Saint Johns River in Florida. The historical distribution in the United States included approximately 38 rivers from Saint Croix River in Maine to the Saint Johns River in Florida, including spawning populations in at least 35 rivers. The current distribution in the United States includes 35 rivers, with spawning known to occur in at least 20 rivers. Atlantic sturgeon spawn in freshwater, but spend most of their adult life in the marine environment. Spawning adults generally migrate upriver in the spring/early summer. A fall spawning migration may also occur in some southern rivers. Subadult and adult Atlantic sturgeons emigrate from rivers into coastal waters, where they may undertake long range migrations. Migratory subadult and adult sturgeon are typically found in shallow (33 - 164 ft) near shore waters with gravel and sand substrates. Although extensive mixing occurs in coastal waters, Atlantic sturgeons return to their natal river to spawn (Atlantic Sturgeon Status Review Team 2007). No critical habitat has been designated for the shortnose sturgeon or the Atlantic sturgeon.

5.10.6 Seabeach Amaranth (Threatened)

5.10.6.1 Status, Distribution, and Habitat

Seabeach amaranth was listed as threatened throughout its range in 1993 (58 FR 18035 18042). Historically, this species occurred on coastal barrier island beaches from Massachusetts to South Carolina. Extant populations are currently known from South Carolina, NC, Virginia, Delaware, Maryland, New Jersey, and New York. The number of plants and populations has increased in all states since it was listed in 1993; however, recent trends since 2002 generally show a decline in all states. In contrast, populations in NC have generally been increasing since 2002.

Primary habitats include overwash flats on the accreting ends of islands, lower foredunes, and the upper strand on non-eroding beaches. Seabeach amaranth is an annual, meaning that the presence of plants in any given year is dependent on seed production and dispersal during previous years. Seeds germinate from April through July. Flowering begins as early as June and seed production begins in July or August. Seeds are dispersed by wind and water. Seabeach amaranth is intolerant of competition; consequently, its survival depends on the continuous creation of newly disturbed habitats. Prolific seed production and dispersal enable the colonization of new habitats as they become available. A continuous supply of newly created habitats is dependent on dynamic and naturally functioning barrier island beaches and inlets (USFWS 1996b).

Seabeach amaranth has been found along the entire ocean facing beach and inlet shorelines of Bogue Banks; distribution shifts from year to year. Annual surveys have been conducted on Bogue Banks since 1991. The entire island was surveyed from 1992 through 1995 and 2001 through 2009. Partial surveys were conducted in 1991 and 1997-2000. No surveys were conducted during 1996 due to the occurrence of Hurricanes Bertha and Fran. The total number of plants observed during complete survey years has varied widely, ranging from 130 to 23,180 plants. The Bogue Banks population increased from 2,935 plants in 2004 to 23,180 plants in 2005, and subsequently declined to 251 plants in 2006.

5.11 Recreation and Tourism

5.11.1 Commercial and Recreational Fishing

According to the NC commercial fish landings report produced annually by the NCDMF, the commercial finfish harvest was up 17 percent from 2008 to 2009. However, the commercial shellfish harvest was down 7.3 million pounds in 2009 mostly because of a 43 percent decrease in shrimp harvest from 2009. Total commercial landings in 2009 were 68.6 million pounds which is about 2.5 million pounds lower than in 2008 (NCDMF 2009). NCDMF reported approximately 1,877,577 pounds of commercial seafood landings in Carteret County in 2009 (NCDMF 2010). The top five species included blue crabs, oysters, white shrimp, southern flounder, and hard clams.

Predominant fisheries occurring offshore of the study area include the gill net fishery and shrimp trawl fishery. The gill net fishery generally occurs during the fall and winter at sporadic locations between zero to three miles offshore of the study area. The shrimp fishery occurs throughout the study area from about ¼ mile to three to four miles offshore.

Recreational fishing includes fishing from head boats, charter boats, private boats, piers, and the surf. Fishing from head boats is best in the winter months for snapper and grouper. Fishing from charter boats is excellent for king mackerel and bottom fish during the winter. Offshore gulfstream species like yellowfin tuna (*Thunnus albacares*) and wahoo (*Acanthocybium solandri*) are available. Inside fishing has been successful for inshore species such as red drum, speckled trout, and flounder. Private boat anglers can find bluefin tuna, king mackerel, and other bottom fish species in the offshore. Other species such as speckled trout, red drum, and flounder can be found on the inside areas of the sounds, creeks, and the AIWW.

5.11.2 Other Recreation

The mild climate and easy access to the beaches and waterways support a myriad of outdoor recreational activities in the study area including sunbathing, walking along the beach, surfing, picnicking, surf fishing, boating, etc. The sound sides of Bogue Banks support significant marsh communities with excellent bird watching opportunities and offer unique kayaking experiences. Numerous camps, tour guides, and rental companies are located throughout the study area to support the wide array of outdoor recreational interests.

6.0 ENVIRONMENTAL CONSEQUENCES

The Proposed Action Alternative could have both direct and indirect effects on the environment. The qualitative impact assessment of the alternatives presented in this document uses the categories "no impact," "less than significant impact," and "significant impact" to categorize effects.

6.1 Coastal Processes

6.1.1 Borrow Area

Impact-producing factors in dredge operations in the Proposed Action Alternative include the operation of the hopper draghead on the ocean floor, bottom-disturbing activities such as anchoring, the operation of engines on the dredges and supporting vessels, and the movement of vessels in coastal waters. These activities are described in detail in Section 4.2.

The Proposed Action Alternative would potentially alter the bottom topography compared to existing conditions. The dredging operation would reclaim sand from 197 acres of the 6,900 acres USEPA has permitted as the Morehead City ODMDS. The hopper dredge would remove the sand in furrows averaging two - five ft deep. Changes to the ODMDS, caused by dredging, could conceivably alter localized currents, waves, and bottom sediment type. These localized changes could cause minor and temporary changes in the surrounding environment, including food resources available to species (M&N 2009). However, from a period of 1975 to 2005 there have been 24 disposal events in the ODMDS and therefore is subjected to regular changes in bottom topography. Due to ongoing dredge disposal management, the ODMDS will not experience out of the ordinary perturbations as a result of the Proposed Action Alternative.

Comparisons with previous evaluations of physical effects associated with potential OCS borrow areas closer to shore, as well as characterizations of other OCS borrow areas up and down the Atlantic coast, indicate that the effects on coastal processes such as wave energy, currents, and shoreline erosion would be insignificant (Moffatt & Nichol 2008). This conclusion is based on the substantially greater distance the ODMDS is located offshore relative to other potential borrow sites. In addition, the operational mounding of dredged sand resulting in vertical relief is expected to continue as part of the authorized function of the ODMDS.

The Proposed Action Alternative would cause minor changes in the previously disturbed topography of the ocean floor within the ODMDS, but the effect would be less than significant given the operational nature and depth of the site (40 ft in depth on average), and the historic use of this site as a dredged material management area.

The No Action Alternative would have no effect on the topography of the borrow area as there would be no BOEM authorization for use of OCS material.

6.1.2 Beach Fill

The placement of fill would represent a potential source of direct and indirect impacts of the Proposed Action Alternative. Potential sources of disturbance during sand placement and grading activities include heavy equipment operations and associated noise emissions, night-time lighting, and various other supporting activities involving vehicular operations, generator use, and the presence of construction personnel on the beach. Potential effects on recipient beach habitats include the loss of microhabitat features (e.g., microtopographic relief, wrack lines, tidal pools), changes in beach substrate composition, and changes in beach morphology.

The No Action Alternative would not provide for beach fill placement due to the absence of authorization from BOEM for the use of OCS material. The Proposed Action Alternative would authorize placement of fill within a previously authorized renourished oceanfront shoreline, make use of a compatible sand source, and adhere to routine dredging windows; therefore, resulting in less than significant impacts.

6.2 Water Quality

Localized and temporary turbidity increases would be anticipated, but would disperse rapidly considering the low percentages of non-sand fractions, construction techniques, and the natural longshore dispersion affect. Cleary and Knierim (2001) observed that dredging within Nixon Channel and the associated beach nourishment along the northern portion of Figure Eight Island resulted in a temporary increase of turbidity and TSS primarily at the discharge site located on the ocean shoreline. The highest weekly average of turbidity and TSS recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively (Cleary and Knierim, 2001). Turbidity values at control sites located approximately 10,000 feet from the location of the fill operation averages 7.7 NTU while TSS values averaged 47.7. During the Bogue Inlet Channel Erosion Response Project, turbidity levels were shown to remain within ambient conditions (9.7 to 35.2 NTUs) during the dredging operations.

As discussed in Section 5.3, Phase I of the Bogue Banks Renourishment Project indicated that cross-shore turbidity was highest in the surf zone within the project area and quickly declined seaward of the outer bar to <10 NTU on average (CSE, unpublished data, April 2002). Outside the project area, the cross-shore turbidity was similar to the turbidity inside the project area. Higher turbidity was noted in the shallow, turbulent surf zone (70-120 NTU) but quickly diminished within several hundred feet seaward of the outer bar (~500 ft offshore).

Measurements during Phase 1 indicated that turbidity increases associated with dredging and beach construction tend to remain localized at the pump discharge area and remain at or near background levels within several hundred feet of the discharge. During a similar project in 2001-2002, the USACE dredged the lower portion of the Cape Fear River to renourish Bald Head Island, Caswell Beach, Oak Island, and Holden Beach (NC). Versar (2003) considered that turbidity increases associated with beach renourishment tended to remain isolated close to shore.

The State standard for turbidity is 25 NTU while TSS does not have a defined standard. Any increase in turbidity associated with the excavation of the oceanfront shoreline should be of short duration. Natural conditions support fluctuating turbidity levels in the nearshore and offshore water column of the study area. Storm events, hopper dredging, and standard beach nourishment operations are known to increase these levels due to the resuspension of sand and fine materials (CSE 2001). Because ~98 percent of the excavated material is in the sand size class or larger, it will settle almost immediately and not remain in suspension. Silt and clay-sized material will be decanted from the borrow material by virtue of the hopper dredging process. The excess water pumped into the hopper during loading flows overboard. The effect of turbidity levels in the borrow area is expected to fall within the natural range of background conditions.

Beach compatible sand would be mechanically reclaimed for beneficial placement along the Proposed Action Alternative 7.1-mile footprint. During these sand recovery efforts, localized turbidity levels would potentially increase given the borrow source is not 100 percent coarse grain material and any smaller sediment fractions would be re-suspended. Several typical projects have shown sediment settling rates ranging from centimeters/second to meters/second resulting in settlement primarily within the dredge site's immediate area (Bohlen 2002). Larger grain sizes within the plume settle more rapidly and their precipitation is referred to as the dynamic phase. Coarse sands (> 2 millimeters) and gravels settle almost immediately, often within a distance of less than 50 meters from the dredger (Challinor 2000). Table 8 shows 98 percent of the borrow source material is identified as sand [15A NCAC 07H .0312 (Technical Standards for Beach Fill Projects): granular sediment (≥ 2 millimeters and < 4.76 millimeters)]. The potential for indirect turbidity effects are limited by the borrow source's sand percentage and rapid fallout during removal and placement.

As discussed, these localized and temporary plumes would rapidly diffuse given the predominant grain size, offshore flow, and circulation patterns within the borrow source location (USACE 2009). Considering the relative high sand fraction percentages, these reclamation activities would not significantly affect the water column's chemistry, salinity, dissolved oxygen, or temperature. Transport corridors used by the dredging fleet would affect the water column spatially, but would not significantly alter current patterns, salinities, or temperatures.

Shoreline sand placement would be directed by use of diffusion plates and temporary diversion berms. These shoreline construction techniques induce a parallel slurry flow directing the sand slurry down the beach above the swash zone. The sand/water mix would traverse the beach with the heavier coarse sand precipitating. As the slurry ultimately reaches the wave run-up zone, the remaining sediment fractions would be carried into the nearshore water column. Localized and temporary turbidity increases would be anticipated, but would disperse rapidly considering the low percentages of non-sand fractions, construction techniques, and the natural longshore dispersion affect.

The potential indirect effects from the sand reclamation and placement efforts would possibly be seen if a turbidity plume migrated from the active recovery or placement zones. Such a potential could result from a non-compatible pocket of sediment, or if a plumbing-run leaks. Such potentials exist and appropriate responses (e.g. discharge redirection, work zone relocation, valve/gasket replacement) would be planned using preliminary geotechnical data, good engineering and construction techniques, observers, and inspections. Adjacent benthic and water column resources could be indirectly affected from potential temporary turbidity plume migration near the discharge point, but significant adverse effects are not anticipated considering the high sand fraction of the ODMDS material and construction management approaches.

The No Action Alternative would have no effect on water quality, as there would be no BOEM authorization for use of OCS material.

6.3 Air Quality

Criteria air pollutant emissions were estimated for the proposed dredging from the ODMDS and placement along the three reaches within EI and PKS. These emission estimates were developed using approximations of power requirements, duration of operations, and emission factors for the various equipment types. Multiplying horsepower rating, activity rating factor (percent of total power), and operating time yields the energy used. The energy used multiplied by an engine-specific emission factor yields the emission estimate.

Operational data from a similar renourishment/dredging operation in Duval County, Florida, was used to estimate power requirements and duration for each phase of the proposed hopper dredging activity. The horsepower (hp) rating of the dredge plant was assumed for each activity as follows: propulsion (3,500 hp), dredging (2,000 hp), pumping (2,000 hp), and auxiliary (1,165 hp). Different rating or loading factors were used for dredging, propulsion, and pumping. The estimated duration of dredging within the Duval County project was approximately 163 days, which is approximately a month and a half longer than the Proposed Action Alternative timeline. The estimated time to complete each dredge cycle, including idle time, was approximately 12 hours per load. It was assumed that about 3,983 cy of material would be moved in each cycle, requiring about 326 loads to excavate enough material to place 1.048 M cy of sand on the beach. The Proposed Action Alternative would place up to 1 M cy of material.

Emission factors for the diesel engines on the hopper dredge, barge, tugboats were obtained from EPA's *Compilation of Air Pollutant Emissions Factors, AP-42, Volume 1* (2002). Emission factors for tiered equipment used in beach construction were derived from NONROAD model (5a) estimates. Total project emissions of nitrogen oxides (NOx), SO_2, CO, volatile organic compounds (VOC), and particulate matter (PM) are presented in Table 17.

The Proposed Action Alternative may result in small, localized, temporary increases in concentrations of NOx, SO_2, CO, VOC, and PM. Since the Project is located in an attainment area, there is no requirement to prepare a conformity determination. Since the federal waters attainment status is unclassified, there is no provision for any classification in the CAA for waters outside of the boundaries of state waters. Calculating the insignificant and temporary addition in emissions that may occur was conservatively considered by comparing project estimates to 2010 County totals.

Emissions associated with the dredge plant would be the largest contribution to the inventory. However, the total increases are relatively minor in the context of the existing point, nonpoint, and mobile source emissions in Carteret County. Projected emissions from the Proposed Action Alternative would not adversely impact air quality given the relatively low level of emissions. With the Proposed Action Alternative, the criteria pollutant levels from construction-equipment emissions would be temporary and localized, resulting in no long term accumulation of contaminants. In addition, estimated emissions would not jeopardize the County's attainment status therefore, effects would be less than significant.

The No Action Alternative would have no effect on the air quality of area, as there would be no BOEM authorization for use of OCS material.

Table 17. Estimated emissions for the Proposed Action Alternative.

Activity	Emissions (tons)					
	NOx	SO_2	CO	VOC	PM_{25}	PM_{10}
Dredge Plant (Hopper)	64.2	1.1	14.7	1.7	1.0	1.1
Turning/Sail	37.7	0.6	8.6	1.0	0.6	0.6
Pump-out	8.7	0.1	2.0	0.2	0.1	0.1
Idle/Connect-Disconnect	9.1	0.2	2.1	0.2	0.1	0.2
Supporting Offshore Activities	3.9	0.1	0.9	0.1	0.1	0.1
Beach Fill	12.4	2.3	5.9	0.9	1.0	1.0
Project Emission Estimates	135.9	4.3	34.2	4.1	3.0	3.0
*Total Emissions within NC State (2009)	419,224	294,478	NA	505,766	126,342	362,638
**2010 Carteret County Emissions Nonpoint + Mobile (Point and Nonpoint + Mobile)	3,201 (3,221)	166 (196)	28,005 (28,022)	4,790 (4,841)	185 (194)	NA
Project Percentage of 2010 County Emissions	4.2	2.1	0.12	0.08	1.5	N/A

NA indicates data was not available.
*Emissions Inventory Summary, North Carolina Attainment Demonstration, August 2009.
**Personal communication, Laura Boothe, NCDENR, Division of Air Quality, February 2012.

6.4 Noise

The small town nature of the project area (i.e., beach communities) does not support significant point source noise pollution concerns such as major highways, large airports, heavy construction, etc. often associated with large cities. No large manufacturing, industrial, or mining-type operations are on Bogue Banks. Bogue Field, also known as Marine Corps Auxiliary Landing Field Bogue, is located off N.C. 24 between Morehead City and Cape Carteret. It is an auxiliary landing strip allowing pilots to train for a variety of flight operations. This airport does provide occasional background noise within the project area; however it is temporal in nature and does not significantly affect noise levels on the community. Ambient noise associated with breaking waves, wind, etc. is a prominent feature of the beach communities. During peak tourism seasons, traffic along the local roadways and local commercial areas facilitates short-term increases in noise pollution. Each community has local sound ordinances and complaints of municipal residents concerning noise are within normal expectations. The towns do not experience a problem to the extent that maximum densities for residential dwellings have been established, nor have noise level reduction standards (outdoor to indoor or indoor to outdoor) been established.

Open-water coastal environments have a number of underwater ambient noise sources such as commercial and recreational vessel traffic, dredges, wharf/dock construction (e.g., pile driving), natural sounds (e.g., storms, biological), etc. To better assess potential species effects (i.e., disturbance of communication among marine mammals) associated with dredge-specific noise from borrow area dredging operations, Clarke et al. (2002) performed underwater field investigations to characterize sounds emitted by bucket, hydraulic cutterhead, and hopper dredge operations. A summary of results from the study for hopper dredge operations are presented below:

The noise generated from a hopper dredge is similar to a cutterhead suction dredge, except there is no rotating cutterhead. The majority of the noise is generated from the drag-arm sliding along the bottom, the pumps filling the hopper, and operation of the ship engine/propeller. Similar to the cutterhead suction dredge, most of the produced sound energy fell within the 70- to 1,000-Hz range; however, peak pressure levels were at 120 to 140 decibels (dB) (Clarke et al. 2002). Assumed noise emissions and receptors would not permanently jeopardize community background levels; therefore, effects would not be significant.

Robinson et al. (2011) investigated underwater noise produced by marine aggregate dredging in the UK. At frequencies below 500 Hz, dredging noise was similar or less than a typical merchant vessel traveling at slow speed (8-16 knots). However, high frequency broadband dredging noise was more similar to the noise produced by a merchant vessel at high speed with a cavitating propeller. The major source of high frequency broadband dredging noise was the impact/abrasion of the mined aggregate passing through draghead, pipe, and pump; with gravel producing higher broad band noise levels than sand. In terms of acoustic energy deposited into marine environment in a given time, dredges were much less noisy than other sources of anthropogenic noise such as pile driving and geophysical surveying with airgun arrays.

Dredging equipment in the ocean and earthmoving equipment on the beach will result in increased noise levels in the vicinity of the equipment during beach nourishment operations. Beach filling and shaping operations will progress down the beach at a rate of about 400-700 ft per day, ensuring that no single location will experience increased noise levels for more than a few days therefore resulting in less than significant noise effects.

The No Action Alternative would have no effect on noise receptors within the area, as there would be no BOEM authorization for use of OCS material.

6.5 Aesthetics

The Proposed Action Alternative would include the use of the ODMDS to accomplish the nourishment project. Presence of the dredging equipment just off shore, as well as at the ODMDS, could temporarily detract from the visual aesthetics of the area. The sand color of the ODMDS may be slightly different from the sand color of the beach and may detract from the aesthetic quality of the beach. This impact, however, would be short-term since the sediments' color and gradation will lighten and sort naturally by sunlight, rain, and wind over time. The so-called sand "bleaching" effect has been observed along the completed portions of the Bogue Banks FEMA emergency beach nourishment projects (Ophelia and Isabel) that were constructed with the currently proposed ODMDS borrow material.

The No Action Alternative would result in no negative impacts from placement of material or dredging operations due to the absence of authorization from BOEM for the use of OCS material. The Proposed Action Alternative would result in temporary adverse visual impact from construction equipment and long-term positive visual effects from a restored beach; therefore, resulting in less than significant impacts.

6.6 Archaeology/Cultural Resources

As a part of investigations related to development of the engineering plan and EIS for the Bogue Banks Master Beach Nourishment Plan, Mid-Atlantic Technology and Environmental Research, Inc. (M-AT) of Castle Hayne, NC, under a subcontract agreement with Moffat & Nichol Engineers, of Raleigh, NC, conducted underwater archaeological investigations of the ODMDS, the proposed sand borrow area (Hall 2011). This work was conducted pursuant to provisions of Section 106 of the National Preservation Act of 1966 (36 CFR 800, Protection of Historic Properties) and the Abandon Shipwreck Act of 1987 (Abandon Shipwreck Guidelines, National Park Service, Federal Register, Vol. 55, No. 3, 4 December 1990, pages 50116-50145).

The first part of the investigation was a marine remote sensing survey of the ODMDS located offshore Atlantic Beach, NC. As described in Section 4.0, the proposed borrow area is approximately 197 acres in size. The second part of the investigation was an underwater archaeological identification and assessment of six (6) remote-sensing targets that were selected after the completion of the remote sensing survey of the ODMDS Borrow Area.

All of the targets identified during this project were found to be associated with modern debris that is related to the present day ODMDS. No submerged cultural resources or historic artifacts were identified during the investigation of the ODMDS. This remote sensing effort also confirmed no hardbottom resources are located within the proposed borrow sand source template (Hall 2011). BOEM will also work with SHPO should shipwreck remains be unexpectedly discovered (30 CFR 250.194 and 30 CFR 250.1010). Therefore, no significant impacts to cultural resources in the project area (borrow, placement or pump-out areas), as result of the proposed action, are anticipated with implementation of the measures to protect existing identified resources, cease of work if an unexpected discovery occurs, and immediate notification to SHPO so they can determine if the resource is significant or not and make the determination of the best means to protect the resource. The Proposed Action Alternative will have no effect on archaeology/cultural resources within the ODMDS or placement reaches.

The No Action Alternative is unlikely to have impacts on cultural resources, as there would be no dredging within the ODMDS.

Pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106, consultation with SHPO was preliminarily conducted in 2008 to assess potential impacts of dredging within the ODMDS. It was determined pre-construction cultural resource surveys of ODMDS was not necessary as long as the post-project depth of the ODMDS does not exceed the original bottom contour (Appendix H). Additional consultation has been completed thru the CAMA review process (Completed State CAMA permit application as of 08 May 2011). The DCM staff processed the permit application and coordinated the review process with eleven other state agencies, including SHPO, and the USACE. SHPO's response to the CAMA Major Permit is provided in Appendix H.

6.7 Benthic Resources

Beach nourishment may also reduce the availability of intertidal benthic infaunal prey. Sand placement generally causes temporary mass mortality of the intertidal benthic infaunal community. In addition to mortality associated with direct burial, fine sediments may increase turbidity resulting in the death of suspension-feeding organisms and interfering with larval recruitment (Reilly and Bellis 1983, Lindquist and Manning 2001). A number of researchers have reviewed the effects of beach nourishment on benthic infauna (Nelson 1993, Hackney et al. 1996, Greene 2002, and Defeo et al. 2009). Most studies, as discussed by Peterson et al. (2000 and 2006), have reported short term impacts and rapid recovery rates ranging from two weeks to seven months; however, a number of studies have documented longer recovery periods ranging upwards of eighteen months to two years. According to Peterson et al. (2006), previous reports of limited initial impacts and rapid recovery rates (ranging from days to weeks) were associated with the use of compatible sediments.

In contrast, reports of large initial impacts and lengthy recovery periods were associated with uncharacteristically high levels of fines (silts and clays) in the introduced sediments. Peterson et al. (2006) also noted that limited initial impacts and rapid recovery rates occurred on beaches with high rates of longshore transport; whereas, large impacts and slow recovery rates occurred on beaches with low rates of longshore transport. High rates of longshore transport may dilute and disperse incompatible sediments and increase benthic infauna immigration rates, thus increasing the rate of recovery. Nourishment projects that are implemented during the winter avoid critical recruitment and reproductive periods, thus potentially reducing the initial extent of impacts and the length of the recovery period (Reilly and Bellis 1983, Hackney et al. 1996, Donoghue 1999, Peterson et al. 2000, and Versar 2003).

The Proposed Action Alternative is likely to result in possible mortality for non-motile invertebrates in the immediate area of the dredging and the shoreline placement. However, this alternative will have reduced effects based on the high sediment compatibility and the seasonal window minimizing potential long-term benthic suppression.

The No Action Alternative is unlikely to have impacts on benthic resources, as there would be no dredging within the ODMDS or shoreline placements.

6.8 Fish and Wildlife Resources

6.8.1 Terrestrial

6.8.1.1 Maritime Shrub Thicket

The maritime shrub thicket community occurs sporadically throughout EI and PKS, occurring on the backside of the island, north of the main road, and interspersed with marsh areas, which border the sound. Because the community is landward of the proposed project construction limits, no significant effects would be expected.

The No Action Alternative would have no impacts on shrub thicket resources.

6.8.1.2 Beach and Dune

Under the proposed plan, approximately 37,501 ft of beach berm and dune would be constructed. Constructed dunes would be waterward of the first line of stable vegetation and would tie into existing dunes, where practical. This would result in a seaward movement of the shoreline. Project construction would not be expected to have an adverse effect on wildlife found along the beach or the dune areas. However, short-term transient effects could occur to mammalian species using the dune and fore-dune habitat, but those species are mobile and would be expected to move to other, undisturbed habitat areas during construction.

Nourishment operation at EI and PKS would be expected to directly affect ghost crabs through burial (USACE 2004b, Lindquist and Manning 2001, Peterson et al. 2000, and Reilly and Bellis 1983). Because ghost crabs are vulnerable to changes in sand compaction, short-term effects could occur from changes in sediment compaction and grain size. According to Hackney et al. (1996), management strategies recommended to enhance recovery after beach nourishment include: (1) timing activities so that they occur before recruitment and, (2) providing beach sediment that favors prey species and burrow construction. Ghost crabs are present on the project beach year-round (Hackney et al. 1996); therefore, direct effects from burial could occur during the proposed construction time frame of November 16 to March 31. However, the peak larval recruitment time frame would be avoided and only compatible borrow material would be used. Ghost crab populations are expected to recover within one year of post-construction (USACE 2004b, Lindquist and Manning 2001, Peterson et al. 2000, and Reilly and Bellis 1983). Because ghost crabs recover from short-term effects, and recommended management strategies would avoid long-term effects; no significant long-term impacts to the ghost crab population would be expected with the Proposed Action Alternative. In addition, the Proposed Action Alternative would restore a protective beach berm, creating additional foraging habitat within the dune system.

The No Action Alternative would have significant impacts on the beach and dune habitat as protection of dune and beach habitat will be reduced over time.

6.8.2 Marine

During project construction, there will be an increase in the turbidity of the surf zone in the immediate area of sand deposition. Most of the fine material in the beach fill would be expected to wash seaward into the surf zone during construction. This increase in fine material may cause the temporary displacement of various species of fish, causing a negative impact to surf fishing in the area of deposition. A study done by the NMFS on the effects of beach nourishment on nearshore macro infauna concluded that beach nourishment projects have no harmful effects - provided that the sediments are similar to those where they are placed (Saloman and Naughton 1984). The material that would be used for beach fill is similar in composition to the native beach material; therefore, the amount of fine material expected to wash out of the beach fill should be minimal.

With the expected short-term effects to the benthic communities, temporary and spatially restricted fill effects are anticipated on demersal organisms since benthos organisms are a predominant food source; and, in turn, affect pelagic species that feed on demersal species. These organisms, specifically post-larval, juvenile, and adult red drum, spot, croaker, striped mullet, summer flounder, juvenile and adult bluefish, Florida pompano (*Trachinotus carolinus*), southern kingfish, Atlantic menhaden (*Brevoortia tyrannus*), and shrimp species, represent an important commercial value for the fishing industry. However, these effects are expected to be short-lived due to the fact that the project activities will occur during periods of decreased biological activity and outside the peak periods of larval recruitment and will minimize impacts to fauna of the intertidal and subtidal bottom habitats. Impacts to recreational and commercial fisheries are anticipated to be localized, short-term, and not cumulatively significant.

The No Action Alternative would be unlikely to have impacts within the marine environment, as there would be no dredging within the ODMDS or shoreline placement.

6.8.2.1 Non-ESA-Listed Marine Mammals

This section considers potential impacts on species not managed under the ESA. Some cetacean species occur in the project area year-round [e.g., bottlenose dolphin (*Tursiops truncates*), beaked whales (*Ziphiidae* spp.), and pinnipeds], while others (e.g., right whale, humpback whale, and manatee, as discussed further in 6.9) occur seasonally as they migrate through the area. Some marine mammals in the project area are managed under the ESA [ESA; 50 CFR §402; 16 USC §1536(c)]; potential project impacts on those species are considered in Section 6.9 as well as within the BA (DC&A 2012a).

Under the Proposed Action Alternative, some of the smaller marine mammals (primarily bottlenose dolphins), could be attracted to the dredge site by the disturbance and potential availability of prey, then potentially exposed to increased levels of turbidity, noise, and the possibility of entrainment or entrapment in the dredge apparatus. Turbidity caused by re-suspension of sediments during the dredging could adversely affect feeding to the extent that the organisms rely on vision to locate their prey. Noise from the dredging operation could adversely affect marine mammals, or at a minimum, trigger an evasive response.

The NMFS (2003) has established that a received sound level of 180 dB may result in injury or mortality to cetaceans from pile-driving activities. The level for pinnipeds (which are not expected in the Proposed Action Alternative Area) is set at 190 dB. For both pinnipeds and cetaceans, NMFS has set the level of potential behavioral harassment at 160 dB. Given that project-generated sounds from dredging activities would be substantially less than those levels (Section 6.4), the Proposed Action Alternative would be expected to have no significant adverse effects on marine mammals.

The transport of dredged material by hopper dredge from the ODMDS to the placement site on Bogue Banks could have adverse impacts on animals in the path of the vessels due to vessel strikes. Potential leakage of dredged material could cause minor, localized turbidity that could cause avoidance reactions by dolphins and small whales. Animals could be struck by the hopper dredges and/or support vessels as these vessels transport the dredged material to the placement site and return to the ODMDS. The likelihood of dolphins being struck by project-related vessels is very small. Dolphins are accustomed to vessels, even frequenting the bow waves of large vessels, and can easily avoid the relatively slow-moving project vessels.

On 9 December 2008, NMFS established regulations to implement speed restrictions of no more than 10 knots applying to all vessels 65 ft or greater in overall length in certain locations and at certain times of the year along the United States East Coast. The purpose of the regulations is to reduce the likelihood of deaths and serious injuries to endangered North Atlantic right whales that result from collisions with ships (73 FR 30173), but would also reduce the likelihood of deaths and serious injuries to all marine mammals and sea turtles. Accordingly, the Proposed Action Alternative with the speed restrictions on vessels would not be expected to have significant adverse effects on marine mammals attributable to vessel activities.

The No Action Alternative is unlikely to have impacts on marine mammals, as there would be no dredging within the ODMDS.

6.8.3 Avian

Marine birds visiting the ODMDS could be affected by dredging operations. The foraging habitat would temporarily be altered by the lights, noise, and spatial effects of the dredging equipment. Coastal seabirds [e.g., gulls, brown pelicans (*Pelecanus occidentalis*), and terns], and far-ranging pelagic seabirds [e.g., tropicbirds (*Phaethon* spp.), petrels (Hydrobatinae), jaegers (*Stercorarius* spp.), gannets, and shearwaters (*Puffinus* spp.)] could be attracted to the dredging operations. They might avoid the area instead, because of the noise and light, which would deter them from a normal foraging area. It is not possible to predict which reaction would be more likely, although gulls and pelicans are habituated to human activities and are known to frequent vessels, which they associate with food.

The identified project limits avoid important shorebird habitat in Bogue and Beaufort Inlet complexes. Although the project area is heavily developed and sustains heavy recreational use, migratory shorebirds could still use the project area for foraging and roosting habitat. Tern and shorebird nesting colonies at Shackelford Banks, Fort Macon, and within the Bogue Sound complex would not be expected to be affected by the minor increment in vessel traffic in the nearshore environment associated with the Proposed Action Alternative. As mentioned in Section 6.7 of this report, beach nourishment activities could temporarily affect the roosting and intertidal macro-fauna foraging habitat; however, recovery often occurs within one year if nourishment material is compatible with native sediments. A recent two-year study in Brunswick County, NC, (USACE 2004b) indicated that beach nourishment had no measurable impact to shorebird use. Accordingly, the Proposed Action Alternative would be expected to have less than significant impacts on avian resources at the ODMDS and along the dredge routes to the nourishment sites. The potential effects of beach fill would result in a temporary loss of foraging habitat due to short-term burial of benthic invertebrates in the placement area (approximately 189 acres of intertidal habitat, which is defined here as below MHW). Bogue Banks is approximately 26 mi long; therefore, adjacent foraging areas would be available.

The No Action Alternative is unlikely to have impacts on pelagic bird species, as there would be no dredging within the ODMDS.

6.8.4 Essential Fish Habitat and State Managed Species

Dredge operations at the ODMDS could have direct and indirect effects on fish species. Direct effects would include adverse effects from dredging and indirect effects would include changes to the environment caused by the proposed project. Under the Proposed Action Alternative, resident fish and fish attracted to the dredge site by the disturbance and exposure of benthic prey items could be exposed to elevated levels of turbidity, noise, and the possibility of entrainment or entrapment in the dredge apparatus. Eggs and larvae, especially of demersal fish, as well as less motile shellfish, could also be entrained and lost.

It is unlikely that dredging would result in injury or death of substantial numbers of adult fish. The immediate vicinity of the dragheads (i.e., within a few meters) would be a relatively noisy and a potentially turbid area that fish would tend to avoid. Some individuals are likely; however, to become disoriented and entrained in the dredge intake, and early life stages would be unable to avoid the dredge. Given the limited geographic scope of the dredging (approximately 197 acres within the 6,900-acre ODMDS), this impact is expected to be less than significant.

Under the Proposed Action Alternative, elevated levels of turbidity would be limited to the immediate vicinity of the dredge. Fish subjected to those high turbidity levels could experience adverse effects from having their gills clogged by sediment. Turbidity could also affect feeding by fish dependent on vision to locate prey. As in the case of entrainment, the number of fish that might be affected by elevated levels of turbidity is expected to be relatively small, and the effect is expected to be short-lived as the dredge relocates. Accordingly, the impact on fish resources is anticipated to be less than significant.

Anthropogenic noise has the potential for a wide range of impacts on fish; including behavioral responses, masking, temporary hearing effects, physiological effects, and mortality (Normandeau Associates 2012). Intense underwater noise (greater than 120 dB) is thought to produce a number of behavioral changes among fish, and very intense noise (greater than 150 dB) has been implicated in the injury and death of fish. Fish generally respond only to very low or very high frequency sounds and vessel noise can cause either avoidance or attraction (Vella et al. 2001). Studies of fish reactions to vessel noise indicate that avoidance occurs at 118dB within the frequency range of 60-3,000Hz, whereas sounds in the range of 20-60Hz have no effect (Engas et al. 1995). Changes in schooling behavior have also been noted, such as forming tighter formations, increased swimming speeds and turning away from the noise source (McCauley 1994). Studies reviewed by Normandeau Associates (2012) documented responses to seismic airguns and acoustic deterrent devices ranging from avoidance and startle responses to no response. Noise can cause masking of sound important for intraspecific interactions among fish and shellfish (Vasconcelos et al. 2007, Codarin et al. 2009). NMFS (2003) stated that intense sound could affect hearing in fish, but cited studies suggesting that this would be unlikely at received sound levels less than 200 dB re 1 μPa, and that the hearing loss would likely be temporary. Although fish mortality has been reported at locations very close to pile driving sources and in the vicinity of underwater explosions, mortality has not been documented for exposure to other noise sources such as seismic airguns, dredging, and vessel noise (Normandeau Associates 2012).

Most studies have addressed noise from military sonar and oil exploration activities, which are very intense sounds. Few, if any, studies have investigated the effects of routine commercial navigation and in-water construction on fish. Although there is some data on the noise levels associated with bucket dredging (e.g., USACE 2001c), there appear to be minimal comprehensive studies of the noise associated with hydraulic dredging. That noise would be generated by the diesel generator(s) powering the pump and draghead, the mechanical action of the draghead in the sediment, the sediment slurry moving in the pipes, and, in the case of the hopper dredge, the propulsion system (engine noise and cavitation from the propellers). Tyler-Walters and Jackson (1999) state that a working cutter-suction dredge approximates to a received sound pressure level of 130 dB re 1 μPa over a frequency spectrum of 45 - 7,000 Hz at a distance of 330 ft, and that the passing of a small trawler (which would be similar in noise profile to a typical slow-moving hopper dredge) generates a similar noise level. A hopper dredge would generate both types of noise, so that the combined noise sources would produce a total noise level of between 130 - 140 dB re 1 μPa at 330 ft distance (Talisman Energy 2005). Note that values for generated sound pressure levels are typically expressed as the pressure at a distance of 3.3 ft; since that is not relevant to marine life, Tyler-Waters and Jackson (1999) recommend using the pressure at a distance of 330 ft, where levels are typically about 40 dB less due to the attenuation with distance.

The data summarized above suggests that dredging operations are unlikely to generate noise levels high enough to cause harm to fish. Given that fact and the absence of published evidence of widespread harm from dredging operations, it is concluded that the project effects on fish from underwater noise would be less than significant.

A remote sensing investigation of the proposed ODMDS borrow area did not identify any potential hard bottom sites (Hall 2011); therefore, dredging would not impact hard bottom EFH. Soft bottom habitats and associated benthic invertebrate resources at the ODMDS would be directly impacted by dredging. Indirect effects on benthic-foraging fish would include a temporary reduction in soft bottom foraging habitat and associated benthic prey organisms. Benthic community recovery rates at ocean borrow sites may be influenced by a number of factors; including natural disturbance regime, sediment type, spatial scale of disturbance, depth of the borrow pit, and the timing and frequency of disturbance (Wilber and Clarke 2007). Soft bottom benthic communities are generally dominated by opportunistic taxa that are capable of rapid recovery following storm-related disturbance of the seafloor. Benthic community recovery at borrow sites offshore of Kure Beach, NC, occurred relatively quickly (less than nine months), with observed differences being more related to inter-annual variability than sediment removal (Posey and Alphin 2002). Recovery of infaunal abundance, diversity, and community composition occurred within one year at borrow sites in New Jersey; whereas full recovery of sand dollar biomass required 1.5 to 2.5 years (Burlas et al. 2001). Van Dolah et al. (1992) observed short-term reductions in abundance and diversity, with a return to levels comparable to pre-impact conditions within three to six months; although changes in community composition persisted for at least one year at a deep borrow pit where pre-project fine sand substrate was replaced post project by muddy sediment. According to Burlas et al. (2001), there are two primary benthic community responses to borrow site dredging: 1) rapid recovery (<1 year) at relatively shallow borrow pits that are quickly infilled by natural sand transport and 2) development of a depauperate soft-sediment community in deep borrow pits that accumulate fine sediments. Proposed borrow site dredging at the ODMDS would remove shallow layers of sediment in strips, thus increasing the likelihood of rapid infilling and infaunal recolonization. Based on the temporary nature of the impacts, and considering relatively small size of the affected area and the availability of abundant alternative foraging habitat adjacent to the borrow site, effects on trophic interactions and benthic-foraging fish would be minor.

The Proposed Action Alternative would not be expected to cause any significant adverse effects to EFH or HAPC for those species managed by the SAFMC and MAFMC. Effects would be expected to be minor on an individual and cumulative basis.

The No Action Alternative is unlikely to have impacts on EFH or HAPC species, as there would be no dredging within the ODMDS.

6.8.4.1 State Managed Fish Species

There are no SAVs, shell, or hardbottom habitat located within the proposed sand source location, recipient beach locations, or potential transport corridors. Specific areas such as Cape Lookout, Bogue Sound, NC's tidal inlets, NC-designated nursery areas, SAVs, and oyster/shell bottom are considered HAPCs for several managed species. The Proposed Action Alternative would avoid direct and minimize potential indirect effects to these HAPCs. The closest PNAs, as designated by the NCDMF, are three to four mi from Beaufort and Bogue Inlets and the closest SAVs are approximately 0.5 mi away from the inlet mouths (NCDMF 2011). Potential changes in general current patterns, tidal flow, and salinity regimes are not anticipated as a result of the proposed Project. The marine water column, unvegetated sandy bottoms, other EFHs, and managed/associated species' are not anticipated to experience long term adverse effects resulting from the proposed Post-Irene Renourishment Project.

The No Action Alternative is unlikely to have impacts on state managed fish species, as there would be no dredging within the ODMDS.

6.8.4.2 Hardbottoms

There are no hardbottom habitats within the ODMDS reclamation area, transport corridors, or nearshore waters adjacent recipient beaches; therefore, the Proposed Action Alternative would have no impact on hardbottoms.

The No Action Alternative and the Proposed Action Alternative would have no impacts due to the absence of hardbottom within the ODMDS.

6.9 Threatened and Endangered Species

Impacts to threatened and endangered species could result from the operation of the dredge and the transport of dredged material from the borrow site to the fill site on Bogue Banks [see BA (DC&A 2012a) for more detail]. The below section summarizes potential direct and indirect impacts to managed species based on the Proposed Action Alternative.

6.9.1 North Atlantic Right Whale and Humpback Whale

Dredging operations would coincide with right whale and humpback whale migration periods along the NC coast. Consequently, right whales and humpback whales may be present in the vicinity of the ODMDS during dredging operations. Potential impacts associated with dredging operations include vessel collisions and acoustic disturbance. Dredges routinely operate at speeds of less than five knots during dredging operations. During transit between the borrow area and pump-out sites, dredges would adhere to a speed limit of ten knots or less. Protected species observers with at-sea large whale identification experience would be posted on dredges (during excavation and transit) at all times. Additional federal regulations [50 CFR 224.103(c)] prohibit the approach of any vessel within 500 yards of a right whale. If a right whale is sighted at a distance of less than 500 yards, vessels would be required to alter course and move away from the whale at a slow, safe speed. If a right whale is sighted within 500 yards of the dredge, operations would cease until the observers are confident that the whale has left the area. If a whale is sighted during transit, the crew would reduce speed and alter course as necessary to maintain a distance of 500 yards between the vessel and the whale. All whale sightings would be documented and reported to NMFS. The 24-hour presence of endangered species observers, combined with speed restrictions, should greatly reduce the potential for vessel strikes.

Underwater noise has the potential to disrupt marine mammal communication, navigational ability, feeding, and social patterns. Most observations of marine mammal responses to anthropogenic noise have been limited to short term responses involving cessation of feeding, resting, or social interactions. Although shipping and industrial noise may represent a threat to baleen whales (Mysticeti), the severity of this potential threat is unknown (NMFS 2010a). Observed responses of baleen whales to various types of underwater noise include avoidance of the source area, cessation of feeding, rapid swimming away from the source, altered dive patterns, vocalization changes, and changes in respiration (Fisheries and Oceans Canada 2010). There have been studies of the effects of shipping and industrial noise on right whales and humpback whales. Right whales, in the Bay of Fundy summer foraging area, showed no response to experimental shipping noise; however, whales exposed to synthetic alert signals abandoned their foraging dives and remained at the surface for the duration of the exposure period (Nowacek et al. 2004). Responses of Hawaiian humpback whales to experimental shipping noise included changes in diving/surfacing behavior, swimming speed, and direction of travel (Hemphill et al. 2006, Green and Green 1990). Although the potential impacts of dredging noise on right whales are not known, it is assumed that the presence of the dredge and the associated noise output could cause migrating whales to alter their course. However, since whales are transient within the study area and are not actively engaged in critical feeding or mating behaviors, any potential adverse effects on right whales and humpback whales should be minimal.

The No Action Alternative is unlikely to have impacts on whale species, as there would be no dredging within the ODMDS.

6.9.2 West Indian Manatee

Potential effects include direct physical injury as a result of in-water construction activities (i.e., dredging) and associated vessel traffic. However, the proposed beach nourishment construction window (16 November - 31 March) would avoid periods when manatees are likely to be present. Dredging would be restricted to the ODMDS; and therefore, would not affect seagrasses or other potential foraging habitat. Implementation of the above protective measures for the Proposed Action Alternative would result in less than significant impacts to the West Indian manatee.

The No Action Alternative is unlikely to have impacts on manatees, as there would be no dredging within the ODMDS.

6.9.3 Piping Plover

6.9.3.1 Direct Effects

Potential direct project effects include disturbance, habitat alteration, and losses of benthic invertebrate food resources. Potential sources of disturbance during sand placement and grading activities include heavy equipment operations and associated noise emissions, night-time lighting, and various other supporting activities involving vehicular operations, generator use, and the presence of construction personnel on the beach. Potential effects on recipient beach habitats include the loss of microhabitat features (e.g., microtopographic relief, wrack lines, tidal pools), changes in beach substrate composition, and changes in beach morphology. Renourishment projects generally result in burial and temporary mass mortality of the intertidal benthic infaunal community along the recipient beach. In addition, fine sediments may increase turbidity, resulting in the death of suspension-feeding organisms and interfering with larval recruitment (Reilly and Bellis 1983, Lindquist and Manning 2001). Benthic effects may extend beyond the boundaries of the immediate project area as the finer fill material is transported to adjacent beaches via longshore drift.

Adherence to the proposed construction window (16 November - 31 March) would preclude any direct project effects on breeding activity. Construction would occur during a period when migrating and wintering plovers are expected to be present in the area; however, piping plovers are unlikely to occur on the narrow developed ocean-facing beaches that exist within and adjacent to the project areas. Furthermore, the target beaches are separated from likely areas of occurrence at Bogue Inlet and Beaufort Inlet by distances of two and eight miles, respectively. Based on the very low potential for interactions, construction activities are unlikely to disturb migrating or wintering plovers.

Although the rare occurrence of a piping plover within the project area cannot be entirely ruled out; the project beach is not considered to be suitable nesting, foraging, or roosting habitat. Therefore, any general effects on beach habitats and benthic invertebrates are unlikely to affect piping plovers. Compliance with beach fill standards and adherence to environmental windows should minimize the extent and duration of general habitat and benthic effects. Compliance with NC Technical Standards for Beach Fill Projects (15A

NCAC 07H .0312) would ensure compatibility of the fill material, and adherence to the environmental construction window (16 November - 31 March) would reduce effects on benthic infauna. Furthermore, the relatively short length of the target beaches should allow for rapid recovery of the benthic community via immigration from adjacent beaches.

6.9.3.2 Indirect Effects

Projects that alter natural barrier island and inlet processes can lead to indirect effects on piping plover habitat. The primary concern associated with beach nourishment involves potential effects on natural ocean overwash. Natural ocean-to-sound overwash events contribute to the creation and maintenance of piping plover habitats. Overwash events create open sandy habitats and contribute to the maintenance of soundside habitats through sediment transport. Beach scraping, creation of artificial dunes/berms, and beach nourishment may artificially increase the height of the primary dunes and eliminate interdune gaps; thus, reducing natural overwash and limiting habitat development.

Due to the presence of a natural high-elevation primary dune system, overwash is not an important process on Bogue Banks (USFWS 2002). Although rare, overwash events may occur on the narrow central portion of the island; dense development between the primary dune and the sound severely limits the potential for beneficial effects on habitat.

Implementation of protective measures including compliance with beach fill standards and adherence to environmental windows should minimize the extent and duration of general habitat and benthic effects of the Proposed Action Alternative; therefore, resulting in less than significant impacts to the piping plover.

The No Action Alternative is unlikely to have impacts on the piping plover as there would be no dredging within the ODMDS and placement of material on Bogue Banks.

6.9.4 Sea Turtles

6.9.4.1 Sand Placement and Grading

The placement of sand on project area beaches may affect sea turtle nesting habitat. Potential adverse effects on nesting habitat include alteration of beach substrate characteristics and modification of the natural beach profile. Beach substrate characteristics that may be affected by nourishment include density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange (Nelson and Dickerson 1988, Crain et al. 1995). Substrate alteration may affect the ability of female turtles to nest, the suitability of the nest incubation environment, and the ability of hatchlings to emerge from the nest. Unnatural beach profiles and escarpments may prevent nesting females from reaching suitable nesting habitat; resulting in the selection of marginal or unsuitable nesting sites in front of escarpments, or in nest exposure as escarpments recede landward. Numerous studies have described the effects of beach nourishment on nesting success (Crain et al.

1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999, Rumbold et al. 2001, Byrd 2004, and Brock et al. 2009). These studies indicate a reduction in nesting success during the first post-nourishment year, followed by a return to normal levels by the second or third year. Declines in nesting success have been attributed to substrate compaction, escarpment formation, and/or modification of the natural beach profile. Beach nourishment also has the potential to improve poor quality nesting habitats associated with chronically eroded beaches (Brock et al. 2009). Davis et al. (1999) and Byrd (2004) documented increases in nesting success immediately following the nourishment of eroded beaches. Increases in nesting success were attributed to the addition of dry beach habitat.

Embryonic development and hatching success are influenced by temperature, gas exchange, and moisture content within the nest environment (Carthy et al. 2003). Changes in substrate characteristics such as grain size, density, compaction, organic content, and color may alter the nest environment; leading to adverse effects on embryonic development and hatching success (Nelson and Dickerson 1988, Nelson 1991, Ackerman et al. 1991, Crain et al. 1995, Ehrhart 1995, and Ackerman 1996). Nourished beaches often retain more water than natural beaches, thus impeding gas exchange within the nest (Mrosovsky 1995, Ackerman 1996). Uncharacteristically dark sediments absorb more solar radiation, thus potentially resulting in warmer nest temperatures (Hays et al. 2001). Dark sediments may produce nest temperatures that are too high for successful embryonic development (Matsuzawa et al. 2002). Higher temperatures may significantly reduce incubation periods and contribute to a higher incidence of late-stage embryonic mortality (Ernest 2001). Nest temperature also influences sex determination in hatchlings, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2003). Consequently, dark sediments may alter hatchling sex ratios. Investigations of beach nourishment effects on hatching success have reported variable results; including positive effects (Broadwell 1991, Ehrhart and Holloway-Adkins 2000, and Ehrhart and Roberts 2001), negative effects (Ehrhart 1995, Ecological Associates Inc. 1999), and no effect (Raymond 1984, Nelson et al. 1987, Broadwell 1991, Ryder 1993, Steinitz et. al. 1998, Herren 1999, and Brock et al. 2009). The variation in findings has been attributed to differences in the physical attributes of individual projects, the extent of erosion on the pre-nourishment beach, and construction techniques (Brock et al. 2009).

Holloman and Godfrey (2008) studied the effects of multiple beach nourishment events on sea turtle nesting and hatching success on Bogue Banks. This five year study (2002-2007) included monitoring of nesting activity, hatching success, substrate compaction, and nest temperature. A total of 167 nests, including two leatherbacks and one green, were laid during the study period. Nourishment had no significant effect on nesting success (i.e., nest/false crawl ratios). There was no indication that nourishment adversely affected egg development or hatching success, with the exception of one nest on Atlantic Beach that apparently failed due to poor gas exchange. Nourishment had no significant effect on compaction; however, nests in nourished areas were on average 1.9°C warmer than nests laid at the same time on undisturbed beaches. Nourishment on the western end of EI had less of an impact on nest temperature, apparently due to better sand compatibility. Although sex ratios were not determined, Holloman and Godfrey concluded that nourishment probably increased the number of females produced.

The proposed beach nourishment construction window (16 November – 31 March) would avoid the sea turtle nesting and hatching season. Therefore, no direct impacts on nesting activity, nests, or hatchlings are anticipated. Measures to minimize adverse effects on habitat and potential indirect effects on nesting/hatching success would include the use of compatible sediments and monitoring for escarpment formation. Based on avoidance of the nesting season, the high sediment compatibility, and considering the proposed conservation measures and the lack of significant effects from past nourishment projects, beach nourishment is not likely to adversely affect listed sea turtles.

6.9.4.2 Dredging

Dredging of the borrow site would include the use of hopper dredges. Hopper dredging has a long history of sea turtle interactions throughout the southeastern United States. Hopper dredges employ a trailing suction draghead to remove sediment from the seafloor. Sea turtles are injured or killed when they are drawn into the hopper dredge intake pipe, a process referred to as "entrainment." The potential for sea turtle entrainment at the ODMDS would be minimized through a number of conservation measures; including adherence to a (16 November – 31) March seasonal dredging window, mandatory use of the rigid deflector draghead, and the use of protected species observers to monitor operations onboard the dredge. Similar measures are currently required for all USACE dredging projects in the South Atlantic Division, having been developed through a series of past Section 7 ESA consultations between USACE and NMFS (NMFS 1991b, 1995, and 1997). The deflecting draghead creates a sand wave in front of the draghead, thus pushing animals out of the way and reducing the potential for entrainment. Sea turtle entrainment rates have been dramatically reduced when the rigid deflectors are used and deployed correctly (Dickerson et al. 2004). However, if these deflectors are not operated so that they maintain constant contact with the ocean bottom, they can actually act as a trap for sea turtles instead of a deflector (Dickerson et al. 2004). To ensure proper use of the draghead, dredging operations at the ODMDS would be monitored via the Silent Inspector automated dredging quality assurance monitoring system. The Silent Inspector system allows draghead operational monitoring in near real time, thereby minimizing the potential for sea turtle interactions due to improper deployment of the draghead. Protected species observers would be responsible for monitoring the draghead and the hopper inflow screening for evidence of sea turtles. Furthermore, during transit, protected species observers would monitor for the presence of protected species in the vicinity of the dredge.
Although the proposed conservation measures would greatly reduce the likelihood of sea turtle impacts during dredging operations, sea turtles have been entrained by hopper dredges using the defector draghead at Morehead City during late November and December. Based on this history, adverse effects on loggerhead, green, Kemp's ridley, and hawksbill sea turtles cannot be entirely ruled out. Potential dredging impacts are further evaluated in the BA and are being addressed through formal Section 7 ESA consultation between BOEM and NMFS. NMFS will issue a Biological Opinion that may include additional conservation measures or alternative actions to minimize impacts.

The No Action Alternative is unlikely to have impacts on sea turtles, as there would be no dredging within the ODMDS.

6.9.5 Shortnose Sturgeon and Atlantic Sturgeon

The proposed project would use a hopper dredge to excavate sediment within the ODMDS. Atlantic and shortnose sturgeon have been taken by hopper, pipeline, and clamshell dredges along the Atlantic coast. Hopper dredges employ a trailing suction draghead to remove sediment from the seafloor. Sturgeon are injured or killed when they are drawn into the hopper dredge intake pipe, a process referred to as "entrainment." The potential for sturgeon entrainment at the ODMDS would be minimized through a number of conservation measures, including the use of rigid deflecting dragheads and monitoring requirements. The deflecting draghead creates a sand wave in front of the draghead, thus pushing animals out of the way and reducing the potential for entrainment (i.e., sea turtles and sturgeon). Monitoring requirements would include the presence of endangered species observers to monitor dragheads and inflow screening for sturgeon. Although the rigid deflecting draghead likely reduces the potential risk of sturgeon entrainment, takes may still occur due to dredge operator error and difficult dredging conditions (uneven bottom contours, currents, slope, etc.). Although few studies have evaluated the risk of entrainment relative to behavior, size class, and life cycle; the effects of entrainment on adult fish are presumed to be low (Dickerson et al. 2004).

Between 1990 and 2007, dredging operations along the North Atlantic Coast and South Atlantic Coast resulted in the take of 11 Atlantic sturgeons and 11 shortnose sturgeons. All of the shortnose sturgeon takes occurred in rivers along the North Atlantic Coast (Delaware River and Kennebec River). Shortnose sturgeon were taken by cutterhead (5), hopper (5) and clamshell (1) dredges. Atlantic sturgeon takes included two along the North Atlantic Coast and nine along the South Atlantic Coast. Atlantic sturgeons were taken by hopper (9) and clamshell (2) dredges. No sturgeons were taken in the vicinity of the Morehead City Harbor during this period (USACE 2009). Approved protective measures during implementation of the Proposed Action Alternative would minimize effects resulting in less than significant impacts on sturgeon.

The No Action Alternative is unlikely to have impacts on sturgeon, as there would be no dredging within the ODMDS.

6.9.6 Seabeach Amaranth

The proposed construction window (16 November – 31 March) would avoid the majority of the seabeach amaranth growing season. Therefore, no direct effects on plant growth or reproduction are anticipated. Potential indirect beach nourishment effects include the burial of seeds and habitat modification. Sand placement may result in the burial of seeds, potentially affecting their ability to germinate. The relationship between nourishment, seed burial, and germination is not known. In general, seabeach amaranth numbers have increased following past nourishment projects on Bogue Banks, possibly due to the creation of new habitat or the redistribution of seeds along with beach fill sediments (Personal communication, Dale Suitor, USFWS Raleigh Ecological Services Field Office, 2011). Prior to beach nourishment in 2000, no plants were observed at PKS. Following nourishment in 2001/2002, 779 plants were recorded in 2002 and 2,690 plants were recorded in 2003 (Nash 2003). The USACE routinely conducts monitoring for seabeach amaranth on Bogue Banks (USACE, unpublished data, 2012). As stated above, observed numbers of plants are highly variable, ranging from zero to 250 plants in a reach for the Fort Macon, Atlantic Beach and Pine Knoll Shores, portions of Bogue Banks.

The Proposed Action Alternative will have no impact on seabeach amaranth due to avoidance and protective measures implemented during the construction period.

The No Action Alternative is unlikely to have impacts on seabeach amaranth, as there would be no dredging within the ODMDS or beach placement within Bogue Banks.

6.10 Recreation and Tourism

The proposed project would produce temporary and localized restrictions on recreation opportunities during the construction time period (16 November 2012 to 31 March 2013). The economic effects of the Proposed Action Alternative during construction are not expected to be significant. Effects on surf fishing would be limited to the area where material is being placed on the beach. Such localized temporary impacts can easily be avoided by anglers in the area. Nearshore fishing boats can operate around the dredging equipment operating in the area. The Proposed Action Alternative is not expected to affect the operation of commercial fishing boats operating in or going through Beaufort or Bogue Inlet. Unless there is extreme weather, the ocean going dredge would operate continuously. Therefore, the economic impact on commercial and recreational fishing is not expected to change with the project construction.

Additional minor effects include limited and localized noise from construction equipment which is discussed in Section 6.4. However, post-construction will provide an improved and wider beach, increasing recreational opportunities. Recreational opportunities and tourism will benefit in the long term due to a larger beach. Tourism and related economic benefits are expected to be augmented by increased public access adjacent to fill areas and storm protection to oceanfront residential and commercial structures; thereby, maintaining the existing tax base.

6.11 Environmental Justice

As mandated by EO 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” states that “each Federal agency make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high adverse human health and environmental effects of its programs, policies, and activities on minority populations and low income populations.”

The alternatives considered in this document would facilitate the remediation of a recreational oceanfront shoreline. Based on the above discussion on the environmental consequences; reclamation, construction and operation of the proposed project would have less than significant impacts related to environmental justice. The Proposed Action

Alternative would create tourist related jobs as well as increase public access to the recreational beach.

Neither alternative would have impacts related to environmental justice. The Proposed Action Alternative would be of short duration, involve relatively few workers, would not have significant impacts, and would not negatively affect onshore communities. Accordingly, the alternatives would not have impacts that would disproportionately affect minority or economically disadvantaged populations.

7.0 SECONDARY AND CUMULATIVE EFFECTS

Secondary and cumulative effects are those effects on the environment that result from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes the other actions. Time crowded perturbations, space crowded perturbations, indirect and synergistic effects, and combinations thereof are considered in this analysis. The time bounds for this cumulative effects analysis are from the late-1970s through the proposed implementation of the MBNP. Bogue Banks beaches were nourished as early as 1978. This analysis will focus on potential cumulative effects within the Project area since portions of affected beaches under the current proposal have received fill in the past as well as barrier islands within approximately 50 miles of the Project area.

The cumulative effects assessment focused on dredging effects from the proposed ODMDS, and effects of placing sand material on the ocean shoreline. The cumulative effects analysis included a review of several environmental reports prepared for and published by the USDOI, BOEM. These reports included:

Use of Federal Offshore Sand Resources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware, and Virginia (USDOI 1999);

Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration (Byrnes et al. 2003);

USACE Dare County Beaches (Bodie Island Portion) Final Feasibility Report and EIS on Hurricane Protection (USACE 2000);

USACE's Draft Evaluation Report and Environmental Assessment, Morehead City Harbor Section 933 (USACE 2003); and

Final Integrated General Reevaluation Report and Environmental Impact Statement, Shore Protection, West Onslow Beach and New River Inlet (Topsail Beach) (USACE 2009)

Several of the above documents include comprehensive assessments of statewide cumulative effects. In discussing the potential cumulative effects of offshore borrow area dredging and beach nourishment, time- and space-crowded perturbations were considered to be relative to the Proposed Action Alternative.

The State of NC has approximately 320 mi of ocean shoreline. Carteret County, NC is centrally positioned on NC's coast south of Cape Lookout. Bogue Banks is an approximately 26-mile long barrier island located on the low-energy limb of the Cape Lookout foreland with a relatively unique east-west orientation. Beaufort Inlet borders the island to the east, separating Bogue Banks from Shackleford Banks. Bogue Inlet borders Bogue Banks to the west, separating the island from Bear Island. Shackleford Banks is part of the Cape Lookout National Seashore (CLNS), and Bear Island is part of the Hammocks Beach State Park. Bogue Sound, a relatively shallow embayment system encompassing reaches of the Atlantic Intracoastal Waterway (AIWW), separates Bogue Banks from the mainland and Onslow Bay (Atlantic Ocean). There are numerous completed and proposed projects involving beach renourishment, similar to the completed and proposed renourishment activity on Bogue Banks. However, Bogue Banks' south facing orientation and its undeveloped and protected neighboring islands set it apart from many NC shorelines. Most nourishment actions are typically authorized as one-time beach nourishment events as is the case for the Post-Irene effort.

The following are brief summaries of NC shore protection projects or locations whose proximity are the closest to Bogue Banks.

Surf City and North Topsail Beach, NC, Draft Feasibility Study

The USACE – SAW is conducting a federal feasibility study for storm damage reduction and shoreline protection for a 50-year period of analysis along North Topsail Beach and Surf City. The Surf City and North Topsail Beach Shore Protection Project Feasibility Report (USACE 2009) discloses that the most practicable plan of protection is a berm and dune project extending from the southern edge of the Coastal Barrier Resources System (Topsail Unit, L06). Renourishment will occur on a four-year cycle. If protection of this area is found to be in the Federal interest, the project could be implemented as early as 2012.

North Topsail Beach Shoreline Protection Project

The Town of North Topsail Beach has been issued federal and state permits for a beach nourishment/inlet management project. The project involves a proposal to reposition New River Inlet channel, renourish 11.1 mi of oceanfront protecting homes and town infrastructure, and implement an inlet management plan to control the migration of the inlet channel.

West Onslow Beach and New River Inlet, NC, General Revaluation Report and EIS

This approximately five mile federal storm reduction project for the Town of Topsail Beach (designated as the West Onslow Project) consists of a sand dune constructed at 13 ft above mean sea level, fronted (oceanward) by a storm berm constructed at an elevation of nine ft above mean sea level, and a beach berm elevation of seven ft above sea level. The USACE anticipates renourishment will be required every four years. A General Reevaluation Report and EIS have been completed for the project and the project is on hold due to lack of Congressional funding. Funds to initiate detailed engineering and design for the project were not included in the federal budget for 2012; therefore, the construction date for this project is uncertain.

Topsail Beach Interim (Emergency) Beach Fill Project

The Town of Topsail Beach has recently completed an interim beach fill project using material obtained from existing navigation channels and upland dredged material disposal sites located behind the island. The purpose of the one-time project was to protect oceanfront development and infrastructure until such time that the federally authorized West Onslow Project can be implemented. This project covered the oceanfront section of the Town located between Godwin Avenue on the south to a point 2,000 ft northeast of Topsail/Surf City town limits, along a total ocean shoreline length of approximately 4.7 mi.

Shackelford Banks Dredged Material Management

In a 20 August 2010 response to the SAW's proposed DMMP for the Morehead City Harbor, the CLNS clarified the Park Service's position regarding beach nourishment on Shackleford Banks: "sediment disposal and other types of shoreline process interference are permitted in national park units when necessary to restore or mitigate the impacts of human-caused activities." The CLNS further acknowledged the beneficial use of maintenance dredged sediment mitigating the ebb tide delta's deflation. Future uses of Morehead City Harbor's beach quality and non-beach quality maintenance dredged material will be proportionately redistributed based on need, mitigation locations, and material quality. Precise volumes, location rotations, and sediment quality by location have not been finalized.

7.1 General Summary of Beach Nourishment in North Carolina

Many NC communities have either received state or federal permit authorizations to conduct community-wide beach work, or are currently preparing official requests. Carteret County and the SAW, in the past 30+ years, have renourished basically all 26 miles of Bogue Banks, from EI to Atlantic Beach, using material dredged from offshore borrow sites, upland confined disposal facilities, and directly from navigation channels (as described in Section 2).

The following summaries are statewide shoreline efforts related to the SAW's activities (Personal communication, David Timpy, USACE – SAW, November 2011):

Shoreline Sand Placement Activities:

- Average/year is 8.0 mi or 2.5% of total NC ocean beach (320 mi)
- Minimum for any year is 3.5 mi or 1.1 % of total NC ocean beach

Given the small percentage of the total NC shorelines affected, the fact that each project is not conducted on an annual basis, but every two or more years (thereby allowing biological recovery), the dynamic nature of the systems, and the minimal and/or short-term environmental effects associated with each project; the cumulative environmental effects of these combined beach disposal and renourishment projects (including the proposed project) are not considered to be significant.

A relatively small portion, approximately 12% of NC beaches, is presently affected by renourishment activities (USACE 2009). It is unlikely that cumulative impacts from space crowded perturbation are occurring or will occur with the construction of this one-time proposed project. With the Proposed Action Alternative, the affected areas would not increase significantly because the areas proposed for renourishment have previously had sand deposition. The analysis suggests that the potential impact area from the proposed and existing actions is small relative to the area of available similar habitat on a vicinity basis (USACE 2010).

Proposed as a one-time event, assessing potential sea level rise effects on or from the Post-Irene project is temporally and spatially limiting. However, effective coastal planning requires the consideration of climate change and sea level rise. Global mean sea level rose at a rate of approximately 1.7 millimeters per year over the course of the 20th century; however, since 1993, global mean sea level has risen at a rate of approximately three millimeters per year [International Panel on Climate Change (IPCC) 2007). IPCC has predicted an increase in global mean sea level ranging from 0.18 to 0.59 meters by 2100 (IPCC 2007). Based on monthly mean sea level data from 1953 through 2006, mean sea level at Beaufort, North Carolina has risen at a rate of 2.57 millimeters per year (Zervas 2009). An additional study by Zervas (2004) averaged data from the Beaufort station over the period 1973 through 2002, indicating a sea level rise rate of 3.2 millimeters per year or 0.32 meters per century. The NCCRC's Science Panel on Coastal Hazards (2010) used tide gauge data to project sea level rise under varying rates of acceleration. The resulting sea level curves project an increase of 0.4 to 1.4 meters by 2100. An increase of one meter is projected when the linear relationship between temperature and sea level observed during the 20th century is extrapolated through 2100. Based on these projections, the Science Panel on Coastal Hazards has recommended that a rise of one meter by 2100 be adopted as the anticipated increase for policy development and planning purposes. Proposed guidelines are being considered for future land use planning. With a targeted construction date of winter 2012/2013 and the single event nature of the proposed action, sea level rise was not considered a significant factor.

For some species such as sea turtles and seabeach amaranth, beach projects would improve habitat by replacing beach material lost to erosion. Invertebrates in the affected areas would be expected to recover, remaining viable as food resources. The potential that the direct and cumulative effects of the Proposed Action Alternative and other existing similar activities would reach a threshold with high potential for population level effects on important commercial fish stocks and birds is low. The proposed conservation measures limiting work only in time frames when oceanfront and aquatic organisms are least active and by requiring contract mechanisms to further minimize potential effects to the coastal resources; long term cumulative effects are not anticipated. Because of the dynamic nature of the systems, the minimal and/or short-term environmental effects, resource windows, and incorporating special conditions and conservation measures; the cumulative environmental effects are not considered significant.

Both beneficial and adverse cumulative effects may occur when the effects of the Proposed Action Alternative are considered. Considering the relatively small footprint, the short project duration, and the resources' recoverability/reversibility; the Proposed Action Alternative contributes a small incremental effect to potential cumulative effects when considered with other past, present, and reasonably foreseeable actions affecting the project area.

8.0 PROPOSED AVOIDANCE AND MINIMIZATION MEASURES

The following avoidance/minimization measures and reporting requirements are proposed to avoid, reduce, or eliminate environmental effects associated with the Proposed Action Alternative. Avoidance/minimization measures as terms and conditions may be added to BOEM's non-competitive lease and NCDCM Major Permit. Minor modifications to the proposed measures may be made during the negotiated agreement process if comments indicate changes are necessary or if conditions warrant.

The construction timing was specifically scheduled to occur outside the sea turtle nesting season, the West Indian manatee summer occurrence in NC, the piping plover (and other shorebirds) migratory and breeding seasons, and for the most part the seabeach amaranth flowering period. The sand placement and dredge operation would be conducted outside of primary invertebrate production and recruitment periods (spring and fall) limiting effects on amphipods, polychaetes, crabs, and clams. In addition, specific hopper dredging conditions and conservation measures have been incorporated into this proposed project (Appendix I).
Proposed conservation measures resulting in avoidance and minimization of potential effects from dredge activities are bulleted below.

- Dredging quality management will be implemented within the offshore reclamation areas and documented by Global Positioning Systems (GPS) units and Silent Inspectors. These management tools would ensure sand resource removals are within previously surveyed and authorized ODMDS reclamation areas.

- Protected species observers would be a contract stipulation requiring trained and experienced personnel knowledgeable in industrial marine mammal and sea turtle observation and reporting standards.

- Associated dredging vessel speed restrictions (10 knots maximum for transit) would be employed during transiting supplemented by protected species observers to reduce potential collision effects with managed or associated species (northern right whale).

- Hopper dredge operations would require sea turtle deflecting dragheads and inflow screening during all sand reclamation efforts.

- Dredging contract will include a requirement for dredging patterns allowing undisturbed furrows remain within the borrow area. Undisturbed furrows will expedite benthic fauna recovery within the ODMDS.

- Directional, shielding, and intensity managed lighting would be employed minimizing potential nocturnal marine species' effects, while meeting Occupational Safety and Health Administration (OSHA) vessel work standards.

- Contract language would require routine inspection of dredging equipment and transport piping minimizing potential leaks at the dredge plant and along transport corridors.

- Contract language would require spill response capabilities and waste management plans for all dredging fleet equipment.

- In the event that the dredge operators discover any archaeological resource while conducting dredging operations in the ODMDS or in the vicinity of pump-out operations, Carteret County's representative shall require that dredge and/or pump-out operations be halted immediately within 305 m (1000 ft) of the area of discovery. Carteret County representative shall then immediately report the discovery to Mr. James F. Bennett, Chief, Division of Environmental Assessment, BOEM, at (703) 787-1660. If investigations determine that the resource is significant, the parties shall together determine how best to protect it.

Proposed conservation measures resulting in avoidance and minimization of potential effects from recipient beach activities are bulleted below:

- Daily monitoring of beach nourishment activities would be conducted to further ensure the compatibility of the beach fill material. Visual monitoring of the fill material would be conducted at the dredge pipe outfall before it is redistributed along the beach. If any incompatible fill material is detected, the contractor will cease operations and immediately contact the Wilmington District Regulatory Branch and NCDCM to determine the appropriate course of corrective action.

- Immediately after the beach construction operation is complete and prior to 1 May, surveys for escarpments will be conducted within the limits of the construction area. Escarpments that are identified prior to or during the nesting season that interfere with sea turtle nesting (exceed 18 inches in height for a distance of 100 feet) would be leveled to the natural beach profile. If it is determined that escarpment leveling is required during the nesting or hatching season, leveling actions would be coordinated with the USFWS.

- All beach equipment (bulldozers, frontend loaders, pickups, etc) would access current public access areas, no new access cuts would be allowed.

- Existing vegetated dune fields would not be disturbed and equipment/personnel would not be allowed within these dune line buffers.

- Contract language would require equipment refueling locations within designated equipment staging areas away from the active work zone if practicable.

- Contract language would require designated contract spill response capabilities.

- If available, staging areas for construction equipment would be located off the beach.

- Construction equipment not in nighttime use would be stored off the beach if practicable, minimizing potential effects on nocturnally active species.

- Diffusion plates would be a contract stipulation, reducing effluent discharge velocities with directional sand-slurry placement.

- Temporary slurry diversion training walls would be pushed up from existing and received material, extending and directing the sandy effluent's horizontal flow, maximizing sediment retention, and minimizing potential swash zone turbidity effects.

- Visual monitoring would be required during all sand slurry discharging operations with "shut down" and agency notification authorization in the event unsuitable material is encountered.

- Directional, shielding, and intensity managed lighting will be employed minimizing potential nocturnal species' effects, while meeting OSHA work standards.

- Contract language would require routine inspection of slurry transport piping minimizing potential pressurized leaks along the beachfront.

- Heavy equipment would be removed from refurbished shorelines as soon as practicable, restoring unrestricted public access.

The proposed project would use a regularly impacted disposal area (ODMDS) that is EPA designated for use as an ocean disposal area for dredging Beaufort Inlet and the federal navigation channels serving the Port of Morehead City (Figure 1). There are no anticipated effects to the ODMDS area due to the frequent disturbances by the USACE's placement of maintenance dredged material from Beaufort Inlet and the Morehead City Harbor.

9.0 CONSULTATION AND COORDINATION

The USACE and BOEM have integrated NEPA compliance with several other environmental requirements, including the ESA, MSFCMA, Coastal Zone Management Act, and National Historic Preservation Act. The USACE served as the co-lead federal agency for environmental compliance with beach placement and navigation compliance, while BOEM has acted in a co-lead federal agency role for environmental compliance with OCS borrow activities. Pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106, consultation with SHPO was conducted via BOEM in which no opposition for the use of the ODMDS was received (Section 5.6). In addition, consultation as part of the State's CAMA review process resulted in SHPO responding with no objection to the deposition of additional sand on the three known archaeological sites within the proposed placement area (Appendix H). In March 2012, a BA and an EFH Assessment (DC&A 2012b) were submitted to BOEM and the USACE SAW for initiating USFWS and NMFS consultations.

A number of ESA Section 7 consultations have been conducted for previous nourishment projects at Bogue Banks (see below). During previous projects, the USACE was been sole lead agency for ESA Section 7 consultations with both NMFS and USFWS. Section 7 lead agency responsibilities for the current Post-Irene Renourishment Project are divided between BOEM and the USACE. BOEM is consulting with NMFS on the ODMDS dredging aspects of the project, whereas the USACE is consulting with USFWS on the sand placement aspects of the project. Although the USACE is subject to applicable terms and conditions arising from previous consultations (including the RBOs for dredging), these consultations are not applicable to BOEM or the dredging aspects of the current project. Although many of the dredging conservation measures proposed in this EA are based on measures developed under previous consultations, any legally binding terms and conditions for the Post-Irene dredging component will be contained within the impending NMFS consultation.

During pre-project agency coordination for the 2004 Post-Isabel Sand Replacement Project, NMFS responded that consultation was not required provided all conditions of the 1997 RBO were implemented during the project. The USFWS responded that the Post-Isabel project was not likely to adversely affect listed species provided the project implemented minimum shell content standards and all conservation measures contained in the original permit for the BBBRP. During pre-project agency coordination for the 2007 Post-Ophelia Sand Replacement Project, NMFS again responded that consultation was not required provided all conditions of the 1997 RBO were implemented. The USFWS recommended conservation measures similar to those adopted for the original Bogue Banks Restoration Project. Examples of conservation measures adopted and included as conditions of the project permit are: compliance with the 1997 RBO, adherence to a (16 November – 30 April) environmental construction window, measures to ensure compatibility of the fill material, escarpment monitoring, sea turtle nest monitoring, and no storage of construction equipment on the beach between 1 May and 15 November. The Post-Irene Renourishment Project's proposed conservation measures reflect specific stipulations found in the 1997 RBO.

10.0 REFERENCES

Ackerman, R.A. 1996. The nest environment and embryonic development of sea turtles. In: Lutz, P.L. and J.A. Musick (eds.). The Biology of Sea Turtles. CRC Press.

Ackerman, R.A., T. Rimkus, and R. Horton. 1991. The Hydric Structure and Climate of Natural and Renourished Sea Turtle Nesting Beaches along the Atlantic Coast of Florida. Unpublished report prepared by Iowa State University for Florida Department of Natural Resources, Tallahassee.

Alpine. 2012. Final Report Bogue Banks Beach Nourishment Plan. Prepared for Moffatt & Nichol and Carteret County Shore Protection Office. May 2012.

Atlantic Sturgeon Status Review Team. 2007. Status Review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Report to National Marine Fisheries Service, Northeast Regional Office. February 23, 2007.

Anamar and Coastal Planning & Engineering. 2009. Bogue Banks, North Carolina, Shore Protection Project, Hardbottom Resource Confirmation and Characterization Study. Submitted to U.S. Army Corps of Engineers. Contract W912HN-08-C-0009.

Atlantic States Marine Fisheries Commission (ASMFC). 2011. 1050 North Highland Street, Suite 200A-N Arlington, VA 22201 Accessed February 2011. Available online at http://www.asmfc.org.

Barco, S.G., W.A. McLellan, J.M. Allen, R.A. Asmutis-Silva, R. Mallon-Day, E.M. Meagher, D.A. Pabst, J. Robbins, R.E. Seton, W.M. Swingle, M.T. Weinrich, and P.J. Clapham. 2002. Population Identity of Humpback Whales (*Megatera novaeangliae*) in Waters of the US Mid-Atlantic States. J. Cetacean Res. Manage. 4(2):135-141.

Bender, M., T.R. Knutson, R. Tuleya, J. Sirutis, G. Vecchi, S.T. Garner, and I. Held. 2010. Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes. Science 327: 454–458.

Berman, B. D. 1972. Encyclopedia of American Shipwrecks, Boston, Mass.: The Mariners Press.

Bin, O., C.E Landry, C.L Ellis, and H. Vogelsong. 2005. Some Consumer Surplus Estimates for North Carolina Beaches. Marine Resource Economics 20(2): 145-61.

Bohlen, W. 2002. Gravitational Flows and the Dispersion of Dredged Resuspended Sediments: The Forgotten Factor? University of Connecticut, Department of Marine Sciences. Accessed February 2012. Available online at http://massbay.mit.edu/ marinecenter/ conference/abstracts01.html.

Broadwell, A.L. 1991. Effects of beach nourishment on the survival of loggerhead sea turtles. Boca Raton, Florida, Florida Atlantic University, Master's Thesis.

Brock, K.A., J.S. Reece, and L.M. Ehrhart. 2009. The effects of artificial beach nourishment on marine turtles: differences between loggerhead and green turtles. Restoration Ecology 17(2): 297–307.

Burgess, C.C. and A.J. Bianchi. 2004. An Economic Profile Analysis of the Commercial Fishing Industry of North Carolina Including Profiles for State-Managed Species.

NOAA Award No. NA16FW1543. North Carolina Department of Environment and Natural Resources North Carolina Division of Marine Fisheries, License and Statistics Section, Morehead City, NC.

Burlas, M., G.L. Ray, and D.G. Clarke. 2001. The New York District's Biological Monitoring Program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section Beach Erosion Control Project. Final report. US Army Engineer District, New York, and US Army Engineer Research and Development Center, Waterways Experiment Station, Vicksburg, MS.

Byrd, J.I. 2004. The effect of beach nourishment on loggerhead sea turtle (*Caretta caretta*) nesting in South Carolina. Masters Thesis, College of Charleston, Charleston, SC.

Byrnes, M.R., R.M. Hammer, B.A. Vittor, S.W. Kelley, D.B. Snyder, J.M. Côté, J.S. Ramsey, T.D. Thibaut, N.W. Phillips, and J.D. Wood. 2003. Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration. U.S. Department of the Interior, Minerals Management Service, Leasing Division, Sand and Gravel Unit, Herndon, VA. OCS Report MMS 2000-056, Volume I: Main Text 256 pp. + Volume II: Appendices 69 pp.

Cameron, S., D.H. Allen, M.M. Lyons, J.R. Cordes, and S.B. Maddock. 2006. Compilation and Assessment of Piping Plover Wintering and Migratory Staging Area Data in North Carolina. In: Rabon, D.R. (compiler). Proceedings of the Symposium on the Wintering Ecology and Conservation of Piping Plovers. U.S. Fish and Wildlife Service, Raleigh, NC.

Carthy, R.R., A.M. Foley, and Y. Matsuzawa. 2003. Incubation environment of loggerhead turtle nests: effects on hatching success and hatchling characteristics. In: Bolten, A.B. and B.E. Witherington (eds.). Ecology and Conservation of Loggerhead Sea Turtles. University Press of Florida, Gainsville, Florida, pp.145-153.

Challinor, John S.A. 2000. "Scoping the assessment of sediment plumes from dredging." Construction Industry Research and Information Association. CIRIA Publication C547. Accessed February 2012. Available online at http://www.goodmarine.com/article.aspx?id=18&navid=5.

Clarke, D., C. Dickerson, and K. Reine. 2002. Characterization of Underwater Sounds Produced by Dredges. In *Proceedings of the Third Specialty Conference on Dredging and Dredged Material Disposal*. May 5–8 2002, Orlando, FL.

Cleary, W.J. and O.H. Pilkey. 1996. Environmental Coastal Geology: Cape Lookout to Cape Fear, North Carolina Regional Overview. In: Cleary, W.J., (Editor), Environmental Coastal Geology: Cape Lookout to Cape Fear, NC, Carolina Geological Society Fieldtrip Guidebook, 1996, pg. 87-128.

Coastal Planning & Engineering, Inc. April 2004. Bogue Inlet Channel Erosion Response Project Final Environmental Impact Statement (FEIS). Prepared for the Town of Emerald Isle and submitted to the Army Corps of Engineers. Available online at: http://www.saw.usace.army.mil/WETLANDS/Projects/BogueInlet/index.html.

Coastal Science Associates (CSA). April 2006. Bogue Banks beach nourishment: November 2005. Eighth post-dredge environmental monitoring study for Carteret County, Town of Pine Knoll Shores, Town of Indian Beach, and Town of Emerald Isle, North Carolina. CSA, Columbia, SC. 32 pp plus appendices.

Codarin, A., L.E. Wysocki, F. Ladich, and M. Picciulin. 2009. Effects of Ambient and Boat Noise on Hearing and Communication in Three Fish Species Living in a Marine Protected Area (Miramare, Italy). Marine Pollution Bulletin 58(12):1880-1887.

CSA. 2005 (November). Bogue Banks beach nourishment: June 2004. Seventh post-dredge environmental monitoring study for Carteret County, Town of Pine Knoll Shores, Town of Indian Beach, and Town of Emerald Isle, North Carolina. CSA, Columbia, Sc 48 pp plus appendices.

CSA. 2004 (November). Bogue Banks beach nourishment: June 2004. Fifth post-dredge environmental monitoring study for Carteret County, Town of Pine Knoll Shores, Town of Indian Beach, and Town of Emerald Isle, North Carolina. CSA, Columbia, Sc 44 pp plus appendices.

CSA. 2003 (November). Bogue Banks beach nourishment: June 2003. Third post-dredge environmental monitoring study for Carteret County, Town of Pine Knoll Shores, Town of Indian Beach, and Town of Emerald Isle, North Carolina. CSA, Columbia, Sc 42 pp plus appendices.

CSA. 2002 (March). Bogue Banks beach nourishment: June 2001. First pre-dredge environmental monitoring study for Carteret County, Town of Pine Knoll Shores, Town of Indian Beach, and Town of Emerald Isle, North Carolina. Coastal Science Associates Inc (CSA), Columbia, SC, 37 pp + appendices.

Coastal Science & Engineering (CSE). 2001. Environmental Impact Statement - Bogue Banks Beach Restoration Plan, Phase I. Columbia, S.C.

CSE. 2002. Environmental Impact Statement - Bogue Banks Beach Restoration Plan, Phase II. Columbia, S.C.

CSE–Stroud. 2001. Environmental Impact Statement, Bogue Banks beach restoration plan. EIS for NC Department of Environment and Natural Resources, Division of Coastal Management; submitted by Carteret County, NC; prepared by CSE and Stroud, Sections 1–6 and Apps A–G.

Cohen, J.B., R.M. Erwin, J.B. French, Jr., J.L. Marion, and J.M. Meyers. 2010. A review and synthesis of the scientific information related to the biology and management of species of special concern at Cape Hatteras National Seashore, North Carolina: U.S. Geological Survey Open-File Report 2009–1262.

Coles, C.C. and J.A. Musick. 2000. Satellite Sea Surface Temperature Analysis and Correlation with Sea Turtle Distribution off North Carolina. Copeia 2000: 551-554.

Collins, M.R., W. C. Post, and D. Russ. 2001. Distribution of Shortnose Sturgeon in the Lower Savannah River: Results of Research 1999-2000. Final Report to the Georgia Ports Authority.

Crain, D.A., A.B. Bolten, and K.A. Bjorndal. 1995. Effects of beach nourishment on sea turtles: Review and research initiatives. Restoration Ecology 3(2): 95-104.

Davis, R.A., M.V. Fitzgerald, and J. Terry. 1999. Turtle nesting on adjacent nourished beaches with different construction styles: Pinellas County, Florida. Journal of Coastal Research 15(1), 111-120.

Deaton, A.S., W.S. Chappell, K. Hart, J. O'Neal. 2010. North Carolina Coastal Habitat Protection Plan. North Carolina Department of Environment and Natural Resources. Division of Marine Fisheries, NC. 617 pages.

Defeo, O., A. McLachlan, D.S. Schoeman, T.A. Schlacher, J. Dugan, A. Jones, M. Lastra, and F. Scapini. 2009. Threats to sandy beach ecosystems: A review. Estuarine, Coastal and Shelf Science 81: 1-12.

Department of the Navy. 2003. Marine Resource Assessment for the Cherry Point and Southern Virginia Capes (VACAPES) Inshore and Estuarine Areas. Final Report. Department of the Navy, Naval facilities Engineering Command, Norfolk, Virginia. Prepared by Geo-Marine Inc., Plano, TX.

Department of the Navy. 2008. Marine Resource Assessment Update for the Cherry Point Operating Area. Department of the Navy, U.S. Fleet Forces Command, Norfolk, Virginia. Prepared by Geo-Marine Inc., Hampton, VA.

Dial Cordy and Associates (DC&A). 2012a. Biological Assessment for the Post-Irene Renourishment Project. Prepared for Bureau of Ocean and Energy Management. March 2012.

DC&A 2012b. Essential Fish Habitat Assessment for the Post-Irene Renourishment Project. Prepared for Bureau of Ocean and Energy Management. March 2012.

Diaz, H. 1980. The mole crab Emerita talpoida (Say): a case of changing life history pattern. Ecol. Monogr. 50, 437–456.

Dickerson, D.D., M.S. Wolters, C.T. Theriot, and C. Slay. 2004. Dredging impacts on sea turtles in the Southeastern USA: A historical review of protection. In: Proceedings of World Dredging Congress XVII, Dredging in a Sensitive

Environment. 27 September-1 October 2004, Central Dredging Association, ISBN 90-9018244-6, CD-ROM.

Donoghue, C. 1999. The influence of swash processes on *Donax variabilis* and *Emerita talpoida*. University of Virginia, Department of Environmental Sciences Ph.D. Dissertation.

Ecological Associates, Inc. 1999. Martin County Beach Nourishment Project, Sea Turtle Monitoring and Studies, 1997 Annual Report and Final Assessment. Jensen Beach, Florida: Ecological Associates, Inc.

Ehrhart, L.M. 1995. The relationship between marine turtle nesting and reproductive success and the beach nourishment project at Sebastian Inlet, Florida, in 1994. Melbourne, Florida, University of Central Florida, Technical Report to the Florida Institute of Technology.

Ehrhart, L.M. and K.G. Holloway-Adkins. 2000. Marine Turtle Nesting and Reproductive Success at Patrick Air Force Base: Summer 2000. Orlando, Florida, University of Central Florida, Final Report to US Air Force Eastern Space and Missile Center; Patrick Air Force Base, Florida.

Ehrhart, L.M. and K.A. Roberts. 2001. Marine Turtle Nesting and Reproductive Success at Patrick Air Force Base: Summer 2001. Orlando, Florida: University of Central Florida, Final Report to US Air Force Eastern Space and Missile Center; Patrick Air Force Base, Florida.

Engas, A., O.A. Misund, A.V. Soldal, B. Horvei, and A. Solstad. 1995. Reactions of Penned Herring and Cod to Playback of Original Frequency-Filtered and Time-Smoothed Vessel Sound. Fisheries Research, 22: 243-252.

Epperly, S.P., J. Braun-McNeill, and P.M. Richards. 2007. Trends in catch rates of sea turtles in North Carolina, USA. Endangered Species Research 3: 283–293.

Epperly, S.P., J. Braun, and A.J. Chester. 1995a. Aerial surveys for sea turtles in North Carolina inshore waters. Fishery Bulletin 93: 254-261.

Epperly, S.P., J. Braun, and A. Veishlow. 1995b. Sea turtles in North Carolina waters. Conservation Biology 9: 384-394.

Epperly, S.P., J. Braun, A.J. Chester, E.A. Cross, J.V. Merriner, and P.A. Tester. 1995c. The winter distribution of sea turtles in the vicinity of Cape Hatteras and their interactions with the summer flounder trawl fishery. Bull. Mar. Sci. 56: 547-568.

Ernest, R.G. 2001. The Effects of Beach Nourishment on Sea Turtle Nesting and Reproductive Success, a Case Study on Hutchinson Island, Florida Proceedings of the Coastal Ecosystems and Federal Activities Technical Training Symposium August 20-22, 2001.

Ernest, R.G. and R.E. Martin. 1999. Martin County beach nourishment project: sea turtle monitoring and studies, 1997 annual report and final assessment. Unpublished report prepared for the Florida Department of Environmental Protection.

Fisheries and Oceans Canada. 2010. Recovery Strategy for the North Pacific Humpback Whale (*Megaptera novaeangliae*) in Canada [DRAFT]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa.

Goodman, M.A., J.B. McNeill, E. Davenport, and A.A. Hohn. 2007. Protected species aerial survey data collection and analysis in waters underlying the R-5306A Airspace: Final report submitted to U.S. Marine USACE, MCAS Cherry Point. NOAA Technical Memorandum NMFSSEFSC-551.

Green, M. and R. Green. 1990. Short-term impact of vessel traffic on the Hawaiian humpback whale (*Megaptera novaeangliae*). Report to the Animal Behavior Society, SUNY, Buffalo, NY.

Greene, K. 2002. Beach nourishment: a review of the biological and physical impacts. ASMFC Habitat Management Series #7.

Hackney, C.T., M.H. Posey, S.W. Ross, and A.R. Norris. 1996. A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach nourishment. Prepared by the University of North Carolina at Wilmington and the North Carolina National Estuarine Research Reserve for the U.S. Army USACE of Engineers, Wilmington, NC.

Hague, E. and J. Massa. 2010. Benthic Characterization Survey and Grain Size Analysis of the Beaufort Inlet Ebb Tide Delta, Morehead City, Carteret County, North Carolina – Draft Report. Boynton Beach, Florida: Tetra Tech EC, Inc. 22 pp.

Hales, L. Z. 1995. Dredge Plant Equipment and System Processes; Summary Report for Technical Area 3. Technical Report DRP-95-10. Prepared for Department of the Army. Final Report November 1995.

Hall, W. 2011. An Archaeological Remote Sensing and Target Identification Survey of Bogue Banks Offshore Borrow Areas Q2, Y1 and ODMDS, Carteret County, North Carolina. Mid-Atlantic Technology and Environmental Research, Inc. September 8 2011, Castle Hayne, NC.

Hall, W.J., T.I.J. Smith, and S.D. Lamprecht. 1991. Movements and habitats of shortnose sturgeon (*Acipenser brevirostrum*) in the Savannah River. Copeia, 1991, 695-702.

Hays, G.C., J.S. Ashworth, M.J. Barnsley, A.C. Broderick, D.R. Emery, B.J. Godley, and E.L. Jones. 2001. The importance of sand albedo for the thermal conditions on sea turtle nesting beaches. Oikos 93: 87-94.

Hemphill, L., S. King, E. Partee, and C. McCann. 2006. Short-Term Impact of Vessel Traffic on the Hawaiian Humpback Whale (*Megaptera novaeangliae*). The Ocean Mammal Institute

Herren, R.M. 1999. The effect of beach nourishment on loggerhead (*Caretta caretta*) nesting and reproductive success at Sebastian Inlet, Florida. Orlando, Florida: University of Central Florida, Master's Thesis.

Heron, S.D., T.F. Moslow, W.M. Berelson, J.R. Herber, G.A. Steele, and K.R. Susman. 1984. Holocene Sedimentation of a Wave-dominated Barrier Shoreline: Cape Lookout, North Carolina. Marine Geology, 60, pg. 413.

Hildebrand, J.A. 2009. Anthropogenic and Natural Sources of Ambient Noise in the Ocean. Mar. Ecol. Prog. Ser. 395:5-20.

Hine, A.C. and S.W. Snyder. 1985. Coastal Lithosome Preservation: Evidence from the Shoreface and Inner Continental Shelf Off Bogue Banks, North Carolina. Marine Geology 63: 307-330.

Holloman, K.T. and M.H. Godfrey. 2008. Sea turtle monitoring project report, Bogue Banks, North Carolina, 2002-2007 final report. NC Wildlife Resources Commission.

International Panel on Climate Change. 2007. Fourth Assessment Report (AR4), Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed. S Solomon et al. Cambridge, UK: Cambridge University Press.

James, M.C., C.A. Ottensmeyer, and R.A. Meyers. 2005. Identification of High-Use Habitats and Threats to Leatherback Sea Turtles in Northern Waters: New Directions for Conservation. Ecology Letters 8: 195-201.

Jensen, R.E. 2010. Wave Information Studies Project Documentation. US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, MS.

Johnson, D H., and J.A. Dechant-Shaffer (Series Coordinators). 2002. Effects of management practices on wetland birds. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/literatr/wetbird/index.htm (Version 12DEC2003)

Knowlton, A., J. Ring, and B. Russell. 2002. Right whale sightings and survey effort in the mid-Atlantic region: migratory corridor, time frame, and proximity to port entrances. A report submitted to the NMFS Ship Strike Working Group.

Knutson, T.R., J.L. McBride, J. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J.P. Kossin, A.K. Srivastava, and M. Sugi. 2010. Tropical Cyclones and Climate Change. Nature Geoscience 3: 157-163.

Koster, D., L. Sayigh, K. Urian, and A. Read. 2000. Evidence for Year-Round Residency and Extended Home Ranges by Bottlenose Dolphins in North Carolina. Abstracts, Eighth Annual Atlantic Coastal Dolphin Conference, 24-26 March 2000, Wilmington, NC.

Lawrence, R. W. 2007. Archaeological Investigations at Beaufort Inlet: A Summary of Submerged Cultural Resources and Investigations at Beaufort, North Carolina. *Queen Anne's Revenge* Shipwreck Project Research and Bulletin Series, QAR-R-07-02, North Carolina Department of Cultural Resources, Raleigh, NC.

Leber, K. M. 1982. Seasonality of Macroinvertebrates on a Temperate High Wave Energy Sand Beach. Bulletin of Marine Science 32: 86–98.

LeGrand, H.E. 1983. Southern Atlantic Coast Region. American Birds 37:978–980.

Lindquist, N. and L. Manning. 2001. Impacts of Beach Nourishment and Beach Scraping on Critical Habitat and Productivity of Surf Fishes – Final Report.

Manning, L. M. 2003. Ecology of ocean beaches: the importance of human disturbances and complex biological interactions within a physically rigorous environment. PhD thesis, Univ. of North Carolina, Chapel Hill.

Marshall, J.A. 2004. Event Driven Sediment Mobility on the Inner Continental Shelf of Onslow Bay, NC. Master of Science Thesis, University of North Carolina Wilmington.

McCauley, R.D. 1994. Seismic Surveys. In: Swan, J.M., J.M. Neff, and P.C. Young (Eds.) Environmental Implications of Offshore Oil and Gas Development in Australia – The Findings of an Independent Scientific Review. APEA, Sydney.

Mid-Atlantic Fishery Management Council (MAFMC). 2011. Suite 201, 800 N. State St Dover, Delaware. Updated 15 February 2011; Accessed February 2011. Available online at http://mafmc.org/.

Matsuzawa, Y., K. Sato, W. Sakamoto, and K.A. Bjorndal. 2002. Seasonal fluctuations in sand temperature: effects on the incubation period and mortality of loggerhead sea turtle (*Caretta caretta*) pre-emergent hatchlings in Minabe, Japan. Marine Biology 140: 639-646.

Moffat and Nichol (M&N). 2010. Bogue Banks Beach and Nearshore Monitoring Program, 2010 Final Report. Prepared for the Carteret County Shore Protection Office.

M&N. 2009. Charleston ODMDS Sand Borrow Project. Final Environmental Assessment. Prepared for Minerals Management Service, Branch of Environmental Assessment. Published by US Department of the Interior, Minerals Management Service, Environmental Division. October 2009.

M&N. 2008. Coastal Impacts Assessment, Charleston ODMDS Sand Borrow Project. Report prepared for the South Carolina State Ports Authority.

Moser, M. L. and S. W. Ross. 1995. Habitat use and movements of shortnose and Atlantic sturgeon in the lower Cape Fear River, North Carolina. Transactions of the American Fisheries Society 124: 225-234.

Mrosovsky, N. 1995. Temperature and sex ratio. In: Bjorndal, K. (ed.) Biology and Conservation of Sea Turtles, revised edition. Smithsonian Institution Press, Washington, DC, pp. 597–598.

Mullin, K.D. and G.L. Fulling. 2003. Abundance of Cetaceans in the Southern U.S. North Atlantic Ocean during Summer 1998. Fishery Bulletin 101:603-613.

Nash, D. 2003. Seabeach Amaranth and Renourished Beaches in North Carolina. Presentation to the 2003 Annual Meeting of the North Carolina Shore and Beach Preservation Association.

National Climatic Data Center (NCDC). 1998. http://www.ncdc.noaa.gov. Last accessed 04 February 2012.

National Marine Fisheries Service (NMFS). 2010. Recovery plan for the fin whale (*Balaenoptera physalus*). National Marine Fisheries Service, Silver Spring, MD.

NMFS. 2005. Recovery Plan for the North Atlantic Right Whale (*Eubalaena glacialis*). National Marine Fisheries Service, Silver Spring, MD.

NMFS. 2003. Taking of Marine Mammals Incidental to Specified Activities; Construction of the East Span of the San Francisco-Oakland Bay Bridge. Notice of issuance of an incidental harassment authorization. 68 Federal Register 64595-64609.

NMFS. 1998. Recovery Plan for the Shortnose Sturgeon (*Acipenser brevirostrum*). Prepared by the Shortnose Sturgeon Recovery Team for the National Marine Fisheries Service, Silver Spring, MD.

NMFS. 1997. Biological Opinion for Continued Hopper Dredging of Channels and Borrow Areas in the Southeastern United States. National Marine Fisheries Service, Southeast Regional Office.

NMFS. 1995. Biological Opinion for Hopper Dredging of Channels and Beach Nourishment Activities in the Southeastern United States from North Carolina through Florida East Coast. National Marine Fisheries Service, Southeast Regional Office.

NMFS. 1991a. Recovery Plan for the Humpback Whale (*Megaptera novaeangliae*). Prepared by the Humpback Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland.

NMFS. 1991b. Biological Opinion for Dredging of Channels in the Southeastern United States from North Carolina through Cape Canaveral, Florida. National Marine Fisheries Service, Southeast Regional Office.

NMFS and United States Fish and Wildlife Service (USFWS). 2008. Recovery Plan for the Northwest Atlantic Population of the Loggerhead Sea Turtle (*Caretta caretta*), Second Revision. National Marine Fisheries Service, Silver Spring, MD and U.S. Fish and Wildlife Service. Atlanta, GA.

NMFS and USFWS. 2007a. Loggerhead Sea Turtle (*Caretta caretta*) 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD and U.S. Fish and Wildlife Service, Southeast Region, Jacksonville Ecological Services Field Office, Jacksonville, FL.

NMFS and USFWS. 2007b. Green Sea Turtle (*Chelonia mydas*) 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD and U.S. Fish and Wildlife Service, Southeast Region, Jacksonville Ecological Services Field Office, Jacksonville, FL.

NMFS and USFWS. 2007c. Kemp's Ridley Sea Turtle (*Lepidochelys kempii*) 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD and U.S. Fish and Wildlife Service, Southwest Region, Albuquerque, NM.

NMFS and USFWS. 2007d. Hawksbill Sea Turtle (*Eretmochelys imbricata*) 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD and U.S. Fish and Wildlife Service, Southeast Region, Jacksonville Ecological Services Field Office, Jacksonville, FL.

NMFS and USFWS. 2007e. Leatherback Sea Turtle (*Dermochelys coriacea*) 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD and U.S. Fish and Wildlife Service, Southeast Region, Jacksonville Ecological Services Field Office, Jacksonville, FL.

NMFS and USFWS. 1993. Recovery Plan for Hawksbill Turtles in the U.S. Caribbean Sea, Atlantic Ocean, and Gulf of Mexico. National Marine Fisheries Service, St. Petersburg, FL.

NMFS and USFWS. 1991. Recovery Plan for the United States Population of the Atlantic Green Sea Turtle. National Marine Fisheries Service, Washington, D.C.

National Oceanic and Atmospheric Administration (NOAAFS). 2011a. Habitat Conservation, Habitat Protection. EFH Mapper. Silver Spring, Maryland. Accessed January 2011. Available online at http://sharpfin.nmfs noaa.gov/website/EFH_Mapper/map.aspx.

NOAAFS. 2011b. Habitat Conservation, Habitat Protection. EFH Mapper. Silver Spring, Maryland. Accessed January 2011. Available online at http://sharpfin.nmfs.noaa.gov/ website/EFH_Mapper/EFH_Report.htm .

Nelson, W.G. 1993. Beach restoration in the southeastern US: environmental effects and biological monitoring. Ocean and Coastal Management 19: 157–182.

Nelson, D.A. 1991. Issues associated with beach nourishment and sea turtle nesting. Proceedings of the Fourth Annual National Beach Preservation Technology Conference. Florida Shore and Beach Association, Tallahassee, FL, p. 277-294.

Nelson, D.A., and D.D. Dickerson. 1988. Effects of beach nourishment on sea turtles. In L.S. Tait (ed.), Proceedings of the beach preservation technology conference. 1988. Florida Shore & Beach Preservation Association, Incorporated; Tallahassee, Florida.

Nelson, D.A., K.A. Mauck, and J. Fletemeyer. 1987. Physical effects of beach nourishment on sea turtle nesting, Delray Beach, Florida. Technical Report EL-87–15. USACE Waterways Experiment Station, Vicksburg, Mississippi.

Noise Pollution Clearinghouse. 2000. Drowning in Noise, Charles Komanoff and Howard Shaw, Ph. D.; A Report for the Noise Pollution Clearinghouse (NPC). Accessible online at: www.noilsepollution.org/library/drowning/drowning.htm. April 2000.

Normandeau Associates, Inc. 2012. Effects of Noise on Fish, Fisheries, and Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities. A Literature Synthesis for the U.S. Dept. of the Interior, Bureau of Ocean Energy Management. Contract # M11PC00031. 153 pp.

North Carolina Coastal Resource Commission's Science Panel on Coastal Hazards. 2010. North Carolina Sea Level Rise Assessment Report.

North Carolina Department of Environment and Natural Resources. 2009. North Carolina Beach and Inlet Management Plan. Final Report. September 2009.

North Carolina Department of Environment and Natural Resources (NCDENR) - Division of Water Quality (NCDWQ), 2000. Basinwide Assessment Report: White Oak River Basin. June 2000 report, 80 pp. + app. A-P (North Carolina Department of Environmental and Natural Resources).

North Carolina Division of Air Quality. 2010. Annual Monitoring Network Plan for The North Carolina Division of Air Quality Volume 2, Site Descriptions By

Metropolitan Statistical Area H. The Southern Coastal Plain Monitoring Region. Raleigh NC. July 2010.

North Carolina Division of Marine Fisheries (NCDMF). 2011. Primary Nursery Areas Maps. Accessed January 2012. Available online at March 2011, http://www.ncfisheries.net/maps/ FNA_maps/map21.pdf. dated March 2011; and http://www.ncfisheries.net/maps/ FNA_maps/map17.pdf dated March 2011.

NCDMF. 2010. Draft North Carolina Spotted Seatrout Fishery Management Plan. Prepared by the Spotted Seatrout Fishery Management Plan Advisory Committee and the NCDMF. Updated 2/03/11.

NCDMF. 2009. Stock status of important coastal fisheries in North Carolina. <http://www.ncfisheries.net/stocks/index.html>. Accessed May 2010.

NCDMF. 2008. North Carolina Red Drum Fishery Management Plan - Amendment I. Red Drum Fishery Management Plan Advisory Committee and the North Carolina Division of Marine Fisheries. November 2008.

NCDMF. 2007. North Carolina Fishery Management Plan—Bay Scallop. North Carolina Department of Environment and Natural Resources Division of Marine Fisheries, Morehead City, NC.

NCDMF. 2006a. North Carolina Fishery Management Plan – Striped Mullet. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries. April 2006.

NCDMF. 2006b. North Carolina Fishery Management Plan—Shrimp. North Carolina Department of Environment and Natural Resources Division of Marine Fisheries, Morehead City, NC.

NCDMF. 2005. North Carolina Fishery Management Plan – Southern Flounder. North Carolina Division of Marine Fisheries. February 2005.

NCDMF. 2004a. North Carolina Estuarine Striped Bass Fishery Management Plan (Albemarle Sound Area and Central Southern Area). North Carolina Division of Marine Fisheries and North Carolina Wildlife Resources Commission. May 2004.

NCDMF. 2004b. North Carolina Fishery Management Plan—Blue Crab. North Carolina Department of Environment and Natural Resources Division of Marine Fisheries, Morehead City, NC.

North Carolina Division of Water Quality (NCDWQ). April 2003a. "Redbook" Surface Water and Wetland Standard (North Carolina Administrative Code 15A NCAC 02B .0100 & .0200. pp. 127. http://h2o.enr.state.nc.us/admin/rules/rb040103.pdf.

NCDWQ. April 2003b. Classifications and Standards Unit. www.h20.err.state.nc.us/csu.

Nichols, M., and Thompson, G. 1978. A field study of fluid mud dredged material: its physical nature and dispersal. *Technical Report D-78-40, US Army Corps of Engineers Waterways Experiment Station*, Vicksburg, Mississippi, p 91.

North Carolina State Ports Authority. 2001. Port of Morehead City - Radio Island Expansion Final Environmental Impact Statement North Carolina State Ports Authority. Earth Tech. May 2001.

Nowacek, D., M.P. Johnson, and P.L. Tyack. 2004. North Atlantic right whales (*Eubalaena glacialis*) ignore ships but respond to alerting stimuli. Proceedings of the Royal Society of London. Series B. Biological Sciences 271: 227-231.

Peterson, C.H., and J.T. Wells. 2000. Bogue Banks Beach Renourishment Project: Late Fall 1999 Assessment of Benthic Invertebrate and Demersal Fish Resources in the Offshore Mining Sites Prior to Sand Mining. Final Report to Carteret County and CSE Baird, Inc. (As included in CSE and Stroud 2000). 55 p. + appendices.

Peterson, C.H., M.J. Bishop, G.A. Johnson, L.M. D'Anna, and L.M. Manning. 2006. Exploiting beach filling as an unaffordable experiment: benthic intertidal impacts propagating upwards to shore birds. Journal of Experimental Marine Biology and Ecology 338: 205–221.

Peterson, C.H., D.H.M. Hickerson, and G. Grissom Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. Journal of Coastal Research 16: 368–378.

Peterson, C. H., H.C. Summerson, H.S. Lenihan, J. Grabowski, S.P. Powers, Jr., and G.W. Sarfit. 1999. Beaufort Inlet benthic resources survey. UNC-CH,Morehead City, NC, Final Report to the US Army Corps of Engineers.

Pietrafesa, L.J., G.S. Janowitz, and P.A. Wittman. 1985. Physical Oceanographic Processes in the Carolina Capes. Oceanography of the Southeastern U.S. Continental Shelf, pp. 23–32.

Posey, M. and T. Alphin. 2002. Resilience and Stability in an Offshore Benthic Community: Responses to Sediment Borrow Activities and Hurricane Disturbance. Journal of Coastal Research 18(4): 685-697.

Potter, E.F., J.F. Parnell, and R.P. Teulings. 1980. Birds of the Carolinas. University of North Carolina Press, Chapel Hill, NC.

Raymond, P.W. 1984. Effects of beach restoration on marine turtle nesting in south Brevard County, Florida. Orlando, Florida: University of Central Florida, Master's Thesis.

Reilly, F.J. and V.J. Bellis. 1983. The ecological impact of beach nourishment with dredged materials on the intertidal zone at Bogue Banks, North Carolina. Misc. Rept., Vol. 83-3. U.S. Army Engineer Coastal Engineering Res. Center, Fort Belvoir, Virginia.

Riggs, S.R., W.G. Ambrose Jr., J.W. Cook, S.W. Snyder, and S. Snyder. 1998. Sediment production on sediment-starved continental margins: The inter-relationships between hardbottoms, sedimentologic and benthic community processes, and storm dynamics. Journal of Sedimentary Research 68(1): 155–168.

Riggs, S.R., W.J. Cleary, and S.W. Snyder. 1996. Morphology and Dynamics of Barrier and Headland Shorefaces in Onslow Bay, North Carolina. In: Carolina Geological Society, Fieldtrip Guide- book, pp. 33-48.

Robinson, S.P., P.D. Theobald, G. Hayman, L.S. Wang, P.A. Lepper, V. Humphrey, and S. Mumford. 2011. Measurement of Noise Arising from Marine Aggregate Dredging Operations. MALSF (MEPF Ref no. 09/P108), Published February 2011.

Rumbold, D.G., P.W. Davis, and C. Perretta. 2001. Estimating the effect of beach nourishment on (*Caretta caretta*) loggerhead sea turtle nesting. Restoration Ecology, 9(3): 304-310.

Ryder, C.E. 1993. The effect of beach renourishment on sea turtle nesting and hatching success at Sebastian Inlet State Recreation Area. Blacksburg, Virginia, Virginia Polytechnic Institute and State University, Master's Thesis.

Saloman, C.H., and S.P. Naughton. 1984. *Beach restoration with offshore dredged sand: Effects on nearshore macrofauna*. NOAA Tech. Mem. NMFS-SEF-133. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, St. Petersburg, FL.

Schubel, J. R., C. C. Coutant, and P. M. J. Woodhead. 1978. Thermal effects of entrainment. In Schubel, J. R. & B. C. Marcy (eds), Power Plant Entrainment—A Biological Assessment. Academic Press Inc., New York: 19–93.

South Atlantic Fishery Management Council. 1998a. Final Habitat Plan for the South Atlantic Region: Essential Fish Habitat Requirements for Fishery Management Plans of the South Atlantic Fishery Management Council. The Shrimp Fishery Management Plan, The Red Drum Fishery Management Plan, The Snapper Grouper Fishery Management Plan, The Golden Crab Fishery Management Plan, The Spiny Lobster Fishery Management Plan, The Coral, Coral Reefs, and Live/Hardbottom Habitat Fishery Management Plan, The Sargassum Habitat Fishery Management Plan, and The Calico Scallop Fishery Management Plan. Charleston, South Carolina. Prepared by South Atlantic Fishery Management Council. October 1998. Copyright 2009. Accessed February 2011. Available online at www.safmc.net/Default.aspx?tabid=80.

South Atlantic Region (SAR). 2008a. National Marine Fisheries Service Habitat Conservation Division; Southeast Regional Office. Summary of EFH Requirements for Species Managed by the South Atlantic Fishery Management Council Appendix 6. St. Petersburg, Florida. Essential Fish Habitat: A Marine Fish Habitat Conservation Mandate for Federal Agencies. Revision Date August 2008. Accessed March 2011. Available online at http://sero.nmfs.noaa.gov/hcd/pdfs/efhdocs/sa_guide_2008.pdf.

SAR. 2008b. National Marine Fisheries Service Habitat Conservation Division; Southeast Regional Office. Summary of EFH Requirements for Species Managed by the Mid-Atlantic Fishery Management Council Appendix 7. St. Petersburg, Florida. Essential Fish Habitat: A Marine Fish Habitat Conservation Mandate for Federal Agencies. Revision Date August 2008. Accessed March 2011. Available online at http://sero.nmfs.noaa.gov/hcd/ pdfs/efhdocs/sa_guide_2008.pdfhttp://sero.nmfs.noaa.gov/hcd/ pdfs/efhdocs/sa_guide_2008.pdf.

Sauer, J.R., J.E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966-2007. Version 5.15.2008. Patuxent Wildlife Research Center, Laurel, MD.

Searcy, S., 2003. North Carolina State University, Email correspondence to Coastal Planning and Engineering regarding salinity and temperature data collected from the White Oak River, Highway 24, Swansboro from November 2002 to January 2003.

Seaturtle.org. 2011. Sea turtle rehabilitation and necropsy database, North Carolina stranding reports. On-line: http://www.seaturtle.org.

State Climate Office of North Carolina. 2010. Hurricanes – Statistics. Available on-line at: http://www.nc-climate.ncsu.edu/climate/hurricanes/statistics.php.

Steinitz, M.J., M. Salmon, and J. Wyneken. 1998. Beach renourishment and loggerhead turtle reproduction: A seven year study at Jupiter Island, Florida. Journal of Coastal Research 14: 1000-1013.

Street, MW., A.S. Deaton, W.S. Chappell, and P.D. Mooreside. 2005. North Carolina Coastal Habitat Protection Plan. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, NC. 656 pp.

Taggart, J.B. 1980. Fort Macon Park Natural Area. Report compiled for the North Carolina Division of Parks and Recreation.

Tyler-Walters, H. and A. Jackson. 1999. Assessing seabed species and ecosystems sensitivities. Rationale and user guide. Report to English Nature, Scottish Natural Heritage and the Department of the Environment Transport and the Regions from the Marine Life Information Network (MarLIN). Plymouth, Marine

Biological Association of the UK. (MarLIN Report No.4.). January 2000 edition. www.marlin.ac.uk/PDF/ MarLINReport4.PDF.

Underwood, A.J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications 4: 3-15.

United States Army Corps of Engineers (USACE), Wilmington District. 2009. Final Integrated General Reevaluation Report and Environmental Impact Statement, Shore Protection, West Onslow Beach and New River Inlet (Topsail Beach), North Carolina. February 2009 (Revised April 2009).

USACE. 2008. South Atlantic Regional Biological Assessment (SARBA) for Dredging Activities in the Coastal Waters, Navigation Channels [including designated Ocean Dredged Material Disposal Sites (MOREHEAD CITY ODMDS)], and Sand Mining Areas in the South Atlantic Ocean. U.S. Army Corps of Engineers, South Atlantic Division. September 2008.

USACE. 2007. Draft Environmental Impact Statement. North Topsail Beach Shoreline Protection Project. . Prepared for the U.S. Army Corps of Engineers, Wilmington District by Coastal Planning and Engineering, Inc., City, ST.

USACE. 2004a. Environmental Assessment for the FEMA Post-Isabel Restoration Project.Carterety County, North Carolina. Prepared by U.S. Army Corps of Engineers, Wilmington District.

USACE. 2004b. Year 2 Recovery from impacts of beach nourishment on surf zone and nearshore fish and benthic resources on Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, North Carolina: Final study findings. Prepared for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, by Versar, Inc., Columbia, MD.

USACE. 2003. Evaluation Report and Finding of No Significant Impact, Morehead City Harbor Section 933. Carteret County, North Carolina. Wilmington District, U.S. Army Corps of Engineers. May 2003.

USACE. 2002. Dredged Material Management Plan and Environmental Assessment. Atlantic Intracoastal Waterway, North Carolina. Beaufort, North Carolina to South Carolina State Line. May 2002

USACE. 2001a. Final Environmental Assessment, Bogue Banks Beach Nourishment Project, Carteret County, North Carolina. Prepared by Coastal Science & Engineering, PLLC.

USACE. 2001b. Final Environmental Impact Study, Bogue Banks Beach Nourishment Project, Carteret County, North Carolina. Prepared by Coastal Science & Engineering, PLLC.

USACE. 2001c. Characterization of Underwater Sounds. Produced by Bucket Dredging Operations. ERDC Report TN-DOER-E14.

USACE. September 2000. Final Feasibility Report and Environmental Impact Statement on Hurricane Protection and Beach Erosion Control, Dare County Beaches (Bodie Island Portion), Dare County, North Carolina Volume I.

USACE and USEPA. 2009. Morehead City Ocean Dredged Material Disposal Site, Site Management and Monitoring Plan. USACE, Wilmington District and USEPA, Region 4. July 2009.

United States Coast Guard. 2008. Final Environmental Assessment for Maintenance Dredging for US Coast Guard Station at Emerald Isle.

United States Department of the Interior, Minerals Management Service. 1999. Environmental Report, Use of Federal Offshore Sand Sources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware, and Virginia. OCS Study MMS 99-0036. Office of International Activities and Marine Minerals. Prepared by The Louis Berger Group, Inc. Contract Number 1435-01-98-RC30820.

United States Environmental Protection Agency (USEPA). 2010a. Criteria Pollutants. Washington, DC. Updated 26 March 2010, accessed April 2010. Available online at http://www.epa.gov/air/urbanair/http://www.epa.gov/air/urbanair/.

USEPA. 2010b. National Ambient Air Quality Standards. Washington, DC. Updated 26 April 2010, accessed April 2010. Available online at http://www.epa.gov/air/criteria.htmlhttp://www.epa.gov/air/criteria.html

United States Fish and Wildlife Service (USFWS). 2011. Abundance and productivity estimates: Atlantic Coast piping plover population, 1986-2009. Sudbury, Massachusetts.

USFWS. 2009a. Draft (5/18/09) West Indian Manatee (*Trichechus manatus*) Florida Stock Florida subspecies (*Trichechus manatus latirostris*). U.S. Fish and Wildlife Service, Jacksonville, FL.

USFWS. 2009b. Piping plover (*Charadrius melodus*) 5-year review: summary and evaluation. U.S. Fish and Wildlife Service, Hadley, Massachusetts.

USFWS. 2003. Recovery Plan for the Great Lakes Piping Plover *(Charadrius melodus*). Ft. Snelling, Minnesota.

USFWS. 2002. Draft Fish and Wildlife Coordination Act Report, Bogue Banks Shore Protection Project, Carteret County, North Carolina. Raleigh Ecological Services Field Office.

USFWS. 2001. Florida Manatee Recovery Plan, (*Trichechus manatus latirostris*), Third Revision. U.S. Fish and Wildlife Service. Atlanta, GA.

USFWS. 1996a. Piping Plover (*Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. U.S. Fish and Wildlife Service, Hadley, MA.

USFWS. 1996b. Recovery Plan for Seabeach Amaranth (*Amaranthus pumilus*), Southeast Region, Atlanta, Georgia.

Valverde, H.R., A.C. Trembanis, and O.H. Pilkey. 1999. Summary of beach nourishment episodes on the U.S. east coast barrier islands. J. Coast. Res. 15, 1100–1118.

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levisen, and W.A. Roumillat. 1992. A Physical and Biological Monitoring Study of the Hilton Head Beach Nourishment Project. Marine Resources Research Institute, South Carolina Marine Resources Division, Charleston, S.C. 159 pp.

Vasconcelos, R.O., M.C.P. Amorim, and F. Ladich. 2007. Effects of Ship Noise on the Detectability of Communication Signals in the Lusitanian Toadfish. Journal of Experimental Biology 210:2104-2112.

Vella, G., I. Rushforth, E. Mason, A. Hough, R. England, P. Styles, T. Holt and P. Thorne. 2001. Assessment of the Effects of Noise and Vibration from Offshore Windfarms on Marine Wildlife. A Report for the UK DTI by ETSU, Reference W/13/00566/REP: DTI/Pub URN 01/1341.

Versar. 2003. Year 2 Recovery from Impacts of Beach Nourishment on Surf Zone and Nearshore Fish and Benthic Resources on Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, North Carolina: Final Study Findings. U.S. Army Corps of Engineers, Wilmington, North Carolina.

Versar. 2003. Effects of dredged material beach disposal on surf zone and nearshore fish and benthic resources on Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, North Carolina: interim study findings. Prepared for USACE, Wilmington District, NC; Prepared by Versar Inc, Columbia, MD, Vol I, 54 pp.

Waring GT, Josephson E, Maze-Foley K, Rosel, PE, editors. 2011. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2010. NOAA Tech Memo NMFS NE 219; 598 p.

Watts, G. 1992. A Remote Sensing Survey and Reconnaissance Investigations to Identify and Assess Targets Located Along Range A, a Bar Channel Widener, a Channel Extension, and Two Spoil Deposits at Beaufort, Inlet North Carolina. Report on file Environmental Resources Branch U.S. Army Corps of Engineers District, Wilmington, North Carolina

Wibbels, T. 2003. Critical approaches to sex determination in sea turtles. In: Biology of Sea Turtles, Vol. II (Eds. Lutz, P.L., J.A. Musick, and J. Wyneken) pp. 103-134. Boca Raton: CRC Press.

Wilber, D.H. and D.G. Clarke. 2007. Defining and Assessing Benthic Recovery Following Dredging and Dredged Material Disposal. Proceedings XXVII World Dredging Congress 2007, Orlando, FL.

Wolcott, T.G. 1978. Ecological role of ghost crabs, *Ocypode quadrata*, on an ocean beach: scavengers or predators? *Journal of Experimental Marine Biology and Ecology*. 31:67–82.

Wren, P.A. 2004. Sediment Transport Measurements on the Mid-Continental Shelf in Onslow Bay, North Carolina. North Carolina State University, Ph.D. Thesis, Raleigh, NC.

Zervas, C. E. 2009. Sea Level Variations of the United States, 1854-2006. NOAA Technical Report NOS CO-OPS 053.

Zervas, C. E. 2004. North Carolina bathymetry/topography sea level rise project: determination of sea level trends. NOAA Technical Report NOS CO-OPS 041.

Zinski, S. C. 2006. Blue Crab Archives. <http://www.blue-crab.org/spawning.htm>. Updated June 2006. Accessed May 2010.

— EIS —

FINAL

Bogue Banks Beach Restoration Plan

Proposed by:

Carteret County, Town of Pine Knoll Shores,
Town of Indian Beach, and Town of Emerald Isle

Prepared for:

Donna Moffitt, Director
North Carolina Department of
Environment and Natural Resources
Division of Coastal Management
PO Box 27687 Raleigh NC 27611-7687

Prepared by:

Coastal Science & Engineering LLC*
PO Box 8056 Columbia SC 29202-8056

and

Stroud Engineering PA
Hestron Plaza Two (A) 151-A Hwy 24 Morehead City NC 28557

FIRST DRAFT 6 MARCH 2000

SECOND DRAFT REVISED 31 OCTOBER 2000

FINAL REVISED 4 APRIL 2001

[*formerly CSE Baird LLC]

Addendum II to Draft EIS dated 31 October 2000

The present version (4 April 2001) of the EIS for Bogue Banks Beach Restoration Plan includes the following changes and additions.

Correspondence Section (between the main report and Appendix A) — Additional comments and responses from corresponding State Clearinghouse agencies, University of North Carolina Institute of Marine Sciences, and Environmental Defense are provided in chronological order of the original correspondence with a supplementary index.

Addendum I to Draft EIS dated 6 March 2000

The present version (31 October 2000) of the EIS for Bogue Banks Beach Restoration Plan includes the following changes and additions.

Main Report — Changes in the main report (Sections 1-6) are highlighted in **SMALL-CAP BOLD** (text additions) and/or with a ~~strikeout~~ (text deletions).

New Section — "Correspondence" (between the main report and Appendix A). Comments and responses from corresponding agencies are given in chronological order of the original correspondence with a supplementary index.

Revised Appendix C — Final report (revised 11 September 2000) on Bogue Banks beach renourishment project: late fall 1999 assessment of benthic invertebrates and demersal fish resources in the offshore mining sites prior to sand mining by Dr Charles H Peterson and Dr John T Wells, Institute of Marine Sciences, University of North Carolina, Morehead City, NC, 13 pages + appendices.

PREFACE

This Environmental Impact Statement (EIS) is prepared in accordance with North Carolina environmental permitting regulations in the coastal zone. Carteret County has sustained accelerated erosion along Bogue Banks as a result of five hurricanes in quick succession since 1995 (Fig. P1). The county, the municipalities of Emerald Isle, Indian Beach, and Pine Knoll Shores, and the unincorporated area of Salter Path desire to perform beach nourishment at the earliest time for purposes of restoring the recreational beach and reducing the direct threat of erosion to developed property. The most recent hurricane (*Floyd*, September 1999) caused $30 million in damages in the county, most of which occurred along the oceanfront in the municipalities listed above. Beach nourishment is considered to be the only viable alternative among three possible alternatives at this time. Continued erosion will directly threaten the tax base of the entire county if nothing is done because of the effective subsidy of county tax rates provided by Bogue Banks property owners. Property abandonment and relocation would cost much more than the proposed nourishment project in reduced tax revenues and the direct costs of relocation over the next decade.

Time is of the essence, but the county recognizes that projects of this type require careful analysis and design, as well as consideration of the environmental consequences. The county has commissioned a citizens' advisory panel and has reviewed alternatives for the past two years. Drawing on expertise from the local as well as national professional community, beach nourishment has been selected as the interim solution. The panel recognizes that only through site-specific project experience can the true consequences and costs of nourishment be known. It acknowledges that there are risks with projects of this type, and the outcome cannot be predicted with absolute certainty. However, the risks of the other two alternatives are considered to be much greater. Continued damages to property are all but certain if nothing is done. And the timeline for property abandonment and relocation is an exceedingly long process when one factors in the emotional investments of owners and the high probability of legal challenges brought when properties are condemned. Property abandonment and relocation at a large scale would leave the beach degraded for many years because it would necessarily become a piece-meal process. Those opting to abandon would leave derelict structures on the beach, imposing aesthetic, environmental, and financial costs to the county and municipalities.

The proposed plan has been formulated over the past year with preliminary input from many resource agencies. It addresses the specific conditions along Bogue Banks and incorporates best-management practices as recommended by federal and state regulatory agencies. The plan seeks to minimize environmental impacts, provide enhanced beaches for the public, and maintain viable wildlife habitat while reducing future storm damages over the next decade.

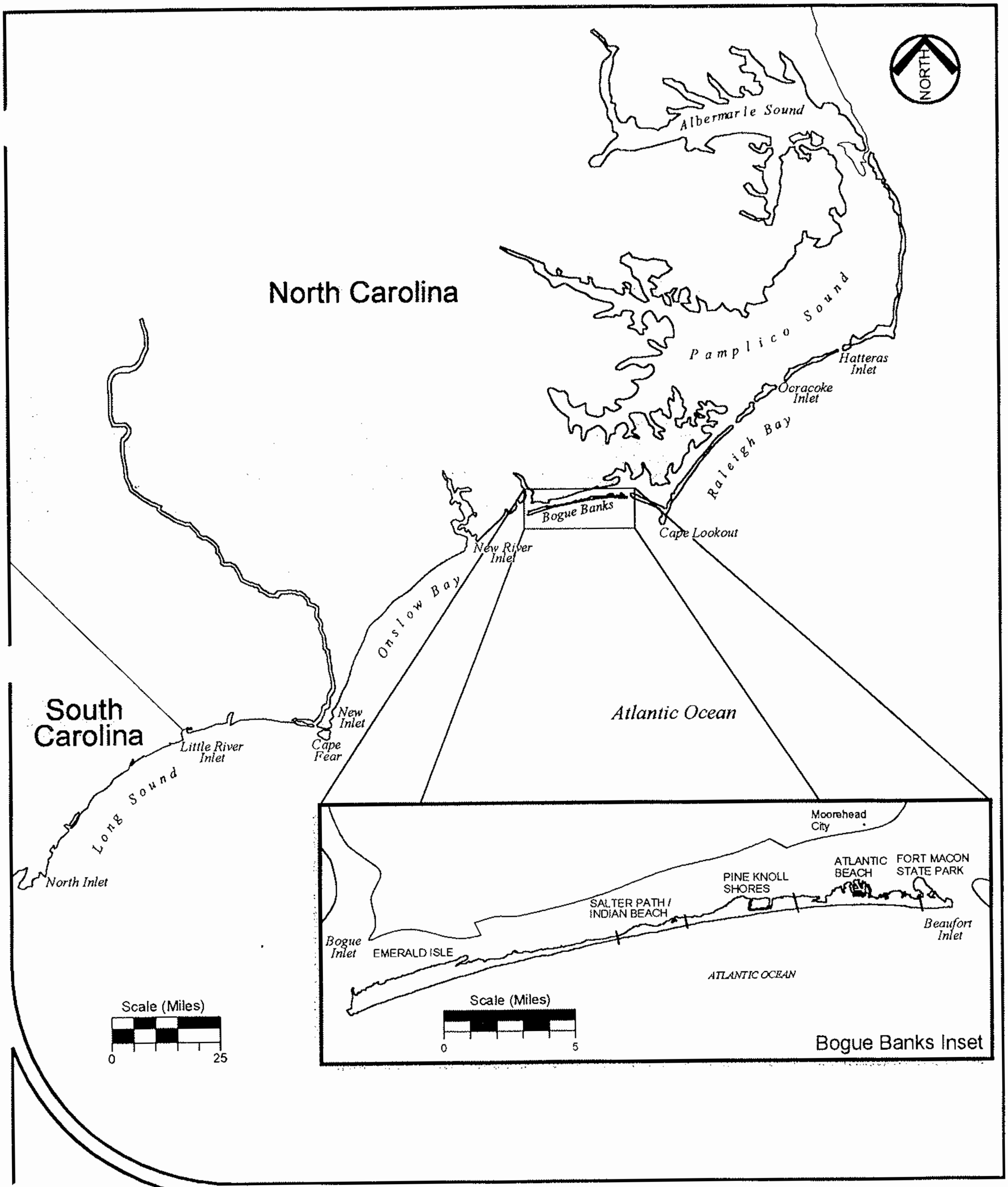


Figure P1
Site location map for Bogue Banks beach restoration project

Coastal Science & Engineering, LLC

TABLE OF CONTENTS

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 PROJECT SPONSOR

The proposed beach nourishment project is being sponsored by Carteret County in conjunction with the Towns of Pine Knoll Shores, Indian Beach and Emerald Isle. Funding is proposed by a combination of locally generated revenue sources. No state or federal funding assistance is currently included.

1.2 PROJECT SETTING

The project area includes the beaches reaching from the town limits of Pine Knoll Shores and Atlantic Beach to the western end of Emerald Isle, ~1 mile east of Bogue Inlet. Total project length of 16.8 miles of shoreline.

Bogue Banks is a barrier island with a southward facing ocean shoreline stretching some 25 miles between two large tidal inlets, Bogue Inlet to the west and Beaufort Inlet to the east. The Banks are surrounded by Bogue Sound on the north and Onslow Bay of the Atlantic Ocean on the south.

Of over 70 miles of barrier island shoreline located in Carteret County, Bogue Banks is the only developed area. The remainder, made up of Shackleford Banks and Core Banks to Ocracoke Inlet, will remain undeveloped in perpetuity as part of the Cape Lookout National Seashore. Bogue Banks is the only ocean shoreline in Carteret County with convenient vehicle access to all citizens.

1.3 PURPOSE AND NEED

Carteret County and the communities on Bogue Banks recognize the oceanfront beaches and adjacent properties as a valuable public economic and ecological resource. Like any valuable resource, it must be protected. From an economic perspective, the need for the proposed Bogue Banks beach nourishment project is to protect and preserve the largest portion of the county's overall economy. Tourism is, by far, the largest industry in Carteret County. The industry contributes ~$208 million annually to the economy of Carteret County, with a direct payroll of more than $38 million to over 3,400 workers.

Bogue Banks represents less than 1 percent of Carteret County's land area but accounts for ~43 percent (over $2 billion of the county's $5.4 billion tax base) of Carteret County's ad valorem property tax base (1997). Approximately 61 percent of all locally generated revenues in the county derive from property taxes with the remainder from sales taxes, occupancy taxes, and fees. Nearly 80 percent of Carteret County's tax levy funds Carteret County schools. Out of 8,483 students in Carteret County schools, only 537 (6.3 percent) reside on Bogue Banks (1997-98). Thus, property owners on Bogue Banks provide almost half the funds for county schools but make up less than 10 percent of the school population. Any reduction of the effective subsidy derived from Bogue Banks property and economic activity would result in increased property taxes over the remainder of the county. Loss of the first row of oceanfront properties (which alone comprise nearly 10 percent of the county tax base) would result in a county-wide tax increase of ~$0.05/$100 (from $0.50/$100 to $0.55/$100) to make up for the reduced tax base.

Oceanfront properties represent an inordinate share of total property tax revenues to the Bogue Banks municipalities. Emerald Isle has a total tax base of ~$1,000,000,000 with ~$300,000,000 of the tax base deriving from oceanfront property. The loss of the oceanfront row of properties in Emerald Isle would result in a property tax increase of ~$0.09/$100 from $0.195/$100 to $0.285/$100. Pine Knoll Shores has a total tax base of ~$415,000,000 with ~45 percent ($185,000,000) of the tax base deriving from oceanfront property. The loss of the oceanfront row in Pine Knoll Shores would result in a property tax increase of ~$0.13/$100 from $0.16/$100 to $0.29/$100. Indian Beach has a total tax base of ~$100,000,000 with $60,000,000 of the tax base deriving from oceanfront property. The loss of the oceanfront row of properties in Indian Beach would result in a property tax increase of ~$0.26/$100 from $0.17/$100 to $0.43/$100.

The county also recognizes the beaches of Bogue Banks as a valuable ecological resource. Of over 70 miles of barrier island shoreline located in Carteret County, Bogue Banks is the only developed portion. The remainder, made up of Shackleford Banks and Core Banks to Ocracoke Inlet, will remain undeveloped in perpetuity as part of the Cape Lookout National Seashore. Bogue Banks serves to draw human activity away from the pristine beaches and ecosystems of Shackleford and Core Banks. The health of the beach environment is essential to a positive experience for the beach visitor. The damage associated with severe storms results in the loss of high oceanfront dunes, scrub and maritime forests. Easily accessible wide dry beach areas, high dunes and maritime forests harbor a wide range of wildlife resources and, because of the effects of erosion, are becoming increasingly rare along North Carolina's shoreline.

The sportfishing industry in Carteret County is second in size only to Dare County. The health of those activities (including fishing, boat building, and outfitting and supply) is dependent on the health of the marine environment.

Project Planning Objectives – In undertaking the beach nourishment project, Carteret County has several objectives that the project must meet. Those objectives are summarized as follows:

- Preservation of the environmental, cultural and aquatic resources of the county.
- Provide an easily accessible recreational beach available to all citizens of the county.
- Provide protection of oceanfront property as a resource of tax revenues to the municipalities of Bogue Banks and the county.
- Maintain the economic viability of tourism, the county's largest industry.

1.4 PROJECT DESCRIPTION

The proposed beach nourishment project will consist of placing the equivalent of ~4.5 million cubic yards of beach-quality sediment along ~16.8 miles of Bogue Banks from the Atlantic Beach/Pine Knoll Shores town line to ~Shipwreck Lane along western Emerald Isle (Fig. 1.1). Nourishment sand will be excavated from up to ~~four~~ **THREE** borrow areas by hopper dredge or hydraulic dredge and placed along as many as six contiguous reaches. [CSE Baird-Stroud. 1999. Shoreline assessment and preliminary beach restoration plan, Bogue Banks, NC. Executive Summary Report, 38 pp.]

Three potential borrow areas (A, B1, and B2) have been sampled and delineated offshore of the project area, and an alternate borrow area (C) has been identified in Bogue Inlet. **AS A RESULT OF COMMENTS FROM NCDENR, BORROW AREA C IS NO LONGER BEING CONSIDERED AS AN ALTERNATE BORROW AREA FOR THE PROJECT**. Sediment quality in each borrow area was compared with native beach sediment quality to determine compatibility indices (R_A, after the method of James, 1975). Twenty samples from the dune, berm, beach face, and low-tide terrace were used to determine the "native" sediment characteristics. The mean grain size computed from 20 samples was ~0.30 mm [versus 0.17 mm used by USACE (1976) for planning along Atlantic Beach].

Borrow area A (revised) had the lowest R_A value (1.16), meaning that ~85 percent of the deposit would be stable as beach fill. Borrow area B1 yielded an R_A value of 2.19; B2 yielded an R_A value of 1.97; and C yielded an R_A value of 1.57. The R_A factors predict how many cubic yards of nourishment material will be required to perform as 1.0 cy of native beach sediment. Variations in R_A factors were used to adjust the required (base) nourishment volume for a particular borrow area. Borrow areas with higher R_A will require proportionately higher excavation volumes to achieve the same performance as native beach sand.

Final selection of borrow area(s) will be based on several factors, including sediment quality, dredging and transportation economics/environmental impacts, and cultural resource impacts. Borrow area A is tentatively identified as the optimal sand source. It extends from ~0.5 to 2.5 miles offshore, centered near the Emerald Isle/Indian Beach town line. Sediments have been confirmed over an ~4.5 square-mile area to a section thickness averaging ~2.25 ft. This yields potentially 10 million cubic yards of beach quality sediment. Only a portion of borrow area A will be required to satisfy the nourishment volume requirements of the project (~5.1 million cubic yards after factoring in the overfill ratio). The average water depth in borrow area A is ~46 ft. The anticipated optimal equipment for excavations will be ocean-certified, self-contained hopper dredges. Such equipment typically excavates shallow trenches (~2 ft of section) in each pass (leaving narrow undisturbed areas at the margin of each cut), then travels to a buoyed pipeline anchored close to shore. Discharge to the beach is via submerged pipeline across the surf zone, then by way of shore-based pipe positioned along the dry beach.

The project will be built in ~1-2 mile sections, optimizing the disposition of pipeline. Sections will be pumped into place with the aid of temporary dikes pushed up by bulldozer in the surf zone. Daily operations will directly impact ~ 500-1000 ft of shoreline as work progresses in either direction from the submerged pipeline. Upon completion of a section, the submerged pipe and beach-building equipment will be shifted to the next section.

The project will add an average of ~50 cy per linear foot along the recreational beach between the base of the foredune and the outer bar. It will displace the shoreline ~75-100 ft seaward after fill adjustment. The backbeach grade for the project will be set close to the existing grade of the dry beach (~+7 ft NGVD). The fill will be sloped in the seaward direction to maintain proper drainage. Where oceanfront development exists at elevations nearly equaling the native dry beach, a low protective dune will be pushed up along the backbeach to prevent the slurry from draining toward buildings.

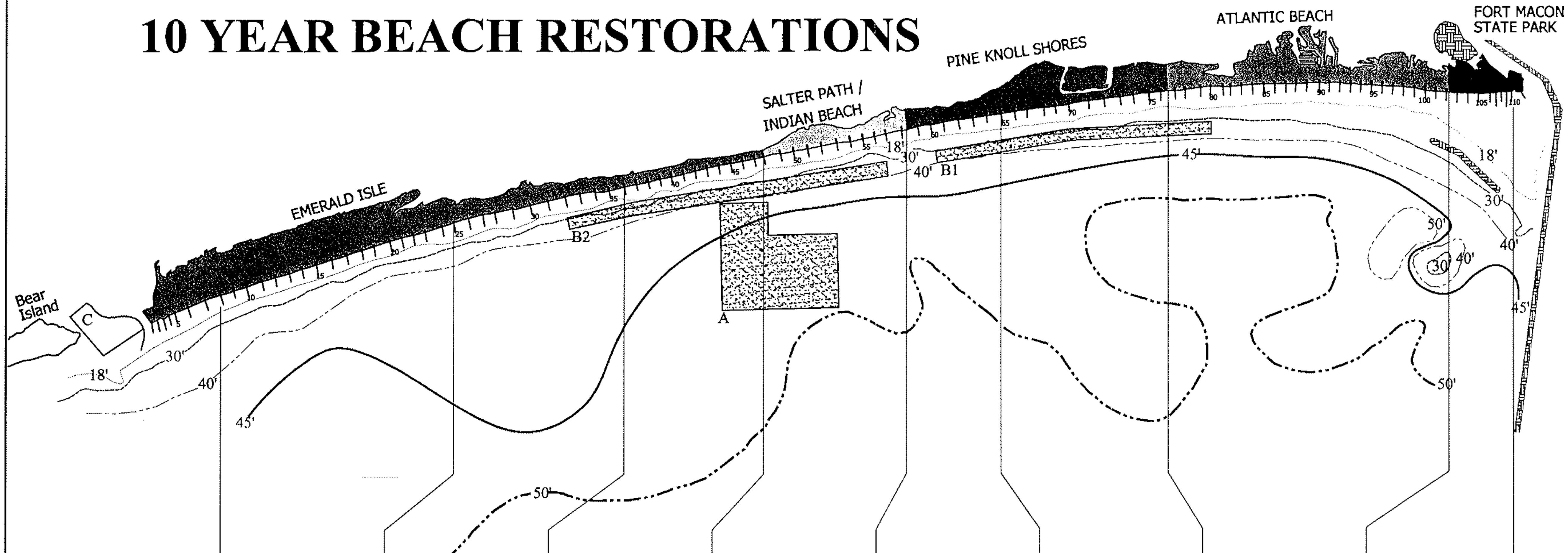
Under normal circumstances, using a single dredge, the project will require 180-300 days to construct (at 15,000-25,000 cy per day average production). The applicant desires to perform construction during winter months to avoid the tourist season, turtle-nesting season, and periods of highest biological productivity. Alternatives involving use of more than one dredge (to shorten the construction period) or splitting construction over two winter seasons are being investigated.

As construction progresses, sections will be graded to final contours, dressed to eliminate low areas, and opened for use by the community. Support equipment will be shifted out of completed sections as soon as practicable, such that construction activities in a given reach will disrupt normal beach use for only a month or so at any locality.

The finished sections will be allowed to adjust to natural processes for several months. Then in applicable areas, dune fencing and/or dune plantings will be installed.

In all likelihood, only portions of the entire project will be constructed under a single mobilization during any particular environmental window. For example, the community of Pine Knoll Shores may secure funding and elect to construct a project within their political boundaries [designated as reaches Pine Knoll Shores East and Pine Knoll Shores West in CSE Baird-Stroud (1999) and this document, Fig. 1.1]. Similarly, the Town of Emerald Isle and the Town of Indian Beach may elect to construct projects for their reaches independent of Pine Knoll Shores. Based on our present understanding of funding availability, it is not likely that the entire 16.8-mile project will be constructed within the same environmental window.

PRELIMINARY PROJECT ALTERNATIVES
10 YEAR BEACH RESTORATIONS



Emerald Isle West 1	Emerald Isle Central 2	Emerald Isle East 3	Indian Beach Salter Path 4	Pine Knoll Shores West 5	Pine Knoll Shores East 6	Atlantic Beach	Fort Macon State Park
Recommended Project: 10 Year	Recommended Project: 10 Year	Recommended Project: 10 Year	Recommended Project: 10 Year	Recommended Project: 10 Year	Recommended Project: 10 Year	Recommended Project: Continue Corps Disposal Project	Recommended Project: Increased Corps Disposal Project
Nourishment Volume: 866,000 cy	Nourishment Volume: 844,000 cy	Nourishment Volume: 1,745,000 cy	Nourishment Volume: 990,000cy	Nourishment Volume: 778,000 cy	Nourishment Volume: 1,466,000 cy		
Length: 23,700 ft	Length: 14,545 ft	Length: 12,900 ft	Length: 13,417 ft	Length: 8,760 ft	Length: 15,437 ft		
Borrow Area C: Bogue Inlet Shores via hopper dredge	Borrow Area A: Salter Path Offshore Deposits	Borrow Area A: Salter Path Offshore Deposits	Borrow Area A: Salter Path Offshore Deposits	Borrow Area A: Inshore Deposits	Borrow Area A: Inshore Deposits		

Summary:

Length: ~88,760 ft - 16.8 miles

10-Yr Profile Volume Required: ~4,424,500 cy

Nourishment Required: 10yr volume x R_a

(Ra = Estimated overfill factor for respected borrow areas.)

NOTE: Nourishment volumes are based on a computed profile volume deficit to the outer bar, background volume erosion rate, and overfill ratio for the indicated borrow area. Use of alternative areas will result in revised nourishment volumes and unit construction costs. The low-end cost estimate assumes shared engineering, permitting, and construction mobilization costs. The high-end cost estimate assumes independently formulated and executed projects. Details are given in CSE Baird/Stroud (1999).

Borrow area key

CSE Borrow Areas

Corps Borrow Areas

R_a values for borrow areas:

Borrow Area A - ~1.16
Borrow Area B1 - ~2.19
Borrow Area B2 - ~1.97
Borrow Area C - ~1.57

Native beach composite

Mean grain size ~0.302mm.

Depth contours (ft below MLW)

18'
30'
40'
45'
50'

CSE
Coastal Science & Engineering, LLC.

STROUD ENGINEERING
151A HIGHWAY 24
MOREHEAD CITY, N.C. 28557
(252) 247-7479

Surveyed By:
Drawn By: PAM TWK
Checked By: TWK
Approved By: TEW

REVISIONS:

Date

PROJECT NORTH

0 5000 10000

Bogue Banks
Beach Nourishment
North Carolina

Prepared For:
Carteret County
North Carolina

Drawing Title:

Fig 1.1

CSE Project Number: 9853-04
Date: February 2000
Printed: 2/11/00
Drawing Number: Fig_00-1.dwg
Sheet Number:

2.0 SUMMARY

2.1 MAJOR CONCLUSIONS

Bogue Banks is the only developed, accessible beach in Carteret County, representing ~35 percent of the county shoreline and 1 percent of the county land area. Residential and business properties on Bogue Banks account for ~43 percent of the county tax base but receive a much lower percentage of county services and investments. Chronic erosion, while occurring at low rates compared to many shorelines, has accelerated recently as a result of five landfall hurricanes in quick succession since 1995. Loss of beach area and a general sand deficit have left nearly 17 miles of oceanfront vulnerable to damage during even minor storms. The most recent hurricane (*Floyd*, 1999) caused upward of $30,000,000 damage in the county, largely concentrated along Bogue Banks' oceanfront, where the beach is narrowest. Little or no property damage occurred along Atlantic Beach, which had a much wider beach as a result of nourishment in 1986 and 1994.

Erosion poses an immediate threat to property, infrastructure, and the county tax base. Loss of oceanfront properties to erosion would result in tax increases ranging from $0.05/$100 for all mainland residents to $0.31/$100 for Indian Beach residents, with Pine Knoll Shores properties in between these amounts.

Tourism, the county's primary industry, will decline if the beach continues to erode. Presently, there is less recreational beach area for the public than five years ago. Property owners have increased the frequency of beach scraping to rebuild foredunes and protect imminently threatened homes. Associated with erosion and dune scraping has been a decline in beach habitats for nesting sea turtles and other organisms.

A citizens' Beach Preservation Task Force, meeting frequently over the past two years, has determined that the only viable alternative is to rebuild the beach via nourishment. Over a ten-year period, nourishment results in lower costs compared to the "no-action" alternative or "property abandonment and retreat" alternative.

A ten-year nourishment project is estimated to require a minimum of 4.5 million cubic yards to restore the sand deficit and provide for average yearly losses over a decade or so. This level of effort would add ~50 cubic yard per foot (cy/ft) along 16.8 miles of beach from Pine Knoll Shores to western Emerald Isle and widen the recreational beach 75-100 ft. The project would restore eroded areas to a similar condition as that of Atlantic Beach.

Viable beach-quality sand exists in several strategic offshore areas close to the shoreline. Preliminary estimates indicate that these deposits can be excavated and placed on the beach via hydraulic dredge at a cost of approximately $25 million. Other potential borrow sources (including shoals in Bogue Inlet, Bogue Sound, and Beaufort Inlet, or existing spoil areas controlled by the USACE) are considered less cost effective because of their distance to the project area or their poorer quality material.

The proposed project will require ~6-8 months to construct if only one dredge is available. The county desires to complete the project at the earliest time and will seek ways to complete construction during cold weather months when environmental impacts are lowest. The ~~planned~~ **EARLIEST** period of construction **FOR ANY PARTICULAR REACH IS NOW ESTIMATED TO BE** November ~~2000~~ **2001** through April ~~2001~~ **2002**. Construction activities will directly impact a particular property for only a few days as nourishment proceeds section by section at an average rate of about 300-500 ft per day. The project will be monitored carefully after construction to quantify its longevity and document environmental change. As the first nourishment along most of Bogue Banks, it will necessarily serve as a prototype for future beach maintenance efforts.

2.2 AREAS OF CONTROVERSY

Beach nourishment, in general, involves three primary areas of controversy: (1) funding, (2) physical impacts, and (3) environmental impacts.

2.2.1 Funding – **FUNDING FOR** the proposed project ~~will be funded entirely using county and~~ **IS UNCERTAIN AT THIS TIME BUT WILL LIKELY INVOLVE MOSTLY** local funds. ~~No federal or state funds will be used.~~ Approximately 64 percent of the project will be funded by property owners in special tax districts on Bogue Banks. Analyses have demonstrated that significant economic benefits accrue to the entire county if the beach is maintained and the tax base on Bogue Banks is preserved.

2.2.2 Physical Impacts – Nourishment is the "only engineered shore-protection alternative that directly addresses the problem of a sand budget deficit . . . improves natural protection while also providing additional recreational area." (NAS, 1995, Beach Nourishment & Protection, pp. 1-2). While it has grown in acceptance in recent years, nourishment engenders polarization between proponents who consider it the preferred solution to erosion and opponents who consider it to be a temporary stop-gap measure against an advancing sea (NAS, 1995). Properly viewed, nourishment should be considered as a sacrificial shore-protection technique which provides a first line of defense against the action of storms and chronic erosion at the coast. Its success **will** depend on the frequency of storms, but more importantly, on the background erosion rate and long-term processes controlling shoreline change at the particular site. Nourishment adds to the littoral budget a measure of sediment which will become subject to onshore/offshore as well as longshore transport. Just as a natural beach waxes and wanes between storms, a nourished beach will adjust to daily and seasonal variations in waves and tides.

Most of the controversy and debate regarding the success of nourishment relates to:

- Insufficient postproject documentation of physical changes.
- Wide disparities in background erosion rates and nourishment sediment quality, making extrapolations from one site to another misleading.
- Use of different criteria for evaluating success.

These controversies are anticipated to persist within the community until such time as there is physical proof of the effect of nourishment along Bogue Banks. Presently, 70 percent of Bogue Banks has no experience with nourishment and has little quantitative data on which to define the background erosion rate or project erosion rates after nourishment. Yet, certain factors suggest that Bogue Banks is a better candidate site for nourishment than many other East Coast beaches.

- Nourishment experience at Atlantic Beach (25 percent of Bogue Banks) provides physical evidence of a wider dry beach and reduced storm damage throughout the 1990s compared to similarly exposed beaches in the proposed project area.
- Several independent erosion estimates confirm that 20-year volumetric losses have averaged 1-3 cy/ft/yr, a rate that is relatively low. This is comparable to Myrtle Beach, SC (1.6 cy/ft/yr) but only a fraction of Hunting Island, SC (~25 cy/ft/yr).
- Linear erosion estimates quoted by Pilkey et al. (1998) and most likely based on NC Division of Coastal Management erosion maps are <2 ft/yr for all Bogue Banks localities except Pine Knoll Shores and Indian Beach, which are estimated at 2-3 ft/yr.
- Bogue Banks is a south-facing beach, partially in the lee of Cape Lookout and less exposed to damaging waves which tend to be more frequent from the northeast.
- Rates of net longshore transport are relatively low along Bogue Banks because of its orientation and placement with respect to Cape Lookout and the prevailing direction of ocean waves.
- The proposed project length of 16.8 contiguous miles would make it one of the longest nourishments on the East Coast. Numerous studies have proven that nourishment longevity is proportional to the **square** of the length of the project (NAS, 1995).
- The proposed borrow area (A) contains sediments that are slightly coarser than the native beach and much coarser than the spoil sediments placed by the Corps along Atlantic Beach. Coarser sediment tends to hold a wider dry beach and require less material for the underwater portion of the profile (Dean, 1991; NAS, 1995).

- The proposed quantity of nourishment (~50 cy/ft) incorporates (a) initial volume to replace the sand deficit and (b) advance nourishment equivalent to approximately ten years of background erosion. In addition, plans call for increasing the nourishment volume in proportion to the overfill ratio (R_A) of the borrow area sediments because a certain fraction will be unstable on the beach (~15 percent if borrow area A is used).

- The proposed project will be surveyed yearly from the dune line to beyond the outer bar and compared against the prenourishment conditions using volumetric calculations. Performance will also be evaluated based on persistence of a dry beach. Success will be defined in relation to how closely the postnourishment volume erosion rate compares with the estimated prenourishment volume erosion rate.

Not all physical impacts are predictable prior to construction. It is widely recognized that isolated erosion "hot spots" sometimes develop after nourishment as "packages" of sediment accumulate in one area, leaving deficits nearby. Nearshore bars also evolve, form runnels and outlets, and create related nearshore cell circulation which may locally cause scour of the berm. Such features occur on unnourished as well as nourished beaches. Regardless of the cause of physical changes, the proposed project area is expected to undergo the same transformations as a natural beach, but to do so with the ocean displaced about 100 ft seaward. By artificially increasing the average separation distance between development and the ocean, private property damage will be reduced for any return-period storm, and the tax base of the county will be preserved for another decade or so. After a decade of monitoring, the community will reevaluate the cost and benefits of nourishment and determine at that time based on experience whether continued nourishment is preferable to doing nothing or abandoning property.

2.2.3 Environmental Impacts – The primary environmental impacts of nourishment relate to mortality of in-situ organisms, changes in habitat, mobilization of fine-grained sediments, and pollution due to accidental spills during construction.

2.2.3.1 Mortality of in-situ organisms – The project will result in the excavation of sediments and organisms in the upper ~2 ft of an approximate four-square-mile area offshore of Bogue Banks. This area represents about 5 percent of the ocean bottom between Bogue Banks and the three-mile state jurisdiction limit. Most of the sessile organisms (predominantly polychaete worms) excavated will die. As fill is placed on the beach, some in-situ organisms (e.g., amphipods, *Donax* clams, and *emerita* mole crabs) will be smothered. These are unavoidable impacts. Studies have shown that borrow areas and nourished beaches recolonize eventually. Natural recovery appears to be most rapid under the following conditions (all of which are applicable for the proposed project):

- Excavations by hopper dredge which tends to make shallow cuts and leaves undisturbed furrows from which rapid recruitment of organisms takes place.

- Use of beach-quality sediment comparable to the native beach.

- Construction during cold-weather months when biological populations are a small fraction of their summer densities.

- Minimization of fines in the borrow area and nourishment area, which elevate turbidity levels.

2.2.3.2 Changes in habitat – The project will leave shallow cuts over the borrow area, exposing older sediments to the water column. These sediments will have been less reworked by organisms but contain similar sediment textures and nutrients as the removed sediments. As such, they will leave an unoccupied niche habitat that is expected to become recolonized at time frames comparable to the life cycles of various species. Some studies have demonstrated that recolonization of borrow areas occurs in a few months or less (e.g., Jutte et al., 1999b), while other studies show recolonization occurring over 1-2 year periods. The proposed borrow area and construction method will be similar to sites where recovery occurred rapidly (a few months). However, because the only way of confirming recovery is by systematic monitoring, the county has initiated benthic sampling before construction and plans to continue benthic sampling after construction to document the degree and rate of recovery at this particular site.

The beach fill will displace the shoreline and inshore topography about 100 ft seaward. This will create more beach habitat (expanded turtle nesting sites), reduce the frequency of dune scarping and associated vegetation loss, and eliminate many chronic escarpments in the foredune. It will also lessen demand by property owners for beach scraping and dune restoration. Frequent beach scraping is believed to cause mortalities and population reductions in surf-zone species. It also introduces coarser sediments in the foredune and inhibits revegetation because of the poorer water retention compared to natural dune sands. Existing littoral habitats will be displaced seaward but will be maintained in similar proportion as the native beach. Nutrients introduced with the nourishment sediments will provide a food source to attract benthic organisms to the new foreshore. Recent studies have found that recolonization of the beach in similar settings as Bogue Banks may occur within one month or less (Jutte et al., 1999a). Because it is uncertain to what degree or how rapidly recolonization will occur, the county plans to monitor benthic recovery along the beach after construction.

2.2.3.3 Mobilization of fine-grained sediments – The proposed project will mobilize silts and clays in the borrow area, raising turbidity in the immediate area of construction. Use of hopper dredges will return some of the silt and clay immediately to the borrow area by on-board drainage as the hoppers are loaded. Fine-grained sediments transported to the beach will be unstable and, during placement, will winnow by normal surf-zone mixing. These fines will raise turbidity levels around the point of discharge, then settle seaward of the longshore bar (lower foreshore). The increase in turbidity due to the project is unavoidable. However, turbidity during similar construction at other sites has been shown to be short-lived (hours to days) and below the natural variations in turbidity observed between storms and calm days.

2.2.3.4 Pollution due to accidental spills – Federal and state regulations place a high burden on contractors to prevent accidental spillage of fuel, grease, and related substances used in the operation of hydraulic or mechanical equipment. Zero releases are unattainable, but detectable discharges are rare. The county will monitor construction and insure that all federal and state requirements for discharge of contaminants are met by the contractors.

2.3 UNRESOLVED ISSUES — There are several unresolved issues at this time.

2.3.1 Borrow area(s) – The county desires to obtain bids from as many qualified contractors as possible. Options for using hopper dredges and shallow-cut "dustpan" dredges are being investigated. It will be uncertain until bids are received which combinations of dredge type and borrow area (A, B1, and B2) will yield the most cost-efficient project. Because the sediments in borrow areas B1 and B2 are finer than those in borrow area A, higher volumes will be required to yield the same performance as A. However, closer proximity to the beach for B1 and B2 may yield lower costs compared to A, even after adjustment for the overfill factor. The indicated borrow areas provide more volume than required for the project. During final design, the borrow area(s) will be refined, incorporating recommendations from resource agencies wherever possible.

2.3.2 Fill area(s) – Nearly 17 miles are planned for nourishment. If for some reason, fewer miles are completed, the project's longevity will decline in relation to the **square** of the length of beach that is not nourished. However, considering that the total project length (16.8 miles) is longer than all but a few nourishment projects out of hundreds in the past 20 years, elimination of a portion of the project will still leave a relatively large-scale, long project.

2.3.3 Opportunities for state cost sharing – The county and local communities are investigating opportunities for matching cost shares from the state. This will not alter the basic plan, but it may cause a modification in the schedule.

2.3.4 Community referendum – The county and local communities ~~plan to hold~~ **HELD** a funding referendum ~~in spring~~ **MARCH 21,2000**. ~~If~~ The referendum ~~does~~ **DID** not pass, **AND SO** the project cannot be completed as planned. **IT IS NOW ANTICIPATED THAT INDIVIDUAL COMMUNITIES WILL UNDERTAKE PORTIONS OF THE PROJECT, UP TO THE LEVEL OF EFFORT PRESENTED IN THE TOTAL PLAN OUTLINED HEREIN.**

2.4 RELATIONSHIP OF PLAN

WITH THE EXCEPTION OF ONE SMALL NOURISHMENT IN THE VICINITY OF THE RAMADA INN IN 1990 INVOLVING LESS THAN 278,000 CY OF VERY FINE SAND (M_Z = 3.67Φ, PETERSON ET AL, 2000), no prior nourishments have been performed between Pine Knoll Shores and Emerald Isle. The preliminary design is based on the present condition of adjacent Atlantic Beach and will leave no gap all the way to western Emerald Isle. It is considered an interim "ten-year" plan for the community–one that must be monitored carefully and used as a basis for formulating a long-range solution from among three alternatives: (1) no action, (2) abandonment and relocation, or (3) continued nourishment.

2.5 COMPLIANCE WITH ENVIRONMENTAL REQUIREMENTS

This submittal is of an EIS, but at a later date an application will be made for State and Federal permits. It is anticipated that the permit application will be made prior to completion of EIS review. (Permit application review will run concurrently with EIS review.)

2.5.1 Federal – CAMA submits copies of the EIS to the Army Corps of Engineers for Federal agencies' review. The Corps coordinates federal review of both the EIS and the CAMA Major Development Permit application. Federal review includes Corps review for compliance with section 10 of the Rivers and Harbors Act of 1899 for work within navigable waters. The Corps also reviews for compliance with Section 404 of the Clean Water Act, covering discharge of dredged materials into navigable waters.

The Corps distributes copies of EIS and permit applications to other federal agencies, including the Environmental Protection Agency, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. These agencies review and comment on the EIS, and these comments must be received and considered by the Corps prior to the coordinated Federal response to the EIS. Likewise these agencies' responses must be received and considered prior to issuance of a Federal permit.

2.5.2 State – North Carolina's Division of Coastal Management coordinates the entire review process, both to state agencies and to the Corps. State approvals required include certification of compliance with the Coastal Area Management Act, the Dredge Fill Act, Water Quality Certification (Section 401), and Easement in Public Trust Areas.

For both the EIS review and the permit-application review, DCM distributes copies to state agencies that include the Wildlife Resources Commission, the Department of Administration, the Department of Transportation, and Divisions of Water Quality, Land Quality, Marine Fisheries, Environmental Health, Archives and History, and Community Assistance. DCM receives and reviews comments from these agencies and the coordinated Federal response prior to approval of Finding of No Significant Impact (FONSI) or a requirement for changes in this Plan.

This project requires compliance with NC EPA. This Environmental Impact Statement is the document being submitted to demonstrate such compliance. Based on the review, DCM either issues the FONSI or requires amendments to this Plan.

2.5.3 Local – The Plan outlined in this EIS is in compliance with the local Land Use Plans for Carteret County and the communities of Bogue Banks.

3.0 EXISTING ENVIRONMENT

3.1 LAND USE

3.1.1 Character of Bogue Banks – Bogue Banks is a barrier island with a southward facing ocean shoreline stretching some 25 miles between two large tidal inlets, Bogue Inlet to the west and Beaufort Inlet to the east. The Banks are surrounded by Bogue Sound on the north and Onslow Bay of the Atlantic Ocean on the south. The island is made up of the Fort Macon State Park, the Towns of Atlantic Beach, Pine Knoll Shores, Indian Beach, and Emerald Isle and the unincorporated area of Salter Path.

Of over 70 miles of barrier island shoreline located in Carteret County, Bogue Banks is the only developed area. The remainder, made up of Shackleford Banks and Core Banks to Ocracoke Inlet, will remain undeveloped in perpetuity as part of the Cape Lookout National Seashore. Bogue Banks is the only ocean shoreline in the county with direct vehicle access.

Topography on Bogue Banks varies from the salt marsh flats and flood prone drainage areas along the island's northern shoreline on Bogue Sound to dune ridges on the island interior and along the ocean shoreline. Dune ridge elevations reach 40 feet (ft) above sea level at some locations.

Bogue Banks' soils vary with Newhan sandy soils in the nearshore, beach and dune zones; Duckston, Corrolla and Newhan soils in the scrub zones; Duckston, Corrolla and Fripp soils in the maritime forest zones; and Carteret soils in the salt marsh zones. Corrolla soils are fine sands, moderately to poorly drained that occur behind the frontal dune line. Fripp sands are excessively well drained and make up the interior dune ridge areas. Duckston fine sands are poorly drained and are in the troughs between dune ridges and on flats between dunes and marshes. Newhan fine sands are excessively well drained and make up the dune ridges that parallel the ocean shoreline. Carteret soils are the fine organic muck found in the salt marsh environment.

Vegetation on Bogue Banks reflects elevation and the amount of exposure to salt spray. As distance from the shoreline increases, sparse beach grasses merge with dense scrub vegetation. Maritime forests thrive in areas where the island is wide enough to provide sufficient protection from salt spray for forest growth. Maritime forests generally occur on lands that have been stable for at least 50 years. Vegetation typical of freshwater wetlands and tidal flats populate flood prone areas and natural and manmade drainage ways.

3.1.2 Typical Development – Development of Bogue Banks ranges from the densely developed portions of Atlantic Beach to the Theodore Roosevelt Natural Area in Pine Knoll Shores. Oceanfront development is, for the most part, residential with pockets of commercial hotels and campgrounds, multi-family condominium developments, and high-density mobile home parks. It is estimated that development of oceanfront lots has reached 90 percent build out.

Setbacks for oceanfront construction are established by regulations of the NC Division of Coastal Management (DCM). Residential construction setbacks are 30 times the long term erosion rate as established by maps prepared by DCM. Maps currently in use were updated in 1992. The setback for large commercial or permanent structures in excess of 5000 square feet is 60 times the long-term erosion rate. The minimum setback is 60 ft in areas with long-term erosion rates less than 2 ft. The line for measurement of setbacks is the first line of stable vegetation. In locations where vegetation is sparse, the line is interpolated from adjacent areas where vegetation exist. The measurement line is typically established in the field by DCM personnel as part of the CAMA permitting process.

3.2 WETLANDS — There are no areas of 404 wetlands or coastal wetlands identified in the project area.

3.3 AGRICULTURAL LANDS — No agricultural land is in or adjacent to the project area. Low water retention capacity of the sandy barrier island soils preclude establishment of agricultural crops.

3.4 LITTORAL PROCESSES — Existing data on the littoral processes on the oceanfront side of Bogue Banks include:

- Historical, but not recent tidal statistics.
- Several versions of wave conditions as outputs from wind/wave models, but no wave measurements.

- Estimates of wave and current energy fluxes along the beach as outputs from different wave-shoaling models, but only brief visual measurements of waves and currents.
- Estimates of longshore sediment transport, especially at Atlantic Beach, from (1) wave-shoaling model studies performed by the Corps of Engineers (USACE) and the University of North Carolina (UNC), and (2) qualitative measures of diffusion/advection of the Atlantic Beach nourishment sand from UNC studies.
- Extensive sets of topographic surveys (beach profiles) for Atlantic Beach (only) from both USACE and UNC, with profile sets for the entire island available from 1978 (USACE) and 1999 (CSE Baird-Stroud).

3.4.1 Tides have been measured at Duke Marine Lab in Beaufort on the **sound** side of the islands continuously since 1973. Tidal measurements at other locations were made only during brief studies in 1960 and 1973 and show (USACE, 1999):

Tide Gauge Location	Tide Range in 1960 (ft) Mean	Tide Range in 1960 (ft) Spring	Tide Range in 1973 (ft) Mean
Atlantic Beach (ocean side)	3.6	4.3	3.6
Morehead City	2.8	3.4	2.9
Duke Marine Lab (Beaufort)	2.5	3.0	2.9
Shell Point (Harkers Island)	1.3	1.6	1.6

The more recent 1973-1989 dataset at Duke Marine Lab shows a tide range of 3.0 ft and a spring tide range of 3.5 ft. (http://www.opsd.nos/noaa.gov/cgi-bin/websql/ftp/staqry.pl) The increases in tide range in the sound may be related to the Corps' dredging operations, since the dredged channel was deepened from 30 ft MLW to 35 ft MLW between the 1960 and 1973 studies.

3.4.2 Hurricanes – Tidal surges from storms add to the astronomically produced tides for a total still-water superelevation. Frequency of occurrence of hurricanes is highly variable (Barnes, 1998). One estimate of hurricane frequency made in the 1970s was 1.6 hurricanes per year for Bogue Banks (Sarle, 1977). North Carolina hurricanes increased in frequency in the 1990s. With respect to beaches, the most important effect of hurricanes is the surge. Surge levels do not necessarily correlate with hurricane strength or "category," since categories are determined by wind and pressure, not surge. For example, surge levels at Atlantic Beach were estimated for *Hazel* (1954, Category 4) at 7.0 ft mean sea level (MSL), for *Ione* (1955, Category 3) at 7.2 ft MSL, and *Donna* (1960, Category 3) at 10.6 ft MSL (USACE, 1966). *Donna* may be an appropriate "design" hurricane for Bogue Banks, since it is the only recent hurricane to have breached the island (near the location of a relict inlet in eastern Emerald Isle).

NCSU (Knowles et al., 1973) estimated surge levels for different return periods of storms, along each section of the North Carolina coast. For the section that includes Bogue, stillwater surge levels in feet above MSL are 7.63 ft for a 25-year storm, 9.33 ft for 50-year, and 10.95 ft for 100-year. These surges were then translated into estimates of resulting dune retreat, using empirical data from several storms. Dune retreat is a function of surge, height and massiveness of the dune, and distance between the dune and the mean water line. In the 70s Bogue's average dune reached 16 ft above MSL and had a toe 8.9 ft above MSL that was 158 ft from mean high water. Estimates of dune retreat were 21 ft for a 25-year storm, 162 ft for 50-year, and 220 ft for 100-year. Bogue's beaches are currently much narrower than in this study (the dunes are closer to the water). However, site-specific measurements after *Floyd* (1999) showed that dune retreat averages somewhat less than these model predictions–about 15 ft.

3.4.3 Waves – Wave heights, frequencies, and directions have been estimated for this area by various sources over the years. However, all such studies are based on observations or estimates of offshore winds, which models then convert into the resulting waves. In some studies these waves are then shoaled into breaking-wave depths using wave-refraction models. Estimating waves in this manner results in large errors compared to wave measurements. Early estimates of wave heights include Nummedal et al. (1977) who used Navy shipboard wind observations to determine offshore wave heights for the area of 5.5 ft, with a 7 ft height exceeded 27 percent of the time. The Corps of Engineers' Wave Information Study's 1956-75 data set of waves (Jensen, 1983) modeled from winds shows mean wave height for the area in 10 meters (m) of water (Phase III dataset) of 4.3 ft (USACE, 1992). Summary wave statistics (from USACE CERC's website) for the deeper (20-27m) Phase II stations are:

Station	Dates	Depth (m)	Mean Height (ft)	Mean Period (sec)	Mean Direction (azimuth degrees)
#45 (25 nm south ofEmerald Isle)	1956-75	27	3.9	6.2	112.5
	1976-95	27	3.9	7.4	112.5
#46 (7 nm southeast of Cape Lookout)	1956-75	20	3.6	6.4	112.5
	1976-95	20	3.9	8.2	90.0

Using a 1976-93 version of the Station #46 WIS dataset, a University of North Carolina study (Roessler, 1998, Fig. 25) found wave heights shoaled all the way into the breakpoint varied considerably depending on the direction of approach, but averaged about 3.9 ft, except at the easternmost end of the island where Bogue is sheltered somewhat by Beaufort Inlet's ebb-tidal delta and the Corps' offshore dredging disposal areas.

3.4.4 Dimensions of Littoral Zone (Depth of Closure) – The depth offshore to which there is active interchange of sediment with the beach is of consequence to beach nourishment projects. The goal is to avoid taking sediment from within the active system, since that sediment is already, to some extent, helping to maintain the beach. The depth of closure is defined in standard texts, such as the Shore Protection Manual (CERC, 1984) as the depth beyond which there is active motion of the seabed for an average of only 12 hours per year. Six different methods and sources of information were utilized in determining this depth for Bogue Banks, and the results are detailed in Appendix G2. Those calculations produce the following conclusions:

1) Hindcast data of extreme (12 hr/yr) conditions produce depths of closure between 13 ft and 18 ft MLW.
2) Measured storm conditions produce closure depths between 16 ft and 22 ft.
3) During the few hours that hurricanes are present in the immediate vicinity, closure depth has been computed as 36 ft.
4) The limit of sediment activity was measured at a nearby but more open-coast site at between 3.9 and 6.4 m (13-21 ft).
5) Mapping sediment types by color, texture, and size result in a boundary between beach and shelf sands between 32 and 33 ft depths.
6) The Corps of Engineers' nearshore berm off of Atlantic Beach in 25-30 ft depths has not exhibited significant motion and has not contributed sediment to the beach.

3.4.5 Littoral Transport – Studies of the potential for longshore sediment transport are detailed in Appendix G4. All of the quantitative studies used waves that are part of the USACE Wave Information Study, which is a compilation of wave **predictions** as modeled from the offshore winds that generate waves. Various versions of these databases have been produced over the years, but no measurements have been made of the directional wave field.

Hindcast studies of waves predict different magnitudes and opposite directions of sediment transport along Bogue Banks, depending on which database is used. Early studies (USACE, 1976) predicted net transport eastward. Updated versions of the winds for the same time period (1956-75) produced significantly greater transports, but still to the east. Recent studies (USACE, 1999) show westward transport, using winds from a different time (1976-95). Other studies (Roessler, 1998) also show westward transport. However, our studies detailed in Appendix G4 show that **the magnitudes and direction of transport are solely a function of which wave database is used.** When we used the same databases as the above studies, we confirmed their results, even though our wave-shoaling methods were different. Thus, the qualitative results (net direction and rough magnitude) do not depend on the different wave-shoaling methods and topographic data used by different investigators.

More reliable than computation of transport from waves modeled from winds are geological indicators of net sediment accumulation. These indicators allow some qualitative conclusions to be reached regarding longshore sediment transport along Bogue.

Net longshore **transport rates are low** along Bogue Banks. Evidence includes:

1) Erosion rates measured from aerial photos and beach profiles do not vary dramatically along the island. The change (divergence) of transport rates along the beach is what causes net erosion/accretion.
2) There are no large accumulations of sand at the end of the cell (western end of Emerald Isle). Although that area is currently accreting, it is not doing so rapidly, and over time the area cycles back and forth between erosion and accretion.
3) A study (Reed, 1997) examined the differences in texture and color between the Corps' nourishment sand at Atlantic Beach and the native sand. These differences allowed tracking of nourishment as a "tracer" and determined that the net transport was quite low, much lower than wave hindcast studies suggest.

3.4.6 Erosion Rates – Rates of erosion/accretion were estimated for all sections of Bogue Banks using both volumetric measures of change, where previous data existed, and linear rates of shoreline change from aerial photography. The methods are detailed in Appendix G5 and the results tabulated in Table G5-1. Final classifications of erosion rates are illustrated in Figure G5-2. There is considerable variability in the results between very different methods, but all methods show an overall slow erosion. The bottom line is that most communities on Bogue have slow but continuing erosion rates (on the order of 1 ft/yr shoreline retreat). However, the erosion does not occur at a steady rate, but in episodic events during storms. The net result of storm erosion (average of 15 ft retreat during Hurricane *Floyd*) and the following recovery is a slow retreat of the shoreline.

3.5 PUBLIC LANDS — The "Public Trust Doctrine" and the State Property Sovereignty Rules preserve the rights of all citizens of North Carolina for use of resources located below the mean high water line. Submerged lands, or waters of the state, commence waterward of the mean high waterline.

3.6 RECREATIONAL AND SCENIC AREAS — The beaches of Atlantic Beach, Emerald Isle, Indian Beach, Salter Path and Pine Knoll Shores are known as the Crystal Coast. This designation probably refers to the color of the ocean waters on clear calm days at the beach. The beaches of Bogue Banks provide a variety of excellent scenic and recreational opportunities for the public. Popular activities include, but are not limited to, surf fishing, swimming, surfing, walking, shell hunting, sunbathing, bird watching, and boating. Scenic vistas of the ocean are many. With erosion of the beach there has been significant losses of dry beach areas limiting many beach activities to low tide periods.

3.7 AREAS OF ARCHAEOLOGICAL OR HISTORIC SIGNIFICANCE — The maritime history of Beaufort, Morehead City and the Cape Lookout area goes back to the late 1600s and early 1700s when whalers established bases of operations on Shackleford Banks and Cape Lookout. The stability and depth of Beaufort Inlet offered a safe, deep channel for ship traffic. Not all vessels were successful navigating the inlet. In November 1718, the pirate Blackbeard lost two vessels on or near the sand bar at Beaufort Inlet.

Around 1841, John Motley Morehead, governor of North Carolina, envisioned establishing a port facility at the eastern terminus of the Atlantic and North Carolina Railroad. In 1855, the decision was made to locate the port at Sheppard's Point. By 1858, and much to the chagrin of the people of Beaufort, the Morehead City Port was prospering. Ships called continually, loading cargo directly to and from rail cars.

Development of the Morehead City port was disrupted by the Civil War. In March 1862, Union forces occupied Morehead City, the Newport River and Beaufort. Soon afterwards, Fort Macon fell under Union control. The occupation of Fort Macon provided Union forces with access to a deep water port and a place of rendezvous to support the blockading squadron during the remainder of the war. Beaufort harbor served as a staging area for the fleets under the command of Admiral David Porter for his assault on Fort Fisher in Wilmington, the last major confederate stronghold in North Carolina. During the war, there were a number of vessel losses near Cape Lookout. Not all vessel losses were attributable to military actions. Several vessels ran aground in rough weather near Beaufort Inlet or were lost due to machinery failures.

Six years after the Civil War, the federal government instituted measures to reduce the severity of maritime losses along the coast. In 1874, seven stations were established along the North Carolina coast by the US Lifesaving Service. Stations were established along Core Banks, at Fort Macon and at Cape Lookout.

Growth of the Morehead City Port was slow during the late nineteenth and early twentieth century. In the 1880s, the federal government began work to improve Beaufort Inlet in hopes of increasing maritime trade to the port communities. By 1889, jetties were constructed on Shackleford Banks and on Fort Macon to stabilize the Beaufort Inlet. Between 1905 and 1907, the channel across Beaufort Inlet was deepened to 20 feet at mean low water. Several Corps of Engineers reports between 1907 and 1914 indicated that both Morehead City and Beaufort were growing centers of maritime trade.

Many vessels transiting the North Carolina coast became victims of maritime hazards. Between July 1889 and June 1908, 82 vessels were reported lost off the North Carolina Coast. To prevent vessels from wrecking off of Cape Lookout, a lightship was placed at Lookout Shoals. Mariners had complained that the lighthouse at Cape Lookout was difficult to see.

During World War I, Cape Lookout Bay served as a rendezvous area for convoys headed to Europe. Morehead City was occasionally used as a distribution point for war supplies. From 1926 to 1938, the federal government made considerable improvements to the Port of Morehead City including increasing the Beaufort Inlet channel depth to 30 feet.

Hostilities were evident in the Cape Lookout vicinity during World War II. German submarines sank four tankers in the Cape Lookout Area during March 1942.

Since the war, Morehead City Harbor has undergone continuous improvement to its present day condition as a deep water port with several large vessels calling at the port each month.

The long maritime history of Beaufort Inlet and the areas near Cape Lookout indicate the possibility that shipwrecks or other valuable submerged historic resources could exist on the offshore borrow areas proposed for this project. The National Historic Preservation Act of 1966 and the Archeological and Historic Act of 1979 establish criteria for identification, documentation and assessment of submerged cultural resources. Compliance with submerged cultural resource legislation is administered by the North Carolina Division of Archives and History and the U. S. Department of the Interior.

Tidewater-Atlantic Research, Inc. (TAR) of Washington, North Carolina was contracted to conduct a remote sensing survey of the offshore borrow areas. The scope of the survey was to locate, identify and assess the significance of any underwater cultural material in the project areas. The details of the survey and report of findings are included as part of this document in Appendix B.

3.8 AIR QUALITY — The Air Quality Section of the North Carolina Department of Environment and Natural Resources has jurisdiction over Air Quality in Carteret County. According to the Wilmington District Office, ambient air quality in Carteret County is in compliance with the National Ambient Air Quality Standards.

3.9 WATER RESOURCES — Water quality around Bogue Banks is generally high due to large tidal flows and resultant flushing associated with Bogue Inlet and Beaufort Inlet. Waters of Bogue Sound west of a line from the mouth of Gales Creek to Rock Point in Indian Beach are classified as outstanding resource waters (ORW), which are waters of the state that are unique and of a special state or national recreational or ecological importance that require special protection to maintain existing uses. Waters east of Rock point in Bogue Sound are classified SA. SA waters are suitable for shellfishing for human consumption. Ocean waters of Onslow Bay off of Bogue Banks are of high quality. This quality is due to the fact that no rivers draining large urbanized watersheds discharge directly into Onslow Bay. The White Oak River in the western end of the County and the Newport River in the east have relatively small agricultural, forested, and lightly developed watersheds.

3.10 GROUNDWATER RESOURCES — Groundwater is plentiful throughout Bogue Banks. It is near the surface in many places, especially in the early spring and winter. The underlying limestone deposits of the Castle Hayne formation are the source for water supplies on Bogue Banks. These formations are below the surficial aquifers in the island consisting of a fresh water lens which varies in depth depending on rainfall amounts and has water that is often salty or has high concentrations of dissolved iron and hydrogen sulfide.

3.11 INTRODUCTION OF TOXIC SUBSTANCES — No chemical analysis of the borrow area materials has been done to date. It is unlikely that the borrow area sediments have accumulated any toxic or hazardous substances regulated by CERCLA or RCRA. There have been no known spillage, storage, treatment or disposal of regulated toxic materials within the borrow areas. There are no known discharges to Onslow Bay that could be a source of contaminants. For this reason, it is doubtful that chemical analysis of the borrow area material would contain heavy metals exceeding the EPA standards. The borrow area sediments consist of medium sands with shell fragments and low mud percentage. These types of inert mineral materials do not typically trap contaminants.

3.12 NOISE LEVELS — Noise levels in the project areas are relatively low. No commercial or industrial activities exist in the project areas that create increased ambient noise levels. Generally, noise levels in the project areas are those associated with public use. The residential nature of the ocean shoreline areas generally equates to low ambient noise levels.

3.13 WATER SUPPLY AND WASTEWATER SYSTEMS

3.13.1 Water Supply – Potable water supply on Bogue Banks is provided by municipal water systems and by privately owned public utility companies. Bogue Banks Water Corporation supplies water to the Town of Emerald Isle. Carolina Water Service provides water to Indian Beach and Pine Knoll Shores. The Town of Atlantic Beach operates and maintains the water supply and distribution system for the Town. The water source for all systems is deep wells to aquifers of the Castle Hayne limestone formations which run beneath Bogue Banks. The water is hard but is otherwise of excellent quality.

3.13.2 Wastewater systems – Wastewater treatment and disposal on Bogue Banks is regulated by the Carteret County Environmental Health Department for systems under 2000 gallons per day, and by the North Carolina Department of Environment and Natural Resources, Division of Water Quality for systems larger than 2000 gallons per day. Treatment and disposal of wastewater on Bogue Banks is accomplished in many conventional and innovative ways. Single family residential systems are nearly all conventional septic tanks with subsurface nitrification fields. In some areas, where soils are not suitable for conventional septic systems, septic tanks with on-site low pressure pumped (LPP) subsurface disposal is employed. Multi-family residential developments and hotels utilize collection systems with centralized treatment and disposal facilities. Treatment is generally by package plants employing extended aeration and on-site subsurface LPP disposal. There are no known direct effluent discharges to Bogue Sound or Onslow Bay from wastewater treatment facilities on Bogue Banks.

3.14 MARINE RESOURCES — The first two regions below are commonly divided by the breaker zone. That is, offshore refers to the area between the breakers and the edge of the continental shelf, and nearshore is the region between breakers and the mean low water line that is the lower boundary of the intertidal zone (CERC, 1984). For purposes of examining environmental impacts, it is more sensible and more common to examine "nearshore" resources out to the depth of closure, rather than the moving boundary of a breakpoint. That is, the boundary between nearshore and offshore will be, for the purposes of this EIS, the seaward limit of sediment motion (by waves), termed the "depth of closure" for beach surveys. Exactly what that depth is for this site is examined in detail in Appendix G2 and summarized in the "Depth of Closure" part of Section 3.4 above. Borrow Areas A and B are outside closure depth. Borrow Area C is in Bogue Inlet in shallow water, but sufficiently far within the inlet to be outside of the littoral system (hundreds of feet inland of the inlet throat).

3.14.1 Offshore Resources

Sediment: Offshore areas in North Carolina have been described as more stable than the nearshore zone, because of the lack of sediment motion by waves. USEPA (1983) describes the offshore region as fine sand with low-to-moderate relief, scattered among hard bottom. Our studies characterizing the offshore sediments included grab samples, cores, long vibracores, sidescan sonar survey, and a magnetometer survey. In addition to identification of potential cultural resources in the borrow areas, the sidescan sonar survey was used to identify any large natural features (rocks). None were found in the borrow areas. The offshore sediment conditions are summarized in Section 3.16 below and described in detail in Appendix E. A map of the shelf sediment types and thicknesses in the vicinity of Bogue Banks is reproduced in the appendix as Figure E1.

Biology: Biological resources in the offshore region of the Carolinas have been categorized as having low biomass, high diversity, and large seasonal variability (USEPA, 1983). The latter characteristic of seasonal variability has a significant impact on monitoring plans and is the reason for our plan of sampling on several dates, detailed below.

Vertebrates: Assessment of the significance of the offshore mining of sands for the renourishment involves evaluation of potential impacts on demersal fishes and crustaceans at the borrow site. The fish and crustacean community changes seasonally, so sampling is needed to document presence and relative abundance of demersal fish and crustaceans and to describe their utilization of benthic invertebrate prey. Trawl sampling was conducted in late fall 1999, coincident with the sampling of the benthos. The results of sampling the fish and mobile crustacean community at and around the proposed offshore borrow sites are included here in a report as Appendix C **(REVISED REPORT BY UNIVERSITY OF NORTH CAROLINA INSTITUTE OF MARINE SCIENCE)**. ~~At least one~~ **TWO** additional trawl samplings ~~will be~~ **WERE** completed later ~~this~~ **IN** winter **2000** ~~(targeted for February)~~ to document over-winter use of the borrow sites by fishes. [Trawl results ~~were received on 14 February 2000 and~~ are included ~~here as an addendum to~~ **IN** Appendix C.] Analysis ~~will~~ includes not only the information on fish and crustacean abundances, but also a description of their diet from gut contents in the late fall 1999 **AND WINTER 2000** collections.

Table 4 in Appendix C presents the results of trawling for fishes and crustaceans. The sampling detected relatively large numbers of demersal fish occupying the sea-floor habitat during this period. Offshore areas were dominated by spot, which accounted for more than 50 percent of total catch and was sufficiently abundant there to create a pattern of slightly higher fish densities offshore than inshore. In addition to spot, pinfish, pigfish, and croaker were the most common species offshore. Inshore fishes were dominated by croaker, silver perch, silversides, and sea mullet.

Invertebrates: Because the benthic invertebrate community at the offshore borrow sites changes across the seasons, it is appropriate to sample in multiple seasons (fall and spring) both before and after the renourishment project to assess impacts and recovery. Because renourishment is planned for winter 2000-2001, an initial set of samples was collected in the fall of 1999 to provide fall baseline data to characterize the benthic invertebrate community at the prospective offshore borrow sites and at nearby control sites that will not be mined prior to any disturbance from the renourishment project. ~~A description of results from an analysis of a subset of those initial samples is included here as Appendix C.~~ Also included is an analysis of composition of surface sediment samples in each of the borrow sites and control sites, so as to characterize the sedimentary habitat in which the invertebrates live. Sedimentary habitat is the prime factor that controls abundance and composition of soft-bottom invertebrate communities. The complete invertebrate data set ~~will be analyzed by May 2000~~ **AND SUMMARY STATISTICS ARE GIVEN IN APPENDIX C**.

Results from the fall 1999 sampling are summarized in Table 2 of Appendix C. Results suggest slightly higher macrofaunal abundances in the borrow areas than in their respective control areas. The polychaetes accounted for more than 50 percent of the total macrofauna in these late-fall 1999 samples. Other common phyla in order of abundance were molluscs, nemerteans, crustaceans, and echinoderms. Table 3 of Appendix C shows the analysis of the 40 belt transects for larger benthic invertebrates. The inshore borrow areas revealed higher numbers of these larger invertebrates than the offshore sites. No consistent difference appeared between borrow and control areas in these data. Gastropods were the most common taxon represented in these samples.

3.14.2 Nearshore Resources

Sediment: Sediment sampling of the nearshore (inland of the borrow sites, but subtidal) occurred at several locations along the project area. The appropriate sample numbers to reference in Appendix E from west to east are C21a1, C20a1, C16a1, C12a1, C9a3, and C7a2. C4a1 was taken in Atlantic Beach outside the project area. Sieve analyses, mud content, and carbonate content are detailed in Appendix E.

Biology: Alterations to seabed sediments in the surf zone will be essentially the same as on the dry beach, except that there will be sorting into a finer size. Quantification of submarine organisms inshore of the borrow areas will thus rely on the dry-beach and intertidal sampling program outlined below. A baseline study of benthos in nearshore waters of South Carolina by Van Dolah and Knot (1984) found that infaunal assemblages at nearshore subtidal areas were more complex than those at intertidal areas. Based on their sampling, 243 species representing 24 major taxa were found. Dominant species were polychaetes and amphipods with oligochaetes, pelecypods, and decapods highly represented. Benthos in the area were identified as those that serve as food for commercially important species and were essential in marine food chains. Commercially important species include adult spots which are benthic feeders, primarily eating polychaetes and benthic copepods, and Atlantic croaker that are also bottom feeders preying on polychaetes and bivalves. Pink and white penaeid shrimp also prefer benthos (USFWS, 1992a). The nearshore benthic communities offshore of North Carolina have been characterized by benthic infaunal assemblages with low abundance and high diversity (USEPA, 1983).

3.14.3 Intertidal Resources

Sediment: Six native-beach samples were taken on the low-tide terrace at six different transects along the island. Sieve analyses, mud content, and carbonate content are detailed in Appendix E. A total of 20 samples (2 on the dune, 6 on the berm, 6 on the beach face, and the 6 low-tide terrace) was used to determine a composite native-beach size distribution.

Vertebrates: Because of the very intermittent nature of fish densities in this narrow region, no sampling of fish in the intertidal zone is planned. Offshore tow samples will be used to determine the preproject and postproject fish densities.

Invertebrates: Organisms in the high-energy sandy intertidal environment include mole crabs, coquina clams, amphipods, isopods, and polychaetes. Although none of these species are commercially important, they constitute considerable biomass and serve as important food source for surf-feeding fish and shore birds. No sampling has yet taken place to serve as the before-renourishment monitoring data for the intertidal invertebrates of Bogue Banks beaches. The invertebrate community of the intertidal beaches is so strongly seasonal that sampling to provide baseline information should occur during the warm season, with subsequent sampling to assess potential impacts and recovery repeated at the same season, but after the project has been completed. The initial preproject sampling is ~~scheduled for~~ **ANTICIPATED IN** summer ~~2000~~ **2001**.

~~We already~~ **UNIVERSITY OF NORTH CAROLINA INSTITUTE OF MARINE SCIENCE** possesses a substantial amount of data on abundances of intertidal beach invertebrates from all along Bogue Banks from 1997-1999 from studies conducted by L. Manning **AND OTHERS** (unpubl: see Table 9 of Appendix C for example). **WE ANTICIPATE REFERENCING RESULTS OF THESE STUDIES WHEN THEY BECOME AVAILABLE UPON COMPLETION OF DISSERTATION(S) IN THE NEAR FUTURE. REVIEWING AGENCIES ARE ADVISED TO CONTACT DR CHARLES PETERSON AT UNC (252-726-6841) IF EARLIER RELEASE OF THESE DATA IS REQUIRED. BECAUSE OF THE EXTENT AND FREQUENCY OF THIS SAMPLING BY UNC, THE APPLICANT BELIEVES THAT THIS WILL PROVIDE AN APPROPRIATE BASELINE FOR EVALUATING POSTPROJECT IMPACTS.** This information will be incorporated into an assessment design to evaluate the potential consequences of the renourishment on the beach system, allowing us to make contrasts between the four summers before renourishment and the summer or summers afterwards as one means of assessing impact and rate of recovery.

3.14.4 Beach and Terrestrial Resources

Sediment: The width of the berm at the base of the dune system varies considerably with location along the island and with season. Along most of the project area, the winter berm is nonexistent, because of the continuing erosion. Dune habitat is now also decreasing due to the erosion of the base or toe of the dunes by waves that travel unimpeded over the eroded wet beach to directly attack the dunes. As a result of the nourishment project, the beach is the one resource area that is expected to have beneficial impacts on the species present, primarily due to increased habitat area. Native-beach samples were taken on the berm and on the beach face at six different transects along the island, along with two dune samples. Sieve analyses, mud content, and carbonate content are detailed in Appendix E. A total of 20 samples (2 on the dune, 6 on the berm, 6 on the beach face, and the 6 low-tide terrace) was used to determine a composite native-beach size distribution.

Biology: The dunes along the beach are covered with American beach grass and sea oats. The dominant vegetation along the ocean side of the dune system also includes grassed areas, shrubs, and ornamental trees. Wildlife found along the ocean side of the island is limited as a result of development. Animals present in the project area are primarily those that can customarily tolerate man's presence, such as sea gulls, pigeons, starlings, house sparrows, and small rodents. The beach and dune system serves as an important nesting and food-source area for certain shorebirds (USFWS, 1992a). Baseline sampling of the nourishment sites and control sites will be conducted on the beach itself in summer 2000.

3.15 THREATENED AND ENDANGERED SPECIES

Species to be considered in this environmental impact statement were provided by USFWS and the NMFS and are listed in the table below, followed by a description of these species. (Section 5.15 contains a description of potential impacts to these species as a result of the proposed beach nourishment project.)

Common Name	Scientific Name	Status	Habitat present?	Known observation*
Mammals				
Eastern cougar	*Felis concolor couguar*	E	no	no
Finback whale	*Balaenoptera physalus*	E	no	no
Humpback whale	*Megaptera novaeangliae*	E	yes	yes**
Right whale	*Eubaleana glacialis*	E	yes	yes**
Sei whale	*Baleanoptera borealis*	E	no	no
Sperm whale	*Physeter catodon*	E	no	no
West Indian manatee	*Trichechus manatus*	E	yes	no
Birds				
Piping plover	*Charadrius melodus*	T	yes	no
Red-cockaded woodpecker	*Picoides borealis*	E	no	no
Roseate tern	*Sterna douglallii*	E	no	no
Wilson's plover	*Charadrius wilsonia*	SR	yes	no
Reptiles				
American alligator	*Alligator mississippiensis*	T(S/A)	no	no
Green sea turtle	*Chelonia mydas*	T	yes	yes**
Hawksbill sea turtle	*Eretmochelys imbricata*	E	yes	yes**
Kemp's ridley sea turtle	*Lepidochelys kempi*	E	yes	yes**
Leatherback sea turtle	*Dermochelys coriacea*	E	yes	yes**
Loggerhead sea turtle	*Caretta caretta*	T	yes	yes
Fish				
Shortnose sturgeon	*Acipenser brevirostrum*	E	no	no
Plants				
Rough-leaf loosestrife	*Lysimachia asperulaefolia*	E	no	no
Seabeach amaranth	*Amaranthus pumilus*	T	yes	yes
Moundlily yucca	*Yucca gloriosa*	SR	yes	yes

KEY

Status	Definition
E	A taxon "in danger of extinction throughout all or a significant portion of its range."
T	A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."
T(S/A)	Threatened due to similarity of appearance - a species that is threatened due to similarity of appearance with other rare species and is listed for its protection. These species are not biologically endangered or threatened and are not subject to Section 7 consultation.
SR	State designation. Species designated as being very rare, generally with 1-20 populations in the state. These species are not subject to Section 7 consultation and are not considered in the biological assessment.

* Observation according to NC Natural Heritage Program data.
** Species is known to migrate along the coast of NC (Wynne, 1999).

The presence of these species in the project area depends on the availability and abundance of appropriate habitat. Since the Bogue Banks project area does not contain any freshwater or forested areas, the eastern cougar, red-cockaded woodpecker, American alligator, shortnose sturgeon, and roughleaf loosestrife are not likely to be found at this site. Listed species that could potentially be located at Bogue Banks are the whale species, West Indian manatee, piping plover, sea turtle species, and seabeach amaranth.

A biological assessment is being prepared and coordinated with the USFWS and the NMFS, pursuant to Section 7 of the Endangered Species Act of 1973, as amended. This assessment has determined that the proposed action may affect the hawksbill sea turtle, leatherback sea turtle, Kemp's ridley sea turtle, green sea turtle, loggerhead sea turtle, and the seabeach amaranth. Other federally listed endangered or threatened species would not be affected. Section 7 coordination will be completed prior to the initiation of the proposed work.

3.15.1 Mammals

- **Right whale, finback whale, humpback whale, sei whale, and sperm whale** – Humpback whales are often found in protected waters over shallow banks and shelf waters for breeding and feeding. They migrate toward the poles in summer and toward the tropics in winter and visit the North Carolina coast during seasonal migrations, especially between December and April (Conant, 1993). They eat schooling fish such as herring and can consume up to 1.5 tons per day of krill. Right whales swim very close to the shoreline and are often noted only a few hundred meters offshore (Schmidly, 1981). They feed primarily on copepods and euphausids. While this whale usually winters in the waters between Georgia and Florida, it can on occasion be found in the waters off North Carolina. Sighting data provided by the Right Whale Program of the New England Aquarium indicates that 93 percent of all North Carolina sightings between 1976 and 1992 occurred between mid-October and mid-April (Chris Slay, 1993). The number of right whales documented in the vicinity of Morehead City during a single season ranges from 2 to 25 (USACOE, 1989).

- **West Indian manatee** – The manatee is an occasional summer resident of the North Carolina coast. The species can be found in shallow (5 feet to usually less than 20 feet), slow-moving rivers, estuaries, saltwater bays, canals, and coastal areas (USFWS, 1991). The West Indian manatee is herbivorous and eats aquatic plants such as hydrilla, eelgrass, and water lettuce (USFWS, 1999). During winter months, the United States' manatee population confines itself to the coastal waters of the southern half of peninsular Florida and to springs and warm water outfalls as far north as southeast Georgia. They are sighted frequently in southeastern North Carolina with most records occurring in July, August, and September, as they migrate up and down the coast (Clark, 1993). However, scattered records of this species in the region span all seasons. Based on this data, the manatee is considered a year-round resident with a maximum population in the late summer months. Manatee population trends are poorly understood, but deaths have increased steadily. A large percent of mortality is due to collisions with water crafts, especially of calves. Another closely related factor in their decline has been the loss of suitable habitat through incompatible coastal development, particularly destruction of sea grass beds by boating facilities.

3.15.2 Birds

- **Piping plover** –The Atlantic Coast piping plover population breeds on coastal beaches from Newfoundland to North Carolina (and occasionally in South Carolina) and winters along the Atlantic Coast from North Carolina south, along the Gulf Coast, and in the Caribbean USFWS, 1996). Since being listed as threatened in 1986, the population has increased from approximately 800 pairs to almost 1350 pairs in 1995, although most of this increase may be attributable to an increase in surveying intensity. Piping plovers nest above the high tide line on coastal beaches, sand flats at the ends of sand spits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, sparsely vegetated dunes, and washover areas cut into or between dunes (USFWS, 1996). Feeding areas include intertidal portions of ocean beaches, washover areas, mud flats, sand flats, wrack lines, and shorelines of coastal ponds, lagoons, or salt marshes. Loss and degradation of habitat due to development and shoreline stabilization have been major contributors to the species' decline.

  Most piping plovers at Bogue Banks have been observed at the west end of Emerald Isle as predominantly a migratory and winter resident (David Allen, pers. comm.). During a 1991 USFWS International Piping Plover Census (winter), four piping plovers were observed and during a 1996 winter census, one individual was observed. ~~However~~ IN ADDITION, both Bogue and Beaufort inlets contain intertidal flats exposed at low tide that are prime feeding and roosting habitats for a variety of shorebirds and colonial waterbirds including pelicans, cormorants, terns, and black skimmers. These areas may be used by piping plovers as well.

- **Roseate tern** – Roseate terns breed primarily on small offshore islands, rocks, cays, and islets. Rarely do they breed on large islands. They have been reported nesting near vegetation or jagged rock, on open sandy beaches, close to the waterline on narrow ledges of emerging rocks, or among coral rubble (USFWS, 1999). This species is primarily observed south of Cape Hatteras, particularly at Cape Point within Cape Hatteras National Seashore, during the months of July and August.

3.15.3 Reptiles

- **Hawksbill sea turtle** – Hawksbill sea turtles are found mainly in tropical waters of the Atlantic, Pacific and Indian Oceans. Nesting in the United States for this species occurs in spring and is generally restricted to Florida. Although it is not considered common along the North Carolina coast, the hawksbill may be found in North Carolina waters all year and can be present in inshore waters April through December (Epperly et al., 1995). The hawksbill is found along submerged rocky areas, reefs, shallow coastal areas, lagoons of oceanic islands and narrow creeks (USFWS, 1991). It is not often seen in water over 65 feet deep. Its diet includes algae, fish, mangrove, barnacles, clams, sponges, snails, and sea urchins.

- **Leatherback sea turtle** – Leatherback sea turtles are found mainly in tropical waters of the Atlantic, Pacific and Indian Oceans. Nesting in the United States for this species occurs in spring and is generally restricted to Florida. Although it is not considered common along the North Carolina coast, the leatherback may be found in North Carolina waters all year and can be present in inshore waters April through December (Epperly et al., 1995). The leatherback is an open-ocean species that sometimes moves into shallow bays, estuaries, and even river mouths. The preferred diet is jellyfish and may also include sea urchins, squid, shrimp, fish, blue-green algae, and floating seaweed. It is also found along the Atlantic coastline from Massachusetts southward to Brazil.

- **Kemp's ridley sea turtle** – Kemp's ridley sea turtles inhabit shallow coastal and estuarine waters, often in association with subtropical shorelines of red mangrove. The entire population nests on ~15 miles of beach in Mexico between the months of April and June (USFWS, 1991). Outside of nesting, the major habitat for adult Kemp's ridleys is the near-shore and inshore waters of the northern Gulf of Mexico, especially Louisiana waters. However, immatures have been observed along the Atlantic coast as far north as Massachusetts. Although the Kemp's ridley has been documented to nest in North Carolina only once, juveniles of the species are known to migrate in estuarine and oceanic waters off of the North Carolina coast (Schwartz, 1977; Epperly et al., 1995). Overharvesting of both eggs and adults for food and the skin has been a major factor in their decline. Currently the major threat is drowning when inadvertently caught in shrimp nets. The total population is currently estimated to be 1500 to 3000 individuals.

- **Green sea turtle** – With an estimated population of no more than 600,000 adults worldwide, the green turtle exists in both tropical and temperate seas and oceans (USFWS, 1992). The North American distribution ranges from Massachusetts to Mexico, and from British Columbia to Baja California. Green sea turtles generally favor protected waters inside reefs, bays, estuaries, and inlets. Primary habitat appears to be lagoons and shoals supporting an abundance of marine grass and algae. These turtles are predominantly herbivorous, feeding upon marine algae and shallow beds of marine grasses. However, additional food sources may include mollusks, sponges, crustaceans, and jellyfish. The major reasons for the decline in green turtle numbers include over-exploitation of eggs and meat for food, commercial fishing and dredging operations, and nesting habitat destruction associated with outer beach development (USFWS, 1992). Green sea turtle nesting habitat consists of open beaches with a sloping platform and minimal human disturbance. Eastern United States nesting is primarily limited to Florida's east coast (300 to 1000 nests reported annually). Although occasional nesting has been documented as far north as North Carolina and false crawls have been documented at Emerald Isle Beach, no nests have been observed within the project site. However, juvenile green sea turtles are known to migrate in estuarine and oceanic waters off of the North Carolina coast (Schwartz, 1977; Epperly et al., 1995).

- **Loggerhead sea turtle** – The loggerhead turtle utilizes the Bogue Banks upper beach fronts for its seasonal (March-October) nesting events. Off the Carolina coast these turtles commonly occur at the edge of the continental shelf when they forage around coral reefs, artificial reefs, and boat wrecks. They feed on benthic invertebrates including mollusks, crustaceans, and sponges (Morrimen, 1982).

They have also been found to eat fish, clams, oysters, sponges, jellyfish, shrimp, and crabs when near shore. Research has shown that the turtle populations have greatly declined in the last 20 years due to loss of nesting habitat along the beachfront and by incidental drowning in shrimp trawl nets. Dredging activities in the warmer months of the year could impact the sub-adults but this has not been well documented. It appears that the combination of poorly placed nests coupled with unrestrained human use of the beach by auto and foot traffic has impacted this species greatly. Eroding steep beach escarpments, lights, sand fences, and other physical barriers (debris) often cause the mature females to select poor nesting sites at the dune toes which causes higher nestling mortality rates. Loggerhead turtles are known to regularly nest from Bogue Inlet to Beaufort Inlet, including the entire stretch of the project site. Between 1995 and 1999, an average of 28 nests/year were recorded within the project area (Ruth Boettcher, pers. comm.). In addition, juveniles are known to migrate in estuarine and oceanic waters off of the North Carolina coast (Schwartz, 1977; Epperly et al., 1995).

3.15.4 Fish

- **Shortnose sturgeon** – This species ranges along the Atlantic seaboard from southern Canada to northeastern Florida (USFWS, 1999). The shortnose sturgeon feeds on invertebrates and stems and leaves of macrophytes. From historical accounts, it appears that this species was once fairly abundant throughout North Carolina waters, however, many of these early records are unreliable due to confusion between this species and the Atlantic sturgeon (*Acipenser oxyrhynchus*). Because of the lack of suitable freshwater spawning areas in the project area and the requirement of low salinity waters by juveniles, any shortnose sturgeons present would most likely be non-spawning adults.

3.15.5 Plants

- **Seabeach amaranth** – Seabeach amaranth is an annual herb that occurs on beaches, lower foredunes, and overwash flats (Fussell, 1996). Weakley (1986) found that in North Carolina the plant is most common on overwash flats on accreting ends of barrier islands. This species occupies elevations ranging from 0.2 to 1.5 m above mean high tide (Weakley and Bucher, 1992). Historically, seabeach amaranth was found from Massachusetts to South Carolina. But according to recent surveys (USACE, 1992-1995), its distribution is now restricted to North and South Carolina with several populations on Long Island, New York. The decline of this species is caused mainly by development of its habitat, such as inlet areas and barrier islands, and increased ORV and human traffic which tramples individuals (Fussell, 1996).

Between 1992 and 1995, annual surveys of amaranth were conducted all along the North Carolina coast including Bogue Banks (NCNHP, 1995). The results are as follows:

	# Plants Observed at Bogue Banks	# Plants Observed within Project Area
1992	2,556	159
1993	3,762	232
1994	1,181	182
1995	14,776	391

No survey was conducted in 1996 because of early summer hurricanes that washed away or buried most of the plants. In 1997, certain sections of Bogue Banks were surveyed, but were found to support very low numbers of amaranth. ~~Because no survey has been conducted since 1997, the size of recent populations are currently unknown.~~ ~~Several hurricanes that hit the North Carolina coast in 1999 may have buried plants and seeds under sand or heavy winds associated with the storms may have dispersed seeds along the project area and into the ocean.~~ In August of 2000, staff of Land Management Group, Inc., performed an amaranth survey along the beaches of Bogue Banks from Bogue Inlet to Beaufort Inlet. Approximately 40 individuals were found. Most plants were located along Atlantic Beach, in areas that have received nourishment in the last ten years. The individuals were located on the foredune at and above the dune toe. On the remaining beach, including Pine Knoll Shores, Salter Path, Indian Beach, and Emerald Isle, six plants were observed. These individuals were located several feet above the dune toe in an area were extensive beach scraping has occurred.

3.15.6 Other Species – In addition to the federally-listed species, two other species with a state status of significantly rare (SR) have been observed in the proposed project area and are discussed here. The Wilson's plover is a state "watch list" species, categories W1 and W5, indicating that it is known to be declining and that there are threats to its habitat. It has been observed on the east side of Bogue Inlet~~, where a potential borrow area (C) is located~~ (NCNHP data). ~~It is a~~ THIS coastal bird species ~~that~~ breeds along the coast from Maryland southward and winters from the Gulf Coast and Florida southward (Fussell, 1996). In North Carolina, this species breeds primarily from Portsmouth Island southward. Wilson's plovers breed mostly on barrier islands and on dredged material islands within estuaries. This species is often found breeding at sites having similar habitat to those preferred by piping plovers, however Wilson's plovers utilize a broader range of habitat, including habitat with greater vegetative cover. The moundlily yucca plant has also been observed within the proposed project site. It was observed at Indian Beach in 1992 by NC Natural Heritage personnel and is generally found in moist depressions in sand dunes (Radford et al, 1964).

3.16 SEDIMENT CHARACTERISTICS

3.16.1 Summary – Extensive geotechnical surveys were completed in 1999 for purposes of identifying alternate borrow sources for nourishment. Details of the Phase I (June 1999) and Phase II (November 1999) sampling are given in Appendix E of this document.

Four potential borrow areas were identified during Phase I: (A) offshore of Indian Beach, (B1) inshore along Pine Knoll Shores, (B2) inshore from Salter Path to eastern Emerald Isle, and (C) Bogue Inlet intertidal shoals (Fig. 3.16A). Later sampling during Phase II (November 1999) confirmed each borrow area and allowed refinement of the boundaries. Delineation of the borrow areas was based on nearly 90 borings within the designated boundaries (15 borings per square mile). Borrow area A provides the most promising deposits with beach compatibility indices averaging an R_A value of 1.16 [method of James (1975) modified to account for percent mud]. Borrow area A potentially yields ~10 million cubic yards of beach-quality sediment, or roughly twice the required volume.

3.16.2 Prior Studies – Appendix E lists prior geology studies used in planning the 1999 borrow area search. The salient points of these studies with respect to nourishment planning and identification of viable borrow areas include the following:

- Bogue Banks is a relatively stable Holocene barrier island within the less exposed western "limits" of the Cape Lookout cuspate foreland with much more relief compared to the rapidly eroding barriers, Core Banks and Portsmouth Island just north of Cape Lookout (Heron et al, 1984).
- Prior to 4000 years ago, the shoreline off Bogue Banks was transgressive under the influence of deglaciation and rapid sea-level rise across the gently sloping continental shelf of the Carolinas.
- Only a thin sediment cover remains offshore--most of the inner continental shelf consists of outcropping Tertiary hard bottom (Hine and Snyder, 1985).
- Since the rate of sea-level rise slowed and approached its present elevation about 4000 years BP, Bogue Banks has accreted seaward and vertically by the spreading of littoral sediments away from prehistoric inlet deltas (Hine and Snyder, 1985).
- Bogue Banks' positional stability allowed accretion of high dune ridges--in some areas, exceeding 40 feet (ft) above sea level and along most of the shoreline reaching 20 ft.
- Subaerial sediments range from medium to coarse sand along the upper beach to fine sand in the dunes to mixtures of sand, coarse shells, and mud in back-barrier areas. The foreshore sediments coarsen toward the step (inshore breakpoint), then fine to the inner trough and bar. Seaward of a shore-parallel bar situated about 400 ft offshore, sediments fine along the lower shoreface.

3.16.3 Sediment Sampling and Analysis – Despite a limited supply of beach-quality sand offshore of Bogue Banks as inferred from the literature (Appendix E), more detailed confirmation was required before ruling out alternative borrow areas. The study team completed a reconnaissance-level survey during initial planning of the Bogue Banks restoration project based on the following desirable criteria:

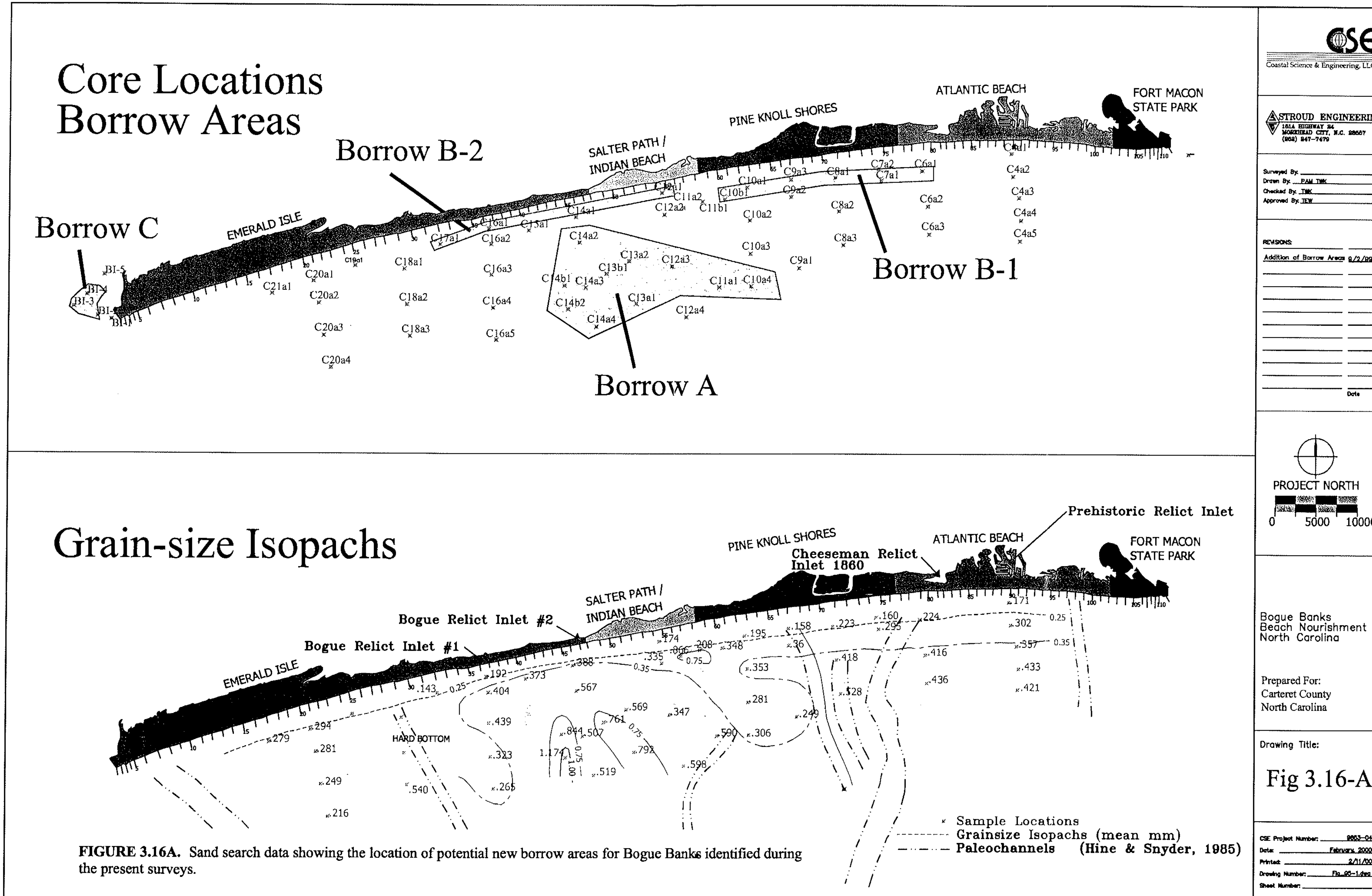


FIGURE 3.16A. Sand search data showing the location of potential new borrow areas for Bogue Banks identified during the present surveys.

- Viable sand deposits closer to the critically eroding areas in the center of the island rather than Beaufort or Bogue Inlets could potentially yield very large cost savings for the project.

- Sediments that are somewhat coarser (on average) than the native beach and coarser than the material typically available from channel maintenance would improve the durability of the nourishment project.

- Deposits with lower mud/fine-sand content than previously used in Corps disposal projects would reduce the rate of fill losses and minimize turbidity in nearshore waters.

- If broad, thin sediment deposits (at least 1-2 ft thick) could be confirmed, efficient hopper dredges or alternate equipment could be used for excavations.

The sediment survey encompassed the following field sampling over two phases between June and November 1999:

- **Beach sampling and textural analysis** (June 1999) to quantify native material — based on 20 samples divided among dune (2), berm (6), beach face (6), and low-tide terrace (6) at six representative transects spanning the length of Bogue Banks.

- **Phase I borrow source sampling** (June 1999)
  - *Offshore reconnaissance* — 53 short cores (~2 ft long) by divers in a regional grid pattern encompassing a 16-mile length of coast from central Atlantic Beach to central Emerald Isle and extending between ~0.25 and 3 miles offshore.
  - *Bogue Inlet* — eight surface grab samples at five stations over intertidal shoals in the middle of Bogue Inlet.

- **Phase II confirmation sampling** (November 1999)
  - *Borrow area A (western half)* — 46 borings (averaging ~2.3 ft) at ~1200-1500 ft spacing; eight vibracores (3-9 ft) at ~3000 ft spacing.
  - *Borrow area B1* — four diver borings (~2.8 ft); three vibracores (7.5-11 ft).
  - *Borrow area B2* — seven diver borings (~2.9 ft); three vibracores (~9-10 ft).
  - *Bogue Inlet intertidal shoals, borrow area "C"* — six short cores (~4 ft).

The only known borings prior to the 1999 survey in the primary offshore region (central Bogue Banks) were those collected in the early 1980s by university researchers (Dr. S.R. Riggs and Dr. A.C. Hine, principal investigators, as reported in Hine and Snyder, 1985). (See Appendix E.)

The present study focused on the uppermost ~2-3 ft layer for three reasons:

1) Preliminary evidence suggested that the "Holocene" section was more likely to contain beach-quality sediments.

2) Hopper dredges reportedly work most efficiently in borrow areas where the depth of cut is of the order 1-2 ft (E. Elefson, Aug. 1999, Weeks Marine, pers. comm.).

3) Environmental recovery of borrow areas appears to be more rapid where hopper dredges are used (Jutte et al., 1999b).

In total, the 1999 sediment surveys accomplished the following:

- Defined a "native" sediment size distribution.
- Characterized the upper 2-3 ft of sediments in an approximate 50 square mile area off Bogue Banks.
- Identified potential offshore borrow areas encompassing six square miles based on ~15 borings per mile.

Appendix E gives the sampling, processing, and analysis techniques. A majority of the samples was analyzed for grain-size distribution, percent mud, percent carbonate, percent coarser than 2 mm, and overfill factor (R_A). Isopach maps were prepared for key parameters to facilitate visualization of sediment quality in potential borrow areas.

Sediment quality and compatibility for beach nourishment relate to the degree of similarity between a particular borrow source and the native beach. Ideally, the nourishment sediment will have the same texture as the existing beach and, after placement, will respond to waves, currents, and winds the same way native sediments do. The most accepted technique for assessing borrow-area compatibility is that of James (1975) (CERC, 1984), whereby a population of potential borrow area samples is compared statistically with the native beach size distribution using a parameter called the overfill factor, R_A. R_As of nearly 1.0 suggest the sample will perform more or less equal to the native population. Higher R_As represent the ratio of non-native "borrow" material required to perform as 1.0 unit of native material. Thus, an R_A equal to 2.0 suggests it will take twice as much material to equal 1.0 unit of native sediment (NAS, 1995).

Experience has shown that borrow sources at least as coarse as the native beach (Dean, 1991; CERC, 1984) or having significant coarse fractions (Kana and Mohan, 1998) perform equal to or better than native sediments (as measured by durability of the dry beach). Borrow sediments that are finer than native or that contain high percentages of fine material perform worse (NAS, 1995).

The resulting R_As using the CERC (1984) nomogram were revised based on the percent mud in each sample and reported as a revised overfill factor. Mud is assumed to winnow out quickly, thus increasing the R_A in direct proportion to the mud percentage. Mud is defined as those sediments testing in the silt-clay range (mean size <0.0625 mm or >4.0ϕ).

3.16.4 Sediment Results – Appendix E contains detailed results.

Native Beach Composites – Native-beach size distributions were established using statistical composites of physical composite results of individual samples. Composite "20" (based on 20 samples: 2 dune, 6 berm, 6 beach face, and 6 low-tide terrace) yielded a mean size of 0.302 mm. Since the proposed nourishment is designed to widen the recreational beach including part of the underwater profile, we elected to use composite "20" as the "native" beach. This weights the composite toward the coarse sizes common along the beach face, berm. and low-tide terrace where the majority of the nourishment sand will be placed. The "native" composite selected for a baseline in the present study is considerably coarser than the native sediment distribution used by the USACE (1976) in planning for potential disposal projects along Atlantic Beach. The Corps sampled at 2 ft intervals from the berm to -30 ft mean low water (MLW) at the eastern end of Bogue Banks. Their statistical composites yielded a mean grain size of 0.17 mm (2.52ϕ). The Corps results confirm the fining of sediments offshore but tend to weight the result toward less stable material. The native composite we chose is more conservative for beach nourishment planning because it eliminates from consideration certain fine deposits that characterize the area seaward of the bar.

Table 3.16A contains sediment compatibility results (R_As) for each borrow area compared against the beach "20" composite. Two R_As were computed during Phase II—the first on washed samples (mud eliminated) and the second factoring in the mud percentage. In the latter, mud adds an incremental volume of nonbeach-compatible material which increases each R_A in direct proportion to the sample mud fraction. This "revised" R_A is given in Table 3.16A and on the summary map in Figure 3.16B.

The potential borrow areas yield revised R_As (factoring in mud percentage) of 1.16 at borrow area A, 1.57 at borrow area C, 1.97 at borrow area B2, and 2.19 at borrow area B1. Overall, borrow area A (revised) provides the deposit likely to perform the best for nourishment because its sediments are slightly coarser than the native beach. Carbonate material (mostly broken or crushed shell) comprises about 44 percent of the sediment in the confirmed section (versus 15-20 percent on the existing beach) and about 20 percent of the deposit is coarser than 2.0 mm (Appendix E). Mud percentage in borrow area A averaged ~4 percent in the upper ~2.3 ft of section.

Borrow area C had the next lowest average R_A at 1.57, meaning ~35 percent more material would have to be placed to yield the same performance as borrow area A. Area B2, while averaging in mean size close to the native beach (composite 20) has areas of poor-quality material. As noted in Table E7, certain samples were omitted from the statistics under the assumption that these areas would not be dredged. Other sections of the EIS for the project provide refined borrow area criteria and suggest revisions in the areas to avoid marginal sections. The confirmed borrow volumes indicate borrow area A alone could potentially provide sufficient quantities for the present project. Similarly, borrow areas B1 and B2 could provide 65 percent of the volume required (after adjustment to account for an overfill factor of ~2.0). Borrow areas B1 and B2 would require much more sand than borrow area A to yield comparable performance as the native beach. Borrow area C is not sufficient by itself to provide the necessary project volume but could serve to supplement borrow areas A, B1, and B2. Further considerations addressed elsewhere in the EIS are the economics of borrowing from multiple areas based on proximity to the project sections.

The revised R_As following Phase II sampling were slightly higher than the preliminary R_As determined for the Phase I samples (area A = 1.16 versus 1.10, area B1 = 2.19 versus 1.62, area B2 = 1.97 versus 1.62, and area C = 1.57 versus 1.15). These differences are due to the much greater number of samples available in Phase II and the incorporation of mud percentages into the analysis. This yields a more accurate representation of sediment quality for each area compared to the preliminary results of Phase I (CSE Baird-Stroud, 1999).

TABLE 3.16A Summary RAs and representative statistics for borrow areas A, B1, B2, and C. Based on Phase II samples plus applicable Phase I samples. See Figure E-7 for Phase II revised borrow area delineations.

Borrow Area	# Samples	Mean Grain Size (mm)	Mean Grain Size (phi)	%mud	RAs revised
A	61	0.51	0.974	4.0	**1.16**
B1	13	0.23	2.105	2.6	**2.19**
B2	17	0.30	1.729	4.1	**1.97**
C	8	0.42	1.255	<1	**1.57**
Native Beach	20	0.302	1.725	<1	1

Borrow Area	Area Acres	%carbonate	% >2mm	Confirmed Thickness (Ft)	Confirmed Borrow Volume (Cubic Yards)
A	2850	~44	~20.5	2.2	10+ million
B1	645	~20	~4.5	2.9	~3 million
B2	760	~22	~7.5	2.8	3+ million
C	370	ND	~5	~5	~3 million
Native Beach		~15-20	~5	NA	

Notes: Phase I & II samples omitted from the above statistics because they are outside the revised borrow area or represent sections below the confirmed thickness.

Area A: C10A4, C11A1, C12A3, C14B2b (lower unit below 1.8 ft), A-11s2 (lower unit below 3.3 ft), A-22s2 (lower unit below 3.0 ft), A-35s2 (lower unit below 2.4 ft), A-58, A-70B (below 1.25 ft).

Area B1: C7A2, ATH 9s2 (lower unit below 3.8 ft).

Area B2: C12A2, C17A1

Area C: Sample BI-4A, BI-4B, BI-3C, C-06

The confirmed borrow volume represents the potential maximum volume of material that could be obtained from the indicated borrow areas. In actuality, shallower cuts over a more select area will be planned during final design, with the idea of optimizing the area for best fill performance and lowest cost of dredging. The final borrow areas will be revised to avoid any cultural artifacts or unique biological habitats identified in other sections of the present EIS.

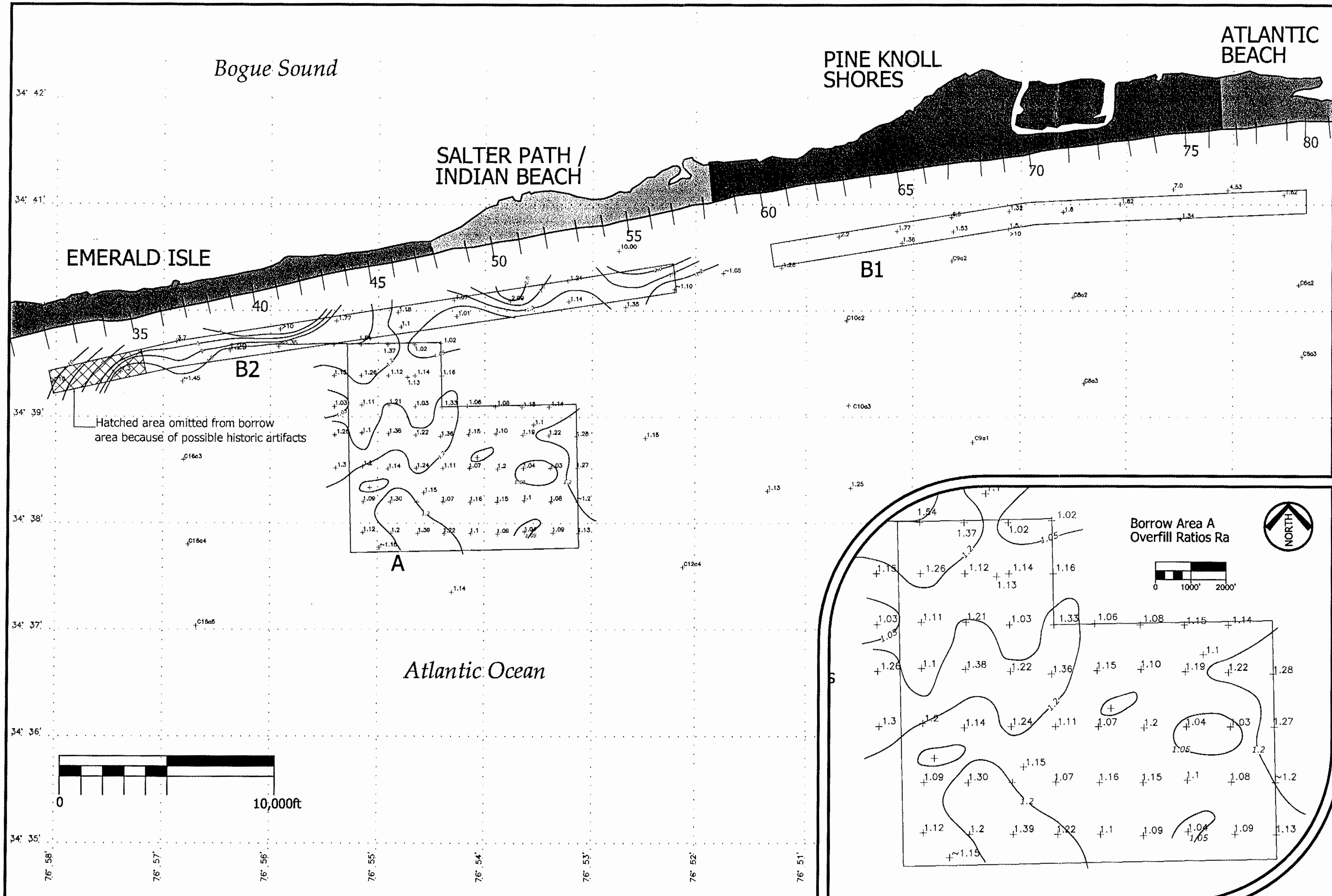


Figure 3.16B
Borrow area sediment capability based on revised overfill factors Ra for potential borrow areas A, B1, B2.

3.17 ECONOMIC AND SOCIAL ENVIRONMENT

3.17.1 Carteret County's Commercial and Tourism Based Economy – The economic environment of Carteret County is shaped by its geography and can be seen in the commercial and tourism related economies of the county. The county's economy, while diverse, is driven primarily by tourism and tourism-related jobs. The commercial and manufacturing segments of the economy are relatively small. The nine largest manufacturers in Carteret County are Atlantic Veneer with 330 employees, Cross Creek Apparel with 185 employees, Bally Refrigerated Boxes with 212 employees, Hankison International with 200 employees, Creative Outlet with 150 employees, Jarrett Bay Boatworks with 125 employees, Parker Marine Enterprises with 125 employees, and Veneer Technologies with 117 employees. Tourism is, by far, the largest industry in Carteret County. The industry contributes approximately $208 million annually to the economy of Carteret County, with a direct payroll of more than $38 million to over 3,400 workers. During 1998, unemployment in the county ranged from 7.8 percent in January to 3.0 percent in June. During 1997 and 1998 retails sales varied from a low of $44,000,000 in February 1998 to a high of $87,300,000 in July 1997, reflecting the seasonal nature of Carteret County's economy and the importance of tourism.

Thirty-nine percent of all tax revenues generated in Carteret County derive from sales taxes, occupancy taxes, fees, etc. Carteret County has a 3 percent occupancy tax. Occupancy taxes in fiscal year 1998-1999 contributed $1,706,788 to the operating budgets of the County and municipal governments. As mandated in the enabling legislation, occupancy tax revenues must be used for tourism related activities. In Carteret County, occupancy tax revenues are used to market the County's tourism attractions, and to operate and maintain the Crystal Coast Civic Center. Approximately 84 percent or $1,432,120 of all occupancy taxes collected in 1998-1999 came from rental of oceanfront properties or hotel occupancy on Bogue Banks.

Carteret County has also become a hub for marine science research. The North Carolina State University, Center for Marine Science and Technology, University of North Carolina at Chapel Hill, Institute of Marine Sciences, Duke University Marine Laboratory, the National Oceanic and Atmospheric Administration and the Division of Marine Fisheries are all located in Carteret County.

3.17.2 Culture of Beach Visitation – The three leading tourist destinations for U.S. travelers (in order) are: beaches, national parks, and historic sites. Beach visitation is an international pastime. Evidence of this trend of man to seek refuge and relaxation at the shorelines of world exist in the ruins and still viable coastal developments developed during the time of the Roman Empire. Carteret County has been a travel destination for centuries. The earliest visitors to the area came in the early 1700s and began to colonize the area with Carteret County officially being formed in 1722. The seasonality of visitation and the economic rewards it brings at peak times has shaped the economy and life of Carteret County residents for hundreds of years.

People visit Carteret County from all over the state, country and world. The Tourism Development Bureau fields over 150,000 inquiries for information on Carteret County each year from people interested in visiting the area. From within North Carolina, the majority of visitors come from Raleigh followed by Greensboro, Highpoint and Charlotte. From within the United States, people travel from Virginia, Pennsylvania, Ohio, New York, New Jersey, and Washington DC, in that order. The majority of international travelers to Carteret County come from Canada, followed by the United Kingdom, Germany, Japan, France, and Brazil.

Many North Carolinians visiting Carteret County own second homes on Bogue Banks and travel to the county on weekends or for the entire summer while still maintaining homes and careers in other cities.

Carteret County has the second largest fleet of sportfishing boats in North Carolina. Sport fishing and construction of sport fishing boats have become a significant economic resource in the County. In addition, the ocean waters off Bogue Banks and Cape Lookout are known to be in the top ten sites in the world for sport diving.

4.0 ALTERNATIVES

4.1 OVERVIEW OF ALTERNATIVES — Under existing federal and state laws, there are only three alternatives for dealing with erosion along Bogue Banks: (1) no action; (2) abandon property, retreat, and relocate; (3) nourish the beach.

Structural shore protection involving seawalls, revetments, and bulkheads is not allowed under present North Carolina coastal zone management (CZM) regulations. Semi-hard solutions involving sand-retaining structures, such as groins and detached breakwaters, plus nourishment are not recommended in areas of low erosion rates away from inlets (NAS, 1995). In general, present CZM policies along ocean coasts favor beach nourishment because it is ". . . the **only** engineered shore protection alternative that directly addresses the problem of sand budget deficit . . ." (NAS, 1995, pg. 1).

Of the three primary alternatives, all have large costs associated with them as described below, and whether nourishment is the lowest cost alternative depends on a combination of four main factors:

- Existing sand deficit with respect to the desired scale of the beach.
- Average, long-term erosion rate at the site.
- Density and value of developed property at risk.
- Proximity of beach-quality borrow sediments and their cost of transportation to the project area.

> *Beach nourishment can provide protection from storm and flooding damage when viewed within human time scales (decades not centuries) in those situations where its use is technically feasible, provided that:*
> - *erosion rates are effectively incorporated into project design . . .*
> - *. . . engineering standards are used for planning design and construction, and*
> - *projects are maintained . . .*
>
> *. . . Beach nourishment may not be technically or economically feasible or justified for some sites, particularly those with high rates of erosion. Government authorities with responsibility for coastal protection should view beach nourishment as a valid alternative for providing natural shore protection and recreational opportunities, restoring dry beach area that has been lost to erosion. (NAS, 1995, p. 3)*

[NOTE: Signatories to this statement include Dr. R.J. Seymour, chair, Scripps; Dr. Robert G. Dean, University of Florida; Dr. Paul Komar, Oregon State University; Dr. Orrin H. Pilkey, Duke University; and Dr. Robert L. Wiegel, University of California Berkeley; among others.]

4.2 DO-NOTHING ALTERNATIVE — The do-nothing or no-action alternative is evaluated based on whether the alternative considered meets the project planning objectives. In terms of those objectives, the no-action alternative is not a viable plan of action for the County. Discussions of each objective are provided below.

Planning Objective: preservation of the environmental, cultural and aquatic resources of the county

The no-action alternative would not meet this objective given the current state of the beach. Continued erosion will increase the frequency of dune scraping. Forty acres of vegetation and its associated habitat will be lost. Turtle nesting habitat will be eliminated because of steep escarpments and unstable back beach areas subject to wave uprush.

Planning Objective: provide an easily accessible recreational beach available to all citizens of the county

The no-action alternative would not meet this objective. Significant recreational beach has been lost due to erosion of the shoreline. In many locations recreational use is limited to low tide periods. When structures are permitted to fail due to erosion of the beach, the costs of demolition and removal are often borne by the municipality. It is estimated, based on expenditures by municipalities and the county over the past four years, that without a substantial berm, costs for cleanup of debris on the beach will be $400,000 per year. Accounting for escalation and normalized to present worth, debris cleanup costs are $3,509,000. The costs associated with rebuilding beach access structures borne by homeowners, municipalities, the county and by homeowners associations is estimated at $2.1 million per year. A

survey of the beach indicated that in excess of 80 percent of access structures either had been repaired or were in need of repair. It was observed that, in areas of Atlantic Beach and west Emerald Isle where a wide berm exists, few access structures were repaired. It is estimated that the average repair costs is $3000. Escalating the costs and normalizing to present value results in costs for access structure repair of $19,161,950.

Planning Objective: provide protection of oceanfront property as a resource for tax revenues to the municipalities of Bogue Banks and to the county

The no-action alternative would not achieve this objective. Based on the number of oceanfront properties that it is estimated will be lost over the ten-year analysis period, the net present value of **property tax revenues lost** for the municipalities and the county is $6,332,889. This is present worth for a ten-year project period.

In addition to loss of revenue to municipalities and the county, there would be a negative economic impact caused by the retarded appreciation of all property on Bogue Banks. The precedent for this trend is Topsail Island in Onslow County. Property on North Topsail Island showed zero appreciation between the last re-evaluation conducted by Onslow County. It is unlikely that Bogue Banks would experience a zero increase over an assessment period. According to assessments conducted in 1989 and 1997, Bogue Banks property appreciated at approximately 4.8 percent annually. Real estate brokers contacted indicate an appreciation over the last five years of 10-15 percent annually. Just a lag of only 2.0 percent in the rate of appreciation would result in an economic loss of some $ 9 to 106 million with escalation over a 10 year period. With escalation and normalized to present worth, that represents over 1.25 billion dollars over a ten-year period. This value manifests itself in lost value to owners, lost revenues to real estate brokers and in reduced appreciation for purposes of tax revenues (estimated ~$8.6 million at the going rate over ten years).

These revenue losses would have to made up by each municipality and the county by increasing ad valorem taxes on non-oceanfront properties and, in the case of the county by additional taxes levied on properties not located on Bogue Banks.

Planning Objective: maintain the economic viability of tourism, the county's largest industry

The no-action alternative would not meet this objective. Healthy beaches providing suitable recreational beach are the main attraction of the tourism industry. Loss or degradation of that attraction would have a significant impact on the tourism industry. Loss of oceanfront properties would eliminate indefinitely the rental income and associated economic activity generated by the income.

In the past five years, there has been an increase in storm frequency, increase in dune scraping frequency, apparent decline in the rate of property value appreciation compared to other beach communities, and increased public perception of erosion. All of these factors contribute to significant economic impacts which can not be quantified precisely. However, it is possible to estimate a range of potential costs based on recent experience in Bogue Banks. Following are potential costs that will accrue over a **ten-year period** to the entire community and property owners on Bogue Banks if the no action is taken in response to continued erosion.

A) Impacts to community (Carteret County) economy – government losses:	
- Reduced Property tax revenues (see above)	$6.3 million
- Loss in Occupancy Tax due to lower beach use	$1.1 - $2.8 million
- Loss in Sales Tax due to lower beach use	$13.1 - $32.8 million
- Debris removal after storms (walkovers, decks, etc.)	$3.5 million
- Reduced property tax revenues (due to lower Bogue Banks property value appreciation)	$8.6 million
Subtotal	$32.5 to $55.9 million
B) Environmental Impacts to Carteret County:	
- Loss of 40 acres of vegetated dunes	not quantifiable
- Reduced turtle nesting area	not quantifiable
- Chronic impacts to beach fauna	not quantifiable
- Loss of recreational beach (computations in Appendix F)	$0.8 - $2.1 million

C) Impacts to Owners in Special Tax Districts on Bogue Banks

- Beach scraping after storms		$2.2 million
- Reconstruction of walkovers and beach access		$19.1 million
	Subtotal	$21.3 million

Poststorm repairs (foundations, sheathing, windows, etc.) — not calculated

D) Other Potential Private Losses:

- Reduction in payroll in tourism industry due to lower beach use	$32.1 - $80.2 million
- Reduction in other (nontax, nonpayroll) tourist expenditures	$90 - $226 million

Total Economic Costs for No-Action Alternative (10 Years)

Community/Governmental (A & B above)	**~$53.8 million – $77.2 million**
Private [C & D above]	**~$143 million – $327 million**

Estimates are present worth of escalated annual costs. Details of determination of costs are presented in Appendix F.

The above estimates have been determined for the 10 year project life. Given the marginal condition of the beach today, it is likely that the cost of repairs will increase faster than the rate of inflation and faster than the above estimates because shoreline damage increases geometrically with decreasing distance to the waterline. In the analysis of Appendix F, we assume that cost occur equally in each of the 10 years for each cost category. Additionally, escalation rates for real estate used in the analyses is 4.8 percent annually compared to a historic appreciation in market value of 10 to 15 percent annually. Therefore estimates are considered conservative.

4.3 RETREAT/RELOCATION ALTERNATIVE — The relocation/retreat alternative involves moving oceanfront structures that are threatened by erosion of the shoreline. As of the date of this EIS, the town building Inspectors of Emerald Isle and Pine Knoll Shores have identified 173 oceanfront properties in Emerald Isle and 36 properties in Pine Knoll Shores that are threatened or, in many cases, condemned due to beach erosion.

Study of the retreat/relocation alternative for this EIS involved identification of oceanfront properties that would be threatened over the 10-year study period. A survey was conducted to locate the toe of the naturally occurring dune along the project area. Using the long-term erosion rates developed in the Shoreline Assessment and Preliminary Beach Restoration Plan Report, a 10-year setback zone was determined for reaches of the beach that fall into one of the six erosion rate zones. Beach erosion rates for each of the six areas are shown in Table 4.1. Note: These erosion rates are considered conservative with respect to the property relocation alternative. Higher erosion rates would impact more properties and result in substantially higher costs.

TABLE 4.1. Erosion rates and 10 year retreat distances for project areas.

Location	Long-Term Erosion Rate (ft/yr)	10-Year Retreat Distance (ft)
West Emerald Isle	2.0	20
Central Emerald Isle	2.0	20
East Emerald Isle	2.0	20
Indian Beach/Salter Path	2.0	20
West Pine Knoll Shores	3.0	30
Central Pine Knoll Shores	2.0	20
East Pine Knoll Shores	3.0	30

A visual survey was made of the oceanfront properties to identify structures that fall into the 10-year setback zones for each reach. This included single family residential structures and condominium units.

Using tax maps, a count of properties was determined in each of two categories: (1) the properties with sufficient land area to allow relocation of the structure on site, and (2) those properties where erosion of the property and street setback requirements will require that the structure be relocated to another lot. Estimates of moving costs are based on discussions with house movers, on costs from R.S. Means Cost database, and on the project cost experience of Stroud Engineering in Carteret County. Detailed breakdowns of the costs for relocation on site, relocation to new lot, and total present day costs for each municipality are provided in Appendix F.

The retreat/relocation alternative is evaluated based on whether the alternative plan meets the project planning objectives. In terms of those objectives, the retreat/ relocation alternative is not a viable plan of action for the County. Discussions of each objective are provided below.

Planning Objective: preservation of the environmental, cultural and aquatic resources of the county
The retreat/relocation alternative would not meet this objective given the current condition of the beach. Continued erosion will increase the frequency of scarping. Forty acres of vegetation and its associated habitat will be lost. Turtle nesting will be eliminated because of steep escarpment and unstable backbeach areas subject to wave uprush.

Planning Objective: provide an easily accessible recreational beach available to all citizens of the county
The retreat/relocation alternative would not meet this objective. Significant recreational beach has been lost due to erosion of the shoreline. In many locations recreational use is limited to low-tide periods. Additionally, with the loss of oceanfront properties, there is loss of beach access areas. In Emerald Isle and Indian Beach, beach access is provided at locations where public street rights-of-way dead end at the back of the dunes. Loss of the oceanfront property will include loss of these beach access areas.

Planning Objective: provide protection of oceanfront property as a resource for tax revenues to the municipalities of Bogue Banks and to the county
The retreat/relocation alternative would not achieve this objective. The total economic loss associated with this alternative is evaluated. Details of the evaluation are provided in Appendix F. The total losses are evaluated and expressed here in terms of the net present worth in year 2000. The evaluation includes annual escalation of construction costs and land values. The losses include the costs of property lost, costs of property that must be purchased in order to relocate a structure, and the costs of relocation. It is assumed in the analysis the condominiums located in the setback zone will have to demolished and reconstructed at another location on the development site. Costs are distributed equally over the 20-year study period with escalations included for real estate value and construction costs.

The present worth of retreat/relocation is shown in Table 4.2. The present worth of the retreat/relocation alternative is $110,940,556 compared to the project costs for beach nourishment of $30,000,000. Both represent year 2000 costs. [Note: This does **not** count the costs associated with the no-action alternative, many of which will also apply under the retreat/relocation alternative.]

Planning Objective: maintain the economic viability of tourism, the county's largest industry
The retreat/relocation alternative will not meet this objective. Healthy beaches providing suitable recreational beach are the main attraction of the tourism industry. Loss or degradation of that attraction would have a significant impact on the tourism industry. As with the no-action alternative, loss of vacation rental revenues is not quantified in this EIS. Loss of oceanfront properties would eliminate indefinitely some rental properties and reduce the remaining number of viable the rental properties thereby reducing rental incomes and associated economic activity generated in the County and municipalities.

TABLE 4.2 Net present worth of retreat/relocation alternative.

[Discount rate = 6.125%. Discount rate is yield on 30-yr treasury bond, latest auction reported in Wall Street Journal, 02/24/2000.]

	ANNUAL COSTS OF RELOCATION / RECONSTRUCTION			
Cash Flow Year	**Single Family Relocate On Site**	**Relocate Off Site**	**Condominiums Rebuild On Site**	**Rebuild MH Sites**
1	$1,076,400	$ 8,991,000	$2,180,250	$156,000
2	$1,108,692	$ 9,393,930	$2,245,658	$160,680
3	$1,141,953	$ 9,796,860	$2,313,027	$165,500
4	$1,176,211	$10,199,790	$2,382,418	$170,465
5	$1,211,498	$10,602,720	$2,453,891	$175,579
6	$1,247,843	$11,005,650	$2,527,507	$180,847
7	$1,285,278	$11,408,580	$2,603,333	$186,272
8	$1,323,836	$11,811,510	$2,681,432	$191,860
9	$1,363,551	$12,214,440	$2,761,875	$197,616
10	$1,404,458	$12,617,370	$2,844,732	$203,545
Present Value	**$9,444,103**	**$82,357,407**	**$19,129,046**	**$1,368,711**
TOTAL NPV	**$110,940,556**			

4.4 PREFERRED ALTERNATIVES — The preferred alternative is beach nourishment at a level which fully restores the profile deficit with respect to a "healthy" beach and provides advance nourishment for approximately ten years to accommodate the background erosion rate. Nourishment is the only practical solution that will offset the sand deficit, maintain the recreational beach, and protect developed property and community infrastructure. There are many ways beach nourishment can be accomplished. This section of the EIS outlines the main implementation alternatives with respect to sand sources, beach fill design, methods of construction, construction schedule, and maintenance.

4.4.1 Alternate Borrow Areas – Based on previous practice along the U.S. East Coast, the following classes of borrow sources have been used for beach nourishment (CERC, 1984):

- – Lagoon sediments
- – Inlet shoals (inshore)
- – Inlet shoals (offshore)
- – Nearshore bars
- – Offshore deposits
- – Recycled spoil sediments
- – Accreting spits/beach deposits
- – Attached bar deposits
- – Inland deposits
- – Freshwater pond deposits
- – Fillets at jetties
- – Imported material

In general, economics favor the borrow source(s) that matches the native beach quality, involves the shortest transportation distance, and minimizes environmental impacts. Large-scale projects such as the present Bogue Banks restoration plan require large volumes of material which may not be available in only one deposit.

4.4.1.1 Unacceptable Sources – The following sediment sources are considered unacceptable for the project.

- *Lagoon deposits in Bogue Sound* – generally much too fine compared to native beach sand and would not provide sufficient quantities of beach-compatible sediment.

- *Nearshore bar(s) along the project area* – part of the active profile and important for wave energy dissipation, therefore inappropriate as a borrow source; sediments too fine for the dry beach in this setting.

- *Accreting spits/beach deposits* – Bogue Banks has insufficient quantities of sand in accreting spits or accreting beach zones (e.g., western Emerald Isle) for the project. At least 20 times more sand is required than resides onshore as "surplus" near the ends of the island.

- *Attached bar deposits* – only very limited reaches near the inlets have any "surplus" sands in attached bars. This would provide only a tiny fraction (of the order 1-2 percent) of the material required for the project.

- *Inland deposits* – most of Bogue Banks is developed or privately owned. Even if a large tract were available and suitable for sand mining, costs of land acquisition in this setting would increase the cost of the project well beyond other alternatives. Other inland deposits on the mainland may be beach quality, but transportation distances make them much more expensive than other alternatives.

- *Freshwater pond deposits* – there are no known freshwater ponds nearby that require maintenance excavations or could provide the quantities of beach compatible sediment required for the project.

- *Fillets at jetties* – there is insufficient excess littoral sand trapped in fillets along the jetties/groins at the inlets adjacent to Bogue Banks.

- *Imported material* – imported beach-quality sediment from sources more than 15 miles from Bogue Banks will be significantly more expensive because of transportation costs than the acceptable sources (listed below).

4.4.1.2 Acceptable Sources – The following sediment sources were evaluated in more detail because of their likelihood of providing acceptable material (Appendix E).

- *Offshore deposits* – a sand search over a 50-square-mile area off Bogue Banks revealed about six square miles of beach-quality sand in close proximity to the project area.

- *Inlet shoals (inshore)* – review of aerial photos and ground-truth sampling confirmed the presence of extensive inlet shoals at Bogue Inlet which contain beach-quality sediment. In a 10 February 2000 letter, the Wilmington District outlined the costs and methods to open a new inlet channel. In this EIS, we are only proposing mining the inshore shoal (borrow area C). Studies by the USACE confirm that beach-quality material exists in some inshore areas of Beaufort Inlet.

- *Inlet shoals (offshore)* – studies by the USACE confirm that beach-quality material exists in offshore shoals of Beaufort and Bogue Inlets.

- *Recycled spoil sediments* – studies by the USACE confirm that beach-quality material resides in certain spoil areas, such as Brandt Island, which can be "recycled" to the beach.

The results of sediment sampling and review of published reports (Section 3.16 and Appendix E) yield the following ranking of acceptable borrow areas with respect to quality (as measured by composite overfill factors, R_A):

1) Offshore, area A
2) Bogue Inlet shoals (inshore)
3) Offshore, area B2
4) Offshore, area B1
5) Beaufort Inlet, outer shoals (inferred)
6) Brandt Island spoil area
7) Beaufort Inlet, offshore disposal mound (inferred)

With respect to transportation distances, the above-listed resources are ranked as follows (best to worst):

1) Offshore, areas B1 and B2, average distance <2 miles
2) Offshore area A, average distance ~5 miles
3) Bogue Inlet shoals, average distance ~10 miles
4) Brandt Island, average distance ~12 miles
5) Beaufort Inlet, average distance ~14 miles

The preferred borrow area is A based on sediment quality and transportation distance.

4.4.2 Alternate Fill Profile — Beach nourishment may be performed at a continuum of scales, depending on the goals of the project, availability of borrow sediment, method of construction, and budget. Since the proposed project area has never been nourished, there are no site-specific data to use as a guide other than the existing natural profile and available erosion rate estimates. Nearby Atlantic Beach has been nourished twice, but its sediment characteristics (after nourishment) differ from those in the proposed project area.

CSE Baird-Stroud (1999) evaluated the condition of the beach and inshore zone along Bogue Banks, using the profile volume method (Kana, 1993; Kana and Mohan, 1996). This method establishes site-specific criteria by which volume deficits can be determined against an ideal or desirable profile volume (i.e., one which contains sufficient dimensions to sustain daily, seasonal, and storm fluctuations of the beach without significant damage to the backshore). The profile volume method, if performed to the estimated depth of closure, integrates all cross-shore variations in profile geometry and is therefore insensitive to the timing of surveys.

Our analyses (CSE Baird-Stroud, 1999) demonstrated that there is a profile deficit averaging ~40 cy/ft along the 16.8-mile reach from western Emerald Isle to Pine Knoll Shores (profiles 8-76), compared to the existing profile volume along Atlantic Beach. Considering the fact that Atlantic Beach sustained Hurricanes *Dennis* and *Floyd* (1999) as well as *Fran* (1996) with only minor damage compared to other sections of Bogue Banks, its profile volume yields a rational minimum value. During final design, the profile volume will be analyzed quantitatively to estimate the level of protection provided.

The desired fill volume is one that restores the deficit (with respect to the criteria and goals of the project) plus adds "advance nourishment" to increase longevity. Advance nourishment is generally related to the anticipated average annual losses from the project area (i.e., the background erosion rate). The Bogue Banks Beach Preservation Task Force evaluated projects which factored in 5-year, 10-year, and 20-year advance nourishment requirements based on best-available background erosion rates. It was the decision of the task force to formulate the project around the 10-year nourishment project (i.e., initial deficit averaging 40 cy/ft plus 10-year advance nourishment averaging 10 cy/ft). This provides a reasonable time period over which the first project can be evaluated and provides a project scale that is practical for dredging. Small-scale projects do not afford economies of scale during construction and result in more frequent nourishments and the associated disruption to normal beach use by people and animals.

The proposed fill will be placed by hydraulic dredge between the base of the foredune and the outer bar. Only the profile above high water is controllable in nourishment construction. Intertidal and underwater portions of the profile will be subject to natural adjustment by waves. Given the relatively high backbeach elevations along most of Bogue Banks and the issue of easements for construction, the majority of the fill will be placed no higher than +7 ft NGVD (the natural elevation of the berm) and seaward of the existing toe of the foredune and all development. Along portions of eastern Emerald Isle, a low dune (elevations <+12 ft NGVD) will be constructed as part of the project to prevent the dredge slurry from flowing landward across developed property (where the foredune is missing).

Other fill profiles considered included:

- **Nourishment entirely below low water** – not the preferred alternative because it is more difficult to control sand placement, does not provide a safe working platform during construction, and does not provide immediate restoration of the dry beach and associated backbeach habitats.

- **Nourishment largely contained in a protective foredune** – not the preferred alternative because (1) a dry beach and healthy underwater profile are necessary prerequisites for a stable foredune; (2) nourishment sediments should be subject to wave action so material will sort naturally, bleach to a natural color, and winnow out fines; and (3) the project's primary goal is to restore a viable recreational beach for broad benefit to the community.

- **Smaller fill sections** – not the preferred alternative because they become more expensive per unit volume to construct due to economies of scale, they will not restore the minimum profile deficit, and they will leave more reaches vulnerable to storm damage.

4.4.3 Alternate Methods of Construction — There are two basic methods for nourishing beaches—via land-based equipment and mechanical placement or via hydraulic equipment (i.e., dredges). In either method, mechanical equipment such as dozers, graders, etc., are used to spread the material in a controlled manner. Some projects involve combinations of hydraulic and mechanical transfer. The preferred method depends on the scale of the project, proximity of the borrow area, and type of borrow area. Hydraulic dredges involve high initial costs to cover the setup of discharge pipeline, etc. Land-based equipment such as trucks or scraper pans can be mobilized at low cost. After mobilization, the unit costs of sand placement depend on transportation distance. In general, unit costs of hydraulic fills are lower because of efficiencies in production and placement. Therefore, large-scale nourishments such as the proposed project tend to be more cost effective if constructed by hydraulic dredge.

4.4.3.1 Methods Considered Unsuitable – The following excavation and sand transfer methods are considered unsuitable for the present project.

- *Over-road trucks* – none of the designated borrow areas are situated inland, and none are directly accessible by road.
- *Mechanical conveyor belt* – none of the designated borrow areas are situated close enough to the project area for this technique to be economic.
- *Dragline* – none of the designated borrow areas are situated close enough to the project area for this technique to be economic.
- *SeadozerÔ* (c/o Cape Fear International, Beaufort, NC) – None of the designated borrow areas are situated close enough to the project area for this technique to be economic. The method would result in more ocean bottom being impacted because it involves "pushing" material by jets/prop wash from borrow areas to the beach, a minimum distance of 0.5 miles. Portions of the project area are situated >>0.5 miles from the nearest borrow source. It is uncertain whether the SeadozerÔ is certified by the U.S. Coast Guard to work seaward of the open-ocean jurisdiction (COLREGS) line, a primary requirement for excavations in the offshore borrow areas (A, B1, and B2).
- *Traditional cutterhead suction dredges* – ocean-certified dredges are required by the U.S. Coast Guard for any excavations seaward of the COLREGS line. Generally, ocean-certified cutterhead suction dredges are the largest of their kind due to the certification requirements. Curtterheads are of the order 5-10 ft in diameter. Such dredges require a minimum operational depth of ~20 ft and work most efficiently if excavations remove at least 4-6 ft of section. Because the designated offshore borrow areas have on the order ~2 ft of beach-quality sediment in the section, cutterhead suction dredges will not be efficient. They would result in deeper cuts and mixing of less compatible material with the beach-quality material. Cutterhead suction dredges are only considered feasible for borrow area C (Bogue Inlet shoals) or Corps maintenance dredging in and around Beaufort Inlet.
- *Miscellaneous methods* – bucket dredging and transfer by barge are not cost effective for areas A, B1, or B2 and are generally not allowed seaward of the COLREGS line. This technique may be feasible for borrow area C where the equipment can work a thicker shoal section. Split-hull barges are not considered feasible because they require a minimum water depth of the order 20 ft for discharge. This depth would place the material too far seaward to achieve the project goals.

4.4.3.2 Methods Considered Suitable

- *Ocean-certified hopper dredge* – Self-propelled hopper dredges with built-in pumpout capability are feasible for borrow areas A, B1, and B2. Ocean-certified equipment typically requires ~25 ft minimum operational depth and is efficient for excavating shallow cuts of the order 1-2 ft. During excavation and loading, the slurry drains via scuppers discharging some fines in situ and leaving coarser material in the hopper compared to the excavated material. When loaded, the dredge travels to a temporary mooring and submerged pipeline near

the project site. It hooks up to the pipeline and pumps the material from the hopper to the beach where it is spread mechanically by dozers.

- *Ocean-certified suction dredge equipped for shallow cuts* – one such dredge exists among U.S. companies which has been specially designed for shallow cuts. This "dustpan" dredge (so nicknamed) is presently owned by Weeks Marine, Inc. (NJ) and is used primarily for beach nourishment involving thin borrow areas offshore (P. Lamourie, Aug'99, pers. comm.). The dredge works most efficiently if the borrow area is close to the project area (e.g., excavations paralleling the beach less than one mile offshore). The slurry is pumped directly to the beach via submerged pipeline and distributed with the aid of dozers and other land-based equipment. In contrast to self-contained hopper dredges, the excavations are pumped only once and therefore transfer more fines to the beach according to the quality of the sediment in the borrow area. Unit costs may be substantially lower than all other methods if the pumping distances are short. This method is considered most feasible for borrow areas B1 and B2.

- *Combined dredge and offroad trucks* – borrow area C and certain Corps spoil and navigation channels may be excavated by hydraulic dredge, transferred to a temporary stockpile area, dewatered, then loaded mechanically into offroad vehicles for distribution along the beach. This alternative is considered most feasible for borrow area C because Bogue Inlet is too shallow for a hopper dredge to exit when fully loaded. Noncertified dredges may legally work in sheltered waters in the inlet and pump a short distance from shoal areas to temporary stockpile areas at the western end of Bogue Banks. From there, offroad dump trucks could transfer material to the project area. Because of the double handling and distances involved, this method is only considered cost effective for the western Emerald Isle reach.

4.4.4 Alternate Construction Schedule — The proposed project involves a substantial volume of sand (>4.5 million cubic yards). Based on project experience elsewhere, one ocean-certified dredge can excavate and place on the order of 15,000-40,000 cy in a 24-hour period. The average production per day varies widely according to transportation distance and specifications of the project. In any case, a substantial period of time will be required to complete the project. For example, if production averages 20,000 cy/day, at least 225 calendar days (~7.5 months) will be required.

Preliminary discussions with environmental agencies indicate construction during colder months is favored because biological productivity tends to be lowest then. Construction during winter also avoids disruption of the peak tourism season.

The following general construction schedules were considered (including advantages and disadvantages).

4.4.4.1 Construction anytime based on dredge availability and lowest bid

- *Advantages* – Likely results in lowest construction cost and substantial financial savings to the community because the contractor controls the schedule around other workload and weather and only mobilizes once. Yields the earliest project completion and initiation of improved storm protection and recreational benefits.

- *Disadvantages* – Likely encroaches on high biological productivity periods, nesting seasons, and tourist season.

4.4.4.2 Construction during limited "environmental" windows between ~November and ~April

- *Advantages* – Direct environmental impacts occur during periods of lowest biological productivity. Avoids prime tourist season. Yields early benefits if the project can be initiated in fall 2000.

- *Disadvantages* – A five-to-six month construction window is insufficient to complete the entire project unless more than one dredge is used. Each dredge introduces large mobilization costs, increasing the total cost of the project. The narrower the dredging window, the fewer contractors will be willing to bid the project, further raising the cost of construction. Down time for weather is more likely during winter than summer. Delays project benefits for at least one year if the winter 2001 construction window is missed.

5.0 ENVIRONMENTAL CONSEQUENCES

5.1 LAND USE — Nourishment of the Bogue Banks beach will not change the land use patterns. Development of shoreline is governed by zoning regulations of the municipalities and County and by the CAMA Land Use Plans approved for each governmental entity. Ocean front development will remain primarily single family residences with patches of multi-family and hotel development. The beach nourishment project is consistent with the approved CAMA Land Use plans for Carteret County, and the Towns of Pine Knoll Shores, Indian Beach and Emerald Isle.

5.2 WETLANDS — No impacts to existing coastal wetlands or 404 wetlands will result from this project. No fill will be placed in 404 or coastal wetlands as part of this project.

5.3 UNIQUE AGRICULTURAL LANDS — The beach nourishment project will result in no impacts to agricultural lands, unique or otherwise.

5.4 LITTORAL PROCESSES

5.4.1 Tides – For borrow areas A and B, the dredging and nourishment operations will take place in the open ocean, so no changes in tidal conditions can occur. Dredging operations only affect tides in closed systems, such as inlets and bays. For borrow area C in Bogue Inlet, tides can be affected only if there is a change in the throat's cross-sectional area of flow. For example, it is thought that the change in tidal range in Beaufort Inlet may be related to the substantially increased cross-sectional flow area caused by dredging the navigation channel. Dredging borrow area C will not impact Bogue Inlet's cross-sectional flow area. Note on the drawing showing borrow area limits (see Fig. 3.16A) that the minimum (controlling) cross-section of Bogue Inlet's throat is well seaward of the borrow area limits. (When we passed along the navigation channel in our boat with a depthsounder, we noticed the ocean-bar minimum cross-section occurred a few hundred feet seaward of the last sample we took, labeled B-1 in Figure 3.16A.)

5.4.2 Hurricanes – Dredging the borrow areas will not change hurricane surge levels, since surges are changes in water-surface elevations. Changes in seabed depths affect surge levels only if enormous changes occur in seabed locations. The main hurricane-related impact of this project is the substantial increase in protection from hurricanes that will occur because of the greatly expanded beach. The biggest improvement will be in protection of the dunes from erosion by waves generated by hurricanes. Currently there is very little distance between the base of the dunes and the water. During the 1999 hurricanes, the dunes on Bogue Banks retreated an average of about 15 ft, with some areas retreating more than 30 ft. In a few low-lying areas there was washover of the dunes during hurricanes. Since the toe of the dune is now so close to the water, hurricane surge raises the water level sufficiently for waves to directly impact the dune toe and erode it away. Most areas of Bogue Banks have sufficiently high dunes to withstand surges. The problem is narrow beaches allowing waves to erode the toe, thus causing the entire dune to retreat.

5.4.3 Waves – Possible changes to waves caused by altering topography in the borrow areas was examined by use of wave shoaling models. The Wave Information Study database of waves from wind-wave models was used as a data source for the shoaling studies over borrow areas A and B. (Borrow area C is well inland of wave barriers, including both the outer protective subaerial shoals and submarine ebb-tidal delta at Bogue Inlet.) Waves were shoaled over A and B for both existing and dredged conditions, with all results shown in Appendix G3. The conclusions are: (1) there will be a temporary increase in wave heights for the sections of the island along the borrow areas of less than 1 percent or 0.1ft; and (2) error bars in the wave directional component of the database are very large. (The error can easily be seen in very contradictory predictions of energy flux, depending on which versions of the WIS database are used.) Thus error in the longshore energy flux predictions (used in estimating potential for longshore sediment transport) is many times larger than the model's predicted 8-9 percent increase in longshore energy flux caused by dredging the borrow areas.

5.4.4 Dimensions of Littoral Zone (Depth of Closure) – Conclusions were presented in Section 3.4 regarding the depth to which there is active motion of sediment. Different methods produced results varying between 13 and 30 ft (methods 1, 2, 4, and 6). Methods 3 and 5 were used to gauge the most extreme condition possible, the time of only a few hours duration when a hurricane was in the immediate vicinity and produces depth-limited waves of 7 meters. Methods 3 and 5 indicated seabed activity between 32 and 36 ft. Only during these extreme hurricane conditions does sediment move in the closest inshore borrow area B, and even then only in the landwardmost portion of the borrow area. The conclusion is that sand in the borrow areas is not within the littoral system, but a relict of past events, such as lowered sea level and relict inlets.

5.4.5 Littoral Transport – Effects of the dredging operation and the beach nourishment on longshore transport of sediment should be considered, since alterations in the transport patterns result in changes to the beach. The usual method for evaluating transport-pattern effects of topographic changes is to include the changes in a model which

uses accurate measures of directional waves. Unfortunately, the usual data for computing the potential for longshore sediment transport, measured directional waves, do not exist for this area.

As detailed in the Appendix G3 on waves, the particular dataset that we used for examining the effects of **borrow-area dredging** resulted in a 8-9 percent increase in longshore energy flux. However, comparisons of the different databases and their effects on littoral transport in Appendix G4 show that both direction and magnitude of transport are solely a function of which database is used. Thus error in the databases far exceed the numerical values of any predictions to the change in longshore energy flux.

The best indicator of effects of the **nourishment** on longshore transport is the behavior of the Corps' nourishment project at Atlantic Beach. When only one stretch of beach is nourished, there are often effects on the neighboring unnourished beaches. Usually the neighboring beaches receive benefits of nourishment sand moving out of the nourishment-project areas, regardless of whether they are on the net updrift or downdrift sides. The reason that updrift beaches also receive sand is that longshore transport occurs in both directions, at different times, and the beach is only updrift in a net-transport sense. Problems can occur, however, if the current patterns are so drastically altered that an already eroding neighboring beach suffers. There is some evidence (Roessler, 1998) from detailed modeling of the current patterns at Atlantic Beach and Pine Knoll Shores that this has, in fact, happened. The obvious solution to such a problem is to not allow such drastic longshore variation in nourishment volumes, especially when a neighboring eroding beach receives no sand at all. The plan for the project proposed in this EIS is to nourish all of the eroding unnourished parts of Bogue Banks, so this problem does not occur. The beach to the east of our proposed project (Atlantic Beach) is already nourished, and the beach to the west (Emerald Isle near Bogue Inlet) is slowly accreting (about 3 ft/yr).

5.4.6 Erosion Rates – Uses of erosion rates in examining environmental impacts include:

- Erosion is one of the factors used in computing nourishment volumes, so the total impact to the borrow areas and nourishment areas depends on erosion rates.
- Erosion rates indicate how rapidly detrimental impacts of the "no action" alternative will affect the oceanfront properties, infrastructure, and tax base.
- After nourishment, erosion rates help to determine how long beneficial impacts will last, both for people and fauna (e.g., increased dry beach width for turtle nesting).

The erosion rates summarized in Appendix G5 were one of the factors used to compute nourishment volumes for this project. The three components of the total nourishment volume are:

- *"Volume deficit"* is the sand needed to increase the beach volume up to some desirable level. The selected level for Bogue is 175 cy/ft, which was the average volume in profiles of Atlantic Beach prior to 1999 hurricanes. The details of computing this volume goal are described in the last section of Appendix G5 entitled "Beach Erosion Analysis used to determine Nourishment Requirement." This component is the largest volume of the three components.
- *"Advance nourishment"* is the volume determined from the erosion rates that is necessary to advance the beach enough to counteract the anticipated future erosion. Various scenarios were computed, and for this project the 10-year protection was selected. This does not mean that in 10 years the nourishment sand will be gone. Rather in 10 years the "advance nourishment" component of the project will be gone. That is, 10 years after the project construction the beach will have eroded back to the still healthy Atlantic Beach-type volume of 175 cy/ft. Of course, if erosion is currently higher than the historical average, as some have argued, then the beach will erode back to the 175 cy/ft Atlantic Beach profile sooner than in 10 years.
- *"Overfill ratio"* is a ratio of how many cubic yards from a borrow area will be needed to produce one cubic yard of material that matches the native beach sand. These ratios have been computed for the different borrow areas, so the total amount of material placed on a section of beach will depend on which borrow areas are used. Final matching of permitted borrow areas with nourishment areas will not be made until construction bids have been received for the project.

Duration of **beneficial impacts** of the project (protecting oceanfront properties, providing a recreational beach, increasing habitat for beach fauna) depend on erosion rates. The erosion rates and selected nourishment volumes show beneficial impacts **well in excess of 10 years**, since the "volume deficit" component of the project is the largest component. As an example, the central reach of Emerald Isle has erosion rates that are roughly average for the island. Duration of the project using a safety factor of two (to account for 100 percent uncertainty in computed erosion rates) is (10 yrs/2)(766,958cy nourishment)/ (226,902cy advance nourishment) = 17 years.

5.5 PUBLIC LANDS — The project will not reduce the existing public rights and use of the beach resources. The "Public Trust Doctrine" and the State Property Sovereignty Rules preserve the rights of all citizens of North Carolina for use of resources located below the mean high water line. Additionally, the County will obtain permanent easements from oceanfront property owners within the project limits. The easements will grant access for construction and measurement and establish permanent rights for the public to cross lands above the mean high water line if those lands are created by filling operations financed with public funds.

5.5.1 Public Access to Beach Resources -- Public access to the beach strand has been developed extensively by the Towns of Emerald Isle, Indian Beach and by Carteret County for the unincorporated area of Salter Path. As part of implementation of this project, the Town of Pine Knoll Shores is developing public access that will meet the USACE guidelines for public access to federally maintained beaches. Before construction begins, the County will require that all municipalities within the project limits meet the Corps of Engineer's guidelines for public access.

5.6 RECREATIONAL AND SCENIC AREAS — Construction of a 100-ft-wide berm, dry beach area will enhance the beach by providing areas on the beach for activities during all tidal conditions. This is a tremendous benefit to Bogue Banks' communities which rely on the beaches and opportunities for beach activities to attract visitors.

The fall season is the peak period for surf fishing on Bogue Banks with activities tapering off during November and December. The beach restoration operations are scheduled to occur between the months of November and April. Surf fishing will not be limited along the beach except in the immediate vicinity of the discharge pipe and earthmoving equipment.

5.7 CULTURAL RESOURCES — To determine the impact of the proposed dredging and beach fill operation on potentially significant submerged cultural resources, a remote sensing survey of the proposed borrow areas was conducted by Tidewater Atlantic Research, Inc. (TAR) of Washington, North Carolina. The survey report prepared by TAR is provided in Appendix B. The survey was designed to locate and identify submerged cultural resources in the study areas, generate sufficient data to make an initial assessment of each target's significance, and provide insight into the necessity for avoidance or additional investigation. The survey was carried out between 7 and 13 December 1999. No magnetic or acoustic anomalies were identified in either borrow area A or borrow area B-1. In borrow area B-2, ten magnetic anomalies were identified near the western end of survey area. Seven of those targets contained signature characteristics indicative of submerged cultural resources. Because they could be associated with an historic shipwreck, either avoidance or additional investigation to positively identify the nature and significance of the material generating the seven anomalies was recommended. To avoid the areas of the seven anomalies identified by the survey, the western portion of borrow area B-2 will be eliminated as a potential source of sand for the project.

5.8 AIR QUALITY — Discharges of pollutants into the air will occur as a result of the operation of dredging equipment offshore and earth moving equipment on the beach. The discharges will be temporary and localized and will not result in any significant impact to ambient air quality standards along Bogue Banks or in Carteret County.

5.9 WATER RESOURCES – Temporary increases in turbidity are associated with both dredging operations and the washing of fine sediments by waves on the nourished beach. The applicable standard required for Section 401 Water Quality Certification quoted here from WQC#2949 issued for a Corps dredging and disposal operation for the nearshore berm off of Atlantic Beach is "that the activity be conducted in such a manner as to prevent significant increase in turbidity outside the area of construction or construction related discharge . . . 25 NTUs in all saltwater classes . . .".

Published measurements of turbidity during beach nourishments are rare. Reference (USACE, 1993, p. 6) is made to turbidity measurements for pipeline discharge of nourishment sediment on Atlantic Beach. Turbidity was a function of distance from the discharge pipe. Measurements ranged up to 250 NTUs in the vicinity of the pipe, but decreased rapidly with distance. That sediment pumped from Brandt Island had a much higher overfill ratio and mud percentage than the borrow areas proposed for this project, so turbidity must necessarily be lower for this project. A fairly comprehensive set of measurements was made for another project with mud percentages more similar to the one proposed here by Hanes (1994). Table 5 in that publication lists measured turbidities for times during and after nourishment and for both the project area and a control site uninfluenced by the nourishment. Turbidities were not measured in the immediate vicinity of the discharge pipe, but rather seaward of the breakers along the nourished stretch of beach. Values are listed for surface, mid-depth, and near bottom in the water column. The control site must have had slightly different conditions, because the after-nourishment numbers showed an average ratio of 0.6 of nourishment site to control site. (The nourished area had less turbidity than the control site well after construction.) But the numerical values were low for this post-construction period: 2.8 to 4.4 NTUs for the nourished area and 4.4 to 9.2 for the control site.

Natural turbidities are usually lower in Florida, where this study occurred, than they are in North Carolina. During construction the nourishment area showed turbidities averaging 50 percent higher than the control site, but again the numerical values were low, ranging between 4.6 and 7.5 NTUs in the nourishment area. These studies show that for turbidities associated with nourishment:

- Turbidities may be quite high in the immediate vicinity of discharge. However, the WQC standard pertains to "outside the area of construction or construction related discharge."

- Neither of the two studies showed turbidities exceeding 25 NTUs outside the discharge area.

- Outside the discharge area, but in the the ocean along the same stretch of beach, **turbidities increased about 50 percent, but the reported increases are less than 10 NTUs.**

- Natural variation in turbidities associated with storms is larger than these increases outside of the discharge area.

Increases in sedimentation associated with nourishment are of concern because of possible impacts on benthic fauna. In the Hanes (1994) study sedimentation rates of fine sediments were compared between the nourished and control sites. The ratio of sedimentation rates between nourished and control was 0.8 before nourishment, 1.3 during, and 1.1 after. Numerical values were in the 15-25 $mg/cm^2/day$ range for all sites. Statistical computations (the Binomial Sign test) which test for the probability that the observed differences were the result of random chance resulted in the conclusion (p. 3029) that **"there were no significant differences in fines sedimentation rates."** Significant differences were observed in sand sedimentation rates, but the wave heights were one-third higher at the nourishment sites with 75 percent higher energies. That increased energy between the sites "is probably the reason for the relatively higher sand sedimentation rates."

5.10 GROUNDWATER QUALITY — No action proposed as part of this project will have an impact on surficial or deep aquifer groundwater.

5.11 INTRODUCTION OF TOXIC SUBSTANCES — No action proposed as part of this project will cause an intentional discharge of hazardous materials into the environment. Insignificant discharges of hazardous substances could possibly occur as a result of operation of mechanical equipment on the dredging platform or by earth moving equipment operating on the beach. State and federal regulations place a high burden of responsibility on the owner and operator of such equipment to prevent hazardous discharges. Regulations for reporting and dealing with discharges are administered by the U.S. Coast Guard. As part of their normal operations, Coast Guard personnel will conduct safety inspections of vessels and equipment operating in the coastal waters. Those inspections include identification of possible discharges of hazardous substances.

5.12 NOISE LEVELS — Dredging equipment in the ocean and earthmoving equipment on the beach will result in increased noise levels in the vicinity of the equipment during beach building operations. Beach filling and shaping operations will progress down the beach at a rate of about 500 ft per day ensuring that no single location will experience increased noise levels for more than several days.

5.13 WATER SUPPLY AND WASTEWATER SYSTEMS — There are no activities associated with this project that will impact existing wastewater collection, treatment, or disposal systems. No activities of this project will impact potable water well sources or distribution systems on Bogue Banks or in Carteret County.

5.14 MARINE RESOURCES

5.14.1 Offshore Resources – Monitoring studies of post-construction borrow areas in the southeast indicate that borrow areas fill in and return to near predredging conditions when there is adequate transport of sediment under the influence of strong currents in the area (Bowen and Marsh, 1988). This project's offshore borrow areas are in depths between 30 and 40 ft MLW (borrow area B) and 40 and 50 ft (borrow area A). Divers at these sites have not observed currents of sufficient magnitude to move sediment. However, most coastal areas in these depths have some rare events (e.g., hurricanes) that generate sufficient flows to move sediment. Thus the conclusion is that sediment levels in borrow areas will return to predredging conditions only during such rare events.

Sediment: The sediment types and areal extents in the offshore region are shown on the map of Figure E1 (Appendix E). Sandy areas are limited in extent, with substantial regions of hard bottom, although none of the borrow areas contain hard bottom. This project's primary expected environmental impact on the substrate in the offshore region is uncovering of buried nutrients in the dredged furrows, resulting in an increase in biological activity.

Biology: There are several environmental issues relating to the benthic habitat and resources that arise in considering a beach renourishment project. The most significant include: (1) impacts to and recovery of the benthic invertebrate community at the borrow sites; (2) potential impacts to commercially or recreationally important demersal fishes and crustaceans in part because of these effects on their benthic invertebrate prey; (3) impacts to and recovery of the benthic invertebrate community on the intertidal and shallow subtidal beach; and (4) potential impacts to commercially and recreationally important fishes in the surf zone and/or shorebirds in large part because of these effects on their benthic invertebrate prey and because of enhanced turbidity along the shoreline. The biological monitoring program summarized here and outlined in Appendix B are intended to address each of these issues.

Vertebrates: Fish, plankton, and other motile animals in the vicinity of the borrow area during dredging are least likely to be affected during dredging, because of their ability to avoid the disturbed areas. Fish species have been observed to leave the area temporarily during dredging operations and return when dredging ceases (Pullen and Naqvi, 1983). A study of nearshore borrow areas after dredging offshore of South Carolina revealed no long-term impacts to fisheries, both fish and planktonic organisms, as a result of the dredging (Van Dolah et al., 1992). Creation of new habitat and the uncovering and suspension of food that attract fish during dredging have been attributed to dredging offshore borrow areas (Naqvi and Pullen, 1982). Dredging of the bottom sediments in the borrow areas can be expected to attract fish (after the dredge leaves) as a result of suspension of bottom material. Impacts to anadromous fish and other estuarine-dependent organisms are not expected to be significant, since construction-related activities in the offshore borrow areas would be localized.

Invertebrates: Benthic organisms in the immediate area being dredged will be largely eliminated during dredging. However, initial recolonization of the dredged areas by opportunistic species is expected to occur soon after cessation of any dredging activities. Further recovery is expected from recolonization from migration of benthic organisms from adjacent areas and by larval transport. Monitoring studies of post-dredging effects and recovery rates of borrow areas indicate that most borrow sites show significant recovery by benthic organisms approximately one year after dredging (Naqvi and Pullen, 1982; Bowen and Marsh, 1988; Van Dolah et al., 1992). To encourage recolonization by organisms from undisturbed substrates, the borrow areas will not be "swept clean." Furrows of undredged materials will remain.

Samples from impact (borrow) areas will be compared with those from control (undisturbed) areas both before and after the sand is removed. [Control areas would have no sand removed, but would otherwise be affected by all other impacts (i.e., storms, shrimping, etc., that affect the impact area).] These samples taken before the removal of the sand will be compared with identical samplings made after the nourishment to evaluate impacts. In addition, the design also calls for spring sampling both before and after the removal of sand to assess the seasonal component, for a total of four sampling periods to complete the assessment of impacts.

5.14.2 Nearshore Resources

Sediment: Nourishment sediment will be placed on the upper part of the beach, but flow down into the surf-zone region. The placed sediments are a close match in size to the sandy beach sediments, but with higher carbonate content, and a few percent mud (Appendix E).

Biology: There are three direct impacts from nourishment projects:

- Very short-lived substantial increases in turbidity during the placement operation (a few days at each location) alter the water column conditions sufficiently that it causes mobile species to leave the area. Return is rapid. Studies have found that speed of return of mobile species is more dependent on the return rate of their prey than on the rapid return of normal turbidity levels.

- Burial of bottom-dwelling organisms essentially destroys the community present, but Reilly and Bellis (1983) found that larval recruitment is rapid, and recovery occurs in one or two seasons.

- Alteration of sediment type necessarily results in changes in type and densities of species. Numerous monitoring studies recommend that the key to minimizing impact is to match the sediment types as closely as possible.

5.14.3 Intertidal Resources

Sediment: During project construction there will be an increase in the turbidity of the surf zone in the immediate area of sand deposition. Most of the fine material in the beach fill is expected to be washed seaward into the surf during construction. This increase in fine material may cause the temporary displacement of various species of sport fish, causing a negative impact to surf and pier fishing in the area of deposition. A study done by the National Marine Fisheries Service on the effects of beach nourishment on nearshore macroinfauna concluded that beach nourishment projects using offshore dredged material have no harmful effects, provided that the sediments are similar to those where they are placed (Saloman and Naughton, 1984).

Vertebrates: In view of the high mobility of fish, it is expected that fish will leave the areas under active construction. Impact on fishing resources in the intertidal zone will be minimized simply by the fact that sand-placement operations will take place at any one location for only a few days and then move further along the beach. Quantitative impacts on fish will be judged from offshore tow counts.

Invertebrates: Impacts on intertidal microfauna in the immediate vicinity of the nourishment project are expected as a result of discharges of nourishment sediment on the beach. A study by Reilly and Bellis (1983) was conducted on Bogue Banks and is used as a seminal study on beach projects throughout the Southeast U.S. "The Ecological Impact of Beach Nourishment with Dredged Materials on the Intertidal Zone at Bogue Banks, North Carolina"

concluded that beach nourishment virtually destroys existing intertidal macrofauna, but that recovery is rapid once the pumping operation ceases. In most cases, recovery occurs within one or two seasons following the sediment placement. "...a speedy recovery largely depended on recruitment from pelagic larval stocks." Most species fell into this category. The few that did not, and recruited instead from neighboring beaches, were slower to recover.

5.14.4 Beach and Terrestrial Resources

Sediment: After construction the beach sediment will be sampled and analyzed. The primary purpose will be to determine how much of the mud in the nourishment sediment still remains and did not decant off during the construction process.

Biology: Since the project is being constructed with offshore sediments, there will be little impact on the upper (dune) portion of the beach. Project construction will result in disturbance and removal of some of the existing vegetation along the seaward side of the existing dune. Dune stabilization with vegetative planting will take place only in the isolated sections of the project where new dunes are built. Most of the project has vegetated dunes. The project is intended to widen the base of the dunes and the beach face, not build up the dune itself. Thus replanting makes sense only for those areas where new dune will be built. The Reilly and Bellis (1983) study that focused on the intertidal zone also encompassed dry-beach sampling. Most species, including all of the larger organisms such as crabs, recruited from pelagic larvae and thus recovered rapidly (one or two seasons). A monitoring program is in place to determine effects of the nourishment on beach species. The pre-project sampling is scheduled for summer 2000. The standard deviations in previous infauna samplings suggest that there will be sufficient statistical power to detect about a 20 percent change in total infaunal density. Analyses of densities of individual families will be less powerful, but an ordination analysis on the entire community data set will have power similar to that of the test of total infaunal density.

5.15 THREATENED AND ENDANGERED SPECIES

5.15.1 Mammals

- **Right whale, finback whale, humpback whale, sei whale, and sperm whale** – Of the five species of whales being considered, only the right whale and the humpback whale would normally be expected to occur within the project area during the construction period. Therefore, the other species of whales are not likely to be affected. Since sections of this beach area have received fill material in the past, this project will not significantly alter nearshore physical conditions. While some food resources may be initially affected by either dredging activities or burial associated with the beach nourishment, most invertebrates will quickly reestablish from adjacent unaffected areas or through recruitment processes. Furthermore, the presence of a hopper dredge in this area should pose no more of a collision threat to migrating whales than normal commercial ship traffic. However, in order to reduce the potential for accidental collision, a whale observer with at-sea large whale identification experience will be present on the hopper dredge from the beginning of hopper dredge use through March 31 to conduct daytime observations. Since habitat conditions and food supplies will be maintained in their current states and the potential for accidental collisions with hopper dredges will be minimized, it has been determined that the proposed project is not likely to adversely affect these whale species.

- **West Indian manatee** – Since the proposed dredging work is currently scheduled to occur during the time of year when manatee populations are expected to be minimal, it is unlikely that there will be any manatees in the project area during the proposed project. Therefore, it has been determined that the dredging of the borrow areas and the subsequent beach nourishment are not likely to adversely affect the West Indian manatee.

5.15.2 Birds

- **Piping plover** – Within Bogue Banks, only the west end of Emerald Isle has been documented to support piping plovers. IN ADDITION, BOTH BOGUE AND BEAUFORT INLETS CONTAIN INTERTIDAL FLATS THAT PROVIDE FEEDING AND ROOSTING HABITAT TO A VARIETY OF COLONIAL WATERBIRD SHOREBIRD SPECIES (DAVID ALLEN, PERS. COMM.). ~~This~~ THESE areas ~~is~~ ARE not located within the project boundaries and will not be affected by beach nourishment or dredging activities. ~~However, one proposed borrow area is located within Bogue Inlet, which contains feeding and roosting habitat for a variety of colonial waterbirds and shorebirds. If this area is chosen for dredging, potential plover feeding habitat may be lost. However, there is sufficient intertidal flat habitat elsewhere in the area to compensate for this potential loss.~~ Therefore, the proposed project will not adversely affect the piping plover.

  HOWEVER, THERE IS CONCERN THAT MOVING SAND TO RENOURISH THE SHORELINE MAY BURY INTERTIDAL MACROFAUNA AND SUBSTANTIALLY REDUCE THE AVAILABLE FOOD RESOURCE TO SHOREBIRDS THAT FORAGE WITHIN THIS AREA. SHOREBIRDS FEED ON WORMS, FLY LARVAE, BEETLES, CRUSTACEANS, MOLLUSCS, AND OTHER INVERTEBRATES PLUCKED FROM THE SAND. THESE POTENTIAL IMPACTS WILL BE REDUCED FOR SEVERAL REASONS. DREDGING AND FILLING ACTIVITIES WILL OCCUR LARGELY DURING WINTER MONTHS, AVOIDING THE LARVAL RECRUITMENT PERIOD OF BOTH MOLE CRABS (EARLY OCTOBER) AND COQUINA CLAMS (SPRING AND SUMMER) (DONAGHUE, 1999). ADDITIONALLY, STUDIES HAVE SHOWN THAT INTERTIDAL MACROFAUNA CAN RECOLONIZE A NOURISHED AREA WITHIN ONE OR TWO SEA-

SONS (ROSS AND LANCASTER, 1996; NATIONAL RESEARCH COUNCIL, 1995; REILLY AND BELLIS, 1978); THEREFORE, IMPACTS WILL BE TEMPORARY. DIRECTLY AFTER IMPACTS TO MACROFAUNA HAVE OCCURRED AND NUMBERS OF THESE SPECIES ARE DEPRESSED, BIRDS THAT PREY UPON THESE INVERTEBRATES WOULD LIKELY MOVE TO ADJACENT UNDISTURBED BEACH AREAS AND OTHER SUITABLE FEEDING AREAS FOR THE TEMPORARY PERIOD OF POPULATION RE-ESTABLISHMENT. LASTLY, SAND OF SIMILAR GRAIN SIZE TO THE EXISTING BEACH WILL BE USED TO REDUCE ANY CHANGES IN PHYSICAL CHARACTERISTICS OF THE BEACH THAT MAY AFFECT NOURISHMENT IMPACTS ON INVERTEBRATES (DONAGHUE, 1999; PETERSON ET AL, 1999; HACKNEY ET AL, 1996). BECAUSE MACRO INVERTEBRATES RECOLONIZE RAPIDLY, NO LONG TERM IMPACTS TO THESE ORGANISMS OR THE SHOREBIRDS THAT PREY UPON THEM ARE ANTICIPATED WITH THIS PROJECT.

- **Roseate tern** – The roseate tern has never been observed within the project site. Bogue Banks is most likely too large and too developed an island to provide appropriate habitat for the roseate tern. Additionally, when the tern is observed in North Carolina, it is mostly during summer months, when this project is not scheduled to occur. Therefore, the project is not likely to affect the roseate tern.

5.15.3 Reptiles

- **Hawksbill, leatherback, Kemp's ridley, and green sea turtles** – The hawksbill, leatherback, and Kemp's ridley sea turtles do not regularly nest along North Carolina coasts. The green sea turtle nests sporadically in North Carolina but has not been observed nesting in the project area. Therefore, beach nourishment activities will not affect any of these sea turtle species. However, all of these species migrate within North Carolina waters throughout the year, mostly between April and December. Hopper dredges will be used to dredge material from borrow areas located within these migratory waters and transport it to the shore. Although the majority of construction activities is planned to occur between November and April to avoid nesting and migrating turtles, dredging activities may begin as early as October and may continue into the spring months in order to complete the project in one season. Therefore, dredging activities may occur during moderate levels of sea turtle migration.

  Hopper dredges move rapidly over the bottom sediments and can injure or kill juvenile turtles lying on the sea bottom. In order to reduce these impacts, certain precautions will be taken. The proposed project will follow NMFS and ACOE hopper dredging protocol (see Appendix). An observer will be present on the hopper dredge (except when water temperatures are cold enough to ensure that turtles will not be present; January and February) to document any takes of turtle species and to ensure that turtle deflector dragheads are used properly. If two sea turtle takes occur within 24 hours, work will cease upon a subsequent take, and will only resume if concurred in by the ACOE. If three takes occur, a risk assessment and appropriate risk management plan will be developed and submitted to the ACOE. Should a total take of five sea turtles occur, all work will be terminated. If a total of two endangered species of sea turtles are taken during a project, work will be suspended until further guidance from the ACOE has been given. Despite these precautions, the chance of impacting migrating sea turtles with a hopper dredge still exists. Therefore, it has been determined that the proposed project may adversely affect the hawksbill, leatherback, Kemp's ridley, and green sea turtles.

- **Loggerhead sea turtle** – The proposed project could potentially affect loggerhead sea turtles in two ways. First, dredging activities proposed to occur offshore may occur in areas used by migrating juveniles. The act of dredging material with a hopper dredge may adversely affect juvenile turtles. However, NMFS and ACOE hopper dredge protocol will be followed to reduce these impacts. Second, nourishing the beach with fill material may affect nesting activities by altering nesting habitat. If the beach becomes too hard through the compaction of deposited nourishment sediments by construction equipment, it could present a physical barrier to turtle nest digging. Furthermore, beach nourishment may influence physical characteristics of beaches (such as sand-grain size and shape, silt-clay content, sand compaction, moisture content, porosity/water retention, gas diffusion rates, and color of sand grains) which could alter the temperature of the beach. These factors could reduce reproductive success of nests laid in nourished areas (Crain et al., 1995; Ackerman, 1996).

  TO MINIMIZE IMPACTS TO NESTING SEA TURTLES IN THE PROJECT AREA, STANDARD PROTOCOL ADOPTED BY THE USFWS AND USED IN PREVIOUS BEACH NOURISHMENT PROJECTS IN NORTH CAROLINA WILL BE FOLLOWED. THIS PROTOCOL INCLUDES THE FOLLOWING GUIDELINES:

  1. ONLY BEACH QUALITY SAND SUITABLE FOR SEA TURTLE NESTING, SUCCESSFUL INCUBATION, AND HATCHLING EMERGENCE SHALL BE USED FOR BEACH NOURISHMENT ON THE PROJECT SITE. FURTHERMORE, SAND OF SIMILAR GRAIN SIZE TO THE EXISTING BEACH WILL BE USED TO REDUCE ANY CHANGES IN PHYSICAL CHARACTERISTICS OF THE BEACH THAT MAY AFFECT NEST SURVIVAL.

  2. IMMEDIATELY AFTER COMPLETION OF THE BEACH NOURISHMENT PROJECT AND PRIOR TO THE NEXT THREE NESTING SEASONS, BEACH COMPACTION SHALL BE MONITORED AND TILLING SHALL BE CONDUCTED AS REQUIRED TO REDUCE THE LIKELIHOOD OF IMPACTING SEA TURTLE NESTING AND HATCHING ACTIVITIES.

3. IMMEDIATELY AFTER COMPLETION OF THIS PROJECT AND PRIOR TO THE NEXT THREE NESTING SEASONS, MONITORING SHALL BE CONDUCTED TO DETERMINE IF ESCARPMENTS ARE PRESENT AND ESCARPMENTS SHALL BE LEVELED AS REQUIRED TO REDUCE THE LIKELIHOOD OF IMPACTING SEA TURTLE NESTING AND HATCHING ACTIVITIES.

4. CARTERET COUNTY WILL ENSURE THAT CONTRACTORS DOING THE BEACH NOURISHMENT AND DREDGING WORK FULLY UNDERSTAND SEA TURTLE PROTECTION MEASURES.

5. BEACH NOURISHMENT AND DREDGING ACTIVITIES ARE PLANNED TO BEGIN AFTER NOVEMBER 1 AND BE COMPLETED BEFORE MAY 1. IF ANY FILLING OCCURS AFTER MAY 1, THE PIPELINE WILL BE PLACED ALONG THE LANDWARD EDGE OF THE BERM.

6. IF ANY BEACH NOURISHMENT OR DREDGING ACTIVITIES TAKE PLACE DURING THE PERIOD FROM MAY 1 THROUGH NOVEMBER 15, A STANDARDIZED NEST MONITORING AND RELOCATION PLAN WILL BE IMPLEMENTED IN ADDITION TO THE MONITORING THAT ALREADY OCCURS. THE PLAN INCORPORATES MONITORING OF THE BEACH DISPOSAL AREA EACH MORNING FROM THE BEGINNING OF THE NESTING SEASON UNTIL ALL EQUIPMENT IS REMOVED FROM THE BEACH AND THE RELOCATION OF ANY NESTS LAID WITHIN THE PROJECT AREA. USING STANDARD NEST RELOCATION TECHNIQUES, ALL NESTS WILL BE LOCATED TO A SUITABLE NURSERY BEACH, AGREED TO PRIOR TO THE START OF RELOCATION EFFORT BY THE U.S. FISH AND WILDLIFE SERVICE AND THE NORTH CAROLINA WILDLIFE RESOURCES COMMISSION. HATCHING SUCCESS OF RELOCATED NESTS WILL BE MONITORED AND REPORTED.

7. IMMEDIATELY AFTER COMPLETION OF THIS PROJECT AND PRIOR TO MAY 1 FOR THREE SUBSEQUENT YEARS, SAND COMPACTION WILL BE MONITORED IN THE AREA OF RESTORATION IN ACCORDANCE WITH A PROTOCOL AGREED TO BY THE SERVICE, THE STATE REGULATORY AGENCY, AND CARTERET COUNTY. AT A MINIMUM, THE PROTOCOL PROVIDED UNDER 7A AND 7B BELOW WILL BE FOLLOWED. IF REQUIRED, THE AREA WILL BE TILLED TO A DEPTH OF 36 INCHES. ALL TILLING ACTIVITY MUST BE COMPLETED PRIOR TO MAY 1. A REPORT ON THE RESULTS OF COMPACTION MONITORING WILL BE SUBMITTED TO THE SERVICE PRIOR TO ANY TILLING ACTIONS BEING TAKEN. AN ANNUAL SUMMARY OF COMPACTION SURVEYS AND THE ACTIONS TAKEN WILL BE SUBMITTED TO THE SERVICE. THIS CONDITION WILL BE EVALUATED ANNUALLY AND MAY BE MODIFIED IF NECESSARY TO ADDRESS SAND COMPACTION PROBLEMS IDENTIFIED DURING THE PREVIOUS YEAR.

7A. COMPACTION SAMPLING STATIONS SHALL BE LOCATED AT 500-FOOT INTERVALS ALONG THE PROJECT AREA. ONE STATION WILL BE AT THE SEAWARD EDGE OF THE DUNE/BERM LINE (WHEN MATERIAL IS PLACE IN THIS AREA); ONE STATION WILL BE MIDWAY BETWEEN THE DUNE LINE AND THE HIGH WATER LINE; AND ONE STATION WILL BE LOCATED JUST LANDWARD OF THE HIGH WATER LINE. AT EACH STATION, THE CONE PENETROMETER SHALL BE PUSHED TO A DEPTH OF 6, 12, AND 18 INCHES THREE TIMES (THREE REPLICATES). MATERIAL MAY BE REMOVED FROM THE HOLE IF NECESSARY TO ENSURE ACCURATE READINGS OF SUCCESSIVE LEVELS OF SEDIMENT. REPLICATES WILL BE LOCATED AS CLOSE TO EACH OTHER AS POSSIBLE, WITHOUT INTERACTING WITH THE PREVIOUS HOLE AND/OR DISTURBED SEDIMENTS. THE THREE REPLICATE COMPACTION VALUES FOR EACH DEPTH WILL BE AVERAGED TO PRODUCE FINAL VALUES FOR EACH DEPTH AT EACH STATION. REPORTS WILL INCLUDE ALL 27 VALUES FOR EACH TRANSECT LINE, AND THE FINAL 9 AVERAGED COMPACTION VALUES.

7B. IF THE AVERAGE VALUE FOR ANY DEPTH EXCEEDS 500 PSI FOR ANY TWO OR MORE ADJACENT STATIONS, THEN THAT AREA WILL BE TILLED PRIOR TO MAY 1 OF THE FOLLOWING YEAR. IF VALUES EXCEEDING 500 PSI ARE DISTRIBUTED THROUGHOUT THE PROJECT AREA BUT IN NO CASE DO THOSE VALUES EXIST AT TWO ADJACENT STATIONS AT THE SAME DEPTH, THEN CONSULTATION WITH THE FISH AND WILDLIFE SERVICE WILL BE SOUGHT TO DETERMINE IF TILLING IS REQUIRED. IF A FEW VALUES EXCEEDING 500 PSI ARE PRESENT RANDOMLY WITHIN THE PROJECT AREA, TILLING WILL NOT OCCUR.

8. VISUAL SURVEYS FOR ESCARPMENTS ALONG THE PROJECT AREA SHALL BE MADE IMMEDIATELY AFTER COMPLETION OF THE BEACH NOURISHMENT PROJECT AND PRIOR TO MAY 1 FOR THREE SUBSEQUENT YEARS. RESULTS OF THE SURVEYS WILL BE SUBMITTED TO THE SERVICE PRIOR TO ANY ACTION BEING TAKEN. ESCARPMENTS THAT INTERFERE WITH SEA TURTLE NESTING OR THAT EXCEED 18 INCHES IN HEIGHT FOR A DISTANCE OF 100 FEET WILL BE LEVELED TO THE NATURAL BEACH CONTOUR BY MAY 1. THE SERVICE WILL BE CONTACTED IMMEDIATELY IF SUBSEQUENT REFORMATION OF ESCARPMENTS THAT INTERFERE WITH SEA TURTLE NESTING OR THAT EXCEED 18 INCHES IN HEIGHT FOR A DISTANCE OF 100 FEET OCCURS DURING THE NESTING AND HATCHING SEASON TO DETERMINE THE APPROPRIATE ACTION TO BE TAKEN. IF IT IS DETERMINED THAT ESCARPMENT LEVELING IS REQUIRED DURING THE NESTING OR HATCHING SEASON, THE SERVICE WILL PROVIDE A BRIEF WRITTEN AUTHORIZATION THAT DESCRIBES METHODS TO BE USED TO REDUCE THE LIKELIHOOD OF IMPACTING EXISTING NESTS. AN ANNUAL SUMMARY OF ESCARPMENT SURVEYS AND ACTIONS TAKEN WILL BE SUBMITTED TO THE SERVICE.

9. FROM MARCH 1 THROUGH APRIL 30 AND NOVEMBER 1 THROUGH NOVEMBER 15, STAGING AREAS FOR CONSTRUCTION EQUIPMENT WILL BE LOCATED OFF THE BEACH TO THE MAXIMUM EXTENT PRACTICABLE. NIGHTTIME STORAGE OF CONSTRUCTION EQUIPMENT NOT IN USE WILL BE OFF THE BEACH TO MINIMIZE DISTURBANCE TO SEA TURTLE NESTING AND HATCHING ACTIVITIES. IN ADDITION, ALL CONSTRUCTION PIPES THAT ARE PLACED ON THE BEACH WILL BE LOCATED AS FAR LANDWARD AS POSSIBLE WITHOUT COMPROMISING THE INTEGRITY OF THE DUNE SYSTEM.

TEMPORARY STORAGE OF PIPES ON THE BEACH WILL BE IN SUCH A MANNER SO AS TO IMPACT THE LEAST AMOUNT OF NESTING HABITAT AND SHALL LIKEWISE NOT COMPROMISE THE INTEGRITY OF THE DUNE SYSTEMS.

By planning to perform the majority of the project during off-season months, monitoring beach hardness, and relocating nests found in unsuitable habitat if project completion delays occur, impacts to nesting loggerhead sea turtles will be minimized. In addition, NMFS and ACOE hopper dredge protocol will be followed to minimize impacts to migrating loggerheads caused by dredges. However, because of the possibility of missing a sea turtle nest during the nest monitoring program, inadvertently breaking eggs during relocation, or injuring a migrating loggerhead with a hopper dredge, it has been determined that the project may affect the loggerhead sea turtle.

5.15.4 Fish

- **Shortnose sturgeon** – It is unlikely that the shortnose sturgeon occurs in the project area (Fritz Rohde, pers. comm.). However, should it occur, its habitat would be only minimally altered by the proposed project. This species feeds on a wide variety of invertebrates and while some food resources may be initially affected by either burial associated with beach nourishment or from dredging activities, most invertebrates will quickly reestablish from adjacent unaffected areas or through recruitment processes. Although hopper dredges can impact shortnose sturgeons, this species is not likely to be present in the project area and, therefore, impacts from dredges are not anticipated to occur. Because of the unlikelihood of shortnose sturgeon being present in the project area and because of the precautions being taken with the hopper dredges, it has been determined that the actions of the proposed project are not likely to affect the shortnose sturgeon.

5.15.5 Plants

- **Seabeach amaranth** – Since dredging of the borrow areas will be done offshore, no impacts to amaranth plants will occur from this action. Furthermore, because beach nourishment will occur in winter months (during seed dormancy) immediate impacts to the amaranth population along the project site will be reduced. However, deeply burying existing seeds could negatively affect the amaranth population in later seasons. Assuming that seeds are located in the general position of former parent plants observed in past surveys, they may be covered by beach nourishment activities. Yet it is not certain whether this deposition will have negative or positive consequences to the seeds since past research is inconclusive. The USACE (1995) found that amaranth at Masonboro Inlet was more abundant in areas that recently received dredged material. In addition, 1995 survey data from the NC Natural Heritage Program found a section of Bogue Banks that was used as a disposal zone in 1994 had an increase in population from 100 to 7300 plants. Dredging activities could uncover buried seeds and allow them to germinate in deposited areas. (This benefit is unlikely to occur during this project if dredged material is supplied from areas offshore that do not contain amaranth seeds.) In contrast, Hancock (1995) concluded that amaranth seedlings generally do not emerge from depths of sand greater than 1 cm. Therefore the added sand may be detrimental if placed on top of seeds already present at Bogue Banks. However, the beach nourishment that is to take place along the coast of Bogue Banks will occur on areas suffering from erosion and should ultimately expand potential habitat for the plant species. AN AMARANTH SURVEY AT BOGUE BANKS IN AUGUST OF 2000 LOCATED INDIVIDUALS IN AREAS THAT HAD RECEIVED NOURISHMENT AND EXTENSIVE BEACH SCRAPING IN THE PAST. YET because known amaranth habitat will be filled, it has been determined that the proposed project may affect seabeach amaranth.

  The USACE has instituted a long-term seabeach amaranth monitoring program at every beach in North Carolina which routinely receives dredged material from federally funded projects. The program is to be conducted until such a time that enough data are available to allow a reasonable prediction of the actual impacts of each planned disposal action on the species in the future. After this beach nourishment project is complete, the project area will be monitored by the applicant to see if and where seeds survived. Within a few monitoring seasons, these data will help predict ultimate impacts of beach nourishment on amaranth at Bogue Banks and will be made available to the Corps' monitoring program.

5.16 SEDIMENT CHARACTERISTICS

5.16.1 **Beach** – Bogue Banks presently contains admixtures of fine, medium, and coarse sands as well as sizable fractions of carbonate material (15-20 percent), and granule-sized material (~3-5 percent). Mean sediment size across undisturbed profiles, which represent less than 5 percent of the shoreline, vary systematically from fine sand in the foredune (elevations >7 ft NGVD) to medium-coarse sand on the berm and beach face (elevations ~+5 to -2 ft NGVD), then fining seaward across the longshore bar (fine sand) and lower shoreface (fine to very fine sand and silt). Shell material spans the widest size range from very fine crushed shell to whole shells in the gravel size range.

The preferred borrow area (A) contains similar admixtures of sediment with the primary difference being the percentage of carbonate material (~40 percent) and mud (~4 percent). Higher carbonate fractions account for the slightly coarser mean grain size in borrow area A compared to the native beach (0.36 mm versus 0.30 mm). Shell material is not considered as suitable for nourishment as quartz sand because it abrades more rapidly (CERC, 1984). At decadal time scales, this is not considered significant. However, over time, shell material introduced via

nourishment will abrade and shift mean grain sizes closer to that of the native beach. Crushed shell material is sometimes preferred by beach goers because it is softer than quartz (hardness of 3 versus 7).

The preferred construction method of hopper dredges will have the effect of eliminating much of the silt/ clay-sized material before transfer to the beach. Remaining fine-grained material will be discharged with the slurry across the beach face during construction and settle offshore beyond the outer bar.

The proposed borrow sediment is expected to yield a slightly more stable dry beach after winnowing of fines and an incrementally steeper equilibrium beach face slope because of its slightly coarser sediment texture compared to the native beach. Because of the presence of the outer bar along Bogue Banks, the nourishment will infill part of the inshore runnel and provide greater wave energy dissipation across the surf zone. It will displace the inshore runnel seaward, but not eliminate it. The process of dredging will eliminate most of the muddy sediments and yield a lighter color-"washed" sediment on the beach. With exposure to sunlight and reworking in the surf, nourished sediments will bleach and abrade to similar color as the native beach. The nourished beach will initially contain twice as much shell material as the existing beach.

5.16.2 Offshore – The preferred borrow area (A) consists of mixed sand and broken shell material with ~4 percent mud in the upper 2-2.5 ft. Medium-scale, symmetric ripples (having a relief of ~0.25-0.5 ft and a crest spacing of ~1-2 ft) occur over ~50 percent of the bottom in borrow area A. Below the confirmed layer, sediments are more variable with some areas containing semilithified limestone and other areas containing thick mud lenses or muddy shell zones. The proposed project will remove a portion of the upper layer (typically ~1.5 ft of section), leaving unconsolidated sediments similar to the dredged sediments exposed in each cut. Hopper dredges are expected to excavate parallel swaths (leaving some undisturbed "furrows" in between) within the borrow area. The undisturbed areas will serve as a "recruitment" area for replacement of organisms in adjacent dredged areas.

Turbidity at the bottom at present is highly variable with about 30 percent of the core sites having high concentrations of silt in the water column (zero visibility in June and November 1999 under relatively calm conditions). Best visibility at the bottom during coring was about 5 ft at ~10 percent of the stations. Typical visibility was about 1 ft in June and November 1999. During dredging, mud will be mobilized, pumped into the hopper, and partially decanted via scuppers back to the water column over the borrow site. Turbidity will be elevated during construction by an uncertain quantity. Prior studies as discussed in Section 5.9 have demonstrated high turbidities in the construction-related discharge, but increases in the area outside the discharge were typically less than 10 NTUs. The area of high turbidity is expected to be restricted to a radius of ~1000-1500 ft from the dredge. Suspended sediment concentrations are expected to return to background levels within a day or so except at the bottom. Newly exposed sediments are expected to produce higher turbidity levels at the bed for several weeks until the new substrate adjusts to ambient flows near the bed.

Inshore waters immediately seaward of the beach will sustain temporarily elevated turbidity levels near the point of discharge. Empirical evidence from other projects suggests temporary sediment plumes will extend in a radius of the order 1000-1500 ft from the point of discharge during construction. All but the finest clays will settle to the bottom beyond the surf zone within hours. Assuming that 2 percent of the nourishment volume delivered to the beach is unstable silt and clay, and that it is dispersed over the project area within 1000 ft seaward of the outer bar, it will incrementally add a layer ~0.025 ft (~0.3 inch) thick to the existing substrate. Presently, the inshore zone seaward of the bar (water depths between 15-30 ft) is very turbid near the bottom with zero visibility (based on scuba surveys in June and November 1999). Isolated patches of soft clay upward of 0.5 ft thick occur across the lower foreshore and inshore zones. These appear to mobilize and migrate over sandy substrate as evidenced by the distinct break in texture at the interface and persistence of small-scale bedforms in the underlying sandy sediment (diver observations in June and November 1999).

The closest outcropping of hard bottom is ~6500 ft from borrow areas A and B2. This distance is ~four times greater than from the expected maximum radius of sediment plumes around the dredge or around the discharge point. The nearest outcrop of hard bottom off the project area occurs about 1600 ft seaward of the bar near transect 11 (Emerald Isle, west reach) and transect 25 (Emerald Isle, central reach). There are no inlets or channelized discharges between the preferred borrow area and adjacent hard bottom areas that could direct a concentrated plume of fine-grained sediments into these habitats.

5.17 **ECONOMIC AND SOCIAL ENVIRONMENT** — The consequences of the beach nourishment project on the economic and social environment of Carteret County are reflected in the project planning objectives, preservation of the county's and towns' tax bases, the health of the tourism industry, and the protection of the oceanfront resource during severe storms. Carteret County's economy is indubitably linked to Bogue Banks. A beach nourishment project on the eroding areas of Bogue Banks would provide protection to the millions of dollars of tax base on Bogue Banks.

In addition, the health of the tourism industry in Carteret County would be impacted positively by the beach nourishment project. As stated previously, the beach is the number one reason tourists visit Carteret County. Tourism

generates over $208 million dollars annually for the Carteret County economy and is the leading North Carolina industry, generating over $2 billion in revenues for the state treasury. A nourishment project would maintain the health of Bogue Banks as an economic resource, and in so doing would maintain the health of the tourism industry in Carteret County.

Finally, the beach nourishment project would provide additional storm protection. By building a wider beach and a protective dune, the nourishment project would provide protection to residential and commercial properties, state and local roads, sidewalks, electric and water utilities, phone and cable facilities, and public beach accesses. The public and private sectors would be saved millions of dollars in repairs. The costs of Hurricane *Floyd* in Carteret County alone were $26,000,000 in residential damage, $2,225,000 in commercial damage and $1,800,000 in governmental damage for a total of $30,025,000. The vast majority of these damage figures were generated from damage sustained on Bogue Banks because of the lack of a wide beach and a protective dune. By comparison, Atlantic Beach, which is located on the eastern end of Bogue Banks, was nourished in 1986 and 1994. The oceanfront of Atlantic Beach faired much better in Hurricane *Floyd* than the sections of Bogue Banks which had not been nourished.

Oak Island, North Carolina, which sustained a direct hit from Hurricane *Floyd* sustained $25 million of damage to private property, $6 million to public infrastructure and beach accesses, lost 70 properties which cannot be replaced, and had clean up costs that have exceeded $2 million. As a result of the damage, Oak Island did not have a fall tourist season which cost them millions of dollars in lost revenue and over 200 oceanfront homes need to be repaired in order to habitable by summer 2000. In total, the economic loss caused by Hurricane *Floyd* will be close to $100 million. A beach nourishment project for Oak Island would cost approximately $5 million and would have saved Oak Island millions of dollars, even after factoring in clean up expenses, in economic losses. During Hurricane *Floyd*, the nourished beaches of Kure Beach, Wrightsville Beach and Carolina Beach, which also experienced direct hits by the storm, had significantly less storm damage when compared to non-nourished beaches of the state.

5.18 MITIGATIVE MEASURES — To minimize potential impacts to threatened and endangered species, several mitigative measures will be taken. The proposed project will follow NMFS and ACOE hopper dredging protocol (see Appendix) to reduce the impacts that hopper dredges may have on wildlife. Although hopper dredging has no seasonal restrictions (NMFS protocol), the majority of construction activities is planned to occur between November and April to avoid nesting and migrating sea turtles, fish, and whales. Furthermore, an observer will be present on the hopper dredge to document any takes of sea turtle species, except when water temperatures are cold enough to ensure that sea turtles will not be present (during January and February), to watch for and alert the dredge operator of whales in the area (from the beginning of hopper dredge use through March 31 for daytime observations), and to ensure that turtle deflector dragheads are used properly. If two sea turtle takes occur within 24 hours, work will cease upon a subsequent take, and will only resume if concurred in by the ACOE. If three takes occur, a risk assessment and appropriate risk management plan will be developed and submitted to the ACOE. Should a total take of five sea turtles occur, all work will be terminated. If a total of two endangered species of sea turtles are taken during a project, work will be suspended until further guidance from the ACOE has been given.

To minimize impacts of beach nourishment on nesting sea turtles and vegetative-stage seabeach amaranth, beach nourishment and dredging activities are planned to begin after November 1 and be completed before May 1, when nesting and germination activities are low. If any beach nourishment or dredging activities take place between March 1 and November 15, a standardized nest monitoring and relocation plan will be implemented. This program will include daily patrols of disposal areas at sunrise, relocation of any nests laid in areas to be impacted by fill placement, and monitoring of hatching success of the relocated nests. Sea turtle nests will be relocated to an area suitable to both the USFWS and the NC Wildlife Resources Commission's Sea Turtle Coordinator. In addition, sand of similar grain size to the existing beach will be used to reduce any changes in physical characteristics of the beach that may affect turtle nest survival. Furthermore, beach compaction shall be monitored and tilling shall be conducted in areas where the post-disposal beach is harder than 500 CPU's to reduce the likelihood of impacting sea turtle nesting and hatching activities.

To minimize impacts to seabeach amaranth populations, the project area will be monitored by the applicant to see if and where seeds survived, after this beach nourishment project is complete. Within a few monitoring seasons, these data will help predict ultimate impacts of beach nourishment on amaranth at Bogue Banks and will be made available to the Corps' seabeach amaranth monitoring program. The beach nourishment that is to take place along the coast of Bogue Banks will occur on areas suffering from erosion and should ultimately expand potential habitat for the amaranth.

6.0 LIST OF PREPARERS

Section

1.0 Bill Forman, P.E. (Stroud) / Tim Kana, Ph.D. (CSE)

2.0 Tim Kana, Ph.D. / Bill Forman, P.E. / Tom White, Ph.D., P.E. (CSE)

3.0 Bill Forman, P.E. / Tom White, Ph.D., P.E. / Tim Kana, Ph.D.

3.4 Tom White, Ph.D. / Tim Kana, Ph.D. / Phil McKee (CSE)

3.7 Gordon Watts, Ph.D., Robin Arnold, Raymond Tubby, Steve Brodie, Mark Padover and Mike Phillips (TAR)

3.14 Tom White, Ph.D. with input from Charles Petersen, Ph.D. (UNC-Institute of Marine Science), and John Wells, Ph.D. (UNC-Institute of Marine Science)

3.15 Kim Williams (Land Management)

3.16 Tim Kana, Ph.D., P.G., with Walter J. Sexton, Ph.D., P.G. (Athena Technologies, Inc.)

3.17 Bill Forman, P.E. with Adrienne Cole (Carteret EDC) and Frank Rush (Carteret County)

4.0 Bill Forman, P.E. / Tim Kana, Ph.D. / Tom White, Ph.D., P.E.

5.0 Tom White, Ph.D., P.E. / Bill Forman, P.E. / Tim Kana, Ph.D. / with input from Charles Petersen, Ph.D. and Hal Summerson (UNC), Kim Williams, Adrienne Cole, and Frank Rush

Appendix

B Tidewater Atlantic Research, Inc., c/o Dr. Gordon Watts and Robin Arnold

C University of North Carolina - Institute of Marine Sciences, c/o Charles H. Petersen, Ph.D., and John T. Wells, Ph.D.

D Land Management, c/o Kim Williams

E CSE Baird LLC – Timothy W. Kana, Ph.D., P.G.; Phil McKee; John J. Hair, III; and Diana Sangster, with input from Walter J. Sexton, Ph.D., P.G. (Athena Technologies, Inc.)

F Bill Forman, P.E.

G CSE Baird LLC – Thomas E. White, Ph.D., P.E., Phil McKee, Diana Sangster, and Tim Kana, Ph.D.

J. W. (BILL) FORMAN, JR., P.E.
PROJECT ENGINEER

EDUCATION

1976 B.S. Civil Engineering
North Carolina State University

1978 M.S. Civil Engineering and Marine Sciences
North Carolina State University

REGISTRATION

Professional Engineer Registered in North Carolina, Florida, and Virginia

PROFESSIONAL ORGANIZATIONS

American Society of Civil Engineers
Chi Epsilon Civil Engineering Honor Society

WORK EXPERIENCE

20 Years Civil and Coastal Engineering Experience

SPECIALTIES

- Site Planning and Design
- Coastal and Waterfront Structures
- Construction Administration
- Stormwater Management
- Dredging and Dredged Material Disposal
- Small Boat Harbor and Marina Planning, Engineering and Permitting
- Environmental Permitting
- Urban Waterfront Redevelopment Planning and Engineering

SPECIFIC PROJECT EXPERIENCE

Mr. Forman brings 20 years of project experience on a broad range of project and client types including military, municipal, state and private clients. Mr. Forman's marina and waterfront project experience includes marina projects with a cumulative total of over 5000 boat slips. He has successfully permitted waterfront structures, marinas, dredging and coastal engineering projects in Florida, Virginia, Maryland and North Carolina and South Carolina. Some representative projects successfully completed under Mr. Forman's direction include:

- Town of Atlantic Beach, Boating Channel Dredging
- Blackbeard Sailing Club, Fixed Breakwater Project
- City of Washington, Downtown Waterfront Redevelopment, Washington, North Carolina
- City of New Bern, Union Point Park Redevelopment, Bulkhead and Promenade
- William's Wharf Landing, Waterfront Redevelopment, Mathews, Virginia
- Moss Planing Mill Redevelopment Study, Washington, North Carolina
- OMC Marina at Gulf Harbors, New Port Richey, Florida
- Oriental Yacht Harbor Marina, Oriental, North Carolina
- Inner Harbor East Marina, Lady Baltimore Marina, Baltimore, Maryland
- Captains Point Marina, Ocean City, Maryland
- Lockwood Marina, City of Charleston, Charleston, South Carolina

ADRIENNE HINER COLE

EXPERIENCE

ASSISTANT DIRECTOR, CARTERET COUNTY ECONOMIC DEVELOPMENT COUNCIL, INC.
Morehead City, North Carolina. February 1, 1999 – Present. Responsibilities: Assisting the Executive Director on all matters within the jurisdiction of the EDC. Specifically, I assist the Executive Director in the following six categories: (i) business retention, expansion and recruitment, (ii) membership services and recruitment, (iii) infrastructure and regulatory issues, (iv) workforce development and coordination, (v) grant writing, (vi) public advocacy, public relations and (vii) special projects as needed.

COUNTY PLANNER AND ECONOMIC DEVELOPMENT DIRECTOR
Pamlico County, North Carolina. March 1997 – January 29, 1999. Responsibilities: As head of the Planning, Economic Development, Building Inspections and Emergency Management Department, I was responsible for the operation and administration of the department including formulating and managing the budget and supervising four employees. Other responsibilities included subdivision and land use administration, land use planning, strategic planning, economic development, infrastructure development, grant writing and special projects.

MARKETING AND PUBLIC RELATIONS VOLUNTEER
THE NATIONAL CAMPAIGN FOR THE ARTS – London, England. October 1996 – December 1996. Responsibilities: Marketing, promoting and advertising the National Campaign for the Arts and arts programs in the United Kingdom. I also served as a liaison between the organization and its sponsors.

INTERIM MEMBERSHIP DIRECTOR, BOONE AREA CHAMBER OF COMMERCE
Boone, North Carolina. January 1996 – April 1996. Responsibilities: Coordinating the Chamber of Commerce membership recruitment and retention activities. Specifically this included organizing volunteers to solicit businesses and establishing incentives for businesses to join the Chamber of Commerce.

INTERN, SOUTHERN APPALACHIAN FOREST COALITION
Asheville, North Carolina. June 1995 – August 1995. Responsibilities: As a graduate school intern, I was responsible for creating a media directory of scientists, politicians, lobbyists, government officials, environmentalists, and others involved in forest issues for the purpose of providing the press with relevant contacts when covering forest issues. In addition, I designed press releases for print and radio and participated in strategic planning and public outreach programs.

EDUCATION

MASTER OF PUBLIC ADMINISTRATION
Appalachian State University, Boone, North Carolina / Graduated with honors / December 1995

BACHELOR OF ARTS, POLITICAL SCIENCE AND HISTORY
Meredith College, Raleigh, North Carolina / Graduated with honors / May 1993

BOARDS AND PROFESSIONAL AFFILIATIONS

Certifications: Economic Development Course, UNC-Chapel Hill, 1999

Boards: Chair of Global TransPark Development Commission's Marketing Advisory Group; Neuse River Development Authority Board of Directors; North Carolina East Board of Directors, NC Ports Committee Board of Directors, Carteret County Chamber of Commerce Board of Directors, Secretary/Treasurer of Carteret County Transportation Committee

Affiliations: North Carolina Economic Developers Association, American Planning Association

Resume

TIMOTHY W. KANA, PhD, PG
Senior Scientist

Education

PhD, Geology (Coastal Processes), 1979, University of South Carolina (USC)
MS, Geology (Coastal Geology), 1976, USC
BA, Natural Sciences (Geological Oceanography), 1971, The Johns Hopkins University

Experience Highlights

Dr. Kana is an internationally recognized coastal scientist with over 20 years' experience in studies of geomorphology, coastal processes, impacts of sea-level rise, estuarine sedimentation, and beach nourishment design. He has supervised over 100 projects in the coastal zone and has been senior author of over 175 journal articles, proceedings papers, technical and consulting reports, and book chapters. Kana has conducted field reconnaissance surveys at more than 50 sites ranging from the Caribbean to Kuwait, France, West Africa, Alaska, and most of the U.S. East and Gulf Coasts.

Pioneering work by Dr. Kana includes:

- Methodology for establishing objective setback lines for coastal development based on the "profile volume" at a particular site. This methodology was incorporated into law in South Carolina (Beach Management Act of 1988/1990).

- Relocation of Captain Sams Inlet (SC), an innovative plan for beach nourishment which resulted in permanent restoration of a two-mile beach for only $300,000 (1983). [This inlet was successfully relocated again in 1996.]

- Post-*Hugo* beach and dune restoration plan developed less than one month after the storm (1989). Kana represented the State of South Carolina in negotiations with FEMA for this $10 million project which helped restore 65 miles of beaches to pre-*Hugo* conditions.

- Two of the earliest case studies of the potential impacts of sea-level rise on coastal wetlands for the U.S. Environmental Protection Agency, which quantified the controlling physical conditions and processes for tidal wetlands evolution.

Dr. Kana has completed coastal erosion and sedimentation studies at a number of tropical sites, including St. Lucia, Jamaica, St. Croix, Grand Cayman, Bimini, and Andros Island. This work involved sediment sampling, mapping of nearshore reefs, measurement of coastal processes, hurricane hindcasts, turbidity measurements, riverine and estuarine profiling, and delineation of mangrove swamps.

A 1990 project in Jamaica involved a design for reduction of turbidity and renourishment of a resort beach. This project required identification and confirmation of the source of episodic turbidity, location of suitable beach-quality sand deposits, and design of a nourishment plan that was sensitive to adjacent reefs.

Expert Testimony (1982-present)

Qualified and admitted in the following areas:

- Marine geology
- Coastal processes
- Estuarine processes
- Beach erosion

He served as a U.S. representative on a United Nations panel studying shoreline erosion in Togo and Benin, West Africa (1979) and testified as an expert witness on shoreline processes in connection with the *Exxon Valdez* oil spill in Prince William Sound, Alaska (1989-1993).

Professional Affiliations

Member — American Geophysical Union
Affiliate Member — American Society of Civil Engineers
Registered Professional Geologist (South Carolina and North Carolina)
PADI Certified Scuba Instructor (#2071)

Resume

THOMAS E. WHITE, PhD, PE
Coastal Engineer

Education

Ph.D., Oceanography, 1987, Scripps Institute of Oceanography (SIO), University of California, San Diego (UCSD)
M.S., Oceanography, 1980 (SIO/UCSD)
B.S.C.E., Civil Engineering, 1978, University of Miami (UM)
B.S., Physics, 1978 (UM)
B.A., German, 1978 (UM)

Registration

Professional Engineer (P.E.), 1994, Florida
P.E., 1997, South Carolina
P.E., 1999, North Carolina
NAUI Advanced Scuba Diver, 1979

Professional Memberships

American Society of Civil Engineers
National Society of Professional Engineers
American Geophysical Union
American Institute of Physics

Teaching

- Designed and taught the Corps of Engineers' graduate course in Coastal Engineering Field Methods.
- Visiting professor at Texas A&M in coastal sediment processes and in field methods.
- Laboratories in soil mechanics and physics.

Experience Highlights

Dr. White is an internationally recognized coastal specialist with more than 20 years of experience in coastal processes. Areas of specialization include sediment transport, methods of monitoring coastal projects, statistical methods for quantifying project behavior,, and all types of instrumentation. Book chapters, proceedings, reports, and invited journal papers document technical expertise in these areas. Dr. White has been principal investigator in major field investigations on all continental U.S. coastlines (Atlantic, Pacific, Gulf, and Great Lakes) and has been the investigator in charge of data collection on international projects at Kuala Baram (Malaysia) and Rio Grande (Argentina).

Pioneering work includes the following.

- *Instrumentation systems:*
  - Sand-tracer dyeing, sampling, and analysis techniques for Sea Grant's Nearshore Sediment Transport Study (California).
  - Laboratory calibration methods, theoretical development, and field deployment of optical backscatter sensors and various acoustic sensors for sediment monitoring (Lake Michigan, Texas, and North Carolina).
  - Electronic data acquisition systems and mechanical sensor deployment/retrieval systems for sensors in both low and high wave environments.
- *Analysis systems:*
  - Methods for translating optical and acoustical measurements into sediment concentrations and fluxes.
  - Objective statistical methods for judging performance of coastal projects, predictive abilities of theories and numerical models, and data quality.
  - Procedures, methods, and techniques for design of monitoring plans for coastal projects of jetty design (Texas and California), beach nourishment (South Carolina), and sand management (California, Michigan, North Carolina, and South Carolina).
- *Predictive methods for coastal behavior:*
  - Internationally acclaimed field test of all available methods for predicting sand transport onto the beach from the seabed.
  - Field tests of methods for predicting total sediment transport along the shore.
  - Development and testing of different methods of predicting transport of finer suspended sediments.

Previous river-related work:

- On the upper Mississippi River, estimates were made of concentrations of sediment due to barge resuspension of various river sediments.
- Developed new instrumentation to determine the flow field and sediment transport in and near the Colorado River (Texas). Current meters, wave gauges, and optical sediment-sensor systems were combined into unique systems and deployed in storm conditions. Recommendations were made for correcting the channel shoaling and alleviating the navigation hazard.
- Analysis of hurricanes, storm waves, wind waves, and tides for elevations of the Stono River (Charleston, SC) bridge replacement. Deployment and data analysis of current meters, wave sensors, and tide gauges for use in scour-protection design.
- Deployment of current meters, wave gauges, and tide gauges to determine flow conditions for design and construction of a port railroad bridge trestle in Tierra del Fuego, Argentina.
- Principal investigator of Cooper River bridge replacement hydraulic analysis. Work on this largest bridge ever built in South Carolina includes deployment and analysis of 12 tide and current gauges plus hydraulic modeling.

CSE

BEACH NOURISHMENT

Coastal Science & Engineering (CSE) has developed plans and supervised construction of the majority of beach nourishment projects in South Carolina during the past 15 years. Among our most innovative projects was the restoration of two miles of beach along Seabrook Island (SC) by inlet relocation, a project that required excavation of a new inlet and closure of an unstable migrating inlet. Upon closure, the shoals of the abandoned tidal delta welded to the shoreline by natural processes, creating a beach over 1,000 feet wide. The project eventually added over 1.5 million cubic yards to Seabrook's beach at a total cost of about $300,000. We have also engineered more traditional nourishment projects involving excavation and placement by hydraulic dredges. Constructed projects through 1999 involved nearly 10 million cubic yards at a cost of ~$28 million.

Project Location	Year Constructed	Cost ($)	Volume Cubic Yards	**
• Myrtle Beach, SC	1985-1987	$4,500,000	850,000 by truck	P/D/CM
• Seabrook Island, SC	1983	$300,000	1,500,000 by inlet relocation	P/D/CM
• Seabrook Island, SC	1983	$250,000	250,000 by scrapers	P/D/CM
• Pawleys Island, SC	1988	$100,000	55,000 by scrapers	P/D
• Isle of Palms, SC	1982-1984	$100,000	150,000 by scrapers	P/D
• Myrtle Beach, SC	1982-1983	$150,000	150,000 by scrapers	P/D
• Kuwait Waterfront Project	1984-1986	$7,000,000 est.	600,000 by truck	P
• Isle of Palms, SC	1984	$1,000,000 est.	350,000 by dredge	P
• Myrtle Beach, SC*	1989-1990	$2,500,000	395,000 by truck	P/D/CM
• North Myrtle Beach, SC*	1989-1990	$1,900,000	377,000 by truck	P/D/CM
• Surfside Beach, SC*	1990	$500,000	70,000 by truck	P
• Garden City, SC*	1990	$1,700,000	165,000 by truck	P
• Pawleys Island, SC*	1990	$600,000	220,000 by scrapers	P
• Debidue Island, SC	1990	$950,000	180,000 by scrapers	P/D/CM
• Seabrook Island, SC	1990	$1,550,000	685,000 by dredge	P/D/CM
• Rose Hall, Jamaiça	1990	$200,000	10,500 by truck	P/D/CM
• Hunting Island, SC	1991	$2,920,000	755,500 by dredge	P/D/CM
• Edisto Beach, SC	1995	$1,600,000	150,000 by dredge	P/D/CM
• Seabrook Island, SC	1996	$600,000	1,250,000 by inlet relocation	P/D/CM
• Debidue Island, SC	1997-1998	$950,000	267,000 by truck	P/D/CM
• Seabrook Island, SC	1998	$85,000	75,000 by scrapers	P/D/CM
• Pawleys Island, SC	1999	$800,000	270,000 by truck	P/D/CM

[*Post-Hurricane *Hugo*; **P = preliminary design/planning, D = final design, CM = construction manager]

CORRESPONDENCE

INDEX

A. Comments Concerning Applicants Responses to Agency Review Comments

1) Memorandum, October 24, 2000, William Wescott, Coastal Coordinator, N.C. Wildlife Resources Commission, Habitat Conservation Program to J. W. Forman, Stroud Engineering
2) Letter, October 6, 2000, Milt Rhodes, SEPA Coordinator, Division of Water Quality to J. W. Forman, Stroud Engineering
3) Memorandum, October 2, 2000, Michael D. Marshall, James Patrick Monaghan, Division of Marine Fisheries to Melba McGee, Environmental Review Coordinator, Department of Environmental and Natural Resources (NCDENR)
4) Memorandum, October 30, 2000, Stephan Hall Division of Parks and Recreation to Melba McGee, Environmental Review Coordinator, NCDENR

B. Responses to Agency Comments by Consultants for the Applicant

1) Letter, September 13, 2000, J. W. Forman, Jr., P.E., Stroud Engineering to James Patrick Monaghan, Division of Marine Fisheries
2) Letter, September 13, 2000, J. W. Forman, Jr., P.E., Stroud Engineering to Franklin T, McBride, North Carolina Wildlife Resources Commission, Division of Inland Fisheries
3) Letter, September 13, 2000, J. W. Forman, Jr., P.E., Stroud Engineering to Milt Rhodes, Division of Water Quality
4) Letter, September 13, 2000, J. W. Forman, Jr., P.E., Stroud Engineering to Stephan Hall, Division of Parks and Recreation
5) Letter, September 13, 2000, J. W. Forman, Jr., P.E., Stroud Engineering to Shannon Stewart, Division of Water Quality, Non-Discharge Branch

C. Comments From Department of Environment and Natural Resources Departmental Review

1) Letter, May 11, 2000, Doug Huggett, Division of Coastal Management to J. W. Forman, Stroud Engineering
2) Memorandum, May 5, 2000, Melba McGee, Environmental Review Coordinator, NCDENR, to Doug Huggett, Division of Coastal Management
3) Memorandum, April 27, 2000, Franklin T. McBride, Wildlife Resources Commission, Division of Inland Fisheries, Habitat Conservation Program, to Melba McGee, Environmental Review Coordinator, NCDENR
4) Memorandum, April 18, 2000, David Taylor and James Patrick Monaghan, Jr., Division of Marine Fisheries to Melba McGee
5) Memorandum, April 17, 2000, Milt Rhodes, Division of Water Quality, to Melba McGee, Environmental Review Coordinator, NCDENR
6) Memorandum, April 13, 2000, Stephen Hall, Division of Parks and Recreation, Natural Heritage Program, to Melba McGee, Environmental Review Coordinator, NCDENR
7) Memorandum, April 10, 2000, Shannon Stewart, John Dorney, Division of Water Quality to Milt Rhodes, Division of Water Quality
8) Memorandum, April 11, 2000, Steve Benton, Division of Coastal Management, to Melba McGee, Environmental Review Coordinator, NCDENR

D. Comments from North Carolina State Clearinghouse

1) Intergovernmental Review Form, February 2, 2001, North Carolina State Clearinghouse, Department of Administration
2) Letter, March 13, 2001, Michelle Duval and Daniel Whittle, Environmental Defense, to Doug Huggett, NCDENR
3) Letter, March 15, 2001, Chrys Baggett, North Carolina Department of Administration, to Doug Huggett, NCDENR
4) Letter, March 15, 2001, Charles Peterson, The University of North Carolina at Chapel Hill, Institute of Marine Science, to Doug Huggett, NCDENR
5) Letter, March 20, 2001,Doug Huggett, NCDENR, tp Coastal Science & Engineering and Stroud Engineering

E. Responses to Comments by Consultants for the Applicant
1) Letter, April 3, 2001, T.W. Kana, PhD, Coastal Science & Engineering, LLC, to Doug Huggett, NCDENR, Division of Coastal Management
2) Letter, April 4, 2001, T.W. Kana, PhD, Coastal Science & Engineering, LLC, to Doug Huggett, NCDENR, Division of Coastal Management

STROUD ENGINEERING, P.A.

HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

October 31, 2000

Ms. Melba McGee
Environmental Review Coordinator
North Carolina Department of Environment and Natural Resources
1601 Mail Service Center
Raleigh, North Carolina, 27699-1601

Re: #1046 Bogue Banks Restoration Plan, Draft EIS, Carteret County

Dear Ms. McGee:

Please find attached letters from the commenting agencies from the initial review of the referenced draft EIS by the Department of Environment and Natural Resources. In all cases the letters indicate that revisions to the DIES and responses provided to each reviewer sufficiently address each reviewers concerns.

Copies of the letters from each reviewer are attached for your information. Also attached are copies of the initial review comments as provided by your office to Doug Huggett and subsequently to this office, and copies of the response letters to each reviewer from this office. All of this correspondence will be attached to the EIS with the index of correspondence.

It is important that review of the EIS proceed on a timely basis. Even though the referendum was voted down by County residents, the Towns of Pine Knoll Shores and Indian Beach are proceeding with preparations to construct a beach nourishment project during the dredging window of years 2001 and 2002. That project will be based on the findings and criteria set out in the referenced EIS.

Doug Huggett has agreed to contact me on the next steps we must take to complete review of the EIS.

If you have any questions concerning the enclosed documents or need additional information, please give me a call.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Attachments

CC: Robert Murphy, County Manager, Carteret County
Doug Huggett, DCM,Raleigh
Ted Tyndall, DCM, Morehead City

North Carolina Wildlife Resources Commission

Charles R. Fullwood, Executive Director

MEMORANDUM

TO: J.W. Forman
Stroud Engineering

FROM: William Wescott, Coastal Coordinator
Habitat Conservation Program

William Wescott

DATE: October 24, 2000

SUBJECT: Bogue Banks Beach Restoration Plan: Comments regarding consultant responses and the final report of benthic invertebrate and demersal fish resources.

We requested a copy of a USACE study investigating the impacts beach nourishment had on benthic invertebrates. Our Coastal Coordinator in Washington received a copy of the study on October 23, 2000. After reviewing the study and consulting with coastal geologists we are able to respond to your September 13, 2000 letter.

Apparently benthic studies have been diligently undertaken to collect and identify the nearshore and offshore benthic communities that would be impacted by the proposed beach nourishment project. The inclusion of this information in the final EIS will address our concerns regarding non-specific and incomplete data.

We remain concerned for foraging shorebirds during all times of the year (breeding season, migration, wintering). If beach nourishment occurs then nourishment activities should be scheduled to avoid peak biological activity of invertebrates. We still advocate that a better long-term solution for protecting beachfront development is to establish wider setbacks on all structures as they are rebuilt after being lost to the sea.

Thank you for the opportunity to comment on this project. We look forward to reviewing a complete EIS document. If you need to discuss these comments please call William Wescott at (252) 946-6481.

Cc: Melba McGee, Office of Legislative & Intergovernmental Affairs
Doug Huggett, Division of Coastal Management

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 733-3633 ext. 281 • Fax: (919) 715-7643

NCDENR

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

KERR T. STEVENS
DIRECTOR

NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

DIVISION OF WATER QUALITY

October 6, 2000

J.W. Forman
Project Engineer
Stroud Engineering, P.A.
Hestron Plaza Two
151-A Highway 24
Morehead City, NC 28557

Dear Mr. Forman:

The Division of Water Quality (Division) has reviewed the responses to initial comments raised during agency review of the Bogue Banks Beach Restoration Plan Draft Environmental Impact Statement. The responses included in this letter submitted by Stroud Engineering and the modifications to the DEIS adequately address the Division's concerns regarding the project's impact to the surrounding environment. Please be advised that the project should meet the turbidity standard set forth in the 401 Water Quality Certification to be issued by the Division.

Sincerely,

Milt Rhodes
Interim DWQ SEPA Coordinator
SEPA Coordination Team

cc. Melba McGee, DENR NCEPA Coordinator

1617 MAIL SERVICE CENTER, RALEIGH, NORTH CAROLINA 27699-1617
website: h2o.enr.state.nc.us PHONE 919-733-5083 FAX 919-733-9919

State of North Carolina
Department of Environment
and Natural Resources
Division of Marine Fisheries

James B. Hunt, Jr., Governor
Bill Holman, Secretary
Preston P. Pate, Jr., Director

NCDENR
NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

MEMORANDUM

TO: Melba McGee

THROUGH: Michael D. Marshall MDM

FROM: James Patrick Monaghan, Jr. JPMJ.

DATE: October 2, 2000

SUBJECT: 1046 -- Bogue Banks Beach Renourishment

This memo is in response to a letter from J.W. Forman, Jr., P.E., Stroud Engineering, dated September 13, 2000.

We have reviewed the applicant's response to our comments on the EIS. Based upon further review of the EIS and recent literature that has come to our attention we recommend the following:

1. **Continue monitoring the offshore borrow areas and nearshore intertidal deposit areas during the summer of 2001. Also, monitor these areas immediately following renourishment and for a period of time sufficient to determine recovery rates of the fauna.**

2. **A dredging window of November 15 through April 15.**

We appreciate the opportunity to comment on this project.

Cc: W.E. Forman
Ted Tyndall

NCDENR

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

DR. PHILIP K. MCKNELLY
DIRECTOR

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

DIVISION OF PARKS AND RECREATION

October 30, 2000

MEMORANDUM

TO: Melba McGee

FROM: Stephen Hall

SUBJECT: Response to Comments – DEIS – Beach Restoration Plan, Bogue Banks

REFERENCE: 1046

In our review of the DEIS, we had concerns about the potential for impacts to piping plovers (*Charadrius melodus*) and loggerhead sea turtles (*Caretta caretta*), both federally and state listed as Threatened. We also had concerns about the use of dredge spoil material from Brandt Island, the site of a colony of an undescribed and apparently very rare butterfly. The applicant (letter from J.W. Forman to S.P. Hall, 9/13/00) has addressed each of these concerns to our satisfaction.

1615 MAIL SERVICE CENTER, RALEIGH, NORTH CAROLINA 27699-1615
PHONE 919-733-4181 FAX 919-715-3085

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Mr. James Patrick Monaghan
North Carolina Department of Environment and Natural Resources
Division of Marina Fisheries
Post Office Box 769
Morehead City, North Carolina 28557

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Mr. Monaghan:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the Division of Marine Fisheries are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff. Also enclosed are revised sections to the Draft EIS. On the revised pages, the replaced text is crossed out, and the revised text is in italics.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (An unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comment: In our review of the scoping document for this project (memorandum dated January 26, 2000) we requested that research be conducted to determine recovery times for benthic populations that are destroyed by pumping and depositing materials. This research has not been fully addressed in the EIS. We realize that sampling needs to continue through early fall for an accurate description of species diversity and species abundance to be completed. We cannot speculate as to what the potential impacts might be from the present EIS. ***We recommend that one complete year of field work be conducted in the offshore borrow areas and the nearshore intertidal deposit areas. Adequate time for data analyses, report preparation, and report review should be allowed and a complete review of these results should be made in the EIS.*** *If possible, data on the benthos should be collected from nearshore and intertidal areas of Fort Macon, Atlantic Beach, and Emerald Isle where pumping has occurred. We* *can provide the research design if requested. We also recommend that the particle size of the existing beach be the size pumped onto the beach since the literature indicates this will lessen recovery times.*

Response: The University of North Carolina, Institute of Marina Sciences, Charles H. (Pete) Peterson have completed the initial phase of the sampling meeting the criteria you have outlined. The results of those studies are provided in the attached report which will replace the preliminary report provided in the draft EIS. Physical and biological impacts and recovery will be monitored systematically following a sampling plan recommended by Dr. Peterson or recognized experts. Your input into that monitoring effort is requested. UNC-IMS has in their possession existing baseline data throughout Bogue Banks. We anticipate using these data when they become available in the published literature to compare construction and post-construction sampling. We requested these data for inclusion in the EIS but were informed that analyses are not available until published. Time is of the essence on this project. The severely eroded condition of the beach means any delay in implementation of a project could lead to higher property damages and losses. Given the existing body of research on impacts to benthic organisms and the natural variability of these systems, we believe that additional pre-nourishment sampling and research will not provide definitive results or allow prediction of impacts more accurate than can be deduced from the experiences in the literature. We believe that the proposed plan will result in reasonably rapid recovery because it will follow the practices discussed below.

There have been numerous studies of recovery of benthic fauna on nourished beaches. Many factors effect the recovery including grain size compatibility of nourishment sand with existing beach sand, seasonal relationship of nourishment to growth period of benthic fauna, depth of sand placed on the beach, levels of turbidity associated with various nourishment sand sources and ability of certain fauna to migrate vertically through the nourished sand. Monitoring of Phase one of the Myrtle Beach Renourishment Project (Jutte, Van Dolah and Levision, March 1999) found that benthic infauna largely recovered after two to three months. The study found that, in some cases, nourishment actually resulted in enhancement of biological assemblages.

The impact of nourishment on beach macro invertebrates has been shown to be highly variable. Virtually all published studies report some initial impact (either confirmed by direct sampling after nourishment, or by inference), However, recovery rates (compared to pre-nourishment densities) have been found the range from days to weeks (e.g. Jutte, et. al. 1999; Gorzelany and Nelson, 1987) to several years (eg. Cutler and Mahadeva, 1982). Studies by Donaghue (1999) at Pea Island (NC) and Peterson et. al.(2000) at Atlantic Beach (NC) quoted by the correspondent generally found longer recovery times the the majority of other researchers, including Van Dolah et/ al (1992) and Baca and Lankford (1987). A fundamental reason for the disparity in results among the various investigators is the extreme natural variability of population densities depending on seasons, variations in sediment compatibility between the natural beach and the nourishment sand, and the frequency of storms. It is generally accepted that the biological populations will recover more slowly if:

Nourished sands do not closely match the native sand grain size distribution,
Nourishment is performed during periods of peak larval recruitment,
The scale of the projects is large relative to the cross-shore dimension, and
Projects are repeated frequently, causing disruption of successive growing cycles.

No study has proven total loss of benthic populations due to nourishment or scraping. The concern is over the rate and scale of recovery compared to natural beaches. The proposed project design seeks to reduce impacts and accelerate recovery in the following ways:

Selection of borrow area the most closely matches the desirable characteristics for the indigenous benthic fauna. Borrow area A has the best overfill ratios but is slightly coarser and has twice the shell content as the native beach. Borrow areas B1 and B2 have lower percentages of shell and slightly finer mean grain size (yielding moderately higher overfill ratios).Some investigators (eg. Peterson, 2000, personal communications) have suggested that borrow areas may be preferable for recruitment and recovery of beach organisms. Others (eg., Stewart, NCDENR-DWQ, comments) suggest borrow area A will yield sediments that produce fewer overall impacts on the nearshore environment. Regardless of which borrow area is selected, the differences compared to the natural beach, are considered relatively small because of the wide range of sediment sizes that occur between the foredune and inshore zone along Bogue Banks.

Nourishment will be performed during periods of low biological recruitment periods (eg., late fall, winter and early spring months).

The scale of the project in the cross-shore dimension is moderate (approximately 50 cy/ft), comparable to nourishment projects that have demonstrated rapid biological recovery such as Myrtle Beach (Baca, et.al, 1987; Jutte et. al, 1999)

- The project will be large enough given the low background erosion rate of the site to avoid frequent repeat nourishment every couple of years so that successive growth cycles are not interrupted as is the case now with frequent beach scraping (bull dozing).

The only means available to verify the impact of the nourishment on the Bogue Banks beach and borrow area fauna is to monitor the impacts through a program that includes characterization of both the physical and biological conditions before, immediately following and for a period sufficient to determine full recovery of the biological resources in the borrow area and on the beaches and to determine the physical performance of the nourishment project.

The Bogue Banks nourishment project will include a program of monitoring of impacts. Specific objectives of the monitoring will be as follows:

1. Document and quantify physical changes in the beach and nearshore zone,
2. Determine the ecological impacts and recovery rates of beach and nearshore biological resources following nourishment, and
3. Document the physical and biological impact and recovery of sand bottom habitats in the borrow area.

Comment: Another primary concern on this project is the time window for dredging. We strongly recommend that the time be shortened from October1 through May 15 to December 1 through March 31. This should reduce effects on recruitment of finfish and minimize effects on traditional beach fisheries.

It appears that, due to funding constraints, the project will have to be constructed in segments as funding becomes available in each of the individual municipalities on Bogue Banks. Construction windows may, therefore, be shortened. However, because of economic considerations and weather contingencies, the applicant wishes to have available the longest possible window for construction. By current state and federal policies, that window runs from November 1 (end of turtle nesting season) to May 15 (beginning of turtle nesting season) in North Carolina.

We believe that the responses provided herein should provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the enclosed information and a response as to the adequacy of the EIS with the revisions indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Franklin T. McBride, Manager
North Carolina Wildlife Resources Commission
Division of Inland Fisheries
1721 Mail Services Center
Raleigh, North Carolina 27699-1721

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Mr. McBride:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the staff biologists with the Wildlife resources Commission are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (An unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comment: The DEIS indicates that erosion is responsible for loss of beach, dune and maritime forest habitats and a wide range of wildlife resources. If this document seeks to identify ceuses of lost wildlife resources and habitat then losses attributed to human disturbance, landscape alteretions and development should also be included as contributing factors especially since this document indicates that Bogue Banks oceanfront has reached 90 percent build-out.

Response: It is not within the scope of the draft EIS to identify causes of lost wildlife resources except for such impacts that might occúr as a result of placement of sand on the beach from the designated borrow areas. Significant habitat losses can be attributed solely to erosion of the beach and the subsequent bulldozing of the beach undertaken to protect property from the ocean. With a stable berm fronting the dune as exist along the nourished beach areas of the Town of Atlantic Beach, the need for annual bulldozing of the beachfront would be eliminated allowing vegetation and the macro invertebrates to recolonize the beach, including the berm and dune face, and reestablish habitat that would otherwise be lost indefinitely.

This is illustrated by a survey of Sea Beach Amaranth conducted during August 2000 of the beaches of Bogue Banks from Bogue Inlet to Beaufort inlet. Twenty-three (23) plant individuals were identified along the entire island by the survey. Of those, 20 were located along the beach in portions of the Town of Atlantic Beach that have been nourished in the last ten years. The individual plants were found on the foredune at and above the dune toe. The stable beach that remains as a result of the nourishment projects in Atlantic Beach has created habitat for this endangered plant to flourish. On the remaining beach including Pine Knoll Shores, Salter Path, Indian Beach and Emerald Isle, only three individuals plants were identified. These were located 4 to 5 feet above the dune toe in Salter Path in an area were extensive beach scraping has occurred. It that area the dune is subject to loss because there is no significant berm width fronting the dune. The vegetation, dunes and dry beach areas that make up wildlife habitat on natural beaches require a long term stable beach for protection from the ocean. The nourishment project will provide that stability along the other beaches of Bogue Banks west of Atlantic Beach.

Of the approximately 335 miles of North Carolina's barrier islands from the Virginia border to Little River Inlet, only 143 miles or 43 percent is either developed or subject to development. The remaining 190 miles or 57 percent remains undeveloped and, for the most part, will remain so in perpetuity. A significant portion of the undeveloped barrier islands are accessible only by boat.

In Carteret County the numbers are even more dramatic. The County's barrier islands stretch from Ocracoke Inlet to Bogue Inlet, approximately 81 miles (measured on a County map). The undeveloped portions, from Beaufort Inlet to Ocrackoe inlet, make up 57 miles or approximately 70 percent of the total barrier island length. The developed portion of the County, Bogue Banks (excluding Fort Macon State Park), makes up 24 miles or approximately 30 percent of the County's total barrier island length. The Bogue Banks Project will not alter that distribution. Along the beach of Bogue Banks, the nourishment project will add the following:

Approximately 100 acres of dry beach (i.e., 16.8 miles, 50 feet wide)
Approximately 30 acres of stable dunes that evolve naturally by aeolian processes versus the unnatural bull dozing of coarse grained sand dunes that has occurred each year since 1995.

Comment: The reviewer referred to studies by C. R. Donahue and Peterson et. al. Indicating that beach nourishment causes a severe depletion of in numbers of macro invertebrates (shorebird food). Population recovery rates of macro invertebrates are dependent on recruitment from pelagic larval stocks and recruit from neighboring beaches.

Response: While these studies are important, the nourishment experience in the cases covered in those case studies differs greatly from that which is proposed at Bogue Banks.

Scale: The Pea Island nourishment site is only one mile long but received a total of approximately 500 c.y. / ft over seven years (versus (50 c.y. / ft. for the proposed project).
Frequency of Nourishment: The Pea Island site was nourished eight times between 1991 and 1997.
Sediment Grain size Compatibility: The Pea Island site received sand much finer than the natural beach (m_z=3.67 phi versus native beach 2.33 phi, Peterson, et. al, 2000).
Timing: Both studies involved beach fill placement during the active biological recruitment times in late spring. We anticipate beach fill operations for the Bogue Banks project to be during the optimal environmental windows as directed by the regulatory agencies via permit conditions.

Comment: We are very concerned for foraging shorebirds during all times of the year (breeding season, migration, wintering). North Carolina's coast is nesting habitat for species such as the willet, American oystercatcher, Wilson's plover, and piping plover and we often think of habitat for these as the most important to protect. However, our coast is also serves as very important wintering and migration habitat for many species of shorebirds. Therefore, we are not only concerned about beach renourishment during the breeding season, but throughout the entire year, especially when considering the cumulative impacts of large-scale renourishment projects. <u>We do not believe that the direct and cumulative impacts to intertidal macro invertebrates and shorebirds have been adequately addressed in the DEIS.</u>

Response: The assessment of the benthic invertebrate resources at Bogue Banks conducted by Peterson and Wells has been revised to include (enclosed for your review and inserted into the revised EIS as Appendix C) states that certain macro invertebrates and fish species are present along inshore and offshore areas at Bogue Banks. Therefore, dredging sand from offshore borrow areas and nourishing the shoreline may bury intertidal macrofauna and reduce the available food resource to birds that feed on these organisms. However, direct impacts to macro invertebrates associated with this project will be reduced for several reasons. Dredging and filling activities will occur largely during winter months, avoiding the larval recruitment period of many of these species, including mole crabs (early October) and coquina clams (spring and summer) (Donaghue, 1999). Additionally, studies have shown that intertidal macrofauna can recolonize a nourished area within one or two seasons (Ross and Lancaster, 1996; National Research Council, 1995; Reilly and Bellis, 1978), therefore, impacts will be temporary. Lastly, sand of similar grain size to the existing beach will be used to reduce changes in physical characteristics of the beach that may affect nourishment impacts on invertebrates (Donaghue, 1999; Peterson et al, 1999; Hackney et al, 1996).

Indirect impacts imposed on shorebirds that feed on macro invertebrates will be minimized as well. After impacts to macrofauna have occurred and numbers of these species are depressed, birds that prey upon these invertebrates, including the threatened piping plover, would likely move to adjacent undisturbed beach areas and other suitable feeding areas for the temporary period of population re-establishment. Because macro invertebrates recolonize rapidly, no long term impacts to these organisms or the shorebirds that prey upon them are anticipated with this project.

Comment: The large scale beach nourishment project will bury whole populations of intertidal macro invertebrates may preclude rapid recovery of those populations and does not allow for shorebirds to shift their foraging to nearby sites.

Response: There have been numerous studies of recovery of benthic fauna on nourished beaches. Many factors effect the recovery including grain size compatibility of nourishment sand with existing beach sand, seasonal relationship of nourishment to growth period of benthic fauna, depth of sand placed on the beach, levels of turbidity associated with various nourishment sand sources and ability of certain fauna to migrate vertically through the nourished sand. Monitoring of phase one of the Myrtle Beach Renourishment Project (Jutte, Van Dolah and Levision, March 1999) found that benthic infauna largely recovered after two to three months. The study found that, in some cases, nourishment actually resulted in enhancement of biological assemblages.

The impact of nourishment on beach macro invertebrates has been shown to be highly variable. Virtually all published studies report some initial impact (either confirmed by direct sampling after nourishment, or by inference), However, recovery rates (compared to pre-nourishment densities) have been found the range from days to weeks (e.g. Jutte, et. al. 1999; Gorzelany and Nelson, 1987) to several years (eg. Cutler and Mahadeva, 1982). Studies by Donahue (1999) at Pea Island (NC) and Peterson et. al.(2000) at Atlantic Beach (NC) quoted by the correspondent generally found longer recovery times the the majority of other researchers, including Van Dolah et/ al (1992) and Baca and Lankford (1987). A fundamental reason for the disparity in results among the various investigators is the extreme natural variability of population densities depending on seasons, variations in sediment compatibility between the natural beach and the nourishment sand, and the frequency of storms. It is generally accepted that the biological populations will recover more slowly if:

Nourished sands do not closely match the native sand grain size distribution,
Nourishment is performed during periods of peak larval recruitment,
The scale of the projects is large relative to the cross-shore dimension, and
Project are repeated frequently, causing disruption of successive growing cycles.

No study has proven total loss of benthic populations due to nourishment or scraping. The concern is over the rate and scale of recovery compared to natural beaches. The proposed project design seeks to reduce impacts and accelerate recovery in the following ways:

Selection of borrow area the most closely matches the desirable characteristics for the indigenous benthic fauna. Borrow area A has the best overfill ratios but is slightly coarser and has twice the shell content as the native beach. Borrow areas B1 and B2 have lower percentages of shell and slightly finer mean grain size (yielding moderately higher overfill ratios).Some investigators (eg. Peterson, 2000, personal communications) have suggested that borrow areas may be preferable for recruitment and recovery of beach organisms. Others (eg., Stewart, NCDENR-DWQ, comments) suggest borrow area A will yield sediments that produce fewer overall impacts on the nearshore environment. Regardless of which borrow area is selected, the differences compared to the natural beach, are considered relatively small because of the wide range of sediment sizes that occur between the foredune and inshore zone along

Bogue Banks.

Nourishment will be performed during periods of low biological recruitment periods (eg., winter and early spring months).

The scale of the project in the cross-shore dimension is moderate (approximately 50 c.y./ ft), comparable to nourishment projects that have demonstrated rapid biological recovery such as Myrtle Beach (Baca, et.al, 1987; Jutte et. al, 1999)

The project will be large enough given the low background erosion rate of the site to avoid frequent repeat nourishment every couple of years so that successive growth cycles are not interrupted as is the case now with frequent beach scraping (bull dozing).

The only means available to verify the impact of the nourishment on the Bogue Banks beach and borrow area fauna is to monitor the impacts through a program that includes characterization of both the physical and biological conditions before, immediately following and for a period sufficient to determine full recovery of the biological resources in the borrow area and on the beaches and to determine the physical performance of the nourishment project.

The Bogue Banks nourishment project will include a program of monitoring of impacts. Specific objectives of the monitoring will be as follows:

1. Document and quantify physical changes in the beach and nearshore zone,
2. determine the ecological impacts and recovery rates of beach and nearshore biological resources following nourishment, and
3. document the physical and biological impact and recovery of sand bottom habitats in the borrow area.

Comment: With a total project length (16.8) miles, this is one the longest beach nourishment projects in the last 20 years. The DEIS presents beach nourishment as a "sacrificial shore-protection technique". There are many examples of how beach nourishment provides at best only minimal protection from the encroaching sea and there are examples of the sand from beach nourishment being washed away within weeks of deposition. We question if this is a wise expenditure of public monies considering the cost of the renourishment, potentially short duration of the benefits and the adverse impacts to the fish and wildlife resources dependent on the project area.

Response: Beach nourishment is not a panacea for shore protection and beach management. Each location must be evaluated on its own merits as a candidate site for a successful nourishment project. For beaches with very high background erosion rates of 10 to 50 feet per year, the economics of beach nourishment will be very different from Bogue banks, which has background erosion rates of 1 to 3 feet per year (N.C. Division of Coastal Management, Long Term Average Annual Shoreline Change Rates, Updated through 1992). Carteret County is fortunate to have a beach nourishment project at Atlantic Beach that demonstrates convincingly the Bogue Banks is an excellent location for beach nourishment. The respondents are advised to drive the beach of Bogue Banks from west to east. From the healthy beaches at the west end of Emerald Isle to Atlantic Beach, the berm is narrow (in many places only a low tide beach exist), there is evidence if extensive structural damage to buildings and access decks and walkways, extensive loss of natural dune and adjoining maritime forest and underbrush where present, and evidence that at least 80 percent of the beach has been scraped to provide dune protection since the fall of 1999. The physical change in the beach shape upon entering the town limits of Atlantic Beach is dramatic. There is a wide berm, stable dunes with vegetation and little or no evidence of structural damage to ocean front buildings and decks. The performance of the nourished beach at Atlantic Beach provides physical evidence of a wider dry beach and reduced storm damage throughout the 1990's compared to exposed (non-nourished) beaches in the project area. The reviewer is referred to section 2.2.2 , Physical Impacts, of the draft EIS for a review of the physical factors that make Bogue Banks and excellent site for successful beach nourishment.

We are not aware of any beach nourishment projects constructed in North Carolina where the beaches have washed away in weeks following placement. If such projects do exist, please identify the projects so that the details of the projects can be investigated to determine the reasons for failure.

We believe that the responses provided herein provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the inclosed information and a response as to the adequacy of the EIS with the revision indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Mr. Milt Rhodes
North Carolina Department of Environment and Natural Resources
Division of Water Quality
Post Office Box 29535
Raleigh, North Carolina 27626-0535

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Mr. Rhodes:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the staff of the wetlands unit and the planning branch of the Division are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff. Also enclosed are revised sections of the Draft EIS. On the revised pages, the replaced text is crossed out, and the revised text is in italics.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (an unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comment: Please supply the Division with a notification of the borrow area selection once it has been made.

Response Three borrow areas have been selected for use in the project, areas, A, B1 and B2. These areas are proposed because they contain the beach-compatable sediments. Use of borrow area A will result in the lowest overfill ratios on the beach, the most durable fill, and will be the most cost effective to excavate using a hopper dredge, a technique preferred over others by some regulatory agencies. Borrow areas B1 and B2 contain somewhat finer material and will result in slightly higher overfill ratios. The higher overfill ratios will result in placement of more cubic yards of material to achieve the same adjusted beach profile and project durability. The additional costs associated with the additional sand volumes may be offset by the economies available due to the proximity of borrow areas B1 and B2 to the beaches.

Comment: The project must meet the turbidity standards set forth in the 401 Water Quality Certification for this project:

Response: Turbidity resulting from the disposal activities on the beach is addressed in section 5.9 of the Draft EIS. Results from two studies of turbidity associated with beach nourishment operations showed that, in both studies, turbidity did not exceed 25 ntu's outside the discharge area. Due to the low mud content of the borrow area sediments identified in borrow areas A, B1 and B2 (Appendix E, Table E6 of the Draft EIS), generally less than 4 percent, we believe that the project will be able to meet the requirements of the 401 Water Quality Certification.

Comment: It is desired that work be conducted between the months of November and April to limit the degree and severity of impact to environmental resources.

Response: It appears that, due to funding constraints, the project will have to be constructed in segments as funding becomes available in each of the individual municipalities on Bogue Banks. Construction windows may, therefore, be shortened. However, because of economic considerations and weather contingencies, the applicant wishes to have available the longest possible window for construction. By current state and federal policies, that window runs from November 1 (end of turtle nesting season) to May 15 (beginning of turtle nesting season) in North Carolina.

We believe that the responses provided herein should provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the enclosed information and a response as to the adequacy of the EIS with the revisions indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Stephen Hall
North Carolina Department of Environment and Natural Resources
Division of Parks and Recreation
1615 Mail Service Center
Raleigh, North Carolina 27699-1615

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Mr. Hall:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the Division of Parks and Recreation are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff. Also enclosed are revised sections to the Draft EIS. On the revised pages, the replaced text is crossed out, and the revised text is in italics.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (An unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comment: One of the potential borrow areas is located within Bogue Inlet. As stated on p. 5-8, if this area is chosen as a source for dredge material, habitat for the piping plover (Charadrius melodus), federally and state listed as threatened, may be lost. We strongly recommend that this area, along with other areas located within the inlets or on the accreting ends of the banks, be excluded as potential borrow sites.

Response: The applicant agrees to delete the shoals in and around Bogue inlet as a potential source of borrow material for the beach nourishment project.

Comment: Possible impacts to the loggerhead sea turtle (Caretta caretta), federally and state listed as Threatened, are also identified (p. 5-8). Impacts may result from the use of inappropriate dredge materials, changes in beach profiles, or from disposal activities taking place within the nesting or hatching periods. The use of nest relocations is proposed to mitigate for some of these impacts, but we regard this *as the least desirable form of mitigation. Instead, we recommend that the standard measures supported by the US Fish and Wildlife Service and the US Army Corps of Engineers be followed regarding the (1) the types of sediments that are acceptable for disposal; (2) the beach profile created by renourishment. Beach nourishment should take place strictly in the off-season for sea turtle nesting– November through April– not as currently requested (p. 4-10) for the months of October and May.*

Response: To minimize impacts to nesting sea turtles in the project area, standard protocol adopted by the U. S. Fish and Wildlife Service and used in previous beach nourishment projects in North Carolina will be followed. This protocol includes the following guidelines:

1. Only beach quality sand suitable for sea turtle nesting, successful incubation, and hatchling emergence shall be used for beach nourishment on the project site. Furthermore, sand of similar grain size to the existing beach will be used to reduce any changes in physical characteristics of the beach that may affect nest survival.

2. Immediately after completion of the beach nourishment project and prior to the next three nesting seasons, beach compaction shall be monitored and tilling shall be conducted as required to reduce the likelihood of impacting sea turtle nesting and hatching activities.

3. Immediately after completion of this project and prior to the next three nesting seasons, monitoring shall be conducted to determine if escarpments are present and escarpments shall be leveled as required to reduce the likelihood of impacting sea turtle nesting and hatching activities.

4. Carteret County will ensure that contractors doing the beach nourishment and dredging work fully understand sea turtle protection measures.

5. Beach nourishment and dredging activities are planned to begin after November 1 and be completed before May 1. If any filling occurs after May 1, the pipeline will be placed along the landward edge of the berm.

6. If any beach nourishment or dredging activities take place during the period from May 1 through November 15, a standardized nest monitoring and relocation plan will be implemented in addition to the monitoring that already occurs. The plan incorporates monitoring of the beach disposal area each morning from the beginning of the nesting season until all equipment is removed from the beach and the relocation of any nests laid within the project area. Using standard nest relocation techniques, all nests will be located to a suitable nursery beach, agreed to prior to the start of relocation effort by the U.S. Fish and Wildlife Service and the North Carolina Wildlife Resources Commission. Hatching success of relocated nests will be monitored and reported.

7. Immediately after completion of this project and prior to May 1 for three subsequent years, sand compaction will be monitored in the area of restoration in accordance with a protocol agreed to by the Service, the State regulatory agency, and Carteret County. At a minimum, the protocol provided under 7a and 7b below will be followed. If required, the area will be tilled to a depth of 36 inches. All tilling activity must be completed prior to May 1. A report on the results of compaction monitoring will be submitted to the Service prior to any tilling actions being taken. An annual summary of compaction surveys and the actions taken will be submitted to the Service. This condition will be evaluated annually and may be modified if necessary to address sand

compaction problems identified during the previous year.

7a. Compaction sampling stations shall be located at 500-foot intervals along the project area. One station will be at the seaward edge of the dune/berm line (when material is placed in this area); one station will be midway between the dune line and the high water line; and one station will be located just landward of the high water line. At each station, the cone penetrometer shall be pushed to a depth of 6, 12, and 18 inches three times (three replicates). Material may be removed from the hole if necessary to ensure accurate readings of successive levels of sediment. Replicates will be located as close to each other as possible, without interacting with the previous hole and/or disturbed sediments. The three replicate compaction values for each depth will be averaged to produce final values for each depth at each station. Reports will include all 27 values for each transect line, and the final 9 averaged compaction values.

7b. If the average value for any depth exceeds 500 psi for any two or more adjacent stations, then that area will be tilled prior to May 1 of the following year. If values exceeding 500 psi are distributed throughout the project area but in no case do those values exist at two adjacent stations at the same depth, then consultation with the Fish and Wildlife Service will be sought to determine if tilling is required. If a few values exceeding 500 psi are present randomly within the project area, tilling will not occur.

8. Visual surveys for escarpments along the project area shall be made immediately after completion of the beach nourishment project and prior to May 1 for three subsequent years. Results of the surveys will be submitted to the Service prior to any action being taken. Escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet will be leveled to the natural beach contour by May 1. The Service will be contacted immediately if subsequent reformation of escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet occurs during the nesting and hatching season to determine the appropriate action to be taken. If it is determined that escarpment leveling is required during the nesting or hatching season, the Service will provide a brief written authorization that describes methods to be used to reduce the likelihood of impacting existing nests. An annual summary of escarpment surveys and actions taken will be submitted to the Service.

9. From March 1 through April 30 and November 1 through November 15, staging areas for construction equipment will be located off the beach to the maximum extent practicable. Nighttime storage of construction equipment not in use will be off the beach to minimize disturbance to sea turtle nesting and hatching activities. In addition, all construction pipes that are placed on the beach will be located as far landward as possible without compromising the integrity of the dune system. Temporary storage of pipes on the beach will be in such a manner so as to impact the least amount of nesting habitat and shall likewise not compromise the integrity of the dune systems.

These guidelines have been incorporated into the revised EIS in section 3.15. By planning to perform the majority of the project during off-season months, monitoring beach hardness, and relocating nests found in unsuitable habitat if project completion delays occur, impacts to nesting loggerhead sea turtles will be minimized.

Comment Use of dredge spoils deposited at Brandt Island (p. 4-6) may potentially affect an undescribed butterfly that is currently known to exist only at Fort Macon State Park, Brandt Island, Radio Island, and

Bear Island. Use of dredge materials stored in the large pit on Brandt Island would probably cause little impact, but we would be very concerned if any dredge materials are taken from areas of the island that have been stabilized by development of a grass cover.

Response: The applicant agrees to eliminate the dredge spoil islands at Brandt Island as a source of borrow material for the beach nourishment project..

We believe that the responses provided herein should provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the enclosed information and a response as to the adequacy of the EIS with the revisions indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Ms. Shannon Stewart
North Carolina Department of Environment and Natural Resources
Division of Water Quality, Non-Discharge Branch
1621 Mail Service Center
Raleigh, North Carolina 27699-1621

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Ms Stewart:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the staff of the Non-discharge Branch of the Division are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff. Also enclosed are revised sections of the Draft EIS. On the revised pages, the replaced text is crossed out, and the revised text is in italics.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (an unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comments: Related to comment concerning impacts associated with selection of borrow areas.

Response: It appears that, due to funding constraints, the project will have to be constructed in segments as funding becomes available in each of the individual municipalities on Bogue Banks. Construction windows may, therefore, be shortened. However, because of economic considerations and weather contingencies, the applicant wishes to have available the longest possible window for construction. By current state and federal policies, that window runs from November 1 (end of turtle nesting season) to May 15 (beginning of turtle nesting season) in North Carolina.

Comment: Comment related to meeting the turbidity standards in the 401 Water Quality Certification for this project.

Response: Turbidity resulting from the disposal activities on the beach is addressed in section 5.9 of the Draft EIS. Results from two studies of turbidity associated with beach nourishment operations showed that, in both studies, turbidity did not exceed 25 ntu's outside the discharge area. Due to the low mud content of the borrow area sediments identified in borrow areas A, B1 and B2 (Appendix E, Table E6 of the Draft EIS), generally less than 4 percent, we believe that the project will be able to meet the requirements of the 401 Water Quality Certification.

Comment: Related to construction schedule:

Response: It appears that, due to funding constraints, the project will have to be constructed in segments as funding becomes available in each of the individual municipalities on Bogue Banks. Construction windows may, therefore, be shortened. However, because of economic considerations and weather contingencies, the applicant wishes to have available the longest possible window for construction. By current state and federal policies, that window runs from November 1 (end of turtle nesting season) to May 15 (beginning of turtle nesting season) in North Carolina.

We believe that the responses provided herein should provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the enclosed information and a response as to the adequacy of the EIS with the revisions indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

NCDENR

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

DONNA D. MOFFITT
DIRECTOR

NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF COASTAL MANAGEMENT

May 11, 2000

Bill Foreman
Hestron Plaza Two
151-A Highway 24
Morehead City, NC 28557

Dear Sirs:

Enclosed please find a response from the Departments SEPA coordinator concerning the Bogue Banks beach renourishment Draft Environmental Impact Statement. The SEPA coordinator has indicated that several comments have been received requesting additional information or clarification, and that these issues must be addressed through a revision of the Environmental Document. Therefore, it is requested that you enter into negotiations with the various commenting agencies in an effort to resolve or address these issues. After such negotiations, a revised EIS document should be prepared which addresses the review agency concerns, and twelve (12) copies of the revised document should be submitted to this office, at which time I will transmit the documents to the SEPA coordinator for additional review.

Please feel free to contact me at (919) 733-2293 if you would like to discuss this matter further.

Sincerely,

Doug Huggett

Doug Huggett
Permits and Consistency Unit Head
Division of Coastal Management

cc: Ted Tyndall, DCM - Morehead City

NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

NCDENR

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

RECEIVED
MAY 10 2000
COASTAL MANAGEMENT

MEMORANDUM

TO: Doug Huggett
Division of Coastal Management

FROM: Melba McGee
Environmental Review Coordinator

RE: #1046 Bogue Banks Restoration Plan, DEIS, Carteret County

DATE: May 5, 2000

The proposed project has been circulated and reviewed by our internal divisions.

Our review efforts raised a number of issues that will need to be addressed before this project is released for state review. After revisions have been made, I recommend the revised document be reviewed again internally prior to State Clearinghouse review.

Thank you for the opportunity to respond.

Attachments

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone 919-733-4984 Fax 919-715-3060 www.enr.state.nc.us/ENR

North Carolina Wildlife Resources Commission

Charles R. Fullwood, Executive Director

MEMORANDUM

TO: Melba McGee
Office of Legislative & Intergovernmental Affairs

FROM: Franklin T. McBride, Manager
Habitat Conservation Program

DATE: April 27, 2000

SUBJECT: Comments for Bogue Banks Beach Restoration Plan, Draft Environmental Impact Study (DEIS), Carteret County. Project # 1046.

Staff biologists with the Wildlife Resources Commission have reviewed the DEIS. Our comments are provided in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et. seq.), the Clean Water Act of 1977 (as amended) and the North Carolina Environmental Policy Act (G.S. 113A-1 et seq., as amended; 1 NCAC-25).

Carteret County is proposing to renourish 16.8 miles of oceanfront beaches in the towns of Pine Knoll Shores, Salter Path, Indian Beach and Emerald Isle. The identified sources of sand for this proposal are located offshore from the project site.

The DEIS indicates that erosion is to blame for loss of beach, dune and maritime forest habitats and a wide range of wildlife resources. If this document seeks to identify causes of lost wildlife resources and habitat then losses attributed to human disturbance, landscape alterations and development should also be included as contributing factors especially since this document indicates that Bogue Banks oceanfront has reached 90% build-out.

Recent studies by C. R. Donoghue "*The Influences of Swash Processes on Donax variablis and Emerita talpoida*" and C. H. Peterson, D. H. M. Hickson, and G. G. Johnson "*Short-term Consequences of Nourishment and Bulldozing on the Dominant Large Invertebrates of the Sandy Beach*" indicate that beach renourishment causes a severe depletion in numbers of macro invertebrates (shorebird food). Population recovery rates of macro invertebrates are dependent on recruitment from pelagic larval stocks and recruitment from neighboring beaches.

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 733-3633 ext. 281 • Fax: (919) 715-7643

State of North Carolina
Department of Environment
and Natural Resources
Division of Marine Fisheries

James B. Hunt, Jr., Governor
Bill Holman, Secretary
Preston P. Pate, Jr., Director

NCDENR
NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

Date April 27, 2000

MEMORANDUM

TO: Melba McGee, Environmental Coordinator
Office of Legislative & Intergovernmental Affairs

FROM: Michael W. Street

SUBJECT: Environmental Assessment
00-E-1046 Bogue Banks Beach Restoration Plan – Carteret County

Attached is the Division's reply for the above referenced project. If you have any questions, please don't hesitate to contact me.

MWS/tn
permits\admin\jpcover.ltr

P.O. Box 769, Morehead City, North Carolina 28557-0769 Telephone 919-726-7021 FAX 919-726-0254

State of North Carolina
Department of Environment
and Natural Resources
Division of Water Quality

James B. Hunt, Jr., Governor
Bill Holman, Secretary
T. Kerr Stevens, Director

NCDENR

April 17, 2000

MEMORANDUM

TO: Melba McGee
Department of Environment and Natural Resources

FROM: Milt Rhodes
Division of Water Quality

SUBJECT: Bogue Banks Beach Restoration Plan Environmental Impact Statement Document and FONSI, DENR# 1046, DWQ# 12652

The Division of Water Quality (Division) has reviewed the Draft Environmental Impact Statement document regarding the Restoration of Bogue Banks Beach and offers the following comments.

This document was reviewed by staff in the wetlands unit and planning branch of the Division for consistency with the State Environmental Protection Act. The full comments are attached to this letter, but in summary, these issues should be addressed in the final document.

1. Please supply the Division with a notification of the borrow area selection once it has been made.

2. The project must meet the turbidity standards set forth in the 401 Water Quality Certification for this project during construction.

3. It is desired that work be conducted between the months of November and April to limit the degree and severity of impact to environmental resources.

Thank you for the opportunity to comment. If you have questions regarding these comments, please contact Milt Rhodes at (919) 733-5083 x 366.

TMR: / Bogue Banks Beach Restoration Plan EIS, DENR-1046

NCDENR

NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

DIVISION OF PARKS AND RECREATION
NATURAL HERITAGE PROGRAM

April 13, 2000

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

DR. PHILIP K. MCKNELLY
DIRECTOR

MEMORANDUM

TO: Melba McGee

FROM: Stephen Hall SH

SUBJECT: DEIS – Beach Restoration Plan, Bogue Banks

REFERENCE: 1046

The assessment is well-written and appears to be quite thorough. It identifies several potential impacts, however, that are of concern to the Division:

- One of the proposed borrow areas is located within Bogue Inlet. As stated on p. 5-8, if this area is chosen as a source for dredge material, habitat for the piping plover (*Charadrius melodus*), federally and state listed as Threatened, may be lost. We strongly recommend that this area, along with any other areas located within the inlets or on the accreting ends of the banks, be excluded as potential borrow sites.
- Possible impacts to the loggerhead sea turtle (*Caretta caretta*), federally and state listed as Threatened, are also identified (p. 5-8). Impacts may result from the use of inappropriate dredge materials, changes in beach profiles, or from disposal activities taking place within the nesting or hatching periods. The use of nest relocations is proposed to mitigate for some of these impacts, but we regard this as the least desirable form of mitigation. Instead, we recommend that the standard measures supported by the US Fish and Wildlife Service and the US Army Corps of Engineers be followed regarding the (1) the types of sediments that are acceptable for disposal; (2) the beach profile created by renourishment. Beach renourishment should take place strictly in the off-season for sea turtle nesting -- November through April -- not as currently requested (p. 4-10) for the months of October and May.
- Use of the dredge spoils deposited at Brandt Island (p. 4-6) may potentially affect an undescribed butterfly that is currently known to exist only at Fort Macon State Park, Brandt Island, Radio Island, and Bear Island. Use of dredge materials stored in the large pit on Brandt Island would probably cause little impact, but we would be very concerned if any dredge materials are taken from areas of the island that have been stabilized by development of a grass cover.

1615 MAIL SERVICE CENTER, RALEIGH, NORTH CAROLINA 27699-1615
PHONE 919-733-4181 FAX 919-715-3085

State of North Carolina
Department of Environment
and Natural Resources
Division of Water Quality

James B. Hunt, Jr., Governor
Bill Holman, Secretary
Kerr T. Stevens, Director

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

MEMORANDUM

TO: Milt Rhodes
THROUGH: John Dorney, DWQ
FROM: Shannon Stewart, DWQ
DATE: April 10, 2000
SUBJECT: Bogue Banks Beach Restoration Plan, Carteret County

Based on a review of the subject EIS, the Division of Water Quality has the following comments:

1. The EIS considers four possible borrow areas for the Bogue Banks Beach Restoration project. In section 3.16.1 of the EIS, it states that borrow area A provides the most promising deposits in terms of beach compatibility and potential yield of beach-quality sediments. Borrow Area A had the lowest R_A value, which indicated that approximately 85% of the deposit would be stable as beach fill in the project area. The other three potential borrow areas (B1, B2, and C) yielded R_A values substantially higher than borrow area A. As noted in the EIS, these areas would therefore require proportionately higher excavation volumes to achieve the same performance as borrow area A. The EIS also states that only a portion of borrow area A will be required to satisfy the nourishment volume requirements of this project – ample beach-quality sediments exist in this location.

   Section 2.3.1 of the EIS lists the selection of borrow areas as an "unresolved issue" at this point in the project. It states that "it will be uncertain until bids are received which combinations of dredge type and borrow area will yield the most cost-efficient project." The Division of Water Quality supports the use borrow area A as the exclusive source for beach-quality sediments for this project. As compared to the other three proposed borrow areas, the use of borrow area A as the sole source for beach sediments would require less material, would improve the durability of the nourishment project, would minimize changes in types and densities of nearshore species, and would reduce the rate of fill loses therefore minimizing turbidity in nearshore waters. Although borrow areas B1 and B2 may result in lower costs related to travel distances, they will have greater impacts on the nearshore environment in and around the project area.

   The Division of Water Quality would also like to request that when a decision is reached on the selection of a borrow area(s) appropriate documentation be provided for comment.

Division of Water Quality • Non-Discharge Branch
1621 Mail Service Center, Raleigh, NC 27699-1621 Telephone 919-733-1786 FAX # 733-9959

http://h2o.enr.state.nc.us/wetlandc.html

NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF COASTAL MANAGEMENT

NCDENR

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

DONNA D. MOFFITT
DIRECTOR

MEMORANDUM

TO: Melba McGee, NC Division of Policy and Development
FROM: Steve Benton, NC Division of Coastal Management
SUBJECT: Review of ~~SCH~~# 00-1046 DEPT DATE: 4·11·2000

___ A COPY OF ALL COMMENTS RECEIVED BY THE SCH IS REQUESTED   ___ REVIEWER COMMENTS ATTACHED

Review Comments:

___ This document is being reviewed for consistency with the NC Coastal Management Program pursuant to federal law and or NC Executive Order 15. Agency comments received by SCH are needed to develop the State's consistency position.

Project Review Number (if different from above) ______________.

A consistencyposition will be developed based upon our review on or before ___________.

___ A Consistency Determination document ___is, or ___may be required for this project pursuant to federal law and or NC Executive Order 15. Applicant should contact Steve Benton or Caroline Bellis in Raleigh, phone (919)733-2293, for information on proper document format and applicable state guidelines and land use plan policies.

___ Proposal is in draft form, a consistency response is inappropriate at this time. A Consistency Determination should be included in the final document.

___ A Consistency Determination Document (pursuant to federal law and/or NC Executive Order 15) is not required.

- ___ A consistency response has already been issued.
  Project Number ___________ Date Issued __________
- ___ Proposal involves < 20 Acres and or a structure < 60,000 Square Feet and no AEC's or Land Use Plan problems.
- ___ Proposal is not in the Coastal Area and will have no significant impacts on any land or water use or natural resources of the Coastal Area.

✓ A CAMA Permit ✓ is, or ___ may be required for all or part of this project. Applicant should contact _______________ in _________________, phone #_____________, for information.

___ A CAMA Permit ___has already been issued, or___is currently being reviewed under separate circulation. Permit Number____________ Date Issued___________

___ Other (see attached).

State of North Carolina Consistency Position:

___ The proposal is consistent with the NC Coastal Management Program provided that all conditions are adhered to and that all state authorization and/or permit requirements are met prior to implementation of the project.

___ The proposal is inconsistent with the NC Coastal Management Program.

___ Other (see attached).

MAILING: 1638 MAIL SERVICE CENTER, RALEIGH, NORTH CAROLINA 27699-1638
PHYSICAL: 2728 CAPITAL BLVD., RALEIGH, NC 27604
PHONE: 919-733-2293 FAX: 919-733-1495

NORTH CAROLINA STATE CLEARINGHOUSE Ref. CO-E-0000-0304
DEPARTMENT OF ADMINISTRATION
INTERGOVERNMENTAL REVIEW

STATE NUMBER: 01-E-4300-0357 H05
DATE RECEIVED: 12/11/2000
AGENCY RESPONSE: 02/08/2001
REVIEW CLOSED: 02/13/2001

DEC

HISTORIC PRESERVATION OFFICE

MS RENEE GLEDHILL-EARLEY
CLEARINGHOUSE COORD
DEPT OF CUL RESOURCES
ARCHIVES-HISTORY BLDG - MSC 4617
RALEIGH NC

REVIEW DISTRIBUTION
DENR LEGISLATIVE AFFAIRS
DEPT OF CUL RESOURCES
DEPT OF TRANSPORTATION
EASTERN CAROLINA COUNCIL

multi SM RB 1/3

PROJECT INFORMATION
APPLICANT: NC Dept of Env & Nat Res
TYPE: State Environmental Policy Act
ERD: Draft Environmental Impact Statement
DESC: Bogue Banks Beach Restoration Plan

NC GB 1/23/0

JCWS aqm 1/29/01

The attached project has been submitted to the N. C. State Clearinghouse for intergovernmental review. Please review and submit your response by the above indicated date. If additional review time is needed, please contact this office at (919)807-2425.

AS A RESULT OF THIS REVIEW THE FOLLOWING IS SUBMITTED:

[X] NO COMMENT

[ ] COMMENTS ATTACHED

SIGNED BY: Renee Gledhill-Earley

DATE: 2/2/01

RECEIVED
FEB - 2001
N.C. STATE CLEARINGHOUSE

JAN 19 2001

DEC 13 2000

e

environmental defense

finding the ways that work

March 13, 2001

Mr. Doug Huggett
CAMA Permit Coordinator
Division of Coastal Management
1638 Mail Service Center
Raleigh, NC 27699-1638
VIA FACSIMILE 919-733-1495

RE: Bogue Banks Beach Restoration Plan – SEPA Draft Environmental Impact Statement

Please accept these comments regarding the proposed project on behalf of Environmental Defense, our 10,000 members in North Carolina and 300,000 members nationwide. In general, we have serious concerns regarding the large-scale, persistent and cumulative effects of this and related beach engineering projects, and the adequacy with which impacts from these projects are addressed. We recognize and acknowledge the efforts of the project sponsor and authors of the draft EIS to address the issues of highest controversy surrounding beach engineering, and offer the following comments regarding those issues for which we have particular concerns:

1) Cumulative and Long Term Impacts: In general, our dominant concern regarding beach engineering projects, particularly ones of such extensive spatial (and potentially temporal) magnitude, is the inadequate assessment of cumulative and long-term impacts to living marine resources and essential fish habitats. Specifically, the impacts of these projects are assessed on a piecemeal, or project-by-project basis, rather than as components of a statewide and regionwide beach engineering effort. We recognize that scientific studies examining the impacts of engineering operations on beach, intertidal and nearshore fauna are ongoing and not yet complete, but enough information exists to warrant a programmatic EIS on *all* of these activities for the North Carolina coast, if not the entire southeast region. We have requested such an evaluation of the Corps of Engineers (see Attachment 1) in a letter dated September 8, 2000. The Corps' response was that such an evaluation was too costly to undertake at the present time.

   Although the current project is proposed to be a one-time placement of sand, designed to "restore the sand deficit and provide for average yearly losses over a decade or so" (DEIS, Section 2.1, p. 2-2), it is clearly stated at the end of the introduction (Section 1.4, p. 1-3) that it is unlikely the entire project could be constructed within the same environmental window. Indeed, it appears that, given the funding needs of the communities, the project will stretch over several environmental windows. We are concerned about the downstream impacts of such discontinuous construction, which, as pointed out in Section 5.4.5 (page 5-2, second paragraph) are not insignificant.

North Carolina Office · 2500 Blue Ridge Road · Suite 330 · Raleigh, NC 27607 · Tel 919 881 2601 · Fax 919 881 2607
New York, NY · Washington, DC · Oakland, CA · Boulder, CO · Austin, TX Project Offices · Boston, MA · Los Angeles, CA
www.environmentaldefense.org

2) Definition of Project Success: As acknowledged in Section 2.2.2 (p. 2-2) one of the major controversies with respect to beach engineering is the development of criteria, or lack thereof, for defining project success. Given the magnitude of resources required for the proposed project, there ought to be a clearly defined set of criteria by which to measure project success, particularly if state cost-share funds are obtained for any portion of the project as discussed in Section 2.3.3. The DEIS state in Section 2.2.2 that "Success will be defined in relation to how closely the postnourishment volume erosion rate compares with the estimated prenourishment volume erosions rate" (page 2-3), yet fails to identify a range of values which would constitute an acceptable or "successful" erosion rate. Although achievement of a certain rate of erosion may constitute success in an engineering sense, it may not necessarily translate into visible success for the project sponsors (i.e., the communities, and potentially state taxpayers if cost-share funding is obtained). Considering that this project is supposed to serve as "prototype" for future beach maintenance efforts (Section 2.1, page 2-1) and as a basis for determining a "long-range solution" from amongst three alternatives (Section 2.4, page 2-5), development of specific evaluation criteria by the project sponsors, rather than the contracted engineering company, would appear to be critical.

3) Project Purpose: Among the four stated objectives (Section 1.3, page 1-2) of the project is "preservation of the environmental, cultural and aquatic resources of the county". We maintain that this project as designed (mainly due to the extensive geographic scale) protects only the unnatural, i.e., manmade "environmental resources". The three remaining planning objectives are a more realistic statement of purpose. Beach engineering projects are rarely, if ever, consistent with protection of the natural environment, and we are unaware of any such projects that have enhanced the nation's living marine resources. We also disagree with the statement that Bogue Banks serves to draw human activity away from the more pristine shores of Shackleford and Core Banks. Although not accessible by vehicle, there is ample transportation available to these locations via public and private ferries, and certainly the number of privately owned boats anchored in Back and Core Sounds during the summer months does not indicate that the public is dissuaded from visiting these areas.

4) Consideration of Alternatives: The DEIS states that "Property abandonment and relocation at a large scale would leave the beach degraded for many years because it would necessarily become a piece-meal process" (page 1). Yet, as referenced previously, the DEIS indicates that if approved, project construction would itself be piecemealed. A retreat and relocation alternative can be planned to initially target those structures most at risk, and can be implemented gradually, rather than in one massive effort. Indeed, should this project be approved, development of a phased relocation and/or exit strategy should be considered, particularly if cost-share funding is obtained. Given that the community plans to reevaluate the costs and benefits of renourishment after a decade of monitoring (Section 2.2.2), development of such a strategy would be proactive. That being said, having once obtained the necessary approval for a beach engineering project (especially if other funding sources are obtained), it is highly likely that the local communities will naturally expect approval for a second project, at an even greater economic and environmental cost.

Also, under the no-action alternative in Section 4.2, page 4-2 one of the stated, yet unquantified, environmental impacts of this alternative is "chronic impacts to beach fauna". We presume that this would be the result of beach scraping. We disagree with this statement, as it implies that placement of dredged sand on the beach would *not* impact beach fauna and that beach scraping would not occur should the project move forward. Incidentally, we find it interesting that "loss of recreational beach" is listed as a quantifiable environmental impact, considering the subjective and intangible nature of the recreational experience, while no attempt is made to quantify the loss of biota.

5) Monitoring Program/Protocol: We applaud the commitment of the project sponsors to develop a comprehensive pre- and post-construction monitoring plan as outlined in Appendix C, and for initiating pre-project benthic monitoring. We feel that such efforts are absolutely necessary in order to assess project impacts accurately over the proposed 10-year project lifetime. We also feel that a periodic (once every three years), publicly available assessment of impacts should be conducted and the results used to adjust the implementation and maintenance of the project and develop a compensatory mitigation plan if warranted, especially if the communities elect to continue beach engineering as a management option. In light of the fact that environmental impacts are not quantified in the analysis of costs and benefits, we feel very strongly that the project sponsors be responsible for funding the monitoring program.

6) NC Marine Fisheries Commission Policies on Beach Dredge and Fill Activities: The North Carolina Marine Fisheries Commission (MFC) has statutory responsibility for protecting the marine and estuarine resources of North Carolina against impacts from both fishing and non-fishing threats. On November 16, 2000, the MFC approved a new policy for the protection of marine and estuarine resources under its authority from the effects of beach dredge and fill activities and related coastal engineering activities (copy attached). The Habitat and Water Quality Standing Advisory Committee of the NC Marine Fisheries Commission developed the policy in response to increasing number of beach engineering projects being developed and the inadequate consideration of cumulative and long-term impacts of these projects. This policy includes numerous issues that have so far not been adequately addressed in the DEIS.

   In addition, the MFC shares responsibility under state law for the development of Coastal Habitat Protection Plans (CHPPs). The statutory goal of these plans is the "net enhancement" of the value to the coastal fishery of each habitat type. The Coastal Ocean CHPP is currently in pre-draft form; it will shortly be issued in public draft. That draft will include a set of policies and procedures to protect the marine and estuarine resources of North Carolina against development activities including beach engineering activities. The CHPP will then be formalized in regulation. The CHPP and its adjunct regulations will become a part of the state's federal coastal zone management plan.

Finally, we would like to explicitly state several requests regarding the Bogue Banks Renourishment DEIS:

- When will a programmatic EIS or comprehensive assessment of beach engineering projects be performed, at least for the state of North Carolina?
- What are the project sponsors' criteria for project success?
- Is there a contract with a research institution to continue the pre-construction benthic monitoring, develop post-project benthic monitoring, as well as develop a pre- and post-construction intertidal monitoring program?
- Should state cost-share monies be obtained, are there plans to proactively develop phased exit strategies in the event that beach engineering is not found to be a viable management alternative?

Until these questions and the other issues we have raised can be sufficiently addressed, we do not feel that the Bogue Banks Renourishment project should move forward. We repeat our request that a programmatic EIS be conducted, including full assessment of cumulative impacts of the multiple projects at various stages of design. We reiterate our willingness to discuss any of the issues that we have raised.

We thank you for the opportunity to comment on this very important project.

Sincerely,

Michelle Duval
Michelle Duval, Ph.D.
Scientist

Daniel Whittle
Daniel J. Whittle
Senior Attorney

Attachment

cc. Chrys Baggett, State Clearinghouse
NC Marine Fisheries Commission
Tracy Rice, Kevin Moody - USFWS

North Carolina
Department of Administration

Michael F. Easley, Governor | Gwynn T. Swinson, Secretary

March 15, 2001

Mr. Doug Huggett
NC Dept of Env & Nat Res
Div of Coastal Mgt
Parker-Lincoln Bldg - 1638 MSC
Raleigh, NC 27699-1638

RECEIVED
MAR 19 2001
COASTAL MANAGEMENT

Dear Mr. Huggett:

Re: SCH File # 01-E-4300-0357; Draft Environmental Impact Statement Bogue Banks Beach Restoration Plan

The above referenced environmental impact information has been reviewed through the State Clearinghouse under the provisions of the North Carolina Environmental Policy Act.

Attached to this letter are comments made by State department(s) in the course of this review. The comment(s) need to be addressed in the Final Environmental Impact Statement. This document should be submitted to the State Clearinghouse upon completion for compliance with the North Carolina Environmental Policy Act.

Best regards.

Sincerely,

Chrys Baggett

Ms. Chrys Baggett
Environmental Policy Act Coordinator

Attachments

cc: Region P
Bill Foreman, Coastal Science & Engineering

116 West Jones Street Raleigh, North Carolina 27603-8003 Telephone 919-807-2425

RECEIVED
MAR 16 2001
COASTAL MANAGEMENT

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Institute of Marine Sciences
252-726-6841
FAX: 252-726-2426

The University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, North Carolina 28557

15 March 2001

Mr. Doug Huggett
CAMA Permit Coordinator
NC Division of Coastal Management
1638 Mail Service Center
Raleigh, NC
FAX- (919)-733-1495

Re: Bogue Banks Beach Restoration Plan

Dear Mr. Huggett:

I enclose here my comments on the Draft EIS for the Bogue Banks Beach Restoration Plan. I make these comments in my professional capacity as a coastal ecologist with the University of North Carolina at Chapel Hill. These opinions are derived from my 25 years of personal experience in quantitative monitoring of the major beach invertebrates on the beaches of Bogue Banks, my years of experimental analyses of how ecological processes on sand beaches are influenced by the physical character of the sediments, my personal experience with two beach nourishment projects at Fort Macon, my 30+ years of professional reading, research, and experience as a marine ecologist, my two decades of teaching barrier island ecology at Duke University and the University of North Carolina, and my recent experience as a member of the IRC charged with development of CHPPs, including the Coastal Ocean Habitat Protection Plan.

In my professional opinion, the proposed Bogue Banks Beach Restoration Plan is inadequately protective of the important natural resources of the intertidal beach and the coastal ocean, including especially the physical habitat and prey invertebrates required to sustain our recreationally and commercially important fisheries and the valued shorebirds of our beaches. Without (1) scientifically rigorous before-after monitoring of physical character of the sediments, impacts and recovery of the invertebrate prey, and consequences of turbidity and habitat change on the fishes, with required mitigation for any substantive impacts, (2) development of a state plan for assessing cumulative impacts based on results of a programmatic EIS covering all these sand mining and beach deposition projects along the entire coast of the state and beyond, as dictated by the range of the important fishes, (3) a match of sediment grain sizes to the natural sediments of the beach in a way that will protect the habitat value of the beach, and (4) restriction of the project to between Dec 1 and March 31 so as to minimize ecological damage and allow recovery to begin to develop during the ecologically significant spring-summer seasons, this project should not be granted a permit.

(1) Scientifically rigorous before-after monitoring of sediments, benthos, and fishes

The draft EIS is grossly deficient in its commitment to the monitoring that is necessary to evaluate the ecological impacts of the project and thereby allow the agencies to learn how to respond to future requests and how to condition projects to protect adequately the public trust resources. While it is true that monitoring of nourishment projects has been done in the past, this project is unique for its spatial scope, its application to pristine shores, and its context in the midst of potentially hundreds of miles of

similar projects coast-wide. Past beach nourishment projects have been done on short stretches of urbanized shore like Atlantic Beach, Wrightsville Beach, and North Topsail. The application to a pristine beach of such a length as to represent a significant fraction of the functional critical habitat for beach fishes, invertebrates, and shorebirds is unprecedented for North Carolina. Past monitoring projects attached to permit applications are almost uniformly poor scientifically, done merely to satisfy a regulatory burden in a way that typically produces inconclusive results. Monitoring should be designed up-front by and reviewed by professional statisticians so that the agency and the public can have reassurance that the important questions can be answered with adequate power to detect effects of ecological significance. That has not been done here. Here we are told that monitoring will be done by the Carteret County monitoring plan. There is no such plan, no detailed statistical design, and no binding commitment by the county, state, or the responsible party to funding such a project. In fact, the necessary before-project sampling has not even been done. In South Carolina projects, the offshore biology has been monitored before and after such projects in each of the four seasons of the year: this proposal includes pre-project monitoring of benthic invertebrates for only one season (autumn), yet the offshore fishery resources here are arguably even more important than off South Carolina. There are no data included on pre-project monitoring of the beach ecosystem and no design that could be evaluated statistically for its rigor and ability (power) to detect important changes. Granting a permit under such inadequacy is not in the public interest.

There is broad and essentially uniform consensus among the scientific community that the impacts of beach nourishment projects on fisheries through modification of their bottom and water column habitats are poorly understood. The monitoring that has been done for such projects in the past (1) has been too restricted to include all the potentially important impacts on fisheries, (2) has lasted for too short a time period to confidently demonstrate recovery, (3) has failed to meet standards of rigor and high power to detect large impacts, and/or (4) has been done for projects occurring on too small a scale to allow extrapolation to the cumulative effects of permitting many miles of beach nourishment. The impacts of concern include both phases of nourishment projects, the mining of sediments from the shelf and the deposition of sediments on the beach.

A minimally adequate monitoring design for either the mining site or the deposition site would include the following components. First, the monitoring design must begin with quantitative data taken before initiation of the project. Such "Before" observations must be made during each season of importance to the biota that comprise and use the habitat. A single year of such "Before" data is an absolute minimum necessary to make rigorous conclusions and multiple years of "Before" data are required to be completely comfortable in estimating the magnitude of effects with confidence. These "Before" data must include observations made in both the putative "Impact" areas and in "Control" areas that are sufficiently distant not to be affected by the project but sufficiently nearby and similar that they can serve to track conditions that would be expected in the "Impact" area in the absence of the project. The observations made during the "Before" period then need to be replicated in the "After" period in both the putative "Impact" areas and the "Control" areas. This monitoring needs to match the seasonal monitoring done during the "Before" period and needs to extend long enough in time to demonstrate recovery or allow inference of recovery with high statistical confidence. The "Control" area should have replication that involves statistically independent sites. This is preferable for the "Impact" areas too, but sometimes impossible because there may be only one project site. In any event, sufficient subsampling must be done at multiple locations to characterize the habitat and its utilization adequately. This monitoring design must be shown to be likely to have high statistical power to detect any magnitude of impact deemed important to fisheries biologists and managers. This requires an effective statistical design. Perhaps the best model for such rigorous project monitoring comes from the paper on BACI (Before-After-Control-Impact) designs by Stewart-Oaten et al. (1986: Ecology). Most monitoring associated with permits is incapable of statistically demonstrating even large impacts of the project with confidence because of inadequate statistical power in the design. The evaluation of cumulative impacts of beach nourishment on a large scale of tens of miles is a particular challenge, fundable perhaps only by creating a monitoring bank from contributions from multiple projects.

(2) Programmatic EIS for cumulative impacts and appropriate monitoring

Besides the needs to evaluate the impacts of this particular project on Bogue Banks, the responsible permitting authorities have a duty to evaluate the cumulative impacts of all such perturbations to the coastal ocean system. This requires first a programmatic EIS that applies the best scientific judgement, open to public review, analysis, and comment, as to cumulative impacts, especially on fishery populations and shorebirds. For a short stretch of urbanized shoreline, it is readily argued that most fish and shorebirds are mobile enough to move elsewhere to feed when their invertebrate prey resources are killed by beach nourishment. Similarly, when prey resources are mined along with sand from the offshore sand bodies, one can argue that the demersal fishes and crustaceans can feed elsewhere. But when projects are large enough and numerous enough and when projects are repeatedly done over time, then the potential for seriously limiting the production of fishes and birds greatly increases. Furthermore, if the physical sedimentary habitat is permanently altered or modified for the long term, then there is great potential for permanent limitation of the extent of critical fisheries habitat both on continental-shelf sand bodies (a limited habitat already in the southern portion of the state) and on intertidal beaches. Nowhere in this Draft EIS for Bogue Banks is there evidence that the public trust resources will be protected from cumulative spatial and cumulative temporal effects. Until such time that evidence exists, no permit should be granted for this project.

(3) Match of sediment grain sizes to protect habitat value of the beach

The recovery of natural ecological functioning of the beach habitat depends upon closely matching the sediment size distribution to that of the natural undisturbed beach. I have shown in a published paper based on study of a previous beach nourishment project on Bogue Banks (Peterson et al. 2000: Journal of Coastal Research) that the US ACOE requirements for matching sediment sizes are inadequate to allow recovery of function of the beach habitat within the following summer season. Incorporation of either too much shell (coarse material) or too much silt/clay (fine material) inhibits recovery. Too much shell inhibits burrowing by the beach invertebrates, which must burrow into the sediments to feed and avoid erosion and wave-transport off the beach face. Too much shell also prevents many shorebirds from feeding on the invertebrates that are present because coarse particles block the biomechanical ability of bills to extract invertebrate prey (see test in published paper by Quammen 1982: Marine Biology). Too much silt/clay likewise prevents sand burrowers from inhabiting a habitat that now lacks the interstitial spaces among sand grains and the penetrability required for burrowing. In addition, silt/clay is readily suspended causing enhanced turbidity, which clogs the filtration apparatus of these suspension-feeding beach invertebrates (mole crabs, coquina clams, some polychaetes, and amphipods) and inhibits surf fishes like pompano, bluefish, and Spanish mackerel from detecting their prey. We possess feeding data from experiments showing this feeding inhibition on pompano in the presence of elevated turbidity. The Bogue Banks project, as proposed in this Draft EIS, plans use of sediments that are much more dominated by shell fragments than the natural pristine Bogue Banks beaches. This will result in long-term (not just transient) reduction in beach invertebrate populations and thus habitat value for surf fishes and shorebirds. I base this judgement upon knowledge of the physical processes that affect sediments on the beach and upon my lab's survey of the biota of North Carolina beaches as a function of shell content. Silts and clays are gradually winnowed away from beach sediments as they become suspended in the water and make it turbid. Shell fragments, in contrast, are left behind to accumulate on beaches, and thus remain to degrade the beach habitat indefinitely until the next nourishment project is needed. Lower densities of the numerically and functionally important large burrowing invertebrates on shellier beaches are dramatic in our unpublished survey data. Thus, the choice to use shell-rich sediments in the Bogue Banks nourishment project will predictably degrade the critical habitat of the intertidal beach indefinitely. Such a poor match with pristine sediments should not be permitted.

(4) Restriction of the project to Dec 1 through March 31

Because of the seasonality of biological use and activity in both the subtidal sand body habitat and the intertidal beach habitat, sand mining and beach deposition should both be restricted to the colder months to minimize ecological injury and to speed up recovery in the next warm season. The draft EIS for the Bogue Banks project does not constrain the project adequately in light of what is known about biological seasonality to protect the functioning of these habitats. Our monitoring of beach invertebrates on Bogue Banks over a period of 25 years shows that the period of December 1 through March 31 is the proper window during which beach invertebrates like mole crabs and coquina clams have migrated to deeper waters, from which they can initiate recovery through migration and reproduction at the end of the project. Furthermore, our sampling of fish abundance at the sand bodies proposed for mining to conduct this Bogue Banks project demonstrated high abundances and high rates of feeding on bottom invertebrates of the sand bodies on November 29 and again in spring, with low levels in February after clod fronts had reduced water temperatures. The Draft EIS for Bogue Banks does not propose a time frame for the project that will adequately protect either of these habitats from the impacts of the project. A permit should not be granted until the window is narrowed to this Dec 1-March 31 season. Furthermore, the public is entitled to a commitment that such a window will be enforced by DCM: similar restrictions have not been enforced in the past and I have little confidence that they will be in the future, absent some new mechanism of assurance.

I trust that my concerns are clearly and fully enough articulated here. If any comments need further elaboration, please ask. In addition, if you need further information from our files, please ask.

Sincerely,

Charles H. Peterson

Charles H. Peterson
Alumni Distinguished Professor

North Carolina
Department of Environment and Natural Resources
Division of Coastal Management

Michael F. Easley, Governor
William G. Ross Jr., Secretary
Donna D. Moffitt, Director

NCDENR

March 20, 2001

Coastal Science and Engineering, LLC
PO Box 8056
Columbia, SC 29202-8056

and

Stroud Engineering
Hestron Plaza 2(A)
151 Hwy. 24
Morehead City, NC 28557

Dear Sirs:

This letter is in reference to the Bogue Banks Beach Restoration Plan Draft EIS (DEIS). As you may be aware, the DEIS completed its initial State Clearinghouse review on March 15th, 2001. It is my understanding that the State Clearinghouse has provided you with copies of the comments received by that office as of the March 15th deadline. In case this is not correct, I have provided a copy of these comments as well. In addition to these comments, an additional set of DEIS review comments were received in this office on March 16th, 2001. Although these comments were received one day after the official review period ended for the review, after discussion with the State Clearinghouse I have determined that it is appropriate and necessary that these comments be considered and addressed in Final Environmental Impact Statement (FEIS). Therefore, I must ask that you address all of the attached comments in the FEIS, and that 12 copies of the document be submitted to this office so that I may initiate the FEIS review process.

Please let me know if you have any questions concerning this matter. I may be reached at (919) 733-2293 or by e-mail at doug.huggett@ncmail.net.

Sincerely,

Doug Huggett

Doug Huggett
Major Permits Coordinator

cc: Carteret County
DCM – Morehead City
Chrys Baggett, State Clearinghouse

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

April 03, 2001

Mr. Doug Huggett, CAMA Permit Coordinator
NC Division of Coastal Management
1638 Mail Service Center
Raleigh NC 27699-1638 Fax: 919-733-1495

RE: Response to Comments dated 15 March 2001 from Dr. Charles H. Peterson, University of North Carolina Institute of Marine Sciences [Ref: EIS #01–E–0357] Bogue Banks Beach Restoration Plan (2049)

Dear Mr. Huggett:

I am writing on behalf of Carteret County and the Towns of Pine Knoll Shores and Indian Beach, in response to the above-referenced comments on the Bogue Banks nourishment project.

The correspondent has urged your agency to require that four conditions be met before a permit for the Bogue Banks nourishment is granted. I wish to outline herein how the applicant plans to meet certain of these conditions and to explain why others are not possible to achieve in any reasonable time or budget.

Dr. Peterson and his colleagues at UNC-IMS contributed valuable information and data in the development of the draft EIS under contract to Carteret County. They provided the initial biological samplings in November 1999 and February 2000, and prepared a detailed report which is Appendix C of the EIS.

Our project team has actively sought Dr. Peterson's guidance and recommendations for design of the project such that environmental impacts can be minimized. His contributions to the project have been important. We have also sought the advice of other experts [including Dr. Robert Van Dolah (SCDNR) and Dr. Bart Baca (Nova University)] and have reviewed the literature regarding impacts of dredging and beach fills on the fauna of similar project sites.

Early in the county's planning process (fall 1999), we were informed by Dr. Peterson that no quantitative biologic sampling data exist in and around our proposed borrow areas. As a result, the county, at its own initiative, contracted with UNC-IMS for a preproject monitoring that could be used as a baseline for future comparisons. The first of two planned samplings was completed by Dr. Peterson's group in November 1999. Detailed data from this survey are reported in Appendix C of the draft EIS.

UNC-IMS reportedly has completed numerous samplings of benthic organisms along the beach as part of a four-year study of the impacts of beach scraping. We requested relevant data from these samplings so they could be incorporated into the EIS but were informed by Dr. Peterson that they will not be available until one of his students completes a dissertation. As outlined in the draft EIS, we plan to use these data to estimate baseline beach conditions for the project when they become public.

Following are our responses to the four conditions outlined by Dr. Peterson.

Item 1) Rigorous before-after monitoring of sediments, benthos, and fishes.
The draft EIS (Appendix C) outlines the sampling protocols used by Dr. Peterson for his offshore surveys. The applicant proposes to follow up these samplings with additional benthic sampling in spring 2001 (preproject). Postproject sampling will be performed using similar sampling protocols and design in consultation with your agency and other reviewing agencies. Because it now appears that the project will be completed in several discrete segments by three towns and the county over several years, we are requesting guidance from NC DENR and National Marine Fisheries regarding what constitutes an acceptable level of biologic sampling. The Towns of Pine Knoll Shores and Indian Beach do not have unlimited resources to fund research that is more properly performed by universities or government agencies or that is more applicable to global concerns. However, the applicants realize the importance of sampling habitats over which their projects may produce direct and quantifiable impacts. Accordingly, we have recommended that the county and cooperating municipalities sponsor the following:

- A second preproject sampling of benthic organisms in spring 2001 in and around the planned borrow areas following the Peterson sampling design given in Appendix C of the draft EIS.

- Annual postconstruction sampling of benthic organisms in and around the borrow area(s) and beach for up to three years after completion of the Pine Knoll Shores and Indian Beach reaches on a schedule acceptable to state and federal agencies.

The results of Appendix C, as well as research published in the literature, suggest that quantification of impacts to fisheries by the proposed project is not possible by any reasonable amount of sampling of the water column for transient species. Such questions are global in nature and will require a major commitment of time and money to answer in any rigorous sense. We believe that the natural variation in pelagic species passing through and utilizing the borrow area(s) and beach is far too great to quantify impacts or prove cause and effect. This problem is not a straightforward sampling exercise. Therefore, the chance of any sampling schedule offering rigorous, predictive results is negligible.

Item 2) Programmatic EIS for cumulative impacts
The question of cumulative impacts is important and should be addressed in some manner by state and federal agencies. However, this is not a trivial exercise and certainly not one that can be accomplished in a reasonable amount of time. It will take years and millions of dollars to even begin to address this problem in any sort of rigorous way, given the wide range of variables that must be sampled, analyzed, modeled, and integrated. This is a global concern. I believe that years of effort would be required just to develop a scientific sample design or statistical model upon which professionals could agree. The question of cumulative impacts spans the disciplines of oceanography, geology, biology, chemistry,

water quality, fisheries, primary production, climate, rainfall, runoff, and anthropogenic inputs of man. This is not something that can be answered before the next damaging storm impacts Bogue Banks and, therefore, should not be a prerequisite for granting a permit for the project.

Item 3) Match sediment grain sizes.

The correspondent expressed concern about the shell percentage and advises that "high" shell content should not used. The draft EIS presents data for three borrow areas (A, B1, and B2). Borrow area A contains a deposit having about twice the shell content of the beach. Borrow areas B1 and B2 contain about the same 20 percent shell content as the native beach. As the draft EIS and permit application states in detail, the applicant proposes to use the particular combination of borrow areas that optimizes the match of grain sizes and costs of dredging. The applicant is continuing to collect borings in borrow areas B1 and B2 (beyond those reported in the draft EIS) in response to Dr. Peterson's recommendation to limit the shell percentage. In fact, more care has gone into the search for a good match of sediment types for this project than any previous nourishment along Bogue Banks. Other investigators have noted how poorly prior projects matched the sediments. (Atlantic Beach was too shelly and the Ramada Inn site was too fine.) The applicant believes that there is insufficient monitoring data from these prior projects to make any definite recommendations regarding shell content. If the agencies will provide quantitative criteria for nourishment sediment characteristics (specifically, a particular range of shell percentages) based on previously published studies, the applicant will strive to match them.

Item 4) Restrict the project to December 1 through March 31.

This restriction would be unprecedented, considering the number of nourishment projects that are completed during the biologically productive summer months. We are aware of no data or published reports that state these dates constitute the only acceptable window for dredging. The applicant has chosen to perform the work in cold-water months rather than request a permit for work in summer as other agencies have done. The period from around 1 November to around 1 May has been an accepted standard for construction outside the normal turtle-nesting period in many East Coast states. By shortening the window to only four months, it is highly unlikely that the project can be completed in one season. This means that equipment will have to re-mobilize and re-impact the project areas at considerable extra expense to the applicant.

If quantifiable data exist and state or federal agencies have a justifiable basis for establishing such a restrictive dredging window for the proposed project, the applicant is prepared to adjust the schedule. However, such restrictions should then be applied universally. I believe the schedule for dredging is important. However, to ultimately avoid any sense of arbitrariness, extensive biologic sampling on a monthly basis for many years should be performed by government agencies such that a sound basis for restricting the dredging window can be developed.

Finally, I would like to reiterate that what the applicant is proposing is a one-time project. It will be the first nourishment of Bogue Banks designed to match properly the texture of sediments in the borrow area with those of the native beach. The project will be performed in sections rather than in one complete pass over 16.8 miles such that adjacent areas have time to adjust and recover their biologic populations before the next sections are constructed. It will reduce the need for and frequency of beach scraping, a recurring adverse impact to biota in recent years. And it will allow dunes to build naturally with fine, windblown sediments that facilitate revegetation.

The present beach/dune system of Bogue Banks is not pristine. Its profile has been altered such that it is steeper and more vulnerable than the native beach to severe damage in storms. Coarse sand and pebbles common to the swash zone now reside in the foredunes, inhibiting revegetation. With loss of recreational beach has come a loss of turtle-nesting habitat and diminishment of a vegetative buffer between the ocean and development.

Bogue Banks is eroding, but not fast enough to create economic incentives to relocate. The proposed project, rather than continuing the present cycle of scraping after every storm, has a better chance of restoring the natural character of the beach and reducing the need to scrape. The project scale proposed by the applicant is sufficient to provide recreation and storm-protection benefits for at least one decade.

In closing, I wish to express my firm's commitment to executing the project in as environmentally sensitive a manner as practicable and reasonable. However, I do not believe it is possible for any project to achieve all four conditions recommended by Dr. Peterson. We will be happy to meet with your agency and UNC-IMS representatives at any time to develop an acceptable biological monitoring plan for the project.

Thank you for your consideration.

Yours truly,

Tim Kana

Timothy W Kana PhD
Project Director

cc: State Clearinghouse, Chrys Baggett
Carteret County, Frank Rush
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
CSE, Bill Forman

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

April 04, 2001

Mr. Doug Huggett, CAMA Permit Coordinator
NC Division of Coastal Management
1638 Mail Service Center
Raleigh NC 27699-1638 Fax: 919-733-1495

RE: Response to Comments dated 13 March 2001 from Environmental Defense
Bogue Banks Beach Restoration Plan (2049) [SCH File #01-E-4300-0357]

Dear Mr. Huggett:

This letter is in response to Environmental Defense comments dated 13 March 2001 on the above-referenced draft environmental impact statement.

Item 1) Concerns regarding cumulative and long-term impacts and schedule for construction
Response: The question of cumulative impacts is important and should be addressed in some manner by state and federal agencies. However, this is not a trivial exercise and certainly not one that can be accomplished in a reasonable amount of time. It will take millions of dollars to even begin to evaluate this problem in any sort of rigorous way, given the wide range of variables that must be sampled, analyzed, modeled, and integrated. This is a global concern. I believe that years of effort would be required just to develop a scientific sample design or statistical model upon which professionals could agree. The question of cumulative impacts spans the disciplines of oceanography, geology, biology, chemistry, water quality, fisheries, primary production, climate, rainfall, runoff, and anthropogenic inputs of man. This is not something that can be answered before the next damaging storm impacts Bogue Banks.

A growing body of research shows that borrow area dredging and beach nourishment produce short-term, temporary impacts (cf, Van Dolah et al, 1992; Jutte et al, 1999a; 1999b; referenced in the draft EIS, Appendix A). These can be minimized by proper matching of sediments and construction in colder months (as planned for the present project). After the project is complete, there will be nearly the same area of intertidal and offshore habitat available as before the project. It will simply be displaced seaward by the width of the new beach. Environmental studies of similar projects suggest impacted areas will recolonize rapidly. The primary questions for project monitoring are how fast will the borrow area and beach communities recover and how closely will the benthic populations match the native conditions. In theory, these should be easy questions to answer. But in reality, natural populations fluctuate over such wide ranges that there can never be assurance that a change in species numbers or diversity is due to anthropogenic impacts like dredging rather than some global impact such as water temperature change. Recently, South Carolina closed its spring shrimp fishery because the white shrimp larvae count was less than 5 percent of normal for this time of year. The decline was attributed to a prolonged cold snap where water temperatures fell below 45°F for more than 18 days. Such order-of-magnitude declines are common in natural systems and will occur off Bogue Banks as well, whether or not the project is constructed.

The correspondent expresses concern about downstream impacts if the project is performed discontinuously in sections and cites page 5-2 of the draft EIS. The study referenced (Roessler, 1998) relates to the possible effect of an offshore disposal mound near Beaufort Inlet encompassing nearly 30 million cubic yards. This artificial feature built over 30 years in connection with USACE navigation projects may have altered wave/current patterns along Atlantic Beach, although no historical data exist to prove this. The proposed project will not alter the nearshore bottom such that it changes the wave and current patterns to the detriment of downstream communities (cf, Appendix G). The scale of the borrow-area changes for the proposed project are dwarfed by changes around Beaufort Inlet and the offshore mound.

Regarding possible adverse end effects of the project, this will be minimized by tapering of the fill sections as described in the draft EIS and in responses to NCDENR comments in the correspondence section of the draft EIS. Adjacent unnourished areas will tend to benefit rather than suffer from the downstream spread of the beach fill. Many nourishment projects, in fact, are designed as "feeder" beaches whereby sand is placed every few years along an updrift reach in order to flow downcoast and nourish other sections (CERC, 1984). Probably the worst "end effects" occur in <u>natural</u> systems where shoals break free of inlets and bypass to the adjacent beach. As the process occurs, the beach in the lee of the shoal accretes rapidly while the adjacent sections erode. This has been documented in many places (cf, Kana et al, 1985; 1999) and is illustrated schematically in Figure A. The reason that natural shoal bypassing produces adverse end effects is because it tends to concentrate large volumes over short lengths of beach. The proposed project will spread sand relatively thinly and evenly along many miles of shoreline such that perturbations in the shoreline will be minimal.

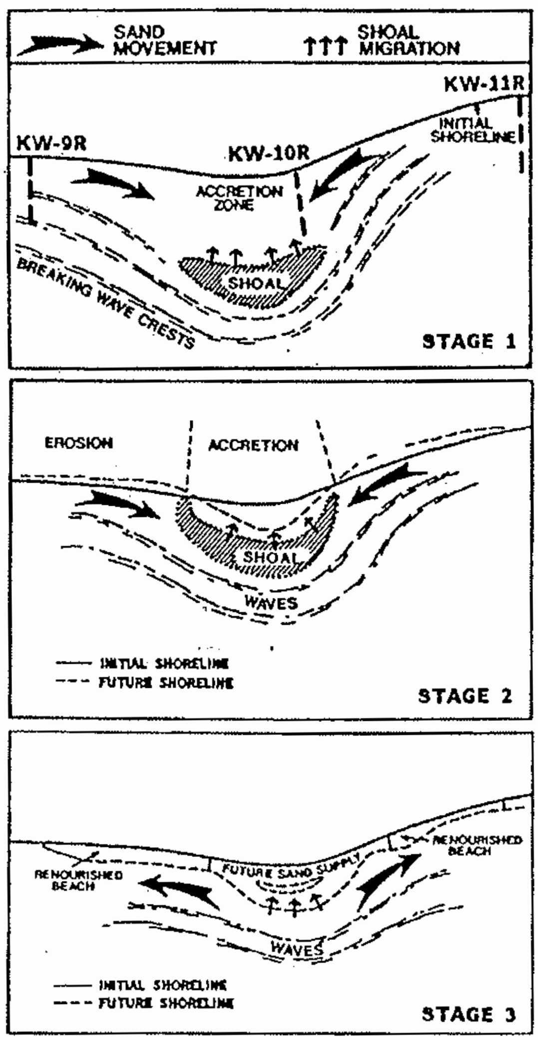


FIGURE A.

CSE

Item 2) Definition of project success
As engineers for the applicant, my firm is developing quantitative criteria for defining project success. The key variable is the volumetric erosion rate. In our review of prior studies, we found no historical profiles or surveys which could be used as a rigorous basis for predicting this rate. The only data available were linear shoreline change rates (eg, movement of mean high water or vegetation lines) and limited sets of wading depth profiles (not comprehensive for the entire project area). We used these data to extrapolate volumetric changes and estimate approximate beach fill requirements for 5-year, 10-year, and 20-year periods (CSE Stroud, 1999). The applicant has initiated annual surveys of the nearshore and has obtained two sets of 110 profiles spanning the length of Bogue Banks. Each profile extends about 1,000 ft offshore and documents changes to the outer bar.

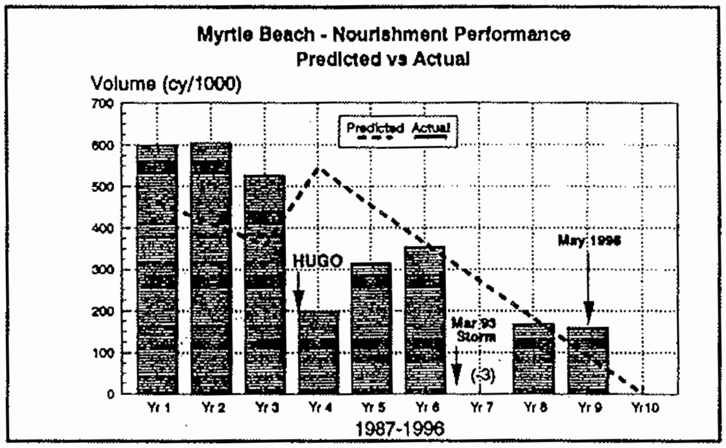
Enclosed is the first beach monitoring report covering the period June 1999 to June 2000. Also contained in the report are about 18 post-*Floyd* profiles from September 1999. The results show a range of erosion and accretion losses and provide more guidance for establishing project erosion rates. However, we consider these data to be insufficient to make any more refined long-term predictions because they only span one year. The applicant plans to resurvey the beach in June 2001 and update these data. As we have represented in the draft EIS, the anticipated volume losses are expected to be of the order 1-5 cy/ft/yr measured to closure depth. The rate will be closer to the high range if borrow areas B1 and B2 (less shelly deposits) are used and closer to the low range if area A (more shelly deposit) is used. Regardless of the rate, the applicant plans to perform annual surveys and quantify the fate of the beach fill such that a more rigorous erosion rate estimate can be developed for Bogue Banks over the next decade.

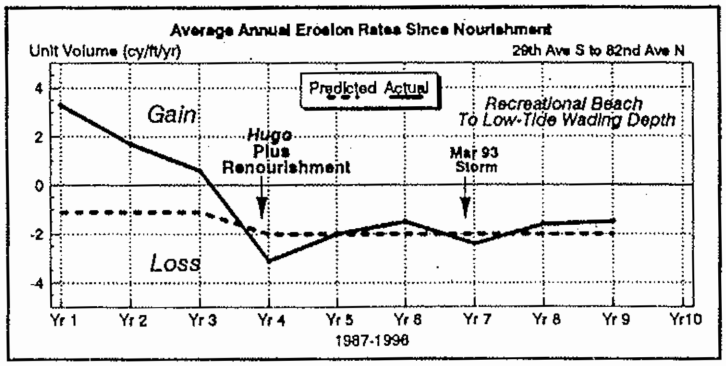
Figure B illustrates similar results for a project in Myrtle Beach (SC). In that particular project, the unit fill volumes were only about one-third the quantities proposed for Bogue Banks. Historical data suggest that Myrtle Beach and Bogue Banks have nearly equal long-term erosion rates.

CSE is in the process of developing "specific evaluation criteria" in consultation with the sponsoring communities. These will be particular to each borrow area(s). In general, the most appropriate criteria are volumetric erosion rates rather than some particular beach width because it is the littoral volume that is important in the long run. Short-term, beach-width fluctuations are poor predictive parameters because they are contour sensitive. For example, Hurricane *Floyd* produced a certain average dune recession (~12 ft) but matched it with seaward movement of mean high water (cf, CSE, 2000 – attached report).

CSE

FIGURE B.





Item 3) The correspondents question one aspect of the project purpose – "preservation of the environmental, cultural and aquatic resources of the county"

We disagree with the correspondent's contention that nourishment projects do not enhance or preserve the nation's living marine resources. It is well established that nourished beaches have restored turtle nesting habitat and vegetated dunes along many coasts that previously were armored with seawalls and had no such habitats (cf, National Academy of Sciences, NRC, 1990; 1995). Nearby Atlantic Beach is one such example. Others include Miami Beach (FL) and Myrtle Beach (SC). Pea Island (NC), a wildlife preserve, has received several inputs of nourishment to counter erosion and maintain protection to valuable back barrier habitats. Considering the biologic value of estuaries and lagoons, any soft solutions like nourishment that maintain the integrity of barrier islands will protect and preserve critical habitats to some degree.

The proposed project will reduce the need for and frequency of sand scraping. This will allow dunes to build gradually with appropriate-sized aeolian sand. Presently, most of the foredunes are composed of medium to coarse sand, pebbles, and shells, an unnatural sediment scraped from the surf zone after recent hurricanes. This is not enhancing the dune habitat.

While undeveloped Core Banks and Shackleford Banks are accessible by boat, only a tiny number of visitors (order of 1-2 percent) go there compared to the numbers visiting Bogue Banks. People want access to the shore. Carteret County strikes a model balance between less accessible beach preserves (~65 percent of shoreline) and accessible recreational beaches (~35 percent). Further, there are no roads through these preserves, unlike the Hatteras National Seashore.

CSE

4) Comment on consideration of alternatives regarding abandonment and relocation
The economics of nourishment versus property abandonment can always be refined. However, at present, they are skewed strongly in favor of maintaining the beach as described in detail in the draft EIS. The correspondents assert that the proposed project will be performed piecemeal just as property abandonment would be piecemeal. However, the definition of piecemeal is not the same in this case. Property abandonment would necessarily be done on a lot-by-lot basis with protracted delays and litigation likely. Nourishment, by contrast, is planned for long segments of beach that encompass hundreds of properties. The first segments planned (Pine Knoll Shores and Indian Beach/Salter Path) span over seven miles. This length would be considered a relatively long nourishment project by any standard (CERC, 1984). The Town of Emerald Isle is presently evaluating the feasibility of completing a three-mile project (Reach 3 and part of Reach 2) in 2002-2003. That reach encompasses nearly 200 properties. Each community must make careful decisions in the future regarding whether to continue nourishment or move toward abandonment. The problem now is that there are insufficient historical data to make this determination. The proposed project will offer an opportunity to establish on a site-by-site basis whether nourishment is viable for Bogue Banks. Evidence from the 1986 and 1994 nourishments of Atlantic Beach suggest overwhelmingly that it is viable in this setting. Further, some longtime opponents of coastal development such as Prof. Orrin Pilkey (Duke University) have stated that Bogue Banks is among the best candidate sites for nourishment in North Carolina.

Regarding the concern about beach scraping, the draft EIS makes clear that the proposed project will reduce the need for and frequency of sand scraping. We did not say it would eliminate it because certain contingencies may move property owners to demand scraping after a major storm. However, we expect the political pressure to scrape will be dramatically reduced after the projects just as it has been along Atlantic Beach. A tour of that site confirms that almost no sand scraping was performed after Hurricane *Floyd*, whereas the communities of Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle scraped nearly the entire foredune.

5) Concerns regarding monitoring programs
The applicant is committed to a self-funded monitoring plan which will be developed in consultation with the appropriate regulatory agencies.

6) Concerns regarding proposed North Carolina Marine Fisheries Commission policies on beach dredge and fill activities
To the best of our knowledge, the referenced policies have not yet been certified by the state. The majority of issues raised by these new policies are addressed in the draft EIS. NCDENR has reviewed and approved the draft EIS. The applicants are striving to improve upon existing nourishment practice and work within the present regulatory framework. In fact, it will only be through properly designed and executed projects and long-term monitoring (as planned by the applicant) that state and federal

CSE

agencies can develop realistic and practical policies for protecting marine resources and maintaining the integrity of developed barrier islands via soft engineering solutions. The applicant expects to contribute knowledge regarding impacts after execution of the project such that our regulatory agencies may improve their management of coastal resources.

I hope the above responses adequately address the concerns raised by Environmental Defense. If you need additional clarification, please contact us at the earliest time.

Thank you for your consideration.

Yours truly,

Tim Kana

Timothy W Kana PhD
Project Director

cc: State Clearinghouse, Chrys Baggett
Carteret County, Frank Rush
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
CSE, Bill Forman

APPENDIX A

APPENDIX A. REFERENCES

Ackerman, R.A. 1996. The nest environment and the embryonic development of sea turtles. In Lutz, P.L. and J.A. Musick (eds), *The Biology of Sea Turtles*, CRC Press, Boca Raton, FL, pp. 83-106.

Allen, D. 2000. North Carolina Wildlife Resources Commission. Personal communication regarding the occurrence and distribution of piping plovers and other rare birds in the Bogue Banks area. February, 2000.

Barnes, J. 1998. *North Carolina's Hurricane History.* The University of North Carolina Press, Chapel Hill & London, 256 pp.

Boettcher, R. 2000. North Carolina Sea Turtle Coordinator, North Carolina Wildlife Resources Commission. Personal communication regarding the number of loggerhead sea turtle nests found in the project area between 1995 and 1999.

Bowen, P.R., and G.A. Marsh. 1988. Benthic faunal colonization of an offshore borrow pit in southeastern Florida. Misc. Rept. No. D-88-5, Dredging Operations Technical Support Program, U.S. Army Corps of Engineers.

CERC. 1984. *Shore Protection Manual.* 4th Edition, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Vir.; U.S. Government Printing Office, Washington, D.C., 2 vols.

CSE Baird/Stroud. 1999. Shoreline assessment and preliminary beach restoration plan: Bogue Banks. Executive Summary Report, 38 pp.

Clark, M.K. 1993. Curator of Mammals, North Carolina State Museum of Natural Sciences. Personal communication regarding seasonal distribution of manatees in the Cape Fear region. In Biological Assessment: Channel Realignment Masonboro Inlet, New Hanover County, NC, August 1995, USACOE, p. 6.

Conant, T. 1993. Humpback whale: *Megaptera novaeangliae.* In *Wildlife Profiles.* Division of Conservation Education, North Carolina Wildlife Resources Commission, Raleigh, NC.

Crain, D.A., A.B. Bolten, and K.A. Bjorndal. 1995. Effects of beach nourishment on sea turtles: review and research initiatives. *Restoration Ecology*, Vol. 3(2), pp. 95-104.

Dean, R.G. 1991. Equilibrium beach profiles: characteristics and applications. Jour. Coastal Research, Vol. 7(1), pp. 53-84.

Donaghue, C.R. 1999. The influence of swash processes on *Donax variabilis* and *Emerita talpoida.* Ph.D. dissertation. University of Virginia.

Elefson, E. 1999. Concerning hopper dredges. Personal communication, Weeks Marine, August.

Epperly, S.P., J. Braun, & A. Veishlow. 1995. Sea turtles in North Carolina waters. *Conservation Biology*, Vol. 9(2), pp. 384-394.

Fussell, J. 1996. Comments about piping plover, beach amaranth, and other declining species on south spit of Figure Eight Island.

Hackney, C.T. and M.H. Posey, S.W. Ross, and A.R. Norris. 1996. A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach renourishment. Report to the U.S. Army Corps of Engineers, Wilmington, NC. 111 pp.

Hancock, T.E. 1995. Ecology of the threatened species seabeach amaranth (*Amaranthus pumilus* Rafinesque). M.S. Thesis, University of North Carolina at Wilmington.

Hanes, D.M. 1994. Turbidity and suspended sediment associated with beach nourishment dredging. In Proc. 24th Intl. Conf., Coastal Engineering '94, ASCE, New York, NY, Vol. 3, pp. 3016-3029.

Heron, S.D., T.F. Moslow, W.M. Berelson, J.R. Herbert, G.A. Steele, and K.R. Susman. 1984. Holocene sedimentation of a wave-dominated barrier-island shoreline: Cape Lookout, North Carolina. *Marine Geology*, Vol. 60, pp. 413-434.

Hine, A.C., and S.W. Snyder. 1985. Coastal lithosome preservation: evidence form the shoreface and inner continental shelf off Bogue Banks, North Carolina. *Marine Geology*, Vol. 63, pp. 307-330.

James, W.R. 1975. Techniques in evaluating suitability of borrow material for beach nourishment. Rept. No. TM-60, CERC, U.S. Army Waterways Experiment Station, Vicksburg, Miss.

Jensen, R.E. 1983. Atlantic coast hindcast, shallow-water significant wave information. WIS Rept. No. 9, Waterways Experiment Station, USACE, Vicksburg, MS, 19 pp. + app.

Jutte, P.C., R.F. Van Dolah, and M.V. Levisen. 1999a. An environmental monitoring study of the Myrtle Beach renourishment project: interitdal benthic community assessment — Phase II, Myrtle Beach. Final Report, SC Dept. Natural Resources, Charleston, 34 pp. + app.

Jutte, P.C., et al. 1999b. An environmental monitoring study of the Myrtle Beach renourishment project: physical and biological assessment of offshore sand borrow sites: Phase I, Cherry Grove borrow area. Final Report, SC Dept. Natural Resrouces, Charleston, 79 pp. + app.

Kana, T.W. 1993. The profile volume approach to beach nourishment. In D.K. Stauble and N.C. Kraus (eds.), *Beach Nourishment Engineering and Management Considerations*, ASCE, New York, N.Y., pp. 176-190.

Kana, T.W., and R.K. Mohan. 1996. Profile volumes as a measure of erosion vulnerability. In Proc. 25th Intl Conf., Coastal Engineering '96, ASCE, New York, NY, Vol. 3, pp. 2732-2745.

Kana, T.W., and R.K. Mohan. 1998. Analysis of nourished profile stability following the fifth Hunting Island (SC) beach nourishment project. Jour. Coastal Engineering, Vol. 33, pp. 117-136.

Knowles, C.E., J. Langfelder, and R. McDonald. 1973. A preliminary study of storm-induced beach erosion for North Carolina. Rept. No. 73-5, North Carolina State University, 14 pp. + figs.

Morrimen, J. 1982. Feeding ecology of sea turtles. *Biology and Conservation of Sea Turtles.* Smithsonian Institute Press, Washington, D.C.

Moser, M.L. and S.W. Ross. 1995. Habitat use and movements of shortnose and Atlantic sturgeons in the Low Cape Fear River, North Carolina. Transactions of the American Fisheries Society. 124 (2): 225-235.

NAS. 1995. *Beach Nourishment and Protection.* Committee on Beach Nourishment and Protection, Marine Board, Commission on Engineering and Technical Systems, National Research Council; National Academy Press, National Academy of Sciences, Washington, DC, 334 pp.

NCNHP. 1995. Seabeach amaranth survey, July 13-14, 1995, for Figure Eight Island, North Carolina. Unpublished data, NC Natural Heritage Program, Raleigh.

NRC. 1995. Beach Nourishment and Protection. National Research Council, National Academy Press. Washington, DC. 334 pp.

Navqi, S.M., and C.H. Pullen. 1982. Effects of beach nourishment and borrowing on marine organisms. Misc. Rept. No. 82-14, CERC, U.S. Army Corps of Engineers.

Nummedal, D., G.F. Oertel, D.K. Hubbard, and A.C. Hine. 1977. Tidal inlet variability — Cape Hatteras to Cape Canaveral. In Proc. Coastal Sediments '77, ASCE, New York, NY, pp. 543-562.

Peterson, C.H., D.H.M. Hickerson, and G. Grissom Johnson. 1999. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of the sandy beach. In press, *Journal of Coastal Research.*

Pilkey, O.H. et al. 1998. *The North Carolina Shore and Its Barrier Islands.* Duke University Press, Durham, NC, 318 pp.

Pullen, E.J., and S.M. Naqvi. 1983. Biological impacts on beach replenishment and borrowing. CERC Reprint 83-3, U.S. Army Corps of Engineers.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1964. *Manual of the Vascular Flora of the Carolinas.* The University of North Carolina Press, Chapel Hill, NC.

Reed, A. 1997. Sediment distribution patterns offshore of a replenished beach: Atlantic Beach and Fort Macon State Park, North Carolina. Unpubl. M.S. Thesis, Univ. North Carolina, Chapel Hill, 74 pp. + app.

Reilly, F.J. Jr. and V.J. Bellis. 1978. A study of the ecological impact of beach nourishment with dredged materials on the intertidal zone. Institute for Coastal and Marine Resources Technical Report. No. 4.

Reilly, F.J., and V.J. Bellis. 1983. The ecological impact of beach nourishment with dredged materials on the intertidal zone at Bogue Banks, North Carolina. USACE, CERC, Ft. Belvoir, VA, Misc. Paper 83-3.

Roessler, T.S. 1998. Effects of offshore geology and the Morehead City harbor project on eastern Bogue Banks, North Carolina. M.S. Thesis, Univ. North Carolina, Chapel Hill, 112 pp.

Rohde, F. 2000. Biological Supervisor, North Carolina Division of Marine Fisheries. Personal communication about the occurrence of shortnose sturgeon within the project area. February 17, 2000.

Ross, S.W. and J.E. Lancaster. 1996. Movements of juvenile fishes using surf zone nursery habitats and the relationship of movements to beach nourishment along a North Carolina beach: pilot project. National Oceanic and Atmospheric Administration Award No. NA570Z0318.

Saloman, C.H., and S.P. Naughton. 1984. Beach restoration with offshore dredged sand: effects on nearshore macrofauna. NOAA Tech. Memo. NMFS-SEF-133, U.S. Dept. Commerce.

Sarle, L.L. 1977. Processes and resulting morphology of sand deposits within Beaufort Inlet, Carteret County, North Carolina. M.S. Thesis, Duke Univ., Durham, NC, 171 pp.

Schmidly, D.J. 1981. Marine mammals of the southeastern United States coast and the Gulf of Mexico. Report No. 80/41, Office of Biological Services, U.S. Fish and Wildlife Service, 165 pp.

Schwartz, F.J. 1977. *Caretta caretta caretta* (Linnaeus), Atlantic loggerhead; *Chelonia mydas* (Linnaeus), Altantic green turtle; *Eretmochelys imbricata imbricata* (Linnaeus), Atlantic hawksbill; *Lepidochelys kempi* (Garman), Atlantic ridley; *Dermochelys coriacea coriacea* (Linnaeus), Atlantic leatherback (pp. 303-308). In Cooper, J.E., S.S. Robinson, and J.B. Funderburg (eds). *1977 Endangered and Threatened Plants and Animals of North Carolina* (444 pp). NC State Museum of Natural History, Raleigh.

Slay, C. 1993. Right Whale research project, New England Aquarium. Personal communication regarding seasonal occurrence of right whales of the Cape Fear region. In Biological Assessment: Channel Realignment Masonboro Inlet, New Hanover County, NC, August 1995, USACOE, p. 5.

USACE. 1966. Beaufort Inlet to Bogue Inlet, North Carolina. U.S. House Document No. 479, 89th Congress, U.S. Army Corps of Engineers.

USACE. 1976. General design memorandum: Morehead City Harbor, North Carolina. Wilmington District, USACE, 41 pp. + app.

USACE. 1978. Bogue Banks historical beach profile data set. Digital files provided by Tom Jarrett, Wilmington District, U.S. Army Corps of Engineers.

USACE. 1989. Supplemental biological assessment: Operation and Maintenance of Morehead City Harbor. Carteret County, North Carolina. July, 1989; pp. 5.

USACE. 1992. Design memorandum and environmental assessment: harbor improvement, Morehead City, North Carolina. U.S. Army Corps of Engineers, 50 pp. + app.

USACE. 1992-1995. Seabeach amaranth surveys. Unpublished data. U.S. Army Corps of Engineers, Wilmington District, NC.

USACE. 1993. Environmental assessment and finding of no significant impact. Disposal of dredged material on the ocean beach of Bogue Banks from combined maintenance dredging and deepening of Morehead City harbor and pumpout of Brandt Island upland diked disposal site, Carteret County, North Carolina. Wilmington District, U.S. Army Corps of Engineers, 12 pp. + app.

USACE. 1995. Environmental assessment: channel realignment maintenance dredging, Masonboro Inlet, New Hanover County, North Carolina. U.S. Army Corps of Engineers, pp. 9-15.

USACE. 1999. Preliminary Section 111 evaluation, Morehead City Harbor/Pine Knoll Shores, North Carolina. Provided by Tom Jarrett, Wilmington District, U.S. Army Corps of Engineers.

USEPA. 1983. Final environmental impact statement (EIS) for Savannah (GA), Charleston (SC), and Wilmington (NC) ocean-dredged material disposal sites designation. U.S. Environmental Protection Agency, Washington, DC.

USFWS. 1991. *Endangered and Threatened Species of the Southeast United States.* U.S. Fish and Wildlife Service.

USFWS. 1992a. Area south of Carolina Beach. Draft Fish and Wildlife Coordination Act Report. Division of Ecological Services, Raleigh Field Office, NC.

USFWS. 1992b. *Threatened and Endangered Species of Texas.* Endangered Species Office, Albuquerque, New Mexico.

USFWS. 1995. Seabeach amaranth technical/agency draft recovery plan, September 1995. U.S. Fish and Wildlife Service, Atlanta, GA, 75 pp.

USFWS. 1996. Piping plover (*Charadrius melodus*), Atlantic coast population, revised recovery plan. Hadley, MA, 258 pp.

USFWS. 1999a. West Indian manatees in North Carolina. http://web.ral.r4.fws.gov/mammal/manatee.html.

USFWS. 1999b. Roseate terns in North Carolina. http://web.ral.r4.fws.gov/birds/rosetern.html.

USFWS. 1999c. Shortnose sturgeon in North Carolina. http://web.ral.r4.fws.gov/fish/shortst.html.

Van Dolah, R.F., and D.M. Knot. 1984. A biological assessment of beach and nearshore areas along the South Carolina Grand Strand. Final Report, Dept. of the Interior, Fish and Wildlife Service. Marine Resources Div., SCWMR, Charleston, SC.

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levison, W.A. Roumillat. 1992. A physical and biological monitoring study of the Hilton Head Island beach nourishment project. Final Report to Town of Hilton Head Island, South Carolina; SC Wildlife & Marine Resources Div., Charleston, 159 pp.

Weakley, A.S. 1986. Summary of information on seabeach amaranth (*Amaranthus pumilus*). NCDHENR, Natural Heritage Program, Raleigh.

Weakley , A.S., and M.A. Bucher. 1992. Status survey of seabeach amaranth (*Amaranthus pumilus* Rafinesque) in North and South Carolina. Report to the North Carolina Plant Conservation Program and Endangered Species Field Office, 178 pp.

Wynne, B. 1999. Scoping information to be used in preparing an environmental document for the dredging of Mason Inlet, New Hanover County. North Carolina Wildlife Resources Commission, Raleigh.

APPENDIX B

A Submerged Cultural Resources Remote Sensing Survey of Three Proposed Borrow Areas for the Bogue Banks Beach Nourishment Project in Carteret County, North Carolina

Submitted to:

CSE Baird LLC
P.O. Box 8056
Columbia, South Carolina 29202-8056

and

Stroud Engineering, P.A.
Hestron Plaza Two, Suite A
151-A Highway 24
Morehead City, North Carolina 28557

Submitted by:

Tidewater Atlantic Research, Inc.
P. O. Box 2494
Washington, North Carolina 27889

3 February 2000

Abstract

Carteret County is planning to conduct a nourishment project to rebuild the beaches along Bogue Banks. The proposed project will require borrowing sand from three areas south of Pine Knoll Shores, Salter Path and Indian Beach. In order to determine the proposed project's impact on potentially significant submerged cultural resources, Stroud Engineering, P.A. and CSE Baird LLC contracted with Tidewater Atlantic Research, Inc., (TAR) of Washington, North Carolina to conduct a systematic proton precession magnetometer and side scan sonar survey. The proposed remote sensing survey was designed to locate and identify submerged cultural resources in the study areas and generate sufficient data to make an initial assessment of each target's significance and provide insight into the necessity for avoidance or additional investigation. That survey was carried out between 7 and 13 December 1999. No magnetic or acoustic anomalies were identified in either Borrow Area A or Borrow Area B-1. In Borrow Area B-2, 10 magnetic anomalies were identified near the western end of the survey area. Seven of those targets contained signature characteristics indicative of significant submerged cultural resources. Because they could be associated with an historic shipwreck, either avoidance or additional investigation to positively identify the nature and significance of material generating the seven anomalies is recommended. If avoidance of the area is possible, no additional investigation should be necessary.

Table of Contents

List of Figures

Introduction

Stroud Engineering, P.A., is working with Carteret County on beach renourishment projects on Bogue Banks. The source material for the project has been identified as three areas south of Pine Knoll Shores, Salter Path and Indian Beach. In order to determine the proposed project's effects on potentially significant submerged cultural resources, Stroud Engineering, P.A. and CSE Baird LLC contracted with Tidewater Atlantic Research, Inc., (TAR) of Washington, North Carolina to conduct a systematic proton precession magnetometer and side scan sonar survey to locate, identify and assess the significance of any underwater cultural material in the proposed borrow areas.

The investigation conducted by TAR was designed to provide accurate and reliable identification, assessment and remote sensing documentation of submerged cultural resources in the prospective project areas in terms of the criteria established in compliance with the National Historic Preservation Act of 1966, as amended and the Archaeological and Historic Preservation Act of 1979, as amended. The results of the investigation will provide Stroud Engineering, P.A. and CSE Baird LLC with the archaeological data essential for complying with submerged cultural resource legislation and regulations.

The methodology employed by TAR combined state of the art technology, experienced personnel and an investigative technique designed to generate appropriate historical and remote sensing data. Fieldwork activities associated with the project were carried out between 7 and 13 December 1999. Analysis of the remote sensing data identified 10 anomalies within the western part of Borrow Area B2. Seven of those targets contained signature characteristics indicative of significant submerged cultural resources and were recommended for further investigation. No magnetic or acoustic anomalies were detected in Borrow Areas A or B1.

Coordination for the survey was provided by Bill Forman, Stroud Engineering, and Phil McKee, CSE Baird. The field project staff included Dr. Gordon P. Watts, Jr., the principal investigator, archaeologists Raymond Tubby and Steve Brodie and archaeological assistants Mark Padover and Mike Phillips. Data analysis, historical research and report preparation were carried out by Gordon Watts, Raymond Tubby and Robin Arnold. All members of the project staff exceed the minimum standards for archaeological personnel identified by the Department of Interior and the North Carolina Division of Archives and History.

Project Location

The three Carteret County Borrow Areas are located south of Bogue Banks between Atlantic Beach and Emerald Isle. Borrow Area A forms an "L"-shaped polygon south-southeast of Salter Path and Indian Beach. Borrow Area B-1 is a long rectangular polygon offshore of and roughly parallel to the shoreline of the west extremity of Atlantic Beach and Pine Knoll Shores. Borrow Area B-2 is a long rectangular polygon offshore of and roughly parallel to the shoreline of Salter Path, Indian Beach and eastern Emerald Isle (Figure 1).

North Carolina State Plane Coordinates, NAD 1983 for Borrow Area A are:

Point	Northing	Easting
A	331043.56	2624077.59
B	341655.89	2623855.74
C	341761.05	2628865.86
D	338728.96	2628929.75
E	338861.61	2635193.01
F	331281.44	2635354.35

North Carolina State Plane Coordinates, NAD 1983 for Borrow Area B-1 are:

Point	Northing	Easting
A	350432.77	2670926.10
B	348405.98	2656162.79
C	346614.84	2644048.87
D	344906.79	2644085.74
E	346309.33	2656016.78
F	348359.78	2670922.61

North Carolina State Plane Coordinates, NAD 1983 for Borrow Area B-2 are:

Point	Northing	Easting
A	340961.55	2610140.28
B	342151.31	2616103.44
C	345657.97	2640081.60
D	343904.64	2640269.91
E	340397.98	2616480.06
F	338957.74	2610391.36

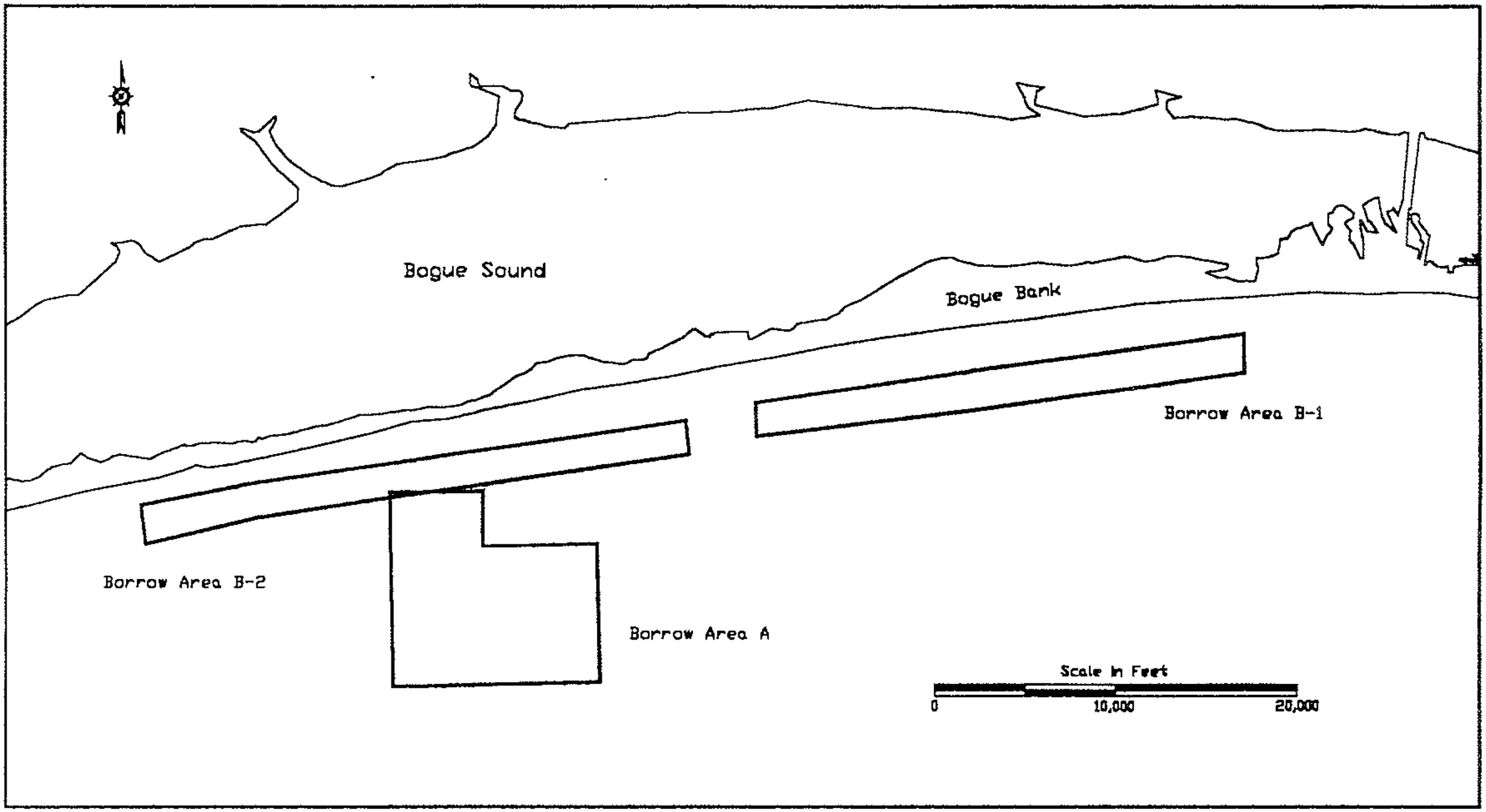


Figure 1. Project Location Map.

Project Research Objectives

The Bogue Banks Borrow Area survey was initiated in order to comply with the criteria of National Historic Preservation Act of 1966, as amended, through 1992 (36 CFR 800, Protection of Historic Properties), the Abandoned Shipwreck Act of 1987 (*Abandoned Shipwreck Act Guidelines*, National Park Service, *Federal Register*, Vol. 55, No. 3, 4, December 1990, pages 50116-50145) and the Secretary of Interior's Standards and Guidelines for Archaeology and Historic Preservation (*Federal Register* 48, No. 190, 1983). In keeping with the intent of that legislation and associated regulations Stroud Engineering and CSE Baird determined that a remote sensing survey would be necessary to assess the potential impact of proposed project activities on submerged cultural resources in the project areas. The remote sensing survey conducted by TAR was designed to identify magnetic and/or acoustic anomalies that might be generated by shipwreck resources, assess the potential significance of each one and determine the necessity for additional investigation designed to generate data to support a preliminary determination of National Register of Historic Places eligibility.

Research Methodology

Literature, Historical and Archival Research

In order to generate historical data to facilitate identification of shipwreck remains in the Beaufort/Morehead vicinity, records from a variety of repositories were examined. At the Underwater Archaeology Unit in Kure Beach, the archaeological site files were surveyed for both historic and prehistoric submerged archaeological sites in the Beaufort Inlet area. Similar surveys of site file inventories were also conducted in the Anthropology Department Research Laboratory and the Program in Maritime History and Underwater Research at East Carolina University in Greenville, North Carolina.

A literature and archival investigation was also initiated by a survey of secondary source materials associated with the historical development of eastern North Carolina. The survey focused on documentation of activities such as exploration, colonization, development, agriculture, industry, trade, shipbuilding, commerce, warfare, transportation and fishing that would have been contributing factors in the loss of vessels in the vicinity of the proposed borrow areas. In examining each of these factors special attention was devoted to activities associated with navigation in the vicinity of Beaufort Inlet.

Preliminary wreck specific information was collected from such secondary sources as: *The Encyclopedia of American Shipwrecks* (Berman 1972); *Merchant Steam Vessels of the United States 1807 - 1868* (Lytle and Holdcamper 1952); *Disasters to American Vessels, Sail and Steam, 1841-1846* (Lockhead 1954); *Shipwrecks of the Civil War, The Encyclopedia of Union and Confederate Naval Losses* (Shomette 1973); *Shipwrecks of the Western Hemisphere* (Marx 1971); *Shipwreck Encyclopedia of The Civil War: North Carolina, 1861-186* (Spence 1991) and other published materials. Additional information was also generated by a survey of selected North Carolina newspapers, the Wreck Information List of the U.S. Hydrographic Office, National Oceanic and Atmospheric Administration and maritime records associated with Beaufort and Morehead City. Select historic maps and charts preserved in the collections of the National Archives Cartographic Branch in College Park, MD and North Carolina repositories of cartographic data were also examined.

Relevant sources of shipwreck data preserved in the North Carolina Division of Archives and History in Raleigh; Underwater Archaeology Unit of the Division of Archives and History at Kure Beach; the Steamship Historical Society, Baltimore; Mystic Seaport Museum, Connecticut; the National Archives and the Mariners Museum at Newport News, Virginia were surveyed for site specific data associated with the Beaufort Inlet, Bogue Bank and Shackleford Bank areas. TAR personnel also contacted and interviewed the head of the Underwater Archaeology Unit, area archaeologists, historians and other individuals knowledgeable in maritime history and shipwreck research to solicit their assistance in generating wreck data.

Field Investigations

To reliably identify submerged cultural resources, TAR conducted a systematic remote sensing survey of the proposed borrow areas identified in the Scope of Work. TAR personnel utilized 31-foot and 25-foot vessels to conduct the survey. In order to fulfill the requirements stated in the Scope of Work, TAR employed both magnetic and acoustic remote sensing equipment. A combination of magnetic and acoustic remote sensing equipment represent the "state-of-the-art" in submerged cultural resource location technology and offers the most reliable and cost effective method of locating and identifying potentially significant targets. Data collection was controlled using a differential global positioning system (DGPS). The DGPS produces the highly accurate coordinates necessary to support a sophisticated navigation program and assure reliable target location.

Magnetic Remote Sensing

An EG&G Geometrics 866 dual channel proton precession magnetometer capable of plus or minus 0.1 gamma resolution was employed to collect magnetic data in the survey areas. To produce the most comprehensive magnetic record, data were collected on a two-second interval and the sensor was deployed and maintained in the water column at a depth of 10 to 12 feet above the bottom surface. An analog recorder provided a continuous permanent record of the magnetic background and target signatures. Because of the historical nature of the area, magnetic data were collected along transects spaced on 100-foot intervals and recorded on both an analog recorder and as a data file associated with the computer navigation system. Data from the survey were contour plotted using QuickSurf computer software to facilitate anomaly location and definition of target signature characteristics. All magnetic data were correlated with the acoustic remote sensing records.

Acoustic Remote Sensing

A 500 kHz Klein 521 high resolution side scan sonar was employed to collect acoustic data in the survey area. During the survey, the side scan sonar transducer was deployed and maintained at a 10-foot elevation above the bottom surface. Because of the historical nature of the area and the requirements for collecting magnetic data, acoustic data were also collected along transects spaced on 100-foot intervals. Sonar range scales were selected to provide a combination of 100% coverage of the survey area and high target signature definition. Acoustic data were recorded on a two channel wet-paper recorder and tied to the magnetic and positioning data by the computer navigation system event marking program.

Positioning System

A differential global positioning system (DGPS) was used to control navigation and data collection in the survey areas. The system has an accuracy of plus or minus three feet, and can be used to generate highly accurate coordinates for the computer navigation system. Differential corrections were received from the United States Coast Guard Beacon at Fort Macon, North Carolina. A Furuno GP-35 differential global positioning system was employed in conjunction with on-board IBM compatible 486-66 BSI and Pentium 233MMX ProStar computers loaded with a Coastal Oceanographics Hypack navigation and data collection software program. All magnetic and acoustic records were tied to positioning events generated by Hypack. Positioning data generated by the navigation system were tied to magnetometer records by regular annotations to facilitate target location and anomaly analysis. Annotations included lane number, date, start and end of lane, direction and target identification.

Data Analysis

To ensure reliable target identification and assessment, analysis of the magnetic and acoustic data were carried out as it was generated. Using QuickSurf contouring software, magnetic data generated during the survey were contour plotted at 10 gamma intervals for analysis and accurate location of the material generating each magnetic anomaly. Magnetic targets were isolated and analyzed in accordance with intensity, duration, areal extent and signature characteristics. Sonagram signatures associated with magnetic targets were analyzed on the basis of configuration, areal extent, target intensity and contrast with background, elevation and shadow image.

Data generated by the remote sensing equipment were developed to support an assessment of each magnetic and acoustic signature. Analysis of each target signature included consideration of magnetic and sonar signature characteristics previously demonstrated to be reliable indicators of historically significant submerged cultural resources. Assessment of each target included recommendations for additional investigation to determine the exact nature of the cultural material generating the signature and its potential National Register significance. Historical evidence was developed into a background that identified possible correlations with magnetic targets. A magnetic contour map of each survey area was produced to aid in the analysis of each target. All targets were listed and described and a map produced that showed their location within the project area.

Historical Overview of Beaufort/Morehead City Vicinity

Among the earliest residents of Shackleford Banks and Cape Lookout during the late 1600s and early 1700s were whalers, who established a series of temporary camps and shelters amid the dunes. By the 1720s, Cape Lookout and Shackleford Banks became a more permanent base of operations for New England whalers (Angley 1982:5). When Beaufort was appointed as "a port for the unloading and discharging [of] vessels," in 1722 it was clear that successful development would also depend on trade entering and clearing through Beaufort Inlet (Paul 1970:370-373; Angley 1982:8). Unlike many of the inlets along the North Carolina coast, Beaufort Inlet was relatively stable and offered a safe and deep channel for ship traffic (Stick 1958:312).

Not all of the vessels bound for Beaufort were successful in navigating the inlet. In November 1718, the pirate Blackbeard lost two vessels on or near the bar. Both the ship *Queen Anne's Revenge* and the sloop *Adventure* were run aground, perhaps deliberately. Many of the crew of the *Queen Anne's Revenge* and the *Adventure* were abandoned on Shackleford Banks while Blackbeard and a hand-picked crew sailed for Bath in the remaining sloop.

Although Beaufort remained a relatively unimportant port during the 18th century it did play a small role in Revolutionary War maritime activity. While the blockade imposed upon the American coast by the British Navy seriously impacted trade for many Colonial ports, shipping through Beaufort provided a portion of the supplies needed by the Patriots in North Carolina. In the years that followed the Revolution, North Carolina experienced an increase in the volume of maritime trade and shipbuilding. Just after the turn of the century, Beaufort Inlet was described as one of the best on the North Carolina coast, with "the channel being generally 3 1/4 to 3 1/2 fathoms" deep. Beaufort was also mentioned as having a fairly vigorous, though small, shipbuilding industry (Tatham 1806). In 1810, Jacob Henry, a former representative from Carteret County to the North Carolina House of Commons, commented upon the local shipbuilding industry at Beaufort:

> The principal trade carried on here is ship building in which they have acquired a very considerable reputation.... Live oak and Cedar are the timbers principally used but the stock is by no means so abundant as it has been. Some of the swiftest sailors and best built Vessels in the United States have been launch'd here, particularly the Ship *Minerva*, a well known Packet between Charleston and New York. There are at present five Vessels at the Stocks, two of which are ready to be launch'd (Newsome 1929:399).

The Beaufort vicinity was severely battered by a hurricane that struck the area in 1815. The storm, later described as "being one of the most violent and disastrous ever known upon the coast," brought about significant changes to the bar at Beaufort. The bar was "injured so that but 12 feet could be brought over it at low water." Fortunately, the channel eventually recovered from the storm's damage and by 1830, the depth on the bar had increased to 18 feet at mean low water. By 1854, the bar channel had decreased to a depth of 15 1/2 feet and migrated slightly to the south (United States Congress, Senate Executive Document, No. 78, 33rd Congress, pp. 3-4).

Around 1841, John Motley Morehead, governor of North Carolina, had a vision of establishing a port facility at the eastern terminus of the Atlantic and North Carolina Railroad. A decision was finally reached in 1855 to locate the proposed port and rail facility on Sheppard's Point (Konkle 1922:339-340).

The editor of the Greensboro *Patriot* described the conditions and natural advantages which he believed would benefit maritime traffic through Beaufort Inlet to the new port facility at Morehead City in September 1858:

> The inlet at Beaufort Harbor is, we understand, about three-quarters of a mile wide, extending from the point on the Shackleford banks on the east to the point at Fort Macon on the west. Ships drawing from eighteen to twenty feet can cross the bar with safety. Ships crossing the bar, enter the harbor near the Shackleford banks, then bear in a westwardly direction toward Fort Macon. From the bar at the inlet, across the Sound to Beaufort, is about three miles, this being about the widest part of the harbor. The channel is in the form of a half-moon, one horn running eastwardly along the Shackleford banks, called Core Sound, and the other westwardly by Morehead and Carolina cities, which are situated on Bogue Sound. The deepest water is along Newport river, which runs in nearly a north direction between Morehead City and Beaufort, touching the railroad wharf in the former place. The main channel is about one mile wide, so that the inside of the channel would be some two miles from Beaufort, though vessels drawing from nine to ten feet water can approach the Beaufort wharves at full tide. Running up the channel about three miles from the bar, we come to the railroad wharf at Morehead City, where vessels drawing eighteen feet can approach with ease, and unload and take in lading with the greatest safety (Konkle 1922:341-342).

Within six months, the rail and port facility at Morehead City was prospering, much to the chagrin of the people of Beaufort. Ships were continually calling at the wharfs and being loaded with cargoes directly from train cars:

> Here a steamer drawing twenty feet of water, and the locomotive weighing twenty or thirty tons, with its whole train, may be along side each other; and this, too, on each side of the wharf at the same time, while in front other vessels may be loading or discharging cargoes (Konkle 1922:360-361).

The development of Morehead City was soon disrupted by the Civil War. On 22 March 1862, Union forces occupied Morehead City. Four days later Union troops crossed the Newport River and took control of Beaufort. Fort Macon also fell into Union forces under General Ambrose E. Burnside following a fierce one-day siege (Stick 1958:148-153). Preceding the final assault on Fort Macon, a Union gunboat and one or two smaller vessels were positioned inside Beaufort Inlet, controlling the approaches and exits to Bogue and Core Sounds. On 22 April, several Union vessels anchored near Harker's Island to the east of Beaufort, including the steamer *Alice Price* that served as General Burnside's temporary headquarters. When the fall of Fort Macon was imminent, Confederate forces burned the bark *Glen* to keep it out of Union hands. On 26 April, Colonel Moses J. White, commander of Fort Macon, surrendered to Generals Parks and Burnside on Shackleford Banks (Angley 1982:34; Stick 1958:148-153).

The occupation of Fort Macon and the surrounding vicinity provided Union naval forces with access to a deep-water port and a place of rendezvous that was used to support the blockading squadron throughout the remainder of the war. During December 1864 and January 1865, fleets under Admiral David Porter massed at Beaufort Harbor in preparation for their assault on Fort Fisher in Wilmington, the last major stronghold of the Confederacy in North Carolina. During the Civil War at least five Confederate vessels were captured at sea in the Cape Lookout area: the schooners *Edwin, Julia, Revere* and *Louisa Agnes* were captured in 1861 and the steamer *Banshee* was taken on 21 November 1863 (Angley 1982:35; Price 1948). One Confederate vessel was lost in the vicinity as a result of enemy action. On 9 July 1864, the side-wheel steamer *Pevensey* was chased ashore and blown up on Bogue Banks, approximately nine miles west of Beaufort Inlet (Hill 1975:11-13). Not all of the known shipwrecks near Beaufort were a result of enemy action. On 12 June 1863, the USS *Lavender* ran aground in heavy seas near Cape Lookout Shoals while en route from the Delaware Capes to Charleston. The *Lavender* was a screw tug of 173 tons. On 20 July 1865, the 186-ton Union screw steamer *Quinnebaugh* went ashore on Beaufort bar in rough weather after her machinery failed. The *Quinnebaugh* was transporting Union troops, refugees and civilians north at the time of her loss (Shomette 1973:88-89; Berman 1972:141; Lytle and Holdcamper 1975:291).

Six years after the Civil War, the federal government began measures to reduce the severity of maritime disasters along the coast by establishing the United States Lifesaving Service. In 1874, seven stations were established along the North Carolina coast. In 1875, a similar station was authorized by Congress for Cape Lookout, though it would be another ten years before it was finally built. Over the following years three other stations were established on Core Banks, and a facility was also established near Fort Macon, just west of Beaufort Inlet (Angley 1982:35-36; Stick 1958:169-170, 310-313).

Menhaden fishing became an important source of income for the Cape Lookout-Beaufort area in the years following the Civil War. From 1865 to 1873, the state's first menhaden processing plant was in operation on Harker's Island. By the turn of the century several plants were in operation at Beaufort and at various points on Bogue and Core Sounds (Hill 1975:16-18).

Growth of Beaufort and Morehead City as ports was slow during the late-19th and early 20th centuries. In the 1880s, the federal government began work on the improvement of Beaufort Inlet in the hopes of increasing the amount of maritime trade to the port communities. The depth over the bar in the later 19th century was just over 15 feet, but it was said that "the harbor entrance was rapidly deteriorating; its width, measured from Fort Macon to Shackleford Point, having increased 500 feet between the years 1864 and 1880" (Stick 1958:312; Angley 1982:39-40). By 1880, the width of the inlet had increased an additional 900 feet. As a means to prevent further erosion, jetties were constructed from both shores into the inlet. Over the next five years, five jetties were constructed on Shackleford Point and another six on Fort Macon Point. By 1889, the deterioration of the inlet had been brought under control (Angley 1982:40; Stick 1958:312).

Between 1905 and 1907, the channel across Beaufort Inlet bar was dredged to a depth of 20 feet at mean low water. A 20-foot channel, 200 feet wide, was also provided inside the inlet to the wharves at Morehead City. A smaller channel, seven feet deep and 100 feet wide, was dredged to the wharves along the Beaufort waterfront (Angley 1982:40). The Army Corps of Engineers submitted several reports between 1907 and 1914 that indicated that both Morehead City and Beaufort were growing centers of maritime trade. The majority of vessels utilizing the two ports were fishing boats and small, shallow-draft cargo vessels (Angley 1982:41). Beaufort Inlet was described in 1907 as being limited in importance:

> The present commerce through the inlet is small, owing in a large measure to the hitherto shallow draft of not generally more than 12 feet at mean low water that could be carried across the bar.
>
> The present annual commerce of Beaufort, N. C., the principal place on the water adjacent to this harbour, amounts to about 64,000 tons annually, valued at $3,500,000, of which only about one-fourth to one-fifth passes through the inlet (United States Congress, House Document No. 1454, p. 3).

Statistics for 1912 reflect that 12 sailing and 35 gasoline powered vessels totaling 570 net tons were registered at Morehead City. For the same year, the registry at the rival port of Beaufort listed 175 sailing vessels, 240 gasoline powered vessels and 6 barges with a net registered tonnage of 6,005 (Angley 1982:42; United States Congress, House Documents No. 1022:4-11 and No. 1108:6-7).

A number of vessels travelling along the coast became victims of maritime hazards. Between 1 July 1898 and 30 June 1908, 82 vessels were reported lost off the North Carolina coast (United States Congress, House Document No. 315, pp. 5-6). Several of those shipwrecks had themselves become hazards to navigation. On 20 and 27 February 1891, notices were printed in the Wilmington *Weekly Star* that the federal government was in the process of removing wrecks that had become obstacles to other vessels:

> Masters and owners of vessels engaged in the coastwise trade will be glad to know that the commanding Officer of the USS *Yantic* has been ordered to cruise along the coast from Sandy Hook to Charleston, S. C. and to destroy, as far as practicable, all abandoned wrecks which are dangerous to navigation. There are a number of these wrecks on the coast of North Carolina and Virginia.
>
> Off the North Carolina coast the *Yantic* will find the schooner *Dudley Farlin*, twenty-four miles northwest of Bodie Island Light; the schooner *Mollie J. Saunders*, seven miles southeast of the same light; the steamer *Glenrath*, south by west of Cape Lookout Light, four or five miles further in shore, the steamer *Aberlady Bay*, and a sunken wreck eighteen miles east-northeast of Frying Pan Shoal Lightship (Wilmington *Weekly Star*, 20 and 27 February 1891).

In a 1897 Congressional report the hazards found at Cape Lookout to maritime traffic were summarized by the captain of the life-saving station at Cape Lookout:

> I ascertain that, since 1888, 19 schooners, 6 steamships, and 1 bark were disabled or ashore around Cape Lookout that would have been unharmed in all probability, if a safe harbor had been near. Two of these steamships and many of the schooners proved total losses. Unknown wrecks are occasionally discovered on or near the shoals. Nine large vessels have been anchored south of the beach at one time during northeasters. When the wind shifted they had to go to sea. Twenty-two schooners have been seen at one time laying to under the lee of Lookout Shoals during a northeast gale, and 57 vessels have been sighted passing by in one day. The locality is being frequented more and more as seafaring men learn the advantage of it. The great danger at present is being caught in the great bight with a southerly gale (United States Congress, House Document No. 25, p. 5).

To prevent vessels from wrecking near Cape Lookout a lighthouse had been in use, but mariners often complained that the light was difficult to see. As a remedy, a lightship was placed at Cape Lookout Shoals in 1904 and remained in operation until 1933 when it was removed (Holland 1968:32-35; Stick 1958:310). In addition to the lightship, a lens lantern was erected in 1900 on Cape Lookout Bight for the "large number of vessels that seek a lee under Cape Lookout" (Holland 1968:32).

During World War I, Cape Lookout Bay served as a rendezvous and staging area for convoys bound for Europe, and Morehead City was occasionally used as a distribution point for war supplies. From 1926 to 1938, the federal government made considerable improvements to the Port of Morehead City by increasing the depth of the channel through Beaufort Inlet to 30 feet (Stick 1952:237-238). In 1923, the tug *Juno* sank in the Beaufort Inlet channel causing considerable difficulty for other vessels to pass. The *Juno* was eventually dynamited to clear the entrance. This earlier event may have been a contributing factor in recognizing the need for channel improvements (*The Evening Dispatch*, 23 July 1923; Berman 1972:128).

Hostilities in the Cape Lookout vicinity were much more evident during the events of World War II. For example, on the night of 18 March 1942, German submarines sank three tankers in the Cape Lookout area: the *Papoose*, the *W. E. Hutton* and the *E. M. Clark*. Five days later another tanker, the *Naeco* was sunk in the same vicinity (Stick 1952:234). As a result of the high number of vessel losses occurring during the early stages of the war, defensive measures were put into place. Coastal communities were systematically blacked out, a more efficient convoy system was devised and additional planes and patrol vessels were put into service for the Cape Lookout area and North Carolina coast in general (Stick 1952:237-239).

In the early 1950s, improvements were once again undertaken at Morehead City. By the summer of 1954, a project to widen the 30-foot channel to 300 feet to the terminal facilities, construct a 600-foot turning basin and dredge a 12-foot channel in Bogue Sound along the city's commercial waterfront was nearly completed (Angley 1982:48). By 1954, the main shipping channel to Beaufort had also been dredged to a depth of 12 feet and a width of 100 feet. The improvements could easily accommodate sports and commercial fishing vessels and pleasure craft, but was inadequate to handle large, deep-draft cargo vessels (Angley 1982:48). Since the mid-1950s, regular maintenance dredging has been undertaken at the channels leading into the Morehead City and Beaufort harbors. Today, Morehead City continues as a major deep-water port with several large vessels arriving monthly.

Summary of Findings

Investigation of the three borrow areas off Bogue Bank identified a total of 10 magnetic anomalies. No magnetic and/or acoustic anomalies were identified during remote sensing of Borrow Area A or Borrow Area B-1 (Figures 2, 3, 4). All ten of the identified anomalies were located in the western part of Borrow Area B-2 (Figures 5, 6). Analysis of the target signatures suggest that seven of the anomalies could be associated with shipwreck remains. It is recommended that those seven targets be avoided. In the event that they cannot be avoided, additional investigation is recommended to identify the nature and assess the significance of material generating the signatures. The remaining three targets contained signature characteristics suggestive of single ferrous objects and are not recommended for additional investigation.

Borrow Area A

No magnetic and/or acoustic targets were identified in Area A.

Borrow Area B-1

No magnetic and/or acoustic targets were identified in Area B-1.

Borrow Area B-2

Target Designation: B2-01

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2611456	341287	262	6

Potential: Low

Target B2-01 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 1 and the contoured signature consisted of data from the anomaly identified as 1.2 in the magnetometer records. The detectable signature had a maximum intensity of 262 gammas and a maximum duration of 6 two-second pulses (Figure 7). The contoured dipolar signature covered an area of approximately 19,800 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, as the anomaly lies on the

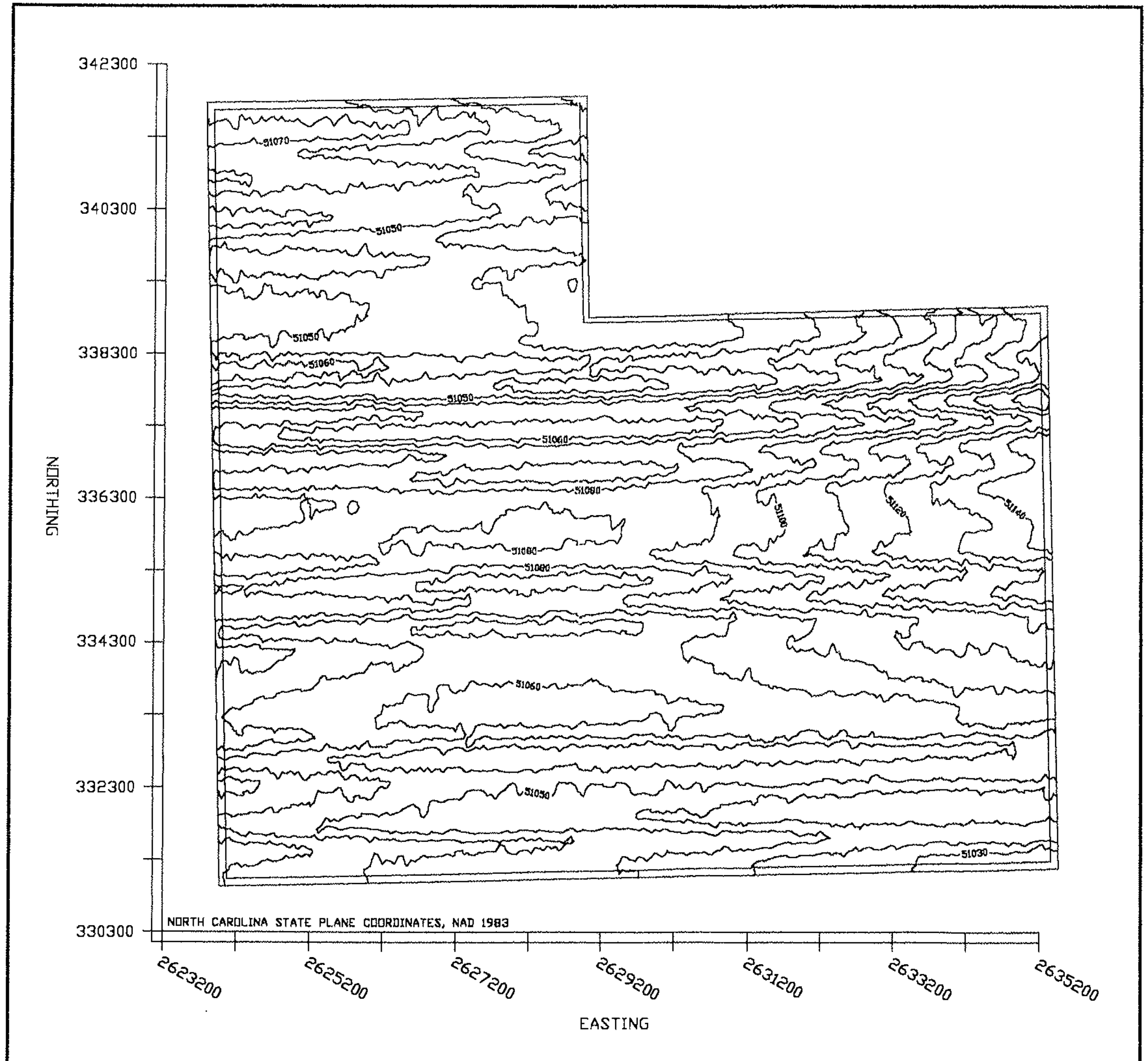


Figure 2. Magnetic contour map of Borrow Area A.

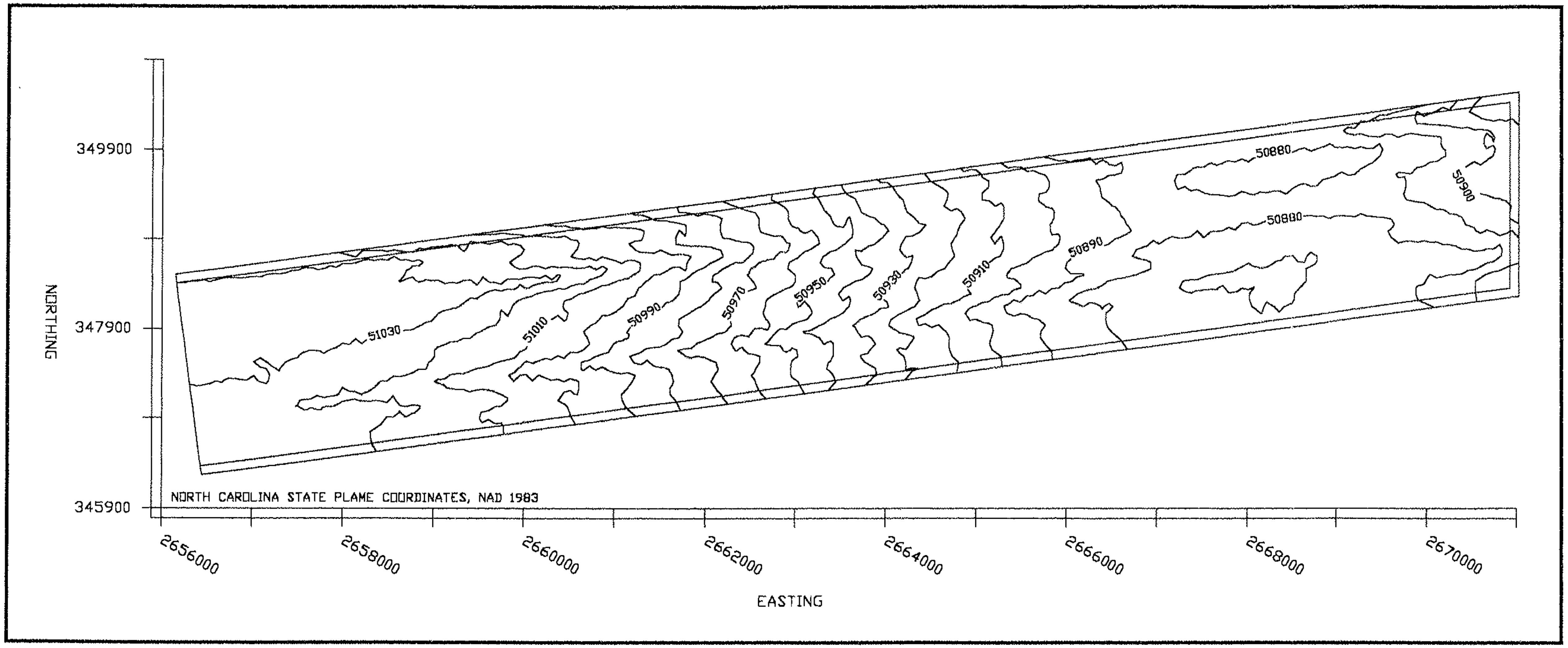


Figure 3. **Magnetic contour map of Borrow Area B-1 east end.**

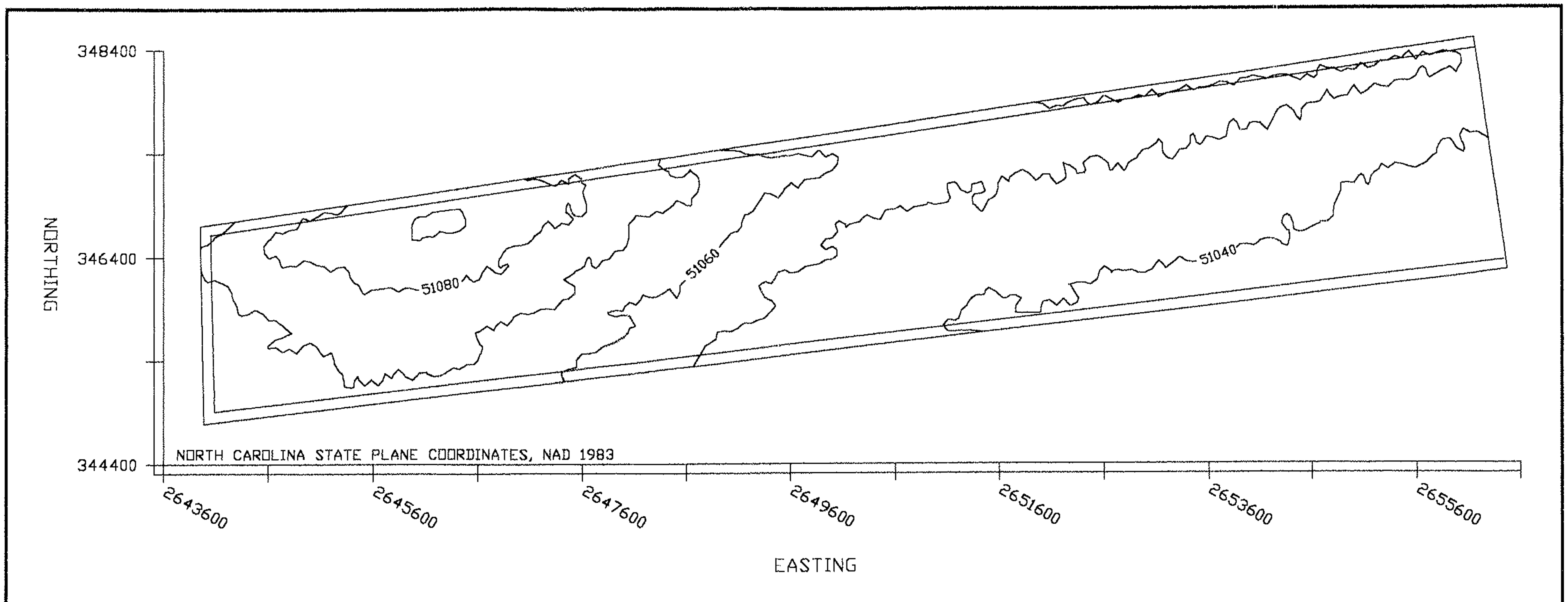


Figure 4. Magnetic contour map of Borrow Area B-1 west end.

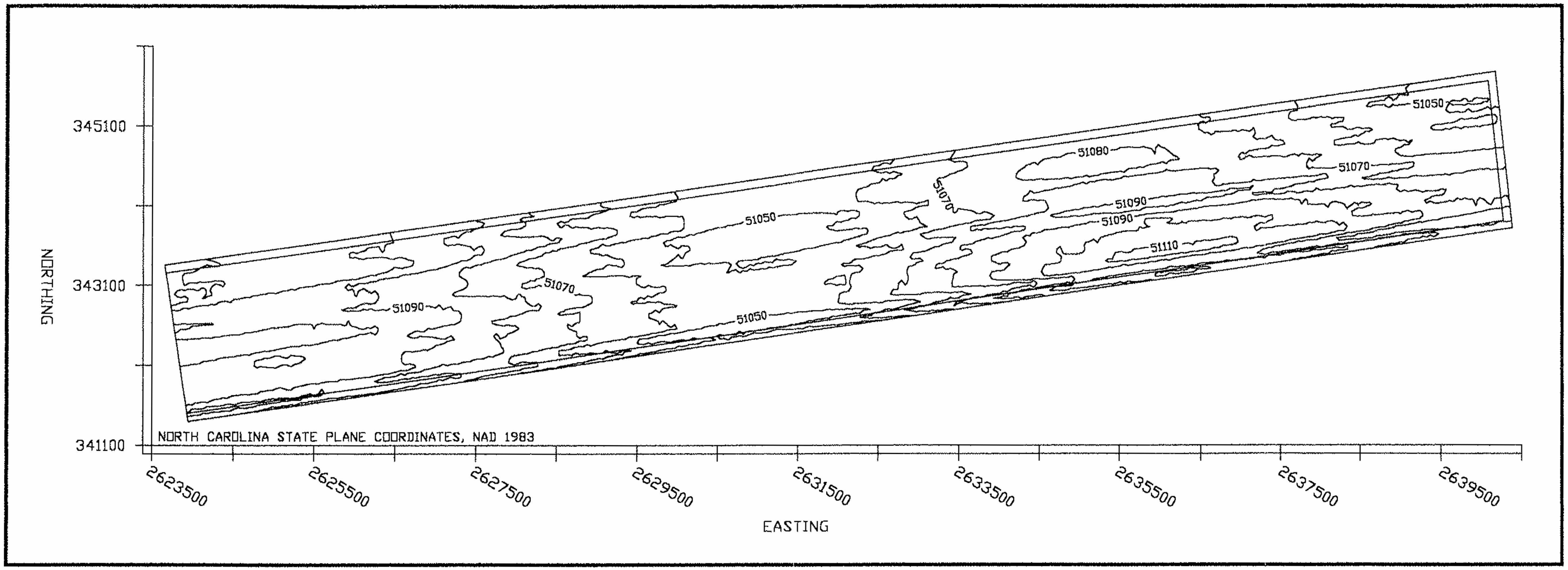


Figure 5. **Magnetic contour map of Borrow Area B-2 east end.**

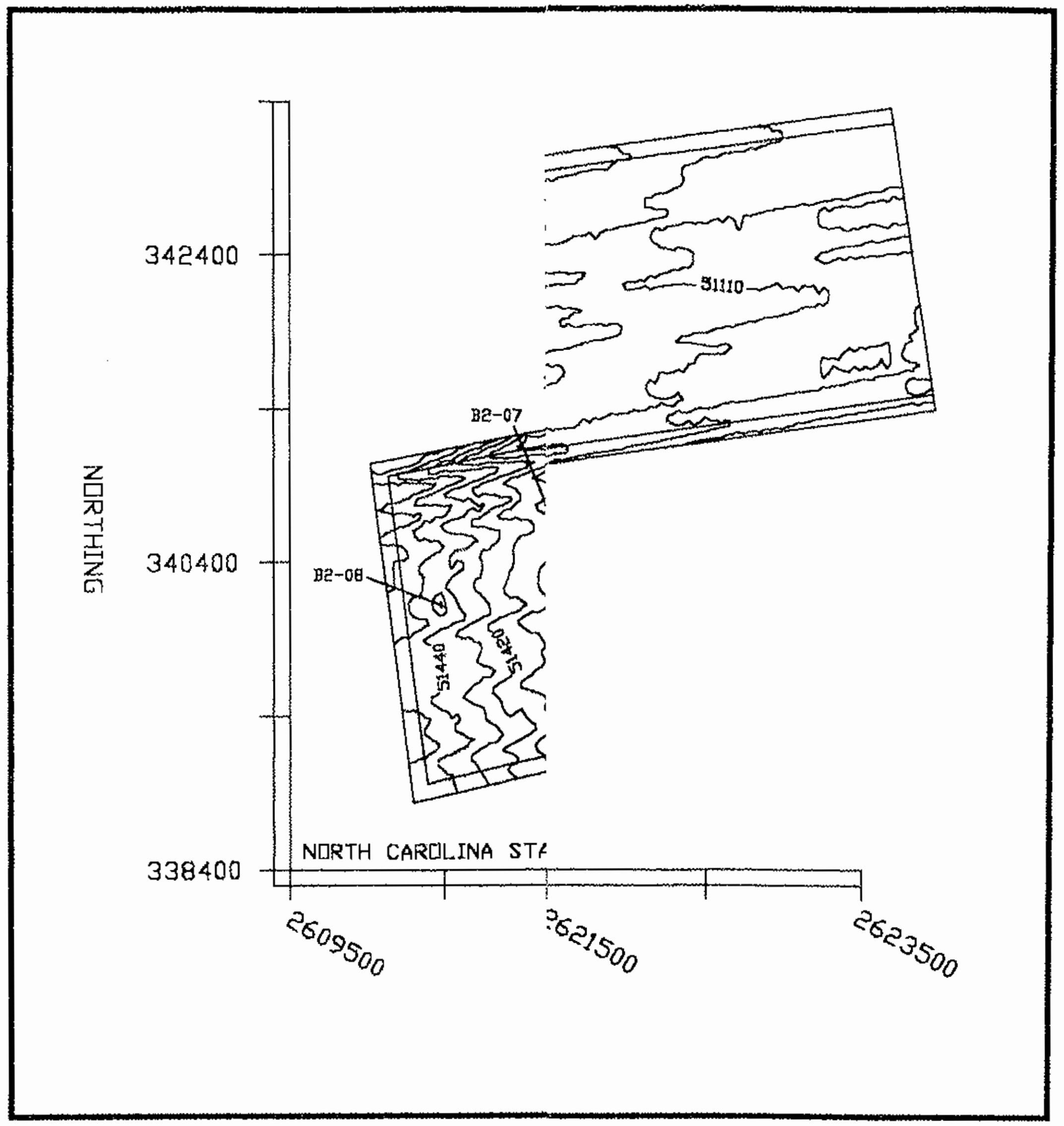


Figure 6. **Magnetic contour map**

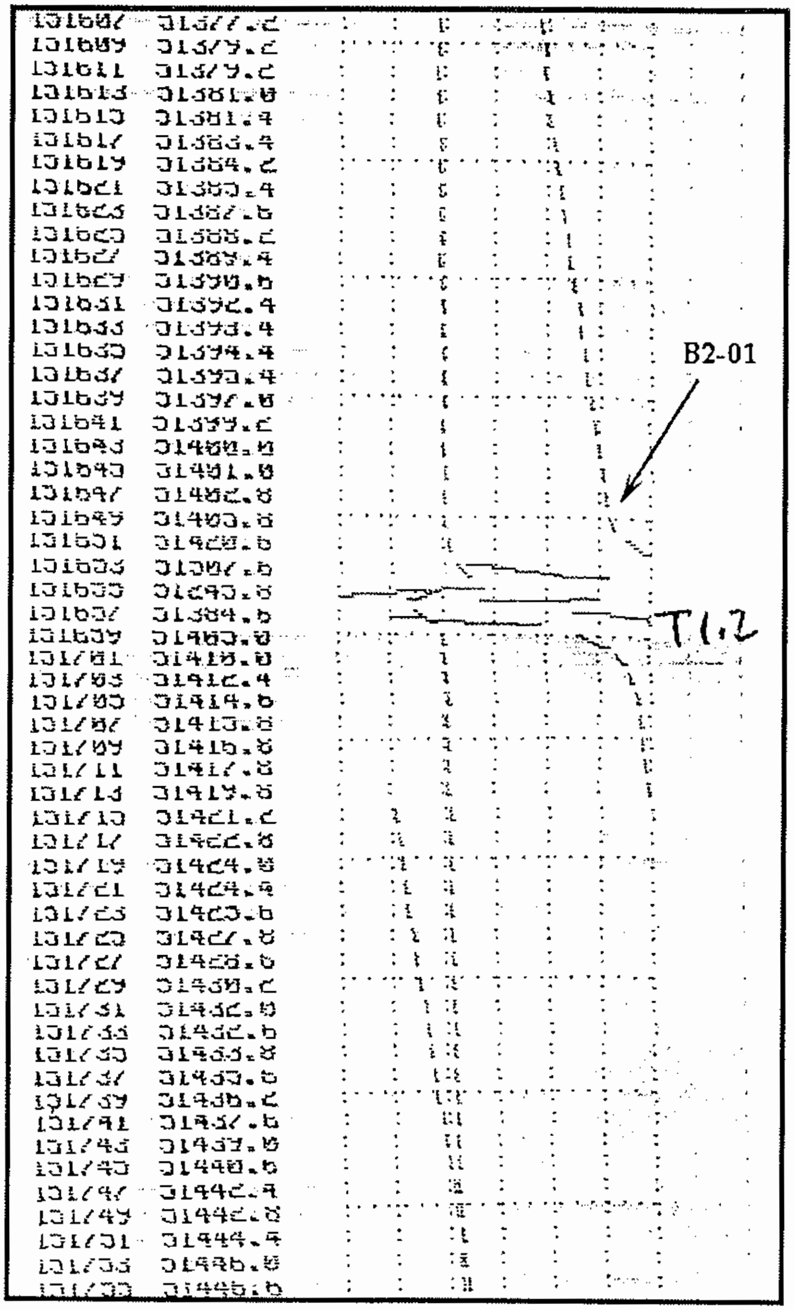


Figure 7. Magnetic Target B2-01.

edge of the survey area, it may potentially be associated with a significant cultural resource adjacent the current project area. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-02

Signature Type: Dipolar

State Plane	**Northing**	**Easting**	**Intensity**	**Duration**
	2612965	341596	59	5

Potential: Low

Target B2-02 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 1 and the contoured signature consisted of data from the anomaly identified as 1.1 in the magnetometer records. The detectable signature had a maximum intensity of 59 gammas and a maximum duration of 5 two-second pulses (Figure 8). The contoured dipolar signature covered an area of approximately 11,220 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-03, B2-04, B2-06 and B2-09 the target may represent scattered debris associated with a shipwreck. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-03

Signature Type: Dipolar

State Plane	**Northing**	**Easting**	**Intensity**	**Duration**
	2613207	341371	27	5

Potential: Low

Target B2-03 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 4 and the contoured signature consisted of data from the anomaly identified as 4.1 in the magnetometer records. The detectable signature had a maximum intensity of 27 gammas and a maximum duration of 5 two-second pulses (Figure 9). The contoured

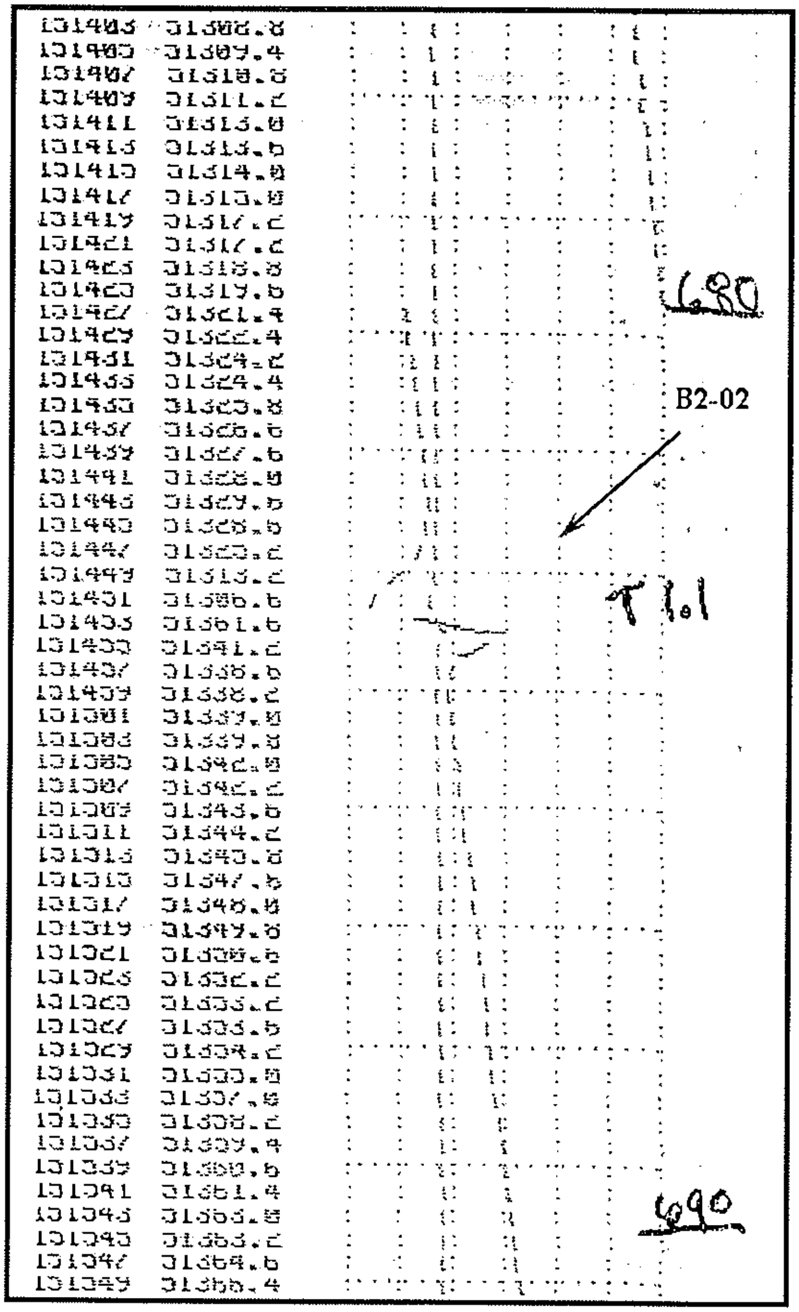


Figure 8. Magnetic Target B2-02.

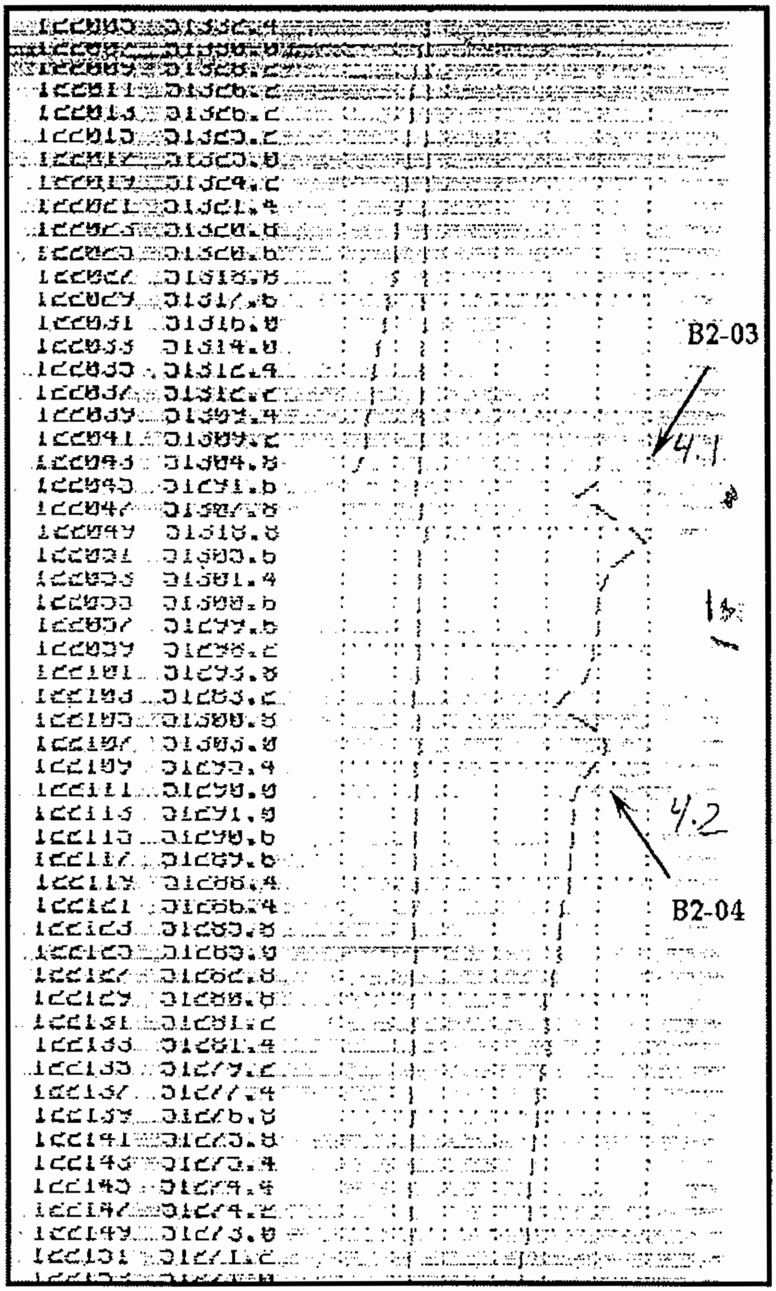


Figure 9. Magnetic Targets B2-03 and B2-04.

dipolar signature covered an area of approximately 8,800 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-02, B2-04, B2-06 and B2-09 the target may represent scattered debris associated with a shipwreck. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-04

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2613393	341404	20	6

Potential: Low

Target B2-04 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 4 and the contoured signature consisted of data from the anomaly identified as 4.2 in the magnetometer records. The detectable signature had a maximum intensity of 20 gammas and a maximum duration of 6 two-second pulses (Figure 9). The contoured dipolar signature covered an area of approximately 9,500 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-02, B2-03, B2-06 and B2-09 the target may represent scattered debris associated with a shipwreck. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-05

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2614359	341393	50	5

Potential: Low

Target B2-05 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 6 and the contoured signature consisted of data from the anomaly identified as 6.0 in the magnetometer records. The detectable signature had a maximum intensity of 50 gammas and a maximum duration of 5 two-second pulses (Figure 10). The contoured dipolar signature covered an area of approximately 8,000 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. The sharp, low intensity signature does not appear to represent the more complex types often associated with shipwreck remains. No additional investigation of the target is recommended in conjunction with the proposed project.

Target Designation: B2-06

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2612754	341037	49	7

Potential: Low

Target B2-06 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 6 and the contoured signature consisted of data from the anomaly identified as 6.1 in the magnetometer records. The detectable signature had a maximum intensity of 49 gammas and a maximum duration of 7 two-second pulses (Figure 11). The contoured dipolar signature covered an area of approximately 14,025 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-02, B2-03, B2-04 and B2-09 the target may represent scattered debris associated with a shipwreck. In the event that the proposed

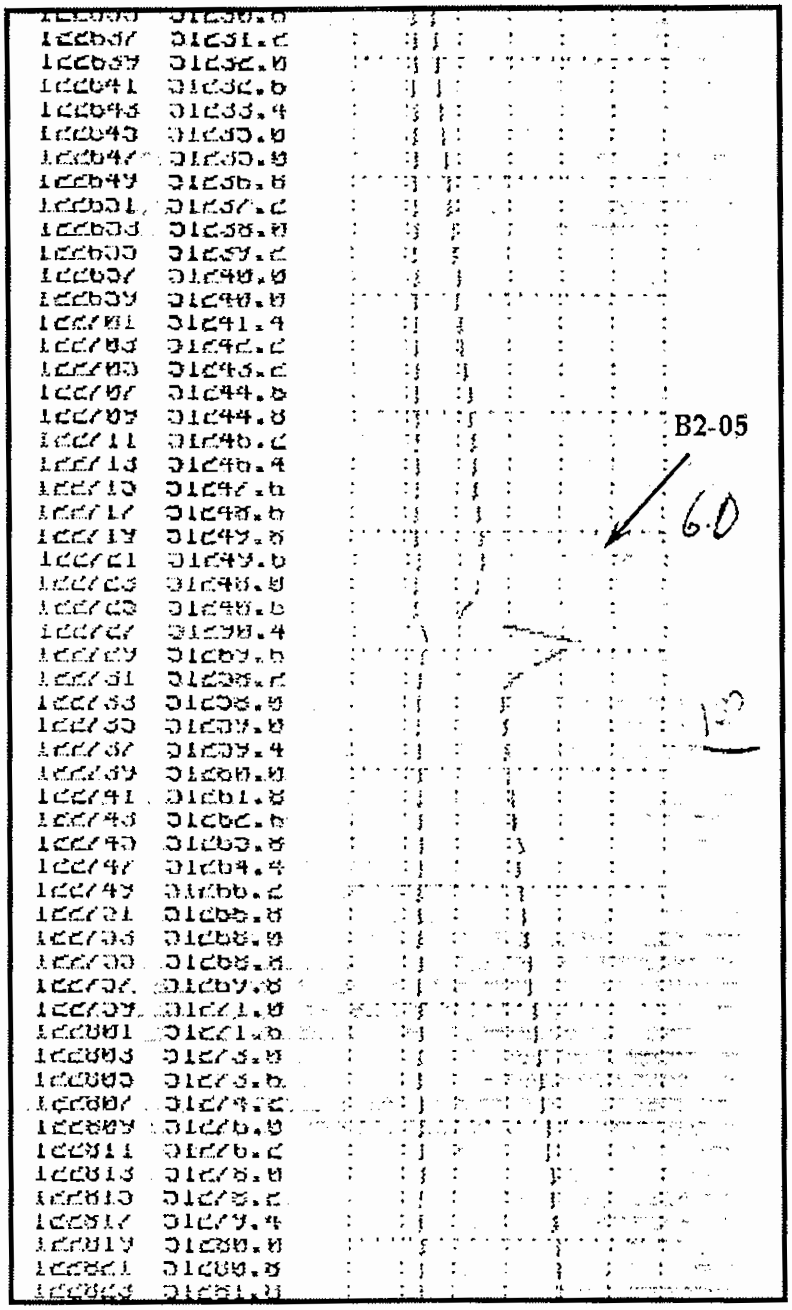


Figure 10. Magnetic Target B2-05.

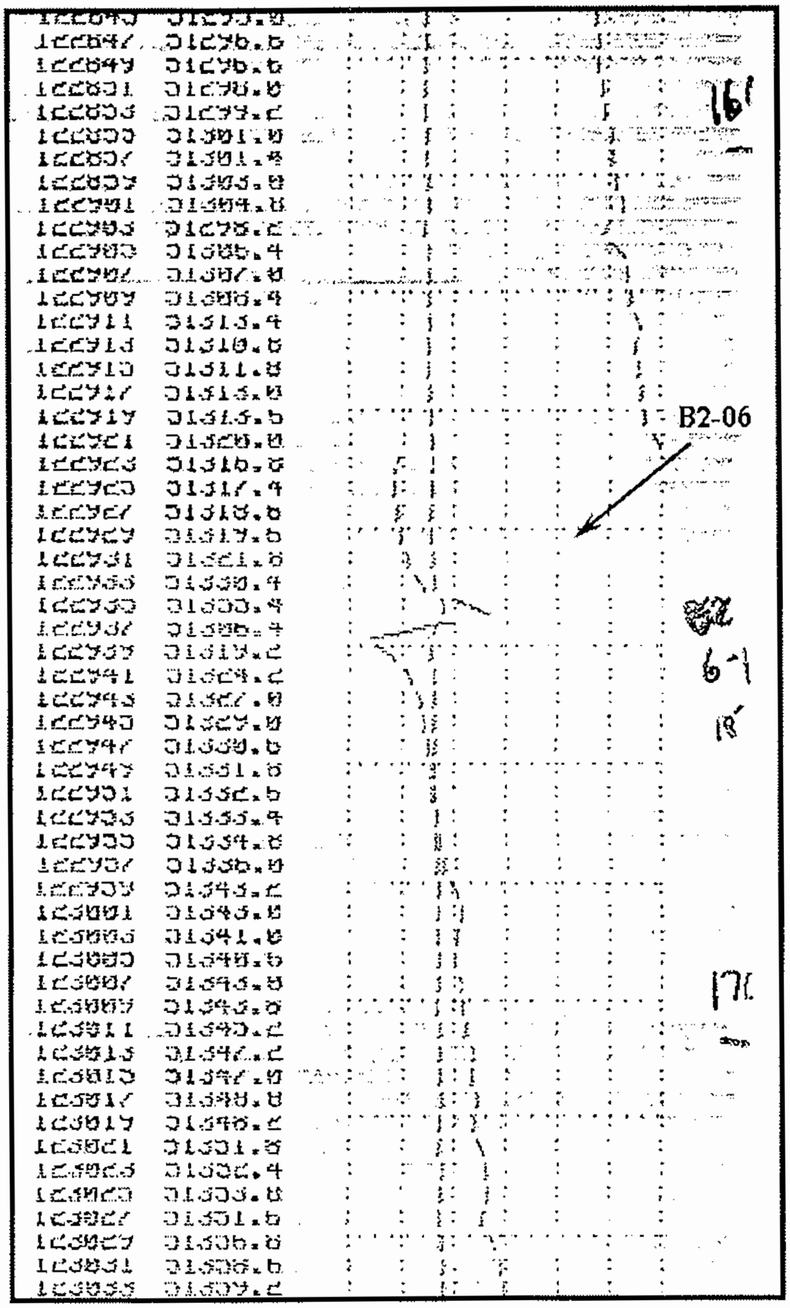


Figure 11. Magnetic Target B2-06.

project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-07

Signature Type: Positive Monopolar

State Plane	Northing	Easting	Intensity	Duration
	2611216	340557	82	5

Potential: Low

Target B2-07 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 8 and the contoured signature consisted of data from the anomaly identified as 8.1 in the magnetometer records. The detectable signature had a maximum intensity of 82 gammas and a maximum duration of 5 two-second pulses (Figure 12). The contoured positive monopolar signature covered an area of approximately 12,000 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. The sharp, moderate intensity signature does not appear to represent the more complex types often associated with shipwreck remains. No additional investigation of the target is recommended in conjunction with the proposed project.

Target Designation: B2-08

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2610512	340108	22	7

Potential: Low

Target B2-08 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 11 and the contoured signature consisted of data from the anomaly identified as 11.1 in the magnetometer records. The detectable signature had a maximum intensity of 22 gammas and a maximum duration of 7 two-second pulses (Figure 13). The contoured dipolar signature covered an area of approximately 11,310 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that

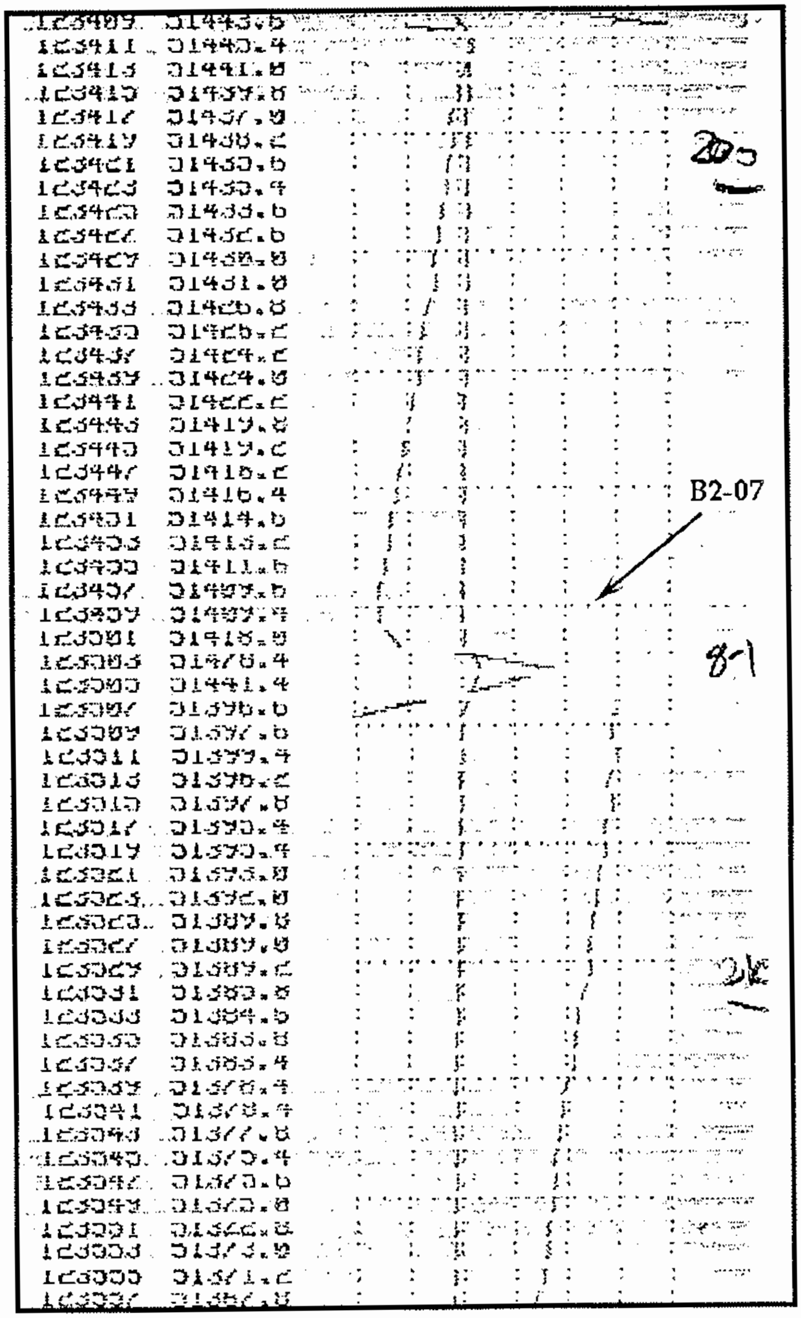


Figure 12. Magnetic Target B2-07.

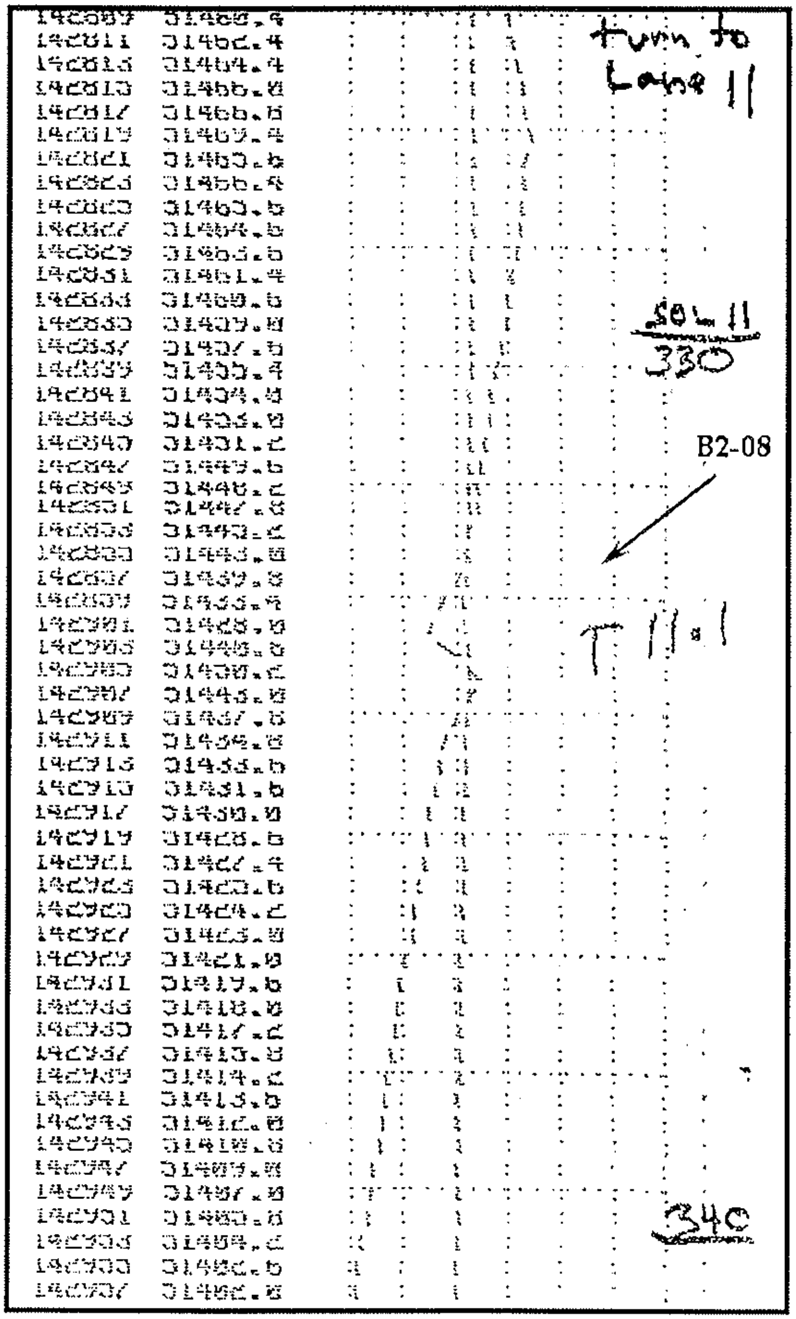


Figure 13. Magnetic Target B2-08.

material generating the anomaly could be a concentration of ferrous objects such as the fasteners of a vessel or other similar hardware. It is possible that the anomaly could be associated with the remains of a vessel as the signature characteristics are similar to those low intensity and long duration anomalies demonstrated to be associated with the remains of wooden hull vessels. In the event that the proposed project will impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-09

Signature Type: Negative Monopolar

State Plane	Northing	Easting	Intensity	Duration
	2613222	340888	49	5

Potential: Low

Target B2-09 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lanes 8 and 9 and the contoured signature consisted of data from the anomalies identified as 8.2 and 9.1 in the magnetometer records. The detectable signature had a maximum intensity of 49 gammas and a maximum duration of 5 two-second pulses (Figure 14). The contoured negative monopolar signature covered an area of approximately 23,000 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-02, B2-03, B2-04 and B2-06 the target may represent scattered debris associated with a shipwreck. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

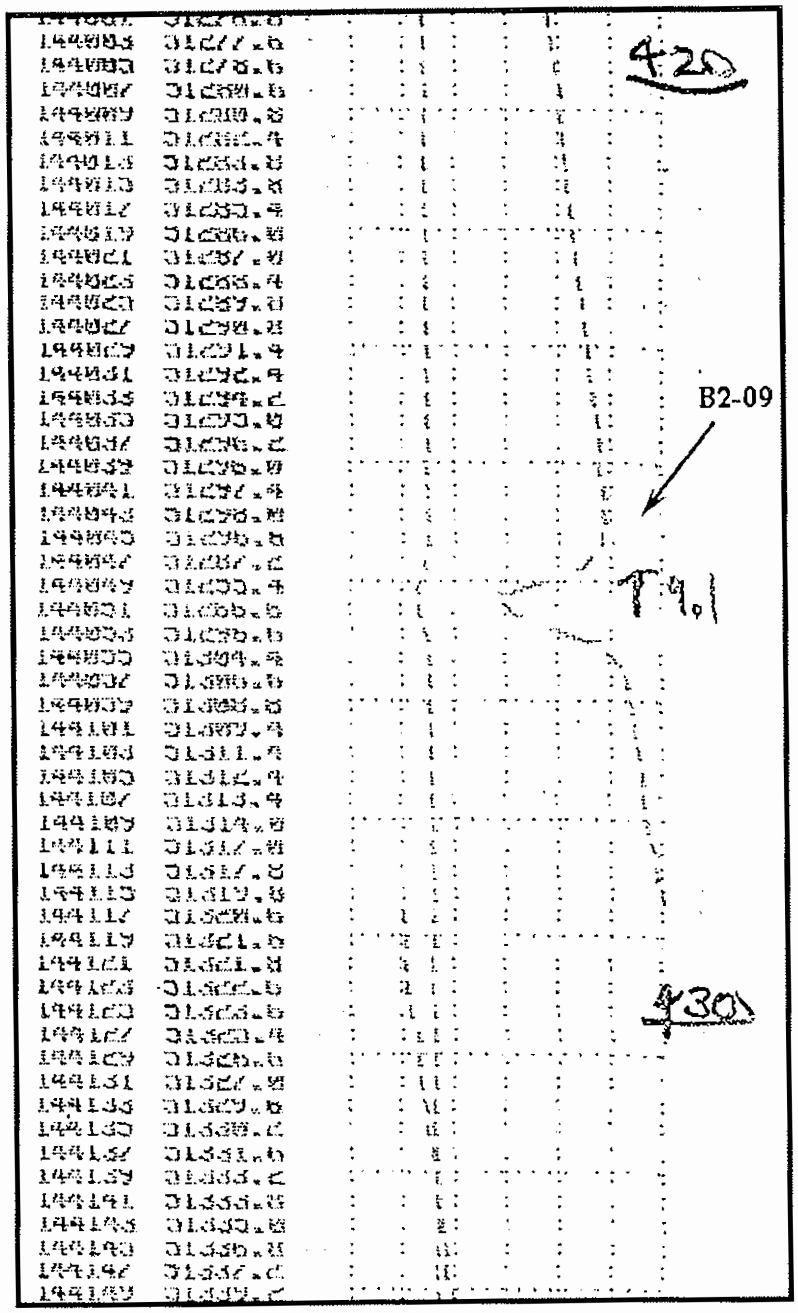


Figure 14. Magnetic Target B2-09.

Target Designation: B2-10

Signature Type: Multi-component

State Plane	Northing	Easting	Intensity	Duration
	2611288	339080	32	7

Potential: Low

Target B2-10 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 23 and the contoured signature consisted of data from the anomaly identified as 23.1 in the magnetometer records. The detectable signature had a maximum intensity of 32 gammas and a maximum duration of 7 two-second pulses (Figure 15). The contoured multi-component signature covered an area of approximately 14,250 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. The sharp, low intensity signature does not appear to represent the more complex types often associated with shipwreck remains. No additional investigation of the target is recommended in conjunction with the proposed project.

Conclusions and Recommendations

A survey of historical and archaeological literature and archival background research confirmed considerable evidence of maritime activity along the southeastern North Carolina coast. That evidence suggests a high probability for submerged cultural resources in the waters around Beaufort Inlet. Discovery of what appears to be the remains of Blackbeard's *Queen Anne's Revenge* and several Civil War vessels reinforce that hypothesis. Both Beaufort and Morehead City provided early settlers with centers of transportation and trade and bases of operations to exploit the natural resources of the Carolina coast. Yet in spite of nature and the scope of maritime activity, there is only one reference to a specific vessel lost in the immediate vicinity of the proposed project. That vessel is the Civil War blockade runner *Pevensey* that was run ashore at the site of the Iron Steamer Pier. No known sites exist in the survey areas in the files of the Underwater Archaeology Unit of the Division of Archives and History.

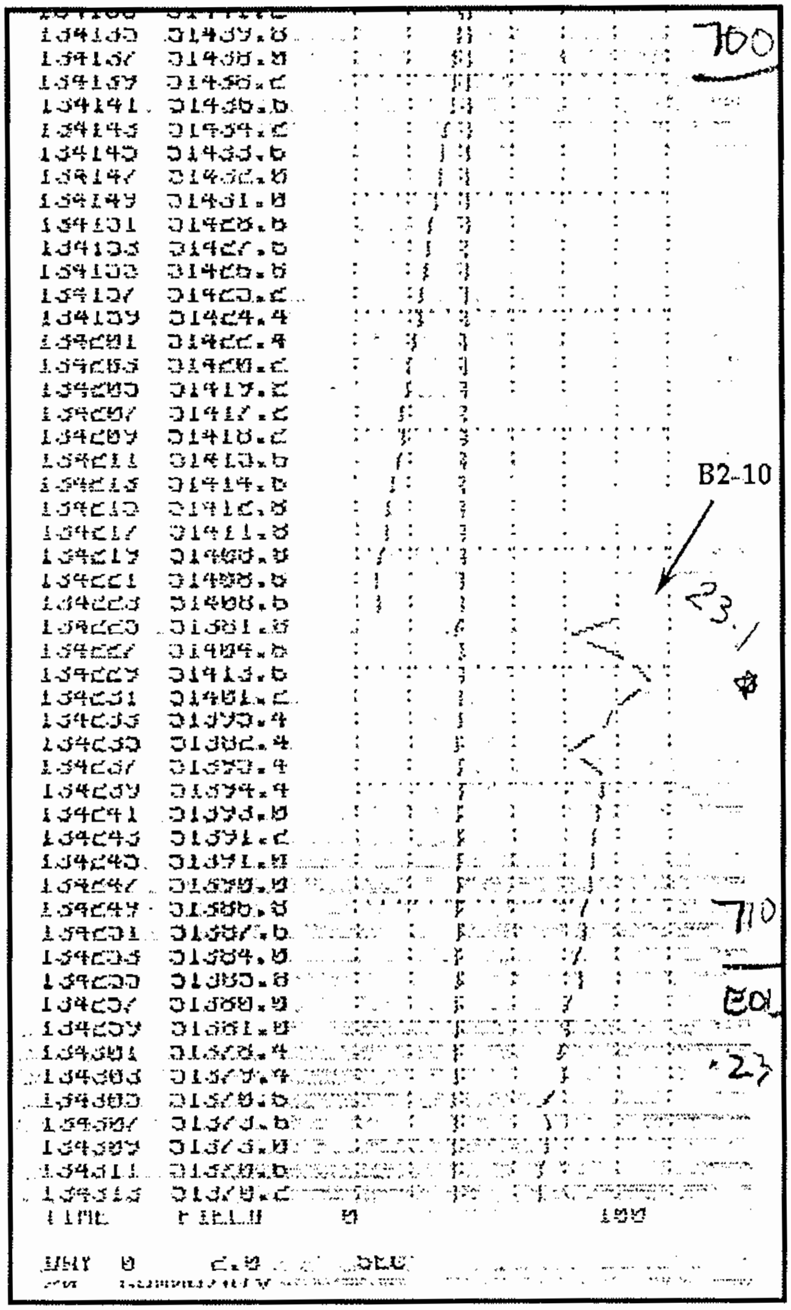


Figure 15. Magnetic Target B2-10.

Analysis of the remote sensing data revealed no magnetic and/or acoustic anomalies in either Borrow Area A or Borrow Area B-1. On the basis of that analysis, no additional investigation of the area is recommended in conjunction with the proposed project.

Analysis of the remote sensing data for Borrow Area B-2 confirmed the presence of 10 magnetic anomalies in the western part of the survey area. Seven of those targets contained signature characteristics consistent with significant submerged cultural resources. Analysis of the target signatures suggests that five of the anomalies, B2-02, B2-03, B2-04, B2-06 and B2-09, may be spatially associated and could represent scattered debris from a shipwreck. Another target, B2-08, contained signature characteristics similar to those commonly associated with wooden hull vessels. Though the final anomaly, B2-01, exhibited signature characteristics suggestive of a single ferrous object its location along the northern edge of the survey area does not rule out a possible association with a significant cultural resource lying adjacent to the project area. The remaining three targets, B2-05, B2-07 and B2-10, contained signature characteristics suggestive of single ferrous objects. With the exception of the above seven anomalies, the proposed project will have no impact on potentially significant submerged cultural resources.

In order to provide reasonable assurance that proposed dredging does not impact targets B2-01, B2-02, B2-03, B2-04, B2-06, B2-08 and B2-09, a buffer zone should be established around each anomaly location. Unfortunately, there is no concrete data regarding the establishment of an effective buffer zone around submerged cultural resource sites. In the absence of such data and due to the nature of the high energy environment off Bogue Banks, it may be appropriate to establish a buffer zone 250 feet in circumference around the center of the target coordinates. In order to assess the buffer zone effectiveness, the target environment at each site should be periodically monitored to determine what, if any, change has occurred. In the event that the target locations cannot be avoided, diver investigation of the seven anomalies is recommended to identify and assess their National Register of Historic Place's eligibility.

References Cited

Angley, Wilson
1982 An Historic Overview of The Beaufort Inlet - Cape Lookout Area of North Carolina. Report on file at the Research Branch, N. C. Division of Archives and History, Raleigh.

Berman, Bruce D.
1972 *Encyclopedia of American Shipwrecks.* The Mariners Press, Boston.

Federal Register
1990 Abandoned Shipwreck Act; Final Guidelines; Notice. National Park Service, U. S. Department of Interior, Part III, 4 December.

Hill, Mrs. Fred
1975 *Historic Carteret County, North Carolina.* Carteret County Historical Research Association, Beaufort.

Holland, F. Ross
1968 A Survey History of Cape Lookout National Seashore. United States Department of the Interior, Washington, D. C.

Konkle, Burton A.
1922 *John Motley Morehead and the Development of North Carolina, 1796-1866.* Philadelphia: William J. Campbell.

Lytle, William M. and Forrest R. Holdcamper
1975 *Merchant Steam Vessels of the United States 1790 - 1868,* "The Lytle Holdcamper List." Staten Island, New York: The Steamship Historical Society of America.

Marx, Robert F.
1975 *Shipwrecks of the Western Hemisphere, 1492-1825.* David McKay and Company, New York.

National Ocean Service
1990 Automatic Wreck and Obstruction Information System. National Oceanic and Atmospheric Administration, U. S. Department of Commerce.

Newsome, A. R. (Editor)
1929 A Miscellany from the Thomas Henderson Letter Book, 1810-1811. *North Carolina Historical Review.*

Paul, Charles L.
1970 Beaufort, North Carolina: Its Development as a Colonial Town. *North Carolina Historical Review.*

Price, Marcus W.
1948 Ships that Tested the Blockade of the Carolina Ports, 1861-1865. *The American Neptune*, July.

Rush, Richard et al.
1894-
1914 *Official Records of the Union and Confederate Navies in the War of the Rebellion.* 30 vols., Government Printing Office, Washington.

Saunders, William L. (Editor)
1886-
1890 *Colonial Records of North Carolina.* 10 vols., State of North Carolina, Raleigh.

Shomette, Donald G.
1973 *Shipwrecks of the Civil War.* Donic Ltd., Washington.

Spence, E. Lee
1991 *Shipwreck Encyclopedia of The Civil War: North Carolina, 1861-1865.* Sullivan's Island, S. C.: Shipwreck Press Inc.

Stick, David
1952 *Graveyard of the Atlantic: Shipwrecks of the North Carolina Coast.* The University of North Carolina Press, Chapel Hill.

1958 *The Outer Banks of North Carolina..* The University of North Carolina Press, Chapel Hill.

Tatham, William
1806 Survéy of the Coast of North Carolina from Cape Hatteras to Cape Fear, 1806. Typed copy of manuscript report. North Carolina Collection of the Louis Round Wilson Library, University of North Carolina, Chapel Hill, North Carolina.

United States Congress, Senate Executive Document, No. 78, 33rd Congress, 1st Session.

United States Congress, House Document No. 25, 55th Congress, 1st Session.

United States Congress, House Document No. 1454, 60th Congress, 2nd Session.

United States Congress, House Document No. 315, 61st Congress, 2nd Session.

Newspapers

The Evening Dispatch [Wilmington, N.C.]
Weekly Star [Wilmington, N. C.]

APPENDIX C

FINAL REPORT
(Revised on September11, 2000)

Bogue Banks beach renourishment project: Late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining

Prepared for

Carteret County and CSE Baird, Inc.

By

Charles H. Peterson & John T. Wells
Institute of Marine Sciences
University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, NC 28557

September 11, 2000

Charles H. Peterson

John T. Wells

TABLE OF CONTENTS

1. Introduction/Purpose

This benthic assessment was conducted under contract with Carteret County, North Carolina in anticipation of a beach renourishment project for Bogue Banks. The purpose of this report is to describe the results of a single fall 1999 sampling of the benthic invertebrates and surficial sediments at the offshore borrow areas and nearby controls and the results of three (late fall-winter-spring) sets of trawl samples for demersal fishes and invertebrates around the borrow areas. This information may ultimately be incorporated into a monitoring scheme and helps in the short term to describe the biological resources at risk in the offshore system. Benthic invertebrates are commonly used in environmental assessments because they are sedentary and show the imprint of any environmental perturbation and because they are important trophic links to higher levels on the food chain, demersal predatory fishes, birds, and crustaceans (Warwick 1993). Many of these consumers have value as targets of commercial and/or recreational fisheries or as attractive charismatic wildlife (McLachlan 1983).

There are several environmental issues relating to the benthic habitat and biological resources that arise in considering a beach renourishment project (e.g., Naqvi and Pullen 1982, Reilly and Bellis 1983, Nelson 1989, Van Dolah et al. 1992, Peterson et al. 2000). The most significant include: (1) impacts to and recovery of the benthic invertebrate community at the borrow areas; (2) potential impacts to commercially or recreationally important demersal fishes and crustaceans in part because of these effects on their benthic invertebrate prey; (3) impacts to and recovery of the benthic invertebrate community on the intertidal and shallow subtidal beach; and (4) potential impacts to commercially and recreationally important fishes in the surf zone and/or shorebirds in large part because of these effects on their benthic invertebrate prey and because of enhanced turbidity along the shoreline.

Each of these issues deserves consideration and typically requires some field monitoring before and after renourishment to evaluate the actual resulting impacts. Because the benthic invertebrate community at the offshore borrow sites changes across the seasons, it is appropriate to sample in multiple seasons (fall and spring, at a minimum, but during four seasons in most previous studies – see Van Dolah et al. 1994) both before and after the renourishment project to assess impacts and recovery. Because renourishment was originally planned for winter 2000-2001, an initial set of samples was collected in the late fall of 1999 to provide fall baseline data to characterize the benthic invertebrate community at the prospective offshore borrow sites and at nearby control sites, which were not planned to be mined, prior to any disturbance from the renourishment project. This report includes a description of results from an analysis of the fall1999 samples. We also include here a complete analysis of composition of surface sediment samples in each of the borrow sites and control sites so as to characterize the sedimentary habitat in which the invertebrates live. Sedimentary habitat is the prime factor that controls abundance and composition of soft-bottom invertebrate communities (Snelgrove and Butman 1994).

The test of the impacts of removing sand from any of the three "Borrow Areas" A, B1, and B2 (Fig. 1) requires the use of a BACI (Before-After-Control-Impact) experimental design (Green 1979, Stewart-Oaten et al. 1986). Such a design is required to separate spatial and temporal variation from impacts of the sand mining activity. In a BACI design, samples from impact (Borrow) areas would be compared with those from control (undisturbed) areas both before and after the sand is removed. Control areas would have no sand removed but would otherwise be affected by all other impacts, i.e. storms, shrimping, etc., that affect the impact area. These samples taken before the removal of the sand can be compared with identically conducted samplings made after sand mining to evaluate impacts. In addition, the design also calls for spring sampling both before and after the removal of sand to assess the seasonal component, for a minimum of 4 sampling periods to complete the assessment of impacts. This report describes only the first of those samplings and thus does not include any spring sampling of the Borrow Areas or any sampling of the intertidal beaches.

Assessment of the significance of the offshore mining of sands for the renourishment also involves evaluation of potential impacts on demersal fishes and crustaceans at the Borrow Area (e.g., Van Dolah et al. 1992). Impacts could occur directly during sand mining and indirectly through modification of the prey community. This effect on prey could last for some unknown time. The fish and crustacean community also changes seasonally so sampling is needed to document presence and relative abundance of demersal fish and crustaceans and to describe their utilization of benthic invertebrate prey. This report describes results of trawl sampling on three dates, late fall, winter, and spring.

No sampling has yet taken place to serve explicitly as the before-renourishment monitoring data for the intertidal invertebrates of Bogue Banks beaches or for sea turtles. The invertebrate community of the intertidal beaches is so strongly seasonal and dynamic within the warm season that sampling to provide baseline information should most appropriately occur throughout the warm season, with subsequent identically designed sampling to assess potential impacts and recovery but after the project has been completed. The complete design for such beach monitoring would include "before and after" (BACI) sampling of control beaches where no renourishment occurs (Green 1979, Stewart-Oaten 1986).

2. Description of Sampling and Analytic Methodologies

A. Benthic Invertebrate Resources

Core sampling was conducted during late fall 1999 from 20 sites, 10 of which were inside and 10 of which outside the three potential borrow areas (Fig. 1). This sampling produced a total of two hundred core samples to characterize the invertebrate macrofauna at all three prospective borrow sites and at control sites near each borrow site (Fig. 1). Ten replicate core samples were taken at each of six sites in Borrow Area A and at each of two sites from Borrow Area B-1 and Borrow Area B-2. Ten replicate cores were also taken at each of ten control sites: six around Borrow Area A and two near each Borrow Area B site. Exact locations of each site were determined using a handheld GPS with differential receiver (Table 1). Water depths ranged from 35 feet at the inshore sites to 47-49 feet at the offshore sites. Cores were taken by divers using a cylindrical corer 9.9 cm in internal diameter (each covering a surface area of 76.4 cm^2) with 500-μm mesh across the top to prevent loss of surface animals. Replicates were haphazardly positioned at each systematically distributed (see Fig. 1) sample station within a 3-m^2 area. All core samples were taken to a depth of 10 cm. After being transported to the boat, the contents were emptied from the core tubes into plastic bags, labeled, and sealed. Immediately upon returning to the lab, the material from the cores was sieved through a 500-μm mesh. Material retained on the sieve was preserved in a 5% aqueous solution of buffered formalin. Rose Bengal vital stain was added to the samples to facilitate sorting. After a week, the formalin was drained off through a 500-μm sieve and replaced with 70% ethanol. Subsequently, animals were separated from detritus by hand picking and identified to family. Several benthic impact studies including especially those by Warwick (1988) of IMER in Plymouth, England have demonstrated that analysis of response at the level of family preserves all the information about community patterns without the high costs of proceeding to species level.

At the same time that the macrofaunal cores were taken, divers collected three 2.65cm-diameter cores to a depth of 2 cm at each site to sample the meiofauna (fauna smaller than 0.5mm and greater than 0.063mm). These samples were iced onboard ship, preserved in the lab with a 5% aqueous solution of formalin, and archived for possible analysis, if required.

Benthic sled sampling was used to collect belt transect samples of larger, more sparsely distributed animals such as hermit crabs and sand dollars. The sled has matching steel blades on both the top and the bottom so that it functions properly no matter how it lands on the bottom. To produce a belt transect, the sled (25 cm tall with a 63 cm wide blade) was towed 15.8 m along the bottom by a line extending to the boat and sampled the top 6 cm of sediment. Sediment passes through the 6 mm mesh and larger organisms are retained. A taut-line buoy attached to the sled allowed for accurate positioning along the marked course. We sampled only on a flat-calm day (9 December 1999) at sea to prevent the sled from bouncing and to control its positioning. Using this sled, we took 40 belt transect samples of 10 m^2 each. This design yielded two replicate belt transect samples at each of the 20 sampling sites (Fig. 1). Animals found in the sled samples were identified, counted, and recorded. Species not immediately identifiable in the field were collected and returned to the lab for identification.

B. Demersal Fish and Crustaceans

In order to provide a semi-quantitative characterization of demersal fishes and crustaceans, including commercially or recreationally important species, that occupy the potential borrow areas and may conceivably be impacted directly by dredging operations or indirectly by loss of their benthic invertebrate prey, we sampled the demersal species of the three borrow areas. This sampling design is similar to that conducted by Van Dolah et al. (1994) in assessing impacts of sand mining on demersal fishes and invertebrates for beach renourishment at Folly Beach, South Carolina. Replicate trawl samples were taken on 29 November 1999, on 4 February 2000, and on 11 May 2000 from the R/V Capricorn using timed 20-minute otter-trawl tows at 4.02k/hr with a 12.3-m otter trawl. Thus the trawl would cover 16,492 m^2 of bottom area if there were no currents. The actual bottom area covered varied according to wind and tidal currents during any specific tow, which is why tows were standardized by time and speed rather than distance covered. These trawl samples were distributed as follows: 4 in Borrow Area A and 2 in each of Borrow Areas B-1 and B-2. The contents of each tow were identified to species, counted, and recorded. In addition, stomachs of up to 20 replicate individual fish of the most abundant species were removed, and preserved by formalin injection onboard ship. Stomach contents for up to twenty of the eight most common fish species from the November trawl survey were identified (when possible) and divided into major taxonomic group (e.g. polychaete, decapod, bivalve, etc.). Fish guts were examined from both inshore areas and offshore areas when possible. The divided categories were then weighed to the nearest 0.0001 g. Detailed inspection of some of the diet remains allowed identification to the family, genus or species level of some of the gut contents.

C. Sediments

At each site where macrofaunal cores were collected, divers also took core samples for grain-size analysis of sediments. Composite bottom samples were obtained at each of the ten Borrow Area sites and each of the ten control sites. Using PVC sampling tubes (16.5 cm [6.5 in] long and 2.5 cm [1 in] wide), divers collected 3 replicate samples of the upper 2 cm of the bottom within a 3-m^2 area at each of the twenty sites. Sample tubes were tightly capped, then brought to the surface and returned to the laboratory for analysis. Loss of fine-grained material, which can occur with conventional grab samplers, is minimized by using diver collections. Samples were assumed to be representative of the surficial material in which most of the macrofauna live.

In the laboratory, the replicate sediment samples were combined in a single container, then washed three times to remove salts and placed in a drying oven. After recording the bulk sample weight, a Calgon dispersant was added and the fine-grained (mud) component (by definition less than 0.063 mm diameter) was rinsed through a #230 mesh wet sieve. The remaining material (sand + gravel/coarse shell) was reweighed and prepared for sieve analysis. Prior to sieving the sand-sized fraction, the gravel/coarse shell fraction (by definition more than 2 mm in diameter) was removed with a #10 mesh sieve and weighed. A Tyler mechanical splitter was used to obtain a 25 g subsample of the remaining material (sand) which was then sieved at ¼ phi intervals (Carver 1971).

Each sieve stack was placed in a mechanical ro-tap for 20 minutes. Individual sieve fractions were weighed and recorded. Small amounts of fine-grained sediment that had not previously washed through the wet sieve were collected in a pan at the bottom of the sieve stack and, for computational purposes, were included with the wet-sieved material. Percentages of gravel/coarse shell, sand, and fine-grained sediment were computed from the bulk sample weights, and percentages of each size fraction in the sand range were computed from the 25 g splits that were sieved. Mean and standard deviation were computed using Excel software and mean phi values were converted to millimeters using the standard conversion, $phi = -log_2(mm)$, where mm corresponds to the intermediate diameter in mm (Folk 1974).

3. Results

A. Benthic Invertebrate Resources

Table 2 (2a for per-core results and 2b normalized to per square meter) presents the results of analyses of the 200 core samples taken to describe the benthic macrofauna at the three Borrow Areas and the surrounding Controls for each. Total macrofaunal densities were slightly greater at the offshore sites (14.1 invertebrates per core at Borrow Area A and 9.3 per core averaged over nearby Control sites) than at the inshore sites (9.7 invertebrates per core averaged over Borrow Areas B-1 and B-2 and 6.6 per core averaged over nearby Control sites). Results suggest slightly higher macrofaunal abundances in the Borrow Areas than in their respective Control Areas (Fig. 2). To test whether these possible differences are the consequence of differences in surficial sediments, we regressed average invertebrate density in cores against mean phi for each sampling site, conducting a separate analysis for the offshore and inshore sites. The inshore sites revealed no significant relationship (Fig. 3a) with a p-value of 0.28. The analogous regression for the offshore sites (Fig. 3b) was statistically significant at $p < 0.0001$, but the direction of the effect was reversed from normal expectation. Benthic infaunal abundance might normally be expected to be lower where sediments are coarser except when fine sediments are organically rich enough to create local reducing conditions and generate toxic hydrogen sulfide. However, here the two anomalous treatment sites in the offshore area with high shell content and low phi values had the highest densities of infaunal invertebrates (Fig. 3b). This relationship may be the indirect consequence of surficial shell inhibiting fish and invertebrate predation on infauna.

The higher taxonomic composition of the benthic infauna sampled in cores did not vary greatly over the sample sites. Over all sites polychaetes accounted for 65 % to 75 % of the total macrofauna in these late-fall 1999 samples. Because of the dominance by polychaetes, they exhibited the same patterns across depth and treatment (Fig. 4) as the total macrofauna (Fig. 2). Other common groups in order of abundance were bivalves (Fig. 5), nemerteans, small crustaceans, echinoderms, and gastropods (Fig. 6). The Appendix presents all the raw data.

Table 3 (3a for per-belt transect results and 3b normalized to per square meter) describes the results of analysis of all 40 belt transects for larger benthic invertebrates. The inshore sites revealed higher numbers of these larger invertebrates than the offshore sites. Borrow Area A contained 3.1 larger invertebrates per $10m^2$ belt transect and its nearby Control sites averaged 2.8, as compared to the average of Borrow Areas B-1 and B-2, which was 0.7 and their nearby control sites of 1.2 (Table 3). No consistent difference appeared between Borrow and Control Areas in this data set (Fig. 7). Gastropods were the most common taxon represented in these samples (Fig. 8), followed by echinoderms (Fig. 9).

B. Demersal Fish and Crustaceans

Trawl sampling detected relatively large numbers of demersal fishes occupying the seafloor habitat during late fall, declining by early February, and increasing again by early May (Table 4 presents the results of trawling for fishes and crustaceans on 29 November 1999; Table 5 presents the 4 February 2000 results; and Table 6 presents the 11 May 2000 results). Fish and mobile crustaceans caught in the trawls showed site averages ranging from 16,531 to 37,149 per km^2 in November, from 1,087 to 9,882 per km^2 in February, and 488 to 120,536 per km^2 in May (Tables 4-6).

In November, offshore areas were dominated by spot, which accounted for more than 50% of total catch and was sufficiently abundant there to create a pattern of slightly higher fish densities offshore than inshore. In addition to spot, pinfish, pigfish, and croaker were the most common species offshore (Table 4a). Inshore fishes were dominated by croaker, silver perch, silversides, pinfish, and sea mullet (Table 4b).

The abundance of most fish species had decreased by 4 February. This February sampling took place after a 3-week cold spell, the first prolonged cold weather of the winter of 1999-2000. The contents of these February 2000 samples (Table 5a,b) contrasted with those of November 1999 (Table 4a,b), showing an average reduction in catch by 81%. Catch in February from inshore stations was 41% and of offshore stations 3.7% of the corresponding catches in November. The abundances of two commercially and recreationally important species, spot and croaker, which made up 51% of the fall catch, dropped by 98.9% and 99.8% respectively. In February, pinfish, menhaden, and silversides made up 96.4% of the total catch. Spot, croaker, pigfish, sea mullet, and silver perch all showed large declines from November to February in both inshore and offshore areas. Pinfish catch in offshore areas was greatly reduced in February compared to November; however, inshore catches of pinfish were similar across dates. Two species of fish, menhaden and southern flounder (both found only in the inshore area), were more abundant in February than in November.

Our sampling on 11 May 2000 revealed higher total abundance of fishes in the inshore areas than we observed in either of our earlier samplings, but total fish abundance in the offshore borrow areas was intermediate between the December and February counts (Table 6a,b). Catch in May from the inshore stations was 1200% higher (Table 6a) than in February, largely due to increases in Atlantic silversides and Atlantic thread herring. In the offshore stations, catch in May was 1600% greater (Table 6b) than observed in February. Pigfish and scup largely accounted for this enhancement in total fish abundance in the offshore.

Examination of the stomach contents of the eight most abundant fish (croaker, gray trout, pinfish, pigfish, sea mullet, silver perch, silversides, and spot) taken from the November 1999 sampling demonstrated that many of the benthic invertebrates found in core samples and belt transects were major diet items of these fish (Table 7). Only about half of all stomachs examined were empty, with some variation among species. Major prey species for croaker and pinfish included polychaete worms, bivalves, and occasionally small shrimp (primarily grass shrimp, *Palaemonetes* sp.) and crabs (primarily pinnotherid crabs). Shrimp (both *Palaemonetes* sp. and penaeids) and to a lesser degree portunid crabs were the primary prey species found in the stomachs of gray trout. Sea mullet prey items were dominated by pinnotherid and portunid crabs and large polychaete worms. Small grass shrimp and other bottom-dwelling crustaceans (amphipods and isopods) were the dominant prey found in silver perch stomachs. Pigfish stomachs contained primarily polychaetes with an occasional grass shrimp present. Some polychaetes and small crustaceans (isopods, cumaceans, and amphipods) were found in the stomachs of spot, but stomachs were relatively empty compared to other species. Finally, silversides fed primarily on harpacticoid (benthic dwelling) and calanoid (planktonic) copepods.

Comparisons between stomach contents of fish collected from inshore and offshore locations were possible for six of the eight species that were caught in abundance in both areas (croaker, gray trout, pinfish, silver perch, silversides, and spot). Examination of the data revealed no consistent pattern in either the proportion of empty stomachs or major prey items between the two areas.

C. Sediments

Data are summarized in Table 8; individual size frequency curves and histograms are provided in Figure 10. With the exception of two treatment sites in Borrow Area A, sands comprised at least 90% of the bottom sediment by weight. In all cases, muds comprised less than 4% of the sediment by weight. Visual inspection of the samples revealed that the coarse fraction, typically less than 8% by weight, was comprised primarily of coarse shell fragments. Using the Wentworth size scale (Folk 1974), mean grain size in 80% of the samples was classified as fine sand and 20% as either medium or coarse sand. Values for standard deviation showed that 85% of the samples were moderately or moderately well sorted. Reed and Wells (2000) found similar sediment distribution patterns off Fort Macon, Atlantic Beach and Pine Knoll Shores, NC, in samples taken at 36 locations during each of two sampling periods, fall 1996 and spring 1997. Their samples showed muddier sediments occurring in the offshore areas but no significant seasonal variations in mean size or sorting.

Comparison of the grain size distributions taken in conjunction with the invertebrate coring and the analysis of grain sizes from the CSE Baird and Athena Technologies cores indicates finer sizes in the cores associated with the invertebrate sampling. This difference can be attributed to several factors: (1) the cores taken in association with invertebrate sampling covered only the uppermost surface layer only (2 cm), which is often covered by a thin mud drape; (2) this set of cores included Control locations outside the Borrow Areas, which were selected for their sand deposits, whereas the controls do not always match this level of coarseness; and (3) the cores associated with invertebrate sampling were collected by hand by divers in a fashion that involved minimal loss of fines during the sampling process.

4. Discussion

The benthic invertebrates occupying the bottom in both the inshore and offshore Borrow Areas represent species that are indeed being consumed by demersal fishes, such as spot, croaker, pinfish, pigfish, and sea mullets. Our gut examinations revealed that feeding was active and intense enough on the benthos in late November to yield gut contents in fishes with gut passage times of 6-12 hours. Compared to other gut data that we have taken from demersal fishes in the Neuse River and the Newport River in summer (pers. obs.), the percentages of empty stomachs in this data set are quite low. The densities of benthic invertebrates (6-16 individuals per 76.4-cm^2 core) are similar to those found occupying sandy bottoms in the Beaufort Inlet in December 1994 (Peterson et al. 1999), which were around 10 individuals per 76.4 cm^2 core (the same used in this study). The Beaufort Inlet samples were taken at a depth of 26-36 feet, similar to the inshore sites sampled in this study. Both surveys showed a general dominance by polychaetes. No other sampling of benthic invertebrates is truly comparable to these because of differences in sieve mesh size, water depth, reef proximity, geography, or sedimentology. Nevertheless, we present some benthic macrofauna data in Tables 9 (total macrofauna) and 10 (major taxa) from these other studies for contrast. Densities of benthic infauna in cores at the Borrow Areas in late November during our sampling period and in the earlier Beaufort Inlet study are lower than those observed near hard-bottom reefs off Wrightsville Beach (Posey and Ambrose 1994) and those observed by Van Dolah (1994) in finer sediments off Hilton Head, South Carolina (Table 8). For those taxa reported in Posey and Ambrose (1994), bivalves, gastropods, scaphopods, amphipods, isopods, polychaetes, and echinoderms, densities were higher than in our sampling of the Borrow Areas (Table 9).

Belt transects for larger invertebrates revealed a similar dominance by gastropod molluscs in our new data set from the Borrow Areas and in our earlier Beaufort Inlet study. These larger invertebrates were slightly more common in the Beaufort Inlet than in the study areas sampled here (Table 11). Greater echinoderm (sand dollar) densities occurred in the vicinity of the Beaufort Inlet. The only other analogous data set on larger invertebrates comes from Dahlgren et al. (1994), although they report only some taxa from belt transects near hard-bottom reefs off Wrightsville Beach. Dahlgren et al. (1994) reported belt transect data (Table 11) for several classes of echinoderms near the same reefs studies by Posey and Ambrose (1994). Dahlgren et al. (1994) observed higher densities of holothuroids (sea cucumbers) than we document in the Borrow Areas but similar densities of echinoids (sand dollars) and stelleroids (sea stars) (Table 11). The difference in sea cucumber densities is likely also a consequence of the finer sediments in the site studied by Dahlgren et al. (1994).

Our fish sampling revealed densities of many fishes as high in December as we routinely find during all the warm months in the vicinity of Beaufort Inlet immediately outside the estuary and as high as Van Dolah et al. (1994) found in the Folly River. The fish assemblage at the proposed borrow sites for the Bogue Banks project was dominated by species of substantial value to commercial and recreational fisheries of North Carolina and neighboring states. These fishes were actively feeding on the benthic macrofauna. Shrimp catches were low, although commercial shrimp trawling was being conducted in the immediate vicinity of all the Borrow Areas at the time of our sampling in late fall 1999. Many species of demersal fish of the estuaries of North Carolina and the Southeast generally are known to exit the sounds and estuaries in the fall on route to offshore sites for overwintering. The precise locations of these overwintering sites are not completely described, but our sampling indicates that this area off Bogue Banks is utilized in abundance during late fall by spot, croaker, pigfish, pinfish, silver perch, and sea mullet. Subsequent sampling during early February revealed emigration of these fishes to unknown locations as the weather became cooler. The only other conceivably comparable data on fish and crustacean abundances from trawl sampling come from Van Dolah et al. (1994). They reported average densities in the Folly River, South Carolina ranging across site and season from about 7,000 to 55,000 per km^2. These densities are similar to our average densities ranging from 500 up to 120,536 per km^2. The densities that we observed around the borrow areas in late November 1999 were judged by our boat captain, who has operated this trawl routinely for 25 years, to be similar to densities in spring, summer, and fall around Beaufort Inlet (J. Purifoy, pers. com.).

Dredging could impact the demersal fishes and crustaceans by direct removal and mortality during dredging, by causing emigration to other areas, where crowding could reduce growth and production, and by creating some unknown period of time when benthic prey abundances had not yet recovered and so growth and production were reduced. If sediment character in the borrow areas changes after sand mining, the new community of benthic invertebrates could differ dramatically from the existing community and could provide less of more food resources for demersal fishes and crustaceans. Van Dolah et al. (1994) demonstrated an effect of sand mining at the borrow area on species richness of demersal fishes and crustaceans that persisted through the first spring and fall after the cessation of the winter project; however, no effect was detected on total fish abundance.

Our sampling was designed to serve as the fall baseline data set for the Borrow Areas in contemplation of a monitoring scheme to assess impacts of and recovery from the sand mining for beach renourishment. This includes not only the benthic macrofauna and demersal fishes but also the sediments on the sea floor. Unfortunately, two sites in the offshore borrow area (A) possesses sediments that are much coarser with much higher shell content than any of the controls (Fig. 3b), so that we have no adequate control for this portion of the borrow area. Unless one of these sites is mined and one is not, any subsequent assessment of impacts of sand mining will be compromised by this sedimentological anomaly. Because the macrofauna is so closely tied to sediment character, the evaluation of any changes in surface sediment character after mining is critical to interpreting the impacts on and recovery of benthic invertebrates and probably also fishes. The limited amount of past literature on impacts of sand mining at borrow sites on the nearshore shelf gives mixed indications of whether recovery of benthic invertebrates will occur rapidly or slowly. Borrow areas in which sedimentation has not dramatically reduced the average size of surficial sediments have tended to show recovery of total benthic abundances in about a year, whereas borrow areas that experienced deposition of fine sediments exhibited recolonization by dramatically different benthic organisms and did not converge to reference or pre-dredge composition even after multiple (3 or more) years (Saloman 1974, Taylor Biological Company 1978, Van Dolah et al. 1992, 1994). There has been no definitive analysis of the conditions that lead to mud deposition in some but not other borrow areas, so no confident predictions can be generated for this specific Bogue Banks project. Presumably, rate of supply of suspended fine sediments and bottom shear stress help determine the degree of deposition of fine sediments.

Baseline sampling of the nourishment sites and control sites on the beach itself would also need to be conducted prior to sand mining, but during the warm months when the intertidal beach is used by macrofauna. We already possess a substantial amount of data on abundances of intertidal beach invertebrates from all along Bogue Banks from 1997-1999 from studies conducted by L. Manning (unpubl.: see Table 11 for an example data set). This information could conceivably be incorporated into an assessment design to evaluate the potential consequences of the renourishment on the beach system, allowing contrasts between the multiple summers before renourishment and the summer or summers afterwards as one means of assessing impact and rate of recovery. This previous sampling was not conducted in a design intended for evaluation of the Bogue Banks renourishment project, so it is unclear whether sufficient sites were sampled throughout the biologically active (warm) seasons in sufficient places to provide a set of replicated reference and treatment (renourished) sites sufficient to achieve adequately powerful tests of impacts on intertidal invertebrates. A review of past studies of the response of beach invertebrates to renourishment projects (Nelson 1989, 1993, Peterson et al. 2000) suggests that return of macroinvertebrates will be rapid if renourishment is restricted to months when invertebrates are largely absent from the intertidal beach and if a good match exists between grain size distributions of the natural beach and the new sands that are added. Finer particles are detrimental to suspension feeders, especially mole crabs (Bowman and Dolan 1985), and slow their recovery. In analyzing short-term effects of renourishment in Pine Knoll Shores on Bogue Banks, North Carolina, Peterson et al. (2000) documented virtual failure to initiate the recovery process by mole crabs and coquina clams, the biomass dominants of the Bogue Banks intertidal beaches, by mid July, 5-10 weeks after termination of the project. This renourishment grossly modified the beach sedimentology, changing average phi from 2.33 to 3.67 (Peterson et al. 2000). A previous renourishment project on Bogue Banks at Fort Macon studied by Reilly and Bellis (1983) documented a similar failure of coquina clams to return to the beach by the first July after project completion, but mole crabs did return with only a one-month time lag relative to the seasonal cycle at control beaches. No information on quantitative sedimentology is provided in that report, although there is a claim of a good match in grain size, which could explain why mole crabs were able to initiate recovery sooner than in the Pine Knoll Shores project studied by Peterson et al. (2000). Manning (unpub. data) also has shown that enhancing shell content on the intertidal beach has a strong negative effect on coquina clams by inhibiting normal rates of burrowing, thereby exposing them to transport off the beach into unfavorable and potentially inhospitable environments.

5. Conclusions and Recommendations

(1) Based on our benthic invertebrate sampling, fish trawling, and observations of fish guts, we conclude that demersal fishes of commercial and recreational value are using the invertebrates on the seafloor at the Borrow Areas as food during the late fall (and presumably also winter and spring). We recommend a targeted evaluation of the degree to which these fishes are food-limited during late fall through spring and the degree to which they rely in all seasons on the prospective Borrow Areas for feeding as compared to nearby bottom habitats and sites, so as to evaluate the significance of reduced abundances of benthic invertebrates in Borrow Areas. It is presently unclear in the absence of sampling other shelf habitats and sites whether the sand bodies proposed for dredging are preferred feeding grounds, relatively low-use feeding grounds, or used in proportion to the bottom area that they occupy.

(2) We conclude that demersal fishes are sufficiently abundant at the Borrow Areas to justify additional sampling at other seasons and in other habitats offshore so as to be able to quantify the importance of the Borrow Areas to the total fish populations.

(3) We conclude that benthic invertebrates are common enough during late fall in the Borrow Areas and important enough as food for demersal fishes as to justify benthic monitoring in other seasons of the year prior to and after mining activities to assess impact and recovery.

(4) We conclude that sampling of intertidal beach invertebrates is necessary to provide the baseline for impact assessment after the renourishment. Such baseline information could conceivably come from historical data, but only if a sufficiently powerful design can be created, based on knowledge of spatial and temporal fluctuations and the project plan.

(5) A review of limited information on recovery rates of sediments and benthic invertebrate resources in offshore borrow areas from other studies suggests that recovery rate is unpredictable, requiring times ranging from a year to indefinite (undetermined) numbers of years.

(6) Results of the most applicable and recent study of impacts of renourishment on beach invertebrates imply effects that could last throughout the warm season if sediments used in renourishment do not match those of the natural beach. We recommend that renourishment occur in winter (the period of low intertidal abundances of beach invertebrates, which is December through March) and that sands used in renourishment be treated to remove shell that exceeds the average on the untreated beach and be selected to avoid deposition of mud balls and silts and clays to minimize duration of negative impacts. It seems that enhancement of the phi size to 3.67 was inadequate to allow rapid recolonization in a previous renourishment of Bogue Banks, but what phi increase is possible without impact on recovery rates of beach invertebrates is unclear.

(7) We conclude that inadequate information exists to recommend one proposed Borrow Area over any other for this project. Sampling of benthic invertebrate resources on only a single date does not provide sufficient seasonal coverage to rank the proposed Borrow Areas by importance as prey for demersal fishes and crustaceans.

(8) We conclude that the Bogue Banks renourishment project could be conducted with minimal adverse ecological damage (a) if the borrow sites were dredged in a way that avoided complete excavation of the sand body and avoided changes in sedimentation processes, thus preventing their transformation into depositional muddy areas, (b) if the dredging were confined to periods of low abundance of demersal fishes and shrimps at the borrow areas (as determined by in situ monitoring prior to dredging), and (c) if the sands deposited on the intertidal beach matched the size distribution of natural sands on the beach with minimal muds and minimal shell and were deposited during the winter (December through March) when these invertebrates are largely absent. These requirements present technical uncertainties because (a) it is not clear that we understand the potential sources of fine sediments and the processes of deposition of fine sediments at the Borrow Areas well enough to have confidence in designing the sand mining in a way that will avoid transformation into muddy bottoms; (b) the costs of placing the dredge on hold while awaiting departure of demersal fishes in late fall may preclude using monitoring to determine exactly when fish impacts will be minimized; and (c) costs of providing a sand resource that matches the sedimentology of the natural beach may be high.

6. Literature Cited

Bowman, M.L., and R. Dolan. 1985. The relationship of Emerita talpoida to beach charactersitics. J. Coastal Res. 1:151-163.

Carver, R.E., 1971. Procedures in Sedimentary Petrology. Wiley-Interscience, New York. pp. 49-127.

Dahlgren, C.P., M.H. Posey, and A.W. Hulbert. 1999. The effects of bioturbation on the infaunal community adjacent to an offshore hardbottom reef. Bull. Mar. Sci. 64:21-34.

Day, J.H., J.G. Field, and M.P. Montgomery. 1971. The use of numerical methods to determine the distribution of the benthic fauna across the continental shelf of North Carolina. J. Anim. Ecol. 40:93-125.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill, Austin, TX.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. Wiley, New York, NY.

McLachlan, A. 1983. Sandy beach ecology: a review. In: McLachlan, A. , and Erasmus, T. (eds.) Sandy beaches as ecosystems, W. Junk, The Hague, pp. 321-380.

Naqvi, S.M., and E.J. Pullen. 1982. Effects of beach nourishment and borrowing on marine organisms. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Misc. Rept. 82-14.

Nelson, W.G. 1989. An overview of the effects of beach nourishment on the sand beach fauna. In: Tait, L.S. (ed.) Beach preservation technology '88: problems and advances in beach nourishment. Tallahassee, FL: Florida Shore and Beach Preservation Association, pp. 295-310.

Nelson, W.G. 1993.Beach restoration in the southeastern US: environmental effects and biological monitoring. Ocean Coastal Manage. 19:157-182.

Peterson, C.H., H.C. Summerson, H.S. Lenihan, J. Grabowski, S.P. Powers, and G.W. Safrit, Jr. 1999. Beaufort Inlet Benthic Resources Survey. Report to the U.S. Army Corps of Engineers, Wilmington District Office, NC.

Peterson, C.H., D.H.M. Hickerson, and G.Grissom Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. J. Coastal Res. 16:368-378.

Posey, M.H. and W.G Ambrose, Jr. 1994. Effects of proximity to an offshore hard-bottom reef on infaunal abundances. Mar. Biol. 118:745-753.

Reed, A.J. and J.T. Wells. 2000. Sediment distribution patterns offshore of a renourished beach: Atlantic Beach and Fort Macon, North Carolina. Journal of Coastal Research (in press).

Reilly, F.J., and V.J Bellis. 1983. The ecological impacts of beach nourishment with dredged materials on the intertidal zone at Bogue Banks, North Carolina. Misc. Rept. 83-3, U.S. Army Corps of Engineers, CERC, Springfield, VA.

Saloman, C.H. 1974. Physical, chemical, and biological characteristics of nearshore zone of sandy key, Florida, prior to beach restoration. Final Report, U.S. Army Corps of Engincers, Coastal Engineering Research Center, Fort Belvoir, VA.

Snelgrove, P.V., and C.A Butman. 1994. Animal-sediment relationships revisited: cause versus effect. Oceanogr. Mar. Biol. Ann. Rev. 32:111-177.

Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker. 1986. Environmental impact assessment: pseudoreplication in time? Ecology 60:1225-1240.

Taylor Biological Company. 1978. Ecological comparison of beaches, offshore borrow sites and adjacent bottom at Anna Maria Island and Treasure Island, Florida. Contract No. DACW17-78-M-1410, U.S. Army Engineer District, Jacksonville, Jacksonville, FL.

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levinsen, and W.A. Roumillat. 1992. A physical and biological monitoring study of the Hilton Head beach nourishment project. Report to the Town of Hilton Head Island, Hilton Head Island, SC, and the South Carolina Coastal Council, Charleston, SC.

Van Dolah, R.F. R.M. Martore, A.E. Lynch, P.H. Wendt, M.V. Levisen, D.J. Whitaker, and W.D. Anderson. 1994. Environmental evaluation of the Folly Beach nourishment project. Report to the U.S. Army Corps of Engineers, Charleston, SC.

Warwick, R.M. 1988. The level of taxonomic discrimination required to detect pollution effects on marine benthic communities. Mar. Poll. Bull. 19:259-268.

Warwick, R.M. 1993. Environmental impact studies in marine communities: pragmatical considerations. Aust. J. Ecol. 18:63-80.

7. List of Figures

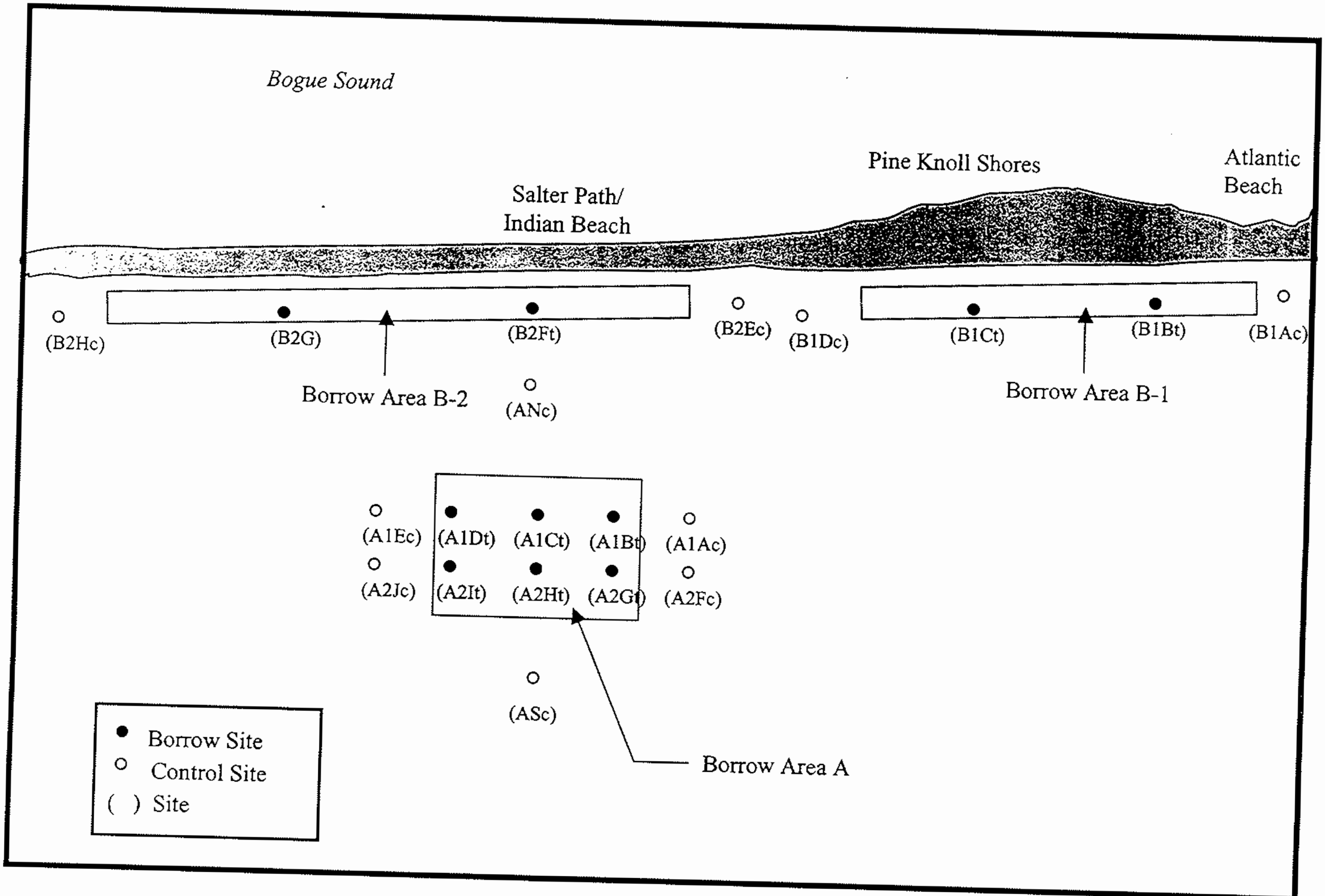


Figure 1. Schematic representation of sampling sites (see Table 1 for precise coordinates of each site).

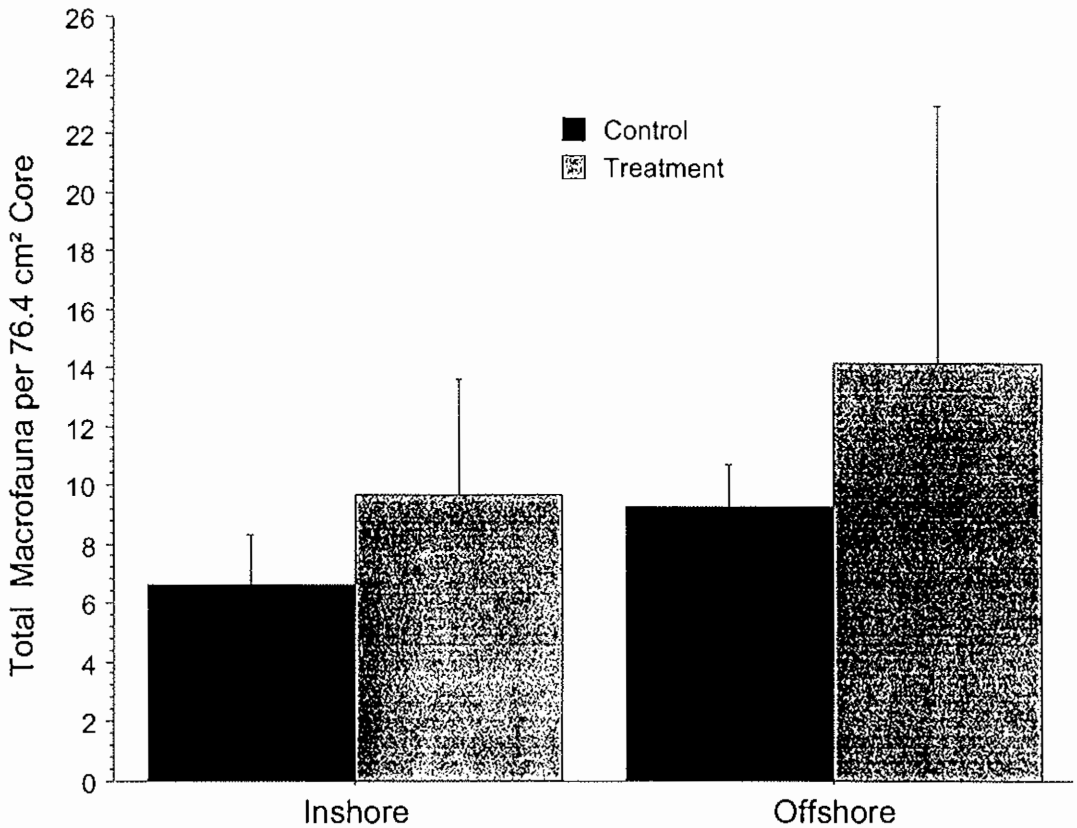


Figure 2. Mean (+standard deviation) abundances of macrofauna from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

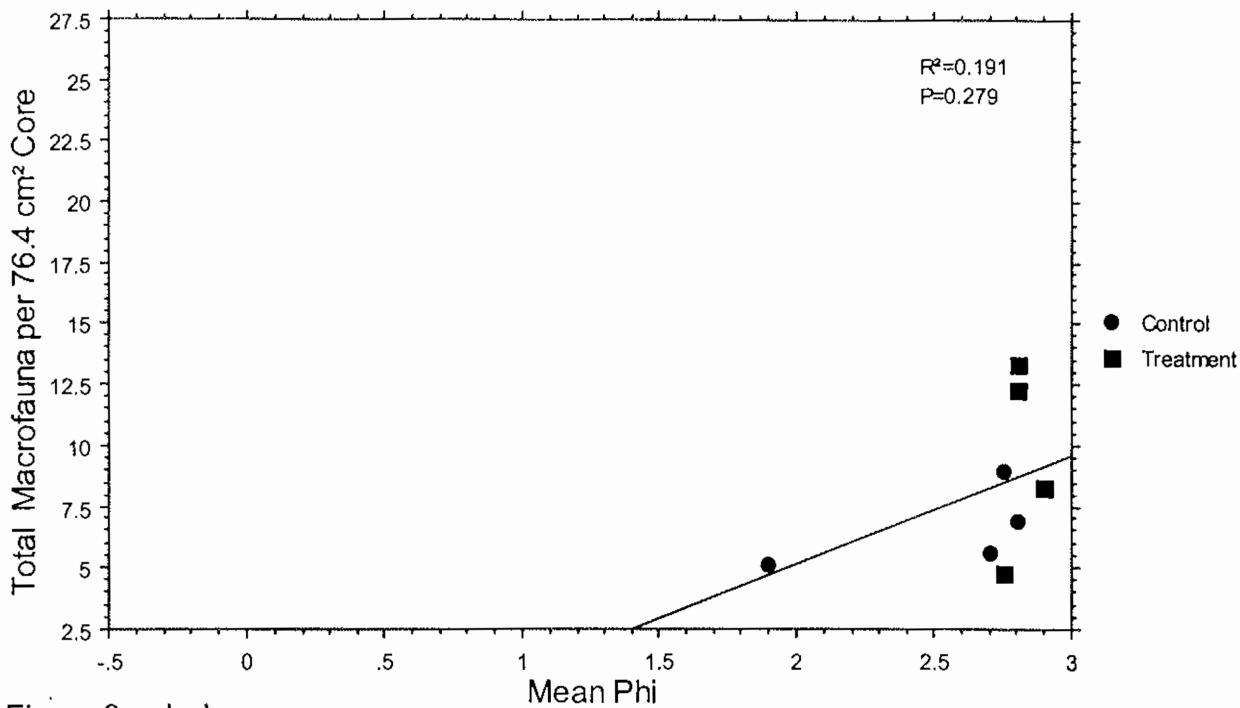


Figure 3a - Inshore

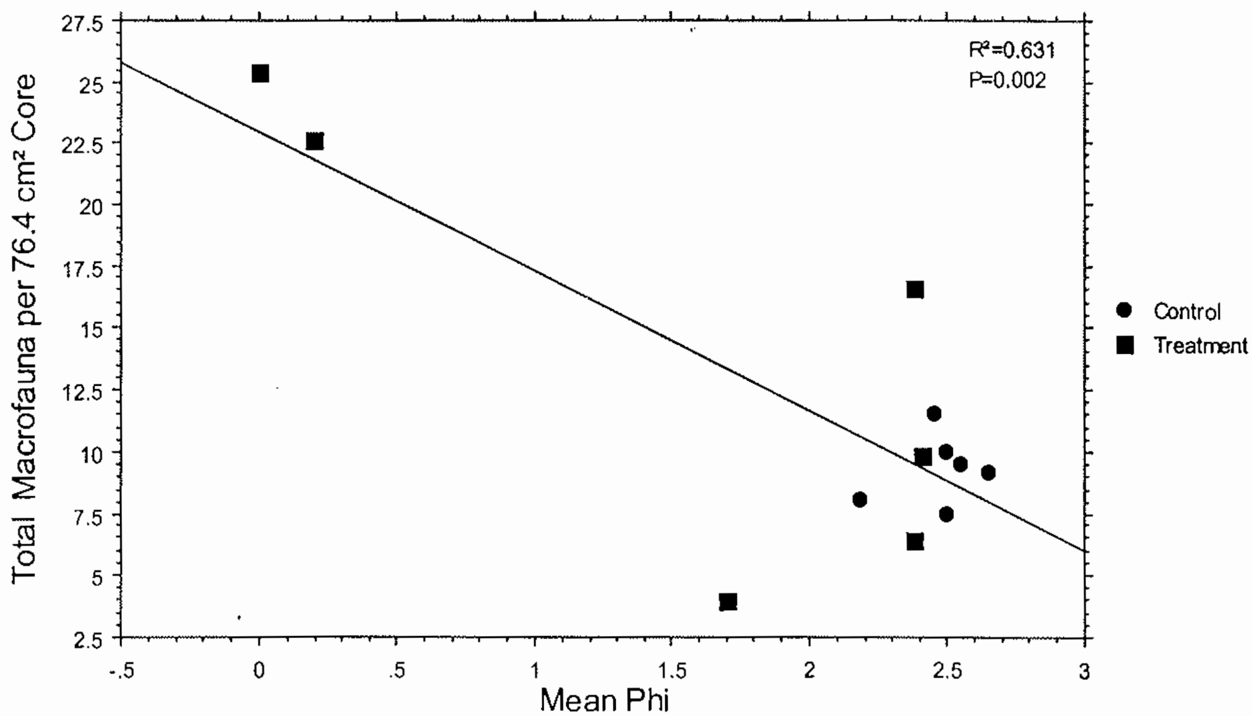


Figure 3b - Offshore

Figure 3. Regressions of mean abundances of macrofauna against sediment mean phi grain size from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore (3a) and offshore (3b). Mean values average ten 76.4 cm^2 cores per site.

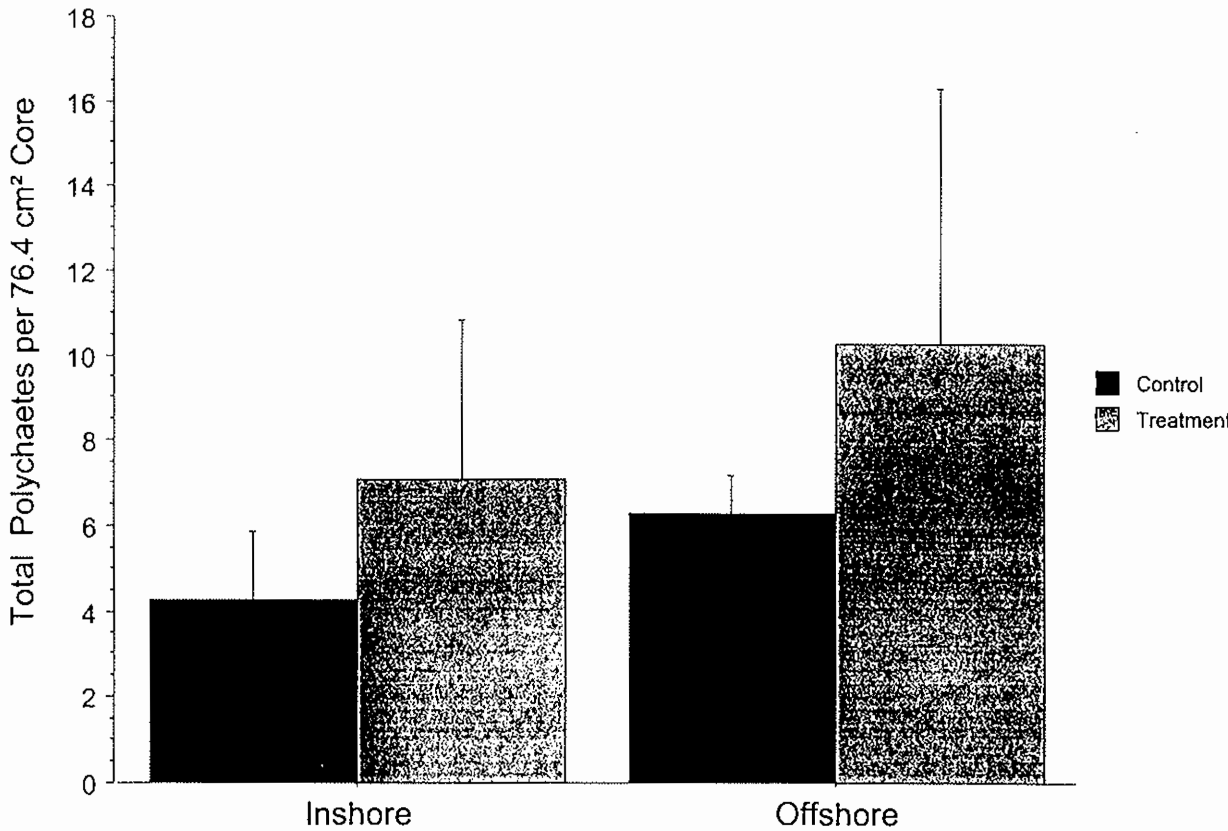


Figure 4. Mean (+standard deviation) abundances of polychaetes from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

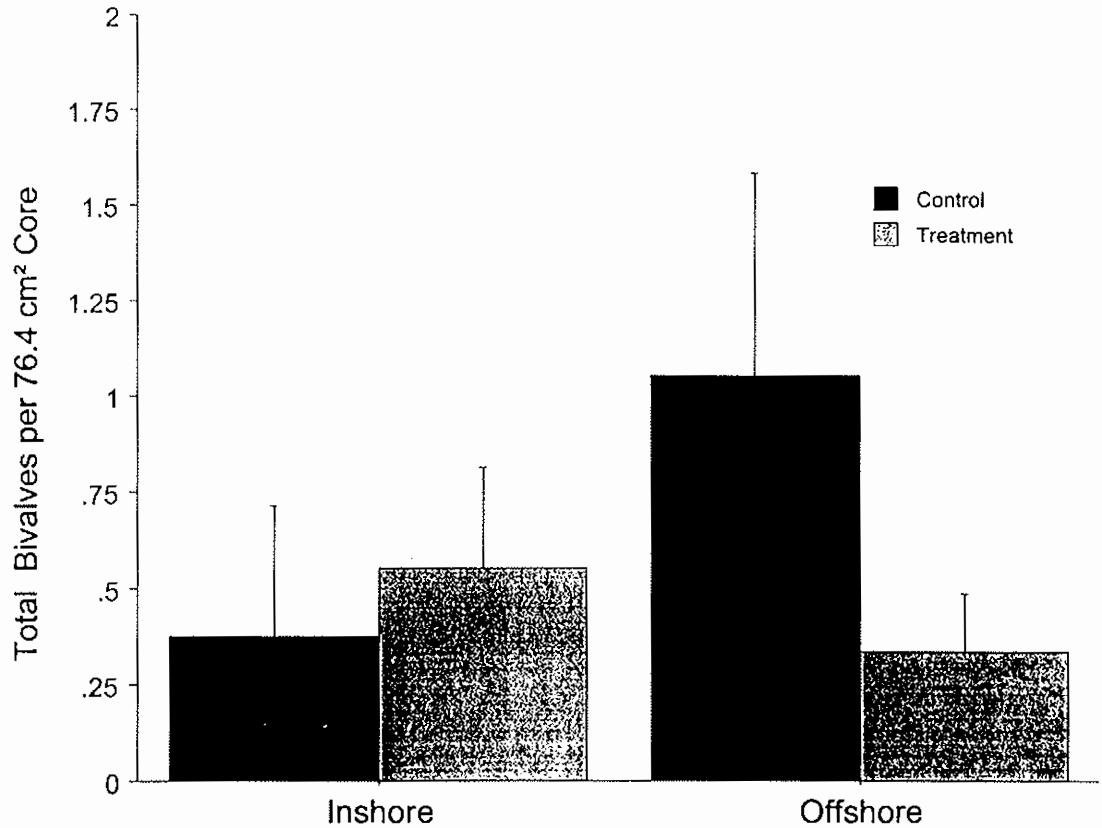


Figure 5. Mean (+standard deviation) abundances of bivalves from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

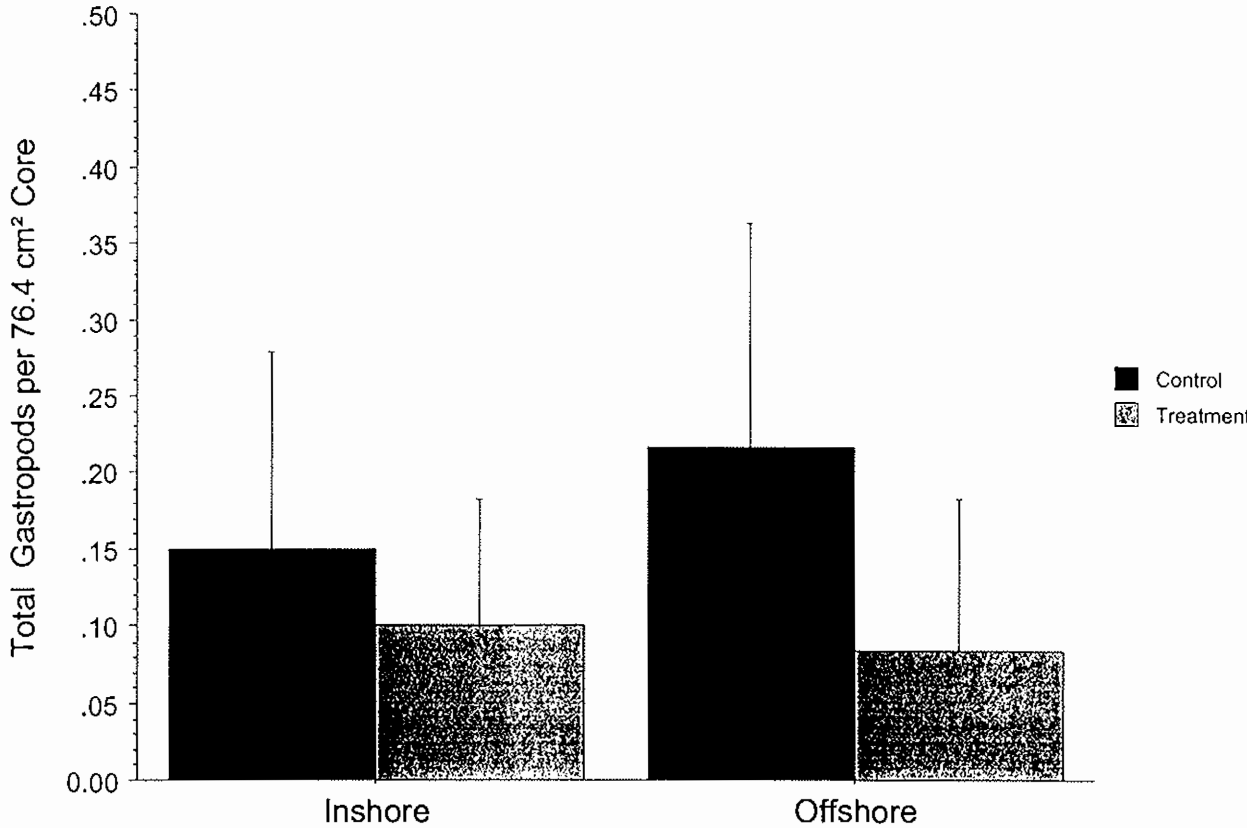


Figure 6. Mean (+standard deviation) abundances of gastropods from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

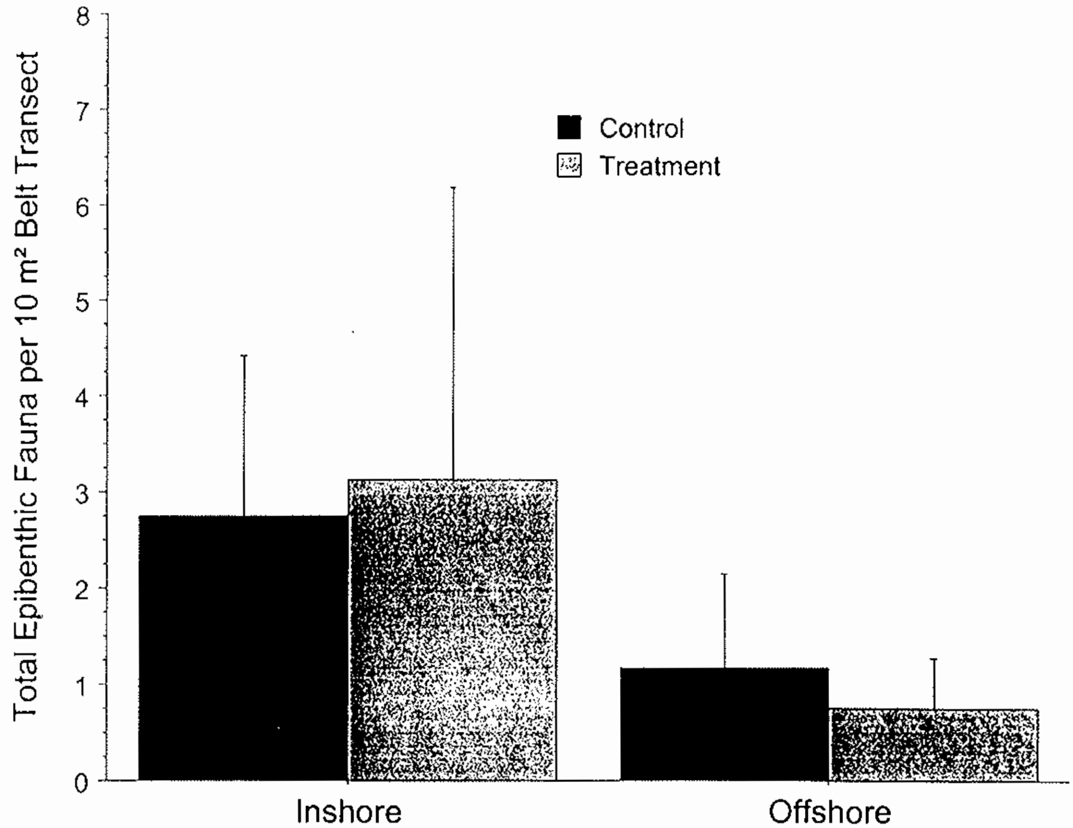


Figure 7. Mean (+standard deviation) abundances of epibenthic fauna from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average two10 m^2 belt transects per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

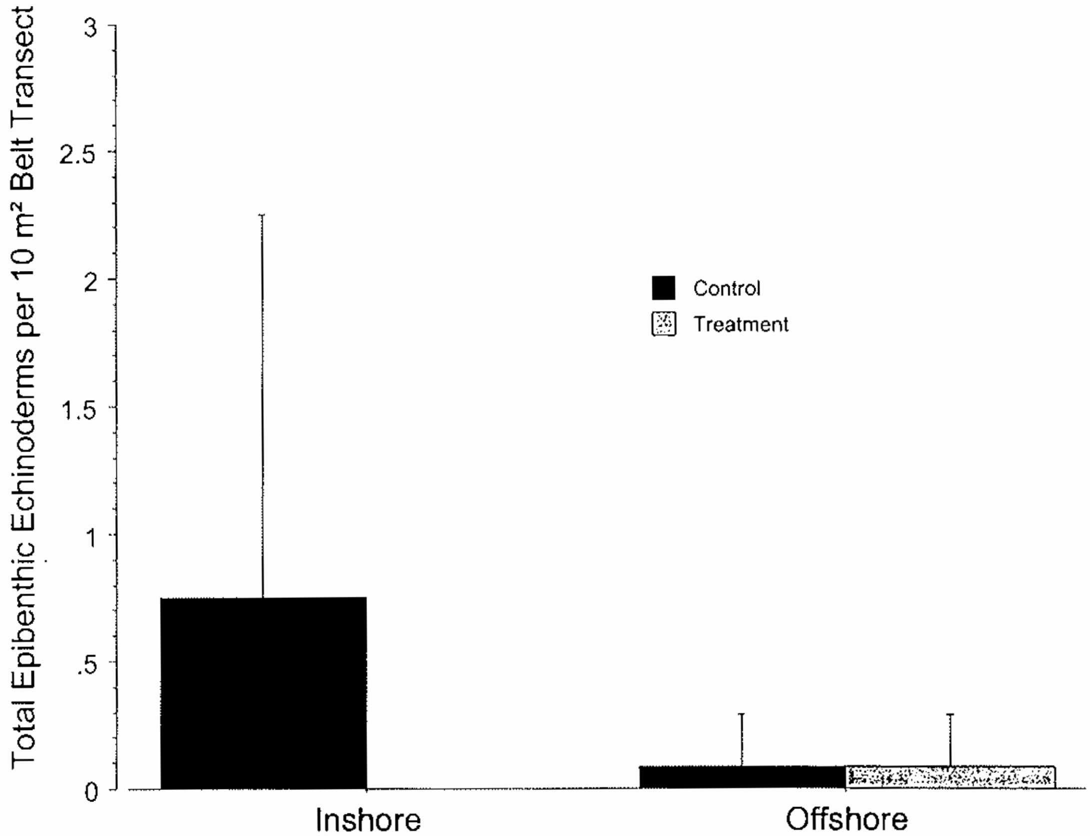


Figure 8. Mean (+standard deviation) abundances of epibenthic echinoderms from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average two10 m^2 belt transects per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

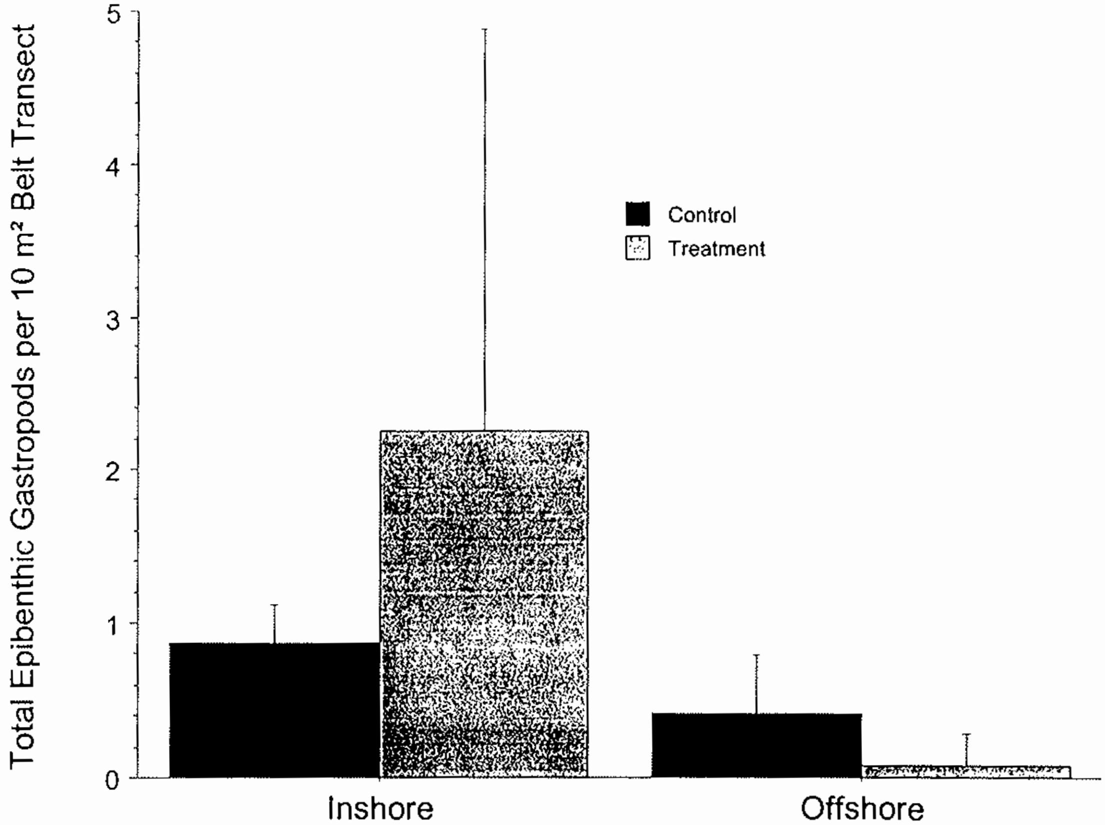
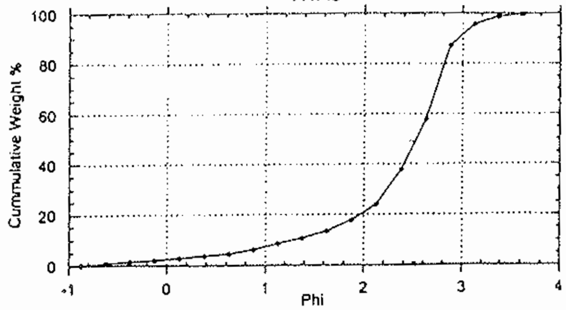


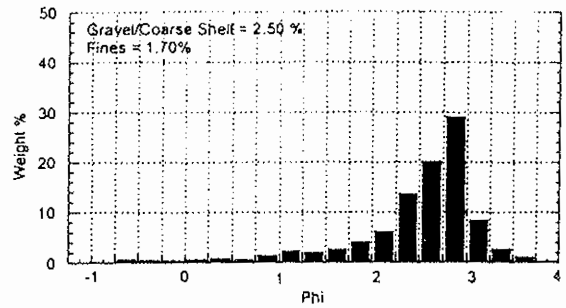
Figure 9. Mean (+standard deviation) abundances of epibenthic gastropods from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average two10 m^2 belt transects per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

Figure 10. Size frequency curves and histograms of composite bottom samples taken at treatment and control sites in Borrow Areas A, B-1, and B-2.

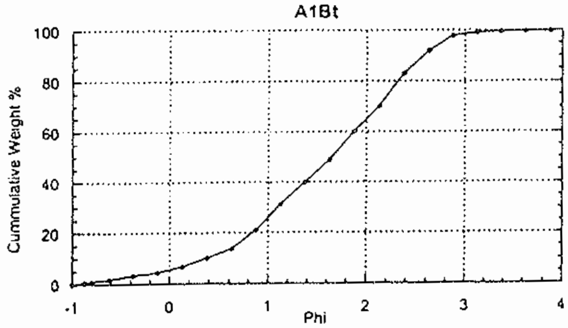
A1Ac



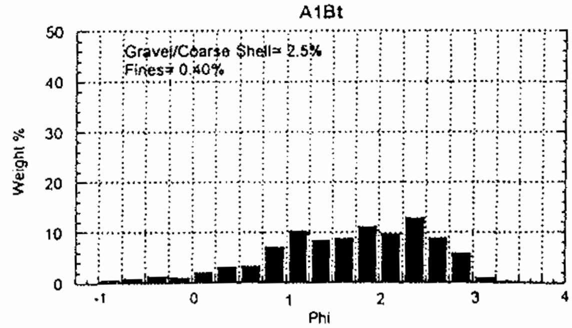
A1Ac



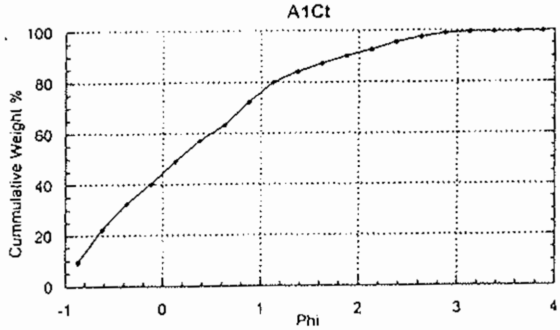
A1Bt



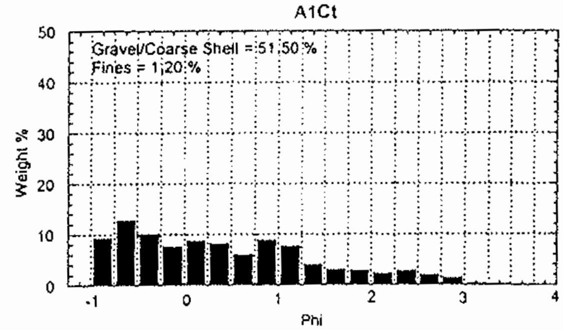
A1Bt



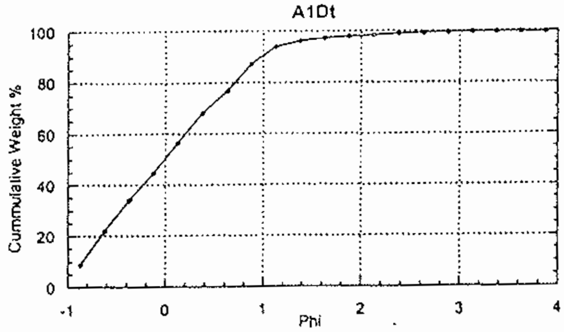
A1Ct



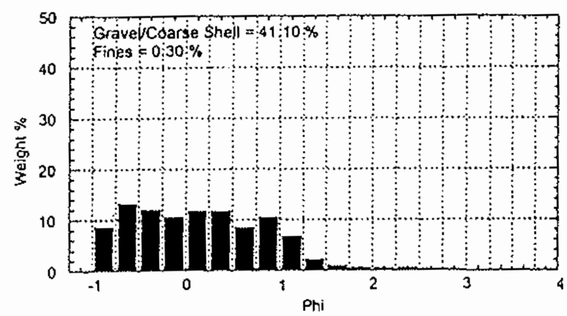
A1Ct



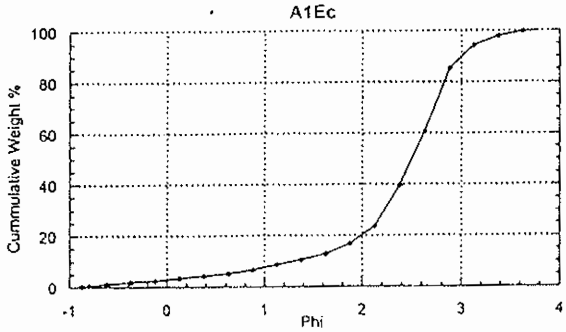
A1Dt



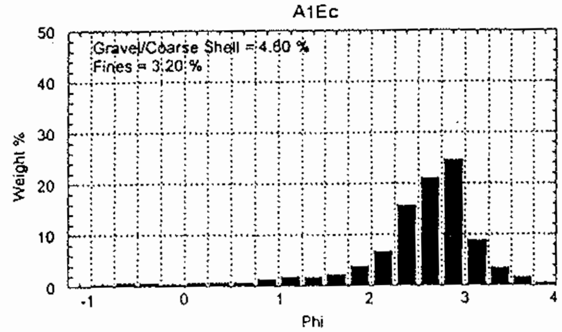
A1Dt

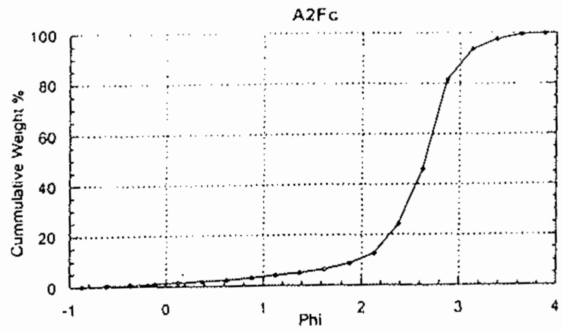


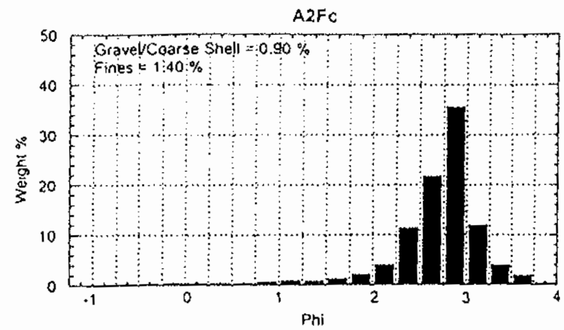
A1Ec

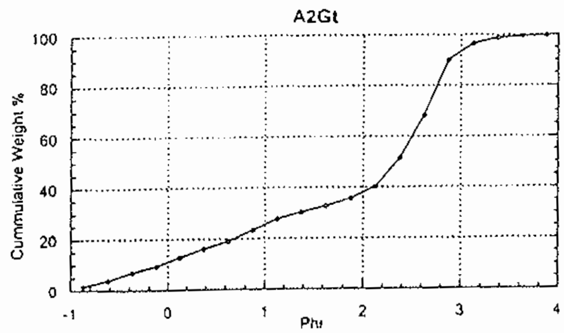


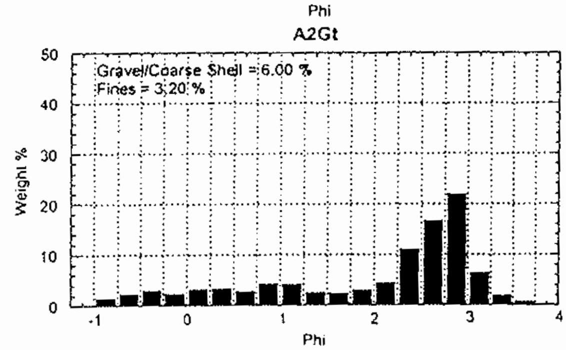
A1Ec

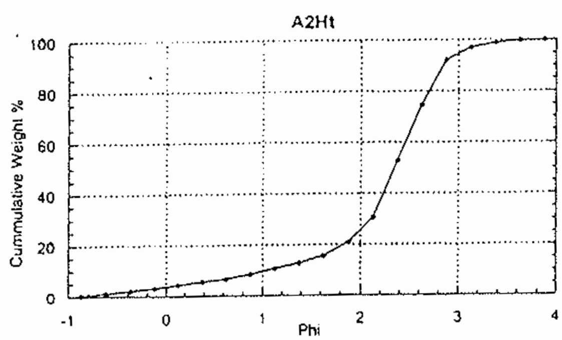


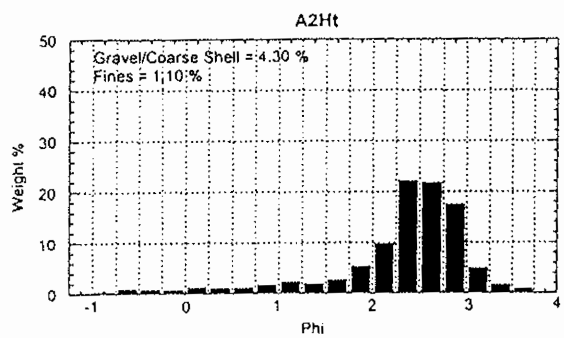

A2Fc
Cummulative Weight %
Phi

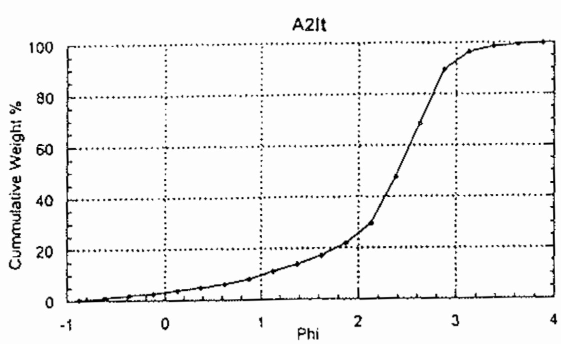

A2Fc
Gravel/Coarse Shell = 0.90 %
Fines = 1.40 %
Weight %
Phi

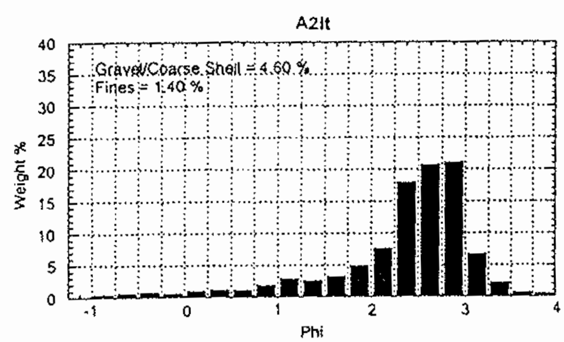

A2Gt
Cummulative Weight %
Phi

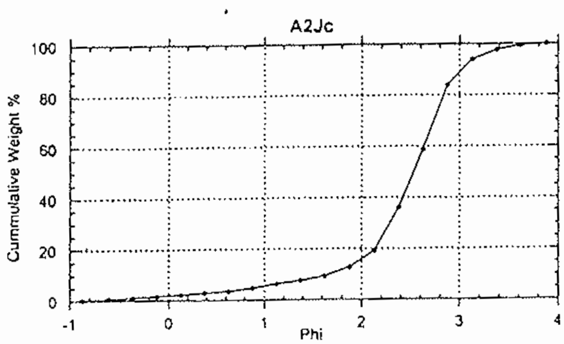

A2Gt
Gravel/Coarse Shell = 6.00 %
Fines = 3.20 %
Weight %
Phi

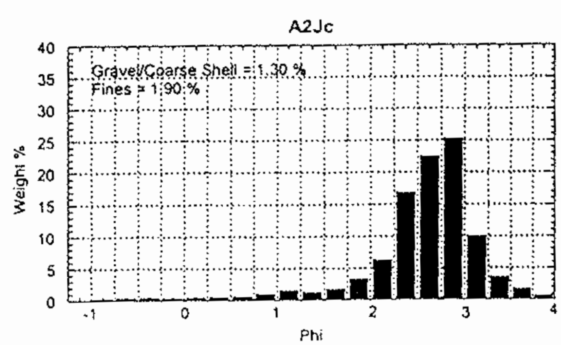

A2Ht
Cummulative Weight %
Phi

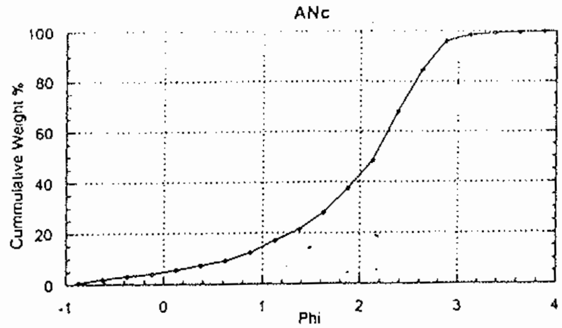

A2Ht
Gravel/Coarse Shell = 4.30 %
Fines = 1.10 %
Weight %
Phi

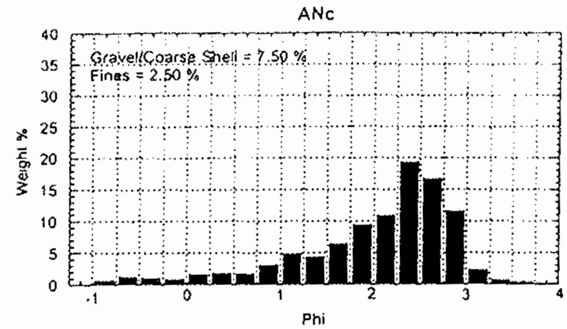

A2It
Cummulative Weight %
Phi

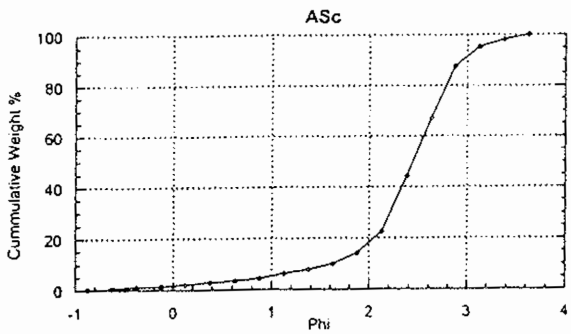

A2It
Gravel/Coarse Shell = 4.60 %
Fines = 1.40 %
Weight %
Phi

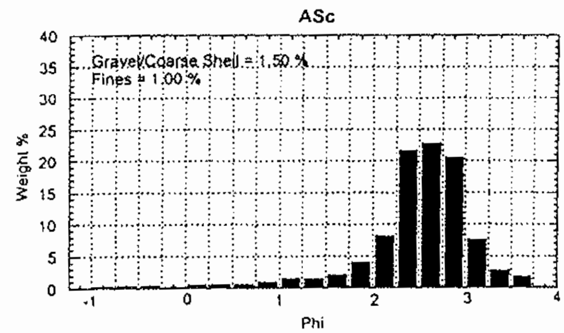

A2Jc
Cummulative Weight %
Phi

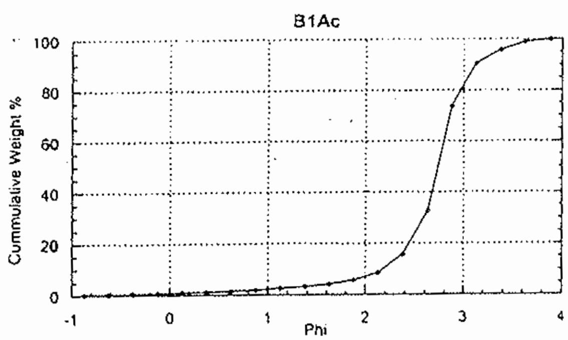

A2Jc
Gravel/Coarse Shell = 1.30 %
Fines = 1.90 %
Weight %
Phi

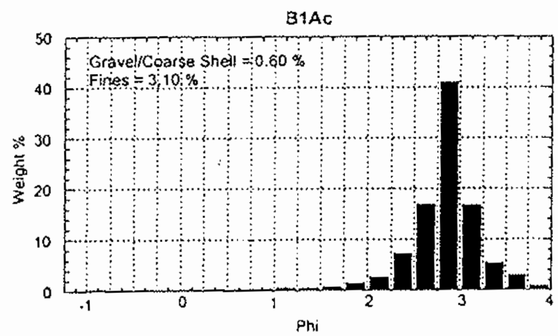

ANc
Cummulative Weight %
Phi

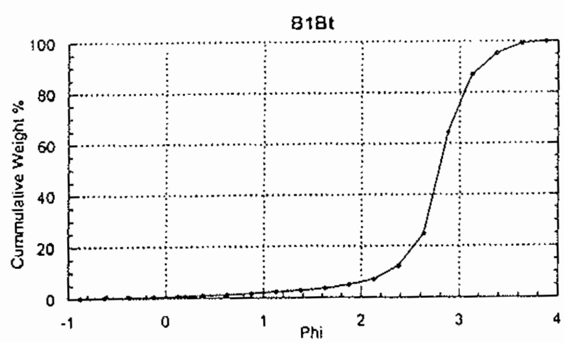

ANc
Gravel/Coarse Shell = 7.50 %
Fines = 2.50 %
Weight %
Phi

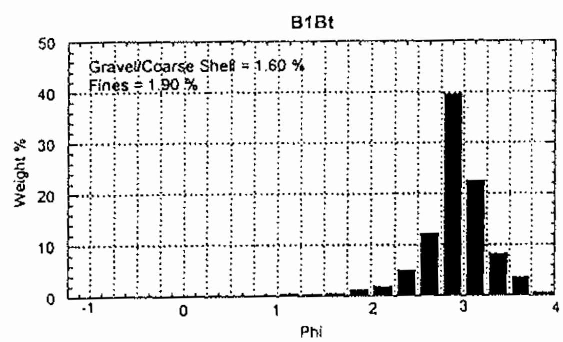

ASc
Cummulative Weight %
Phi

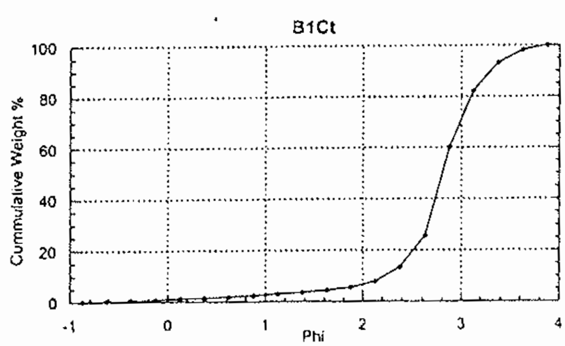

ASc
Gravel/Coarse Shell = 1.50 %
Fines = 1.00 %
Weight %
Phi

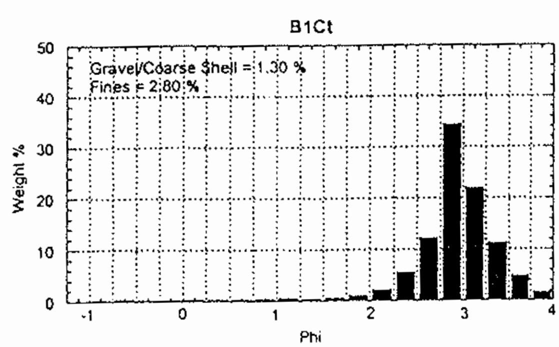

B1Ac
Cummulative Weight %
Phi

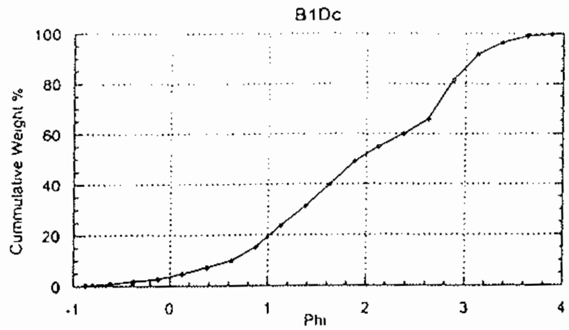

B1Ac
Gravel/Coarse Shell = 0.60 %
Fines = 3.10 %
Weight %
Phi

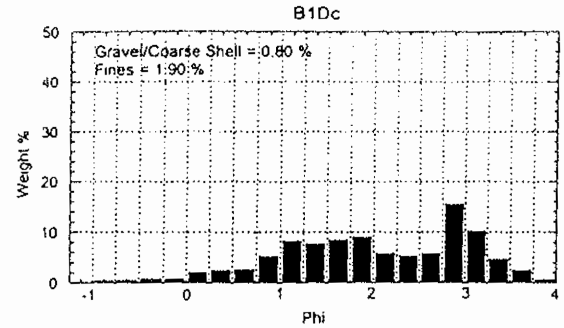

B1Bt
Cummulative Weight %
Phi

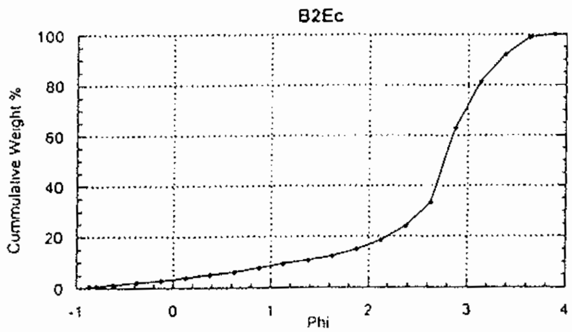

B1Bt
Gravel/Coarse Shell = 1.60 %
Fines = 1.90 %
Weight %
Phi

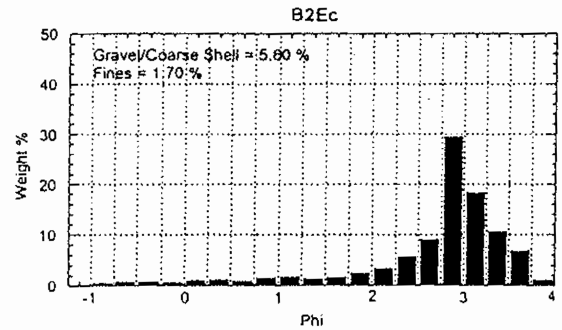

B1Ct
Cummulative Weight %
Phi

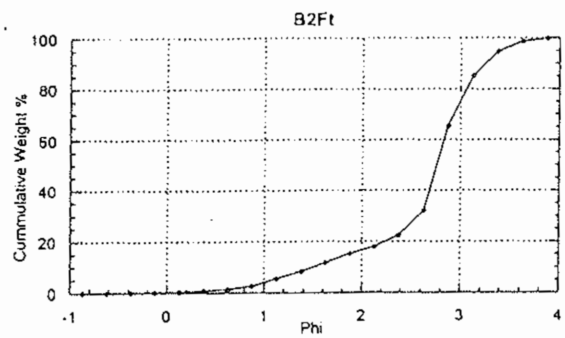

B1Ct
Gravel/Coarse Shell = 1.30 %
Fines = 2.80 %
Weight %
Phi

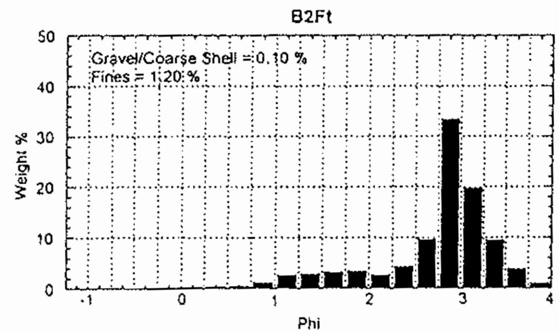

B1Dc
Cummulative Weight %
Phi

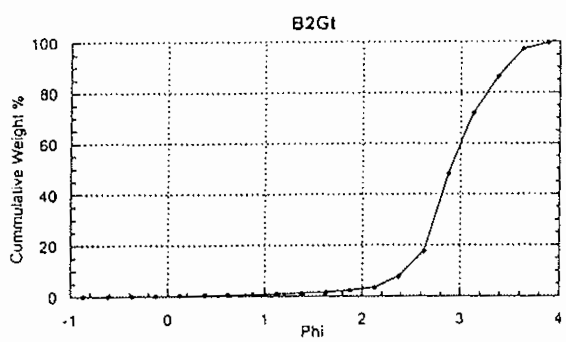

B1Dc
Gravel/Coarse Shell = 0.80 %
Fines = 1.90 %
Weight %
Phi

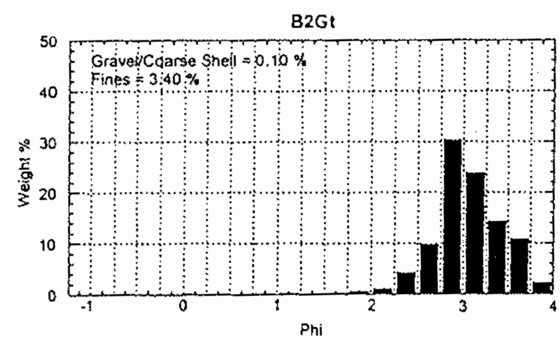

B2Ec
Cummulative Weight %
Phi

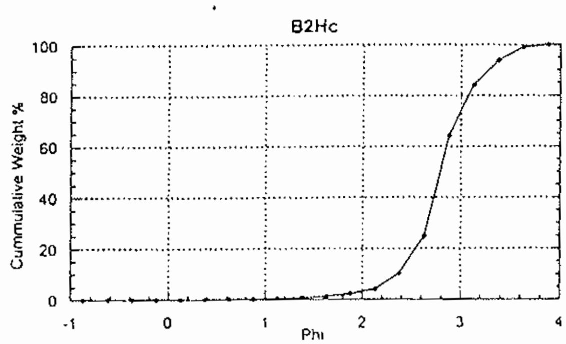

B2Ec
Gravel/Coarse Shell = 5.60 %
Fines = 1.70 %
Weight %
Phi


B2Ft
Cummulative Weight %
Phi


B2Ft
Gravel/Coarse Shell = 0.10 %
Fines = 1.20 %
Weight %
Phi


B2Gt
Cummulative Weight %
Phi


B2Gt
Gravel/Coarse Shell = 0.10 %
Fines = 3.40 %
Weight %
Phi


B2Hc
Cummulative Weight %
Phi

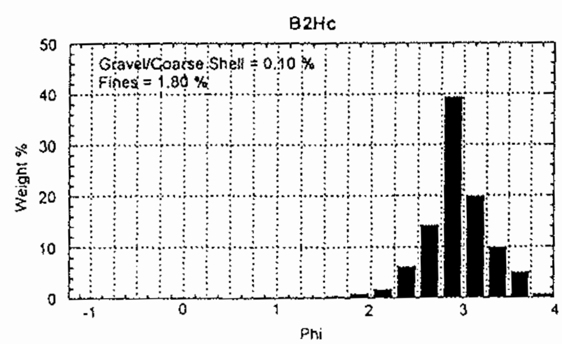

B2Hc
Gravel/Coarse Shell = 0.10 %
Fines = 1.80 %
Weight %
Phi

Table 1. Actual coordinates (in degrees - decimal minutes) of sites sampled in and adjacent to proposed sand Borrow Areas off Bogue Banks, NC. Sites are plotted on Figure 1.

Site	Latitude	Longitude	Site	Latitude	Longitude
Borrow Area 1			**Control**		
A1Bt	N 34° 39.333'	W 76° 53.625'	**A1Ac**	N 34° 39.333'	W 76° 52.875'
A1Ct	N 34° 39.333'	W 76° 54.375'	**A1Ec**	N 34° 39.333'	W 76° 55.875'
A1Dt	N 34° 39.333'	W 76° 55.125'	**A2Fc**	N 34° 38.917'	W 76° 52.875'
A2Gt	N 34° 38.917'	W 76° 53.625'	**A2Jc**	N 34° 38.917'	W 76° 55.875'
A2Ht	N 34° 38.917'	W 76° 54.375'	**ANc**	N 34° 40.067'	W 76° 54.175'
A2It	N 34° 38.917'	W 76° 55.125'	**ASc**	N 34° 38.183'	W 76° 54.375'
Borrow Area B-1*			**Control**		
B1Ct	N 34° 41.06'	W 76° 49.652'	**B1Ac**	N 34° 41.261'	W 76° 45.706'
B1Bt	N 34° 41.227'	W 76° 47.841'	**B1Dc**	N 34° 40.862'	W 76° 51.819'
Borrow Area B-2*			**Control**		
B2Ft	N 34° 40.545'	W 76° 54.374'	**B2Ec**	N 34° 40.797'	W 76° 52.187'
B2Gt	N 34° 40.245'	W 76° 56.44'	**B2Hc**	N 34° 39.891'	W 76° 58.752'

* sampled at 35' contour determined by standardizing for 37' at 34°41.023'N 34°49.702'W

Table 2a. Mean (SD = standard deviation) of abundance of individuals by taxonomic family found in 76.4cm² core samples taken at sites in (Treatment) and adjacent (Control) to inshore and offshore proposed sand borrow areas for the Bogue Banks beach renourishment. Statistics are calculated from the average of 10 cores taken from each of 6 sites sampled both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

			Inshore		Offshore	
			Treatment (n=4)	Control (n=4)	Treatment (n=6)	Control (n=6)
		Family	mean SD	mean SD	mean SD	mean SD
Mollusc	Bivalve	juv	0.05 (0.058)	0.2 (0.141)	0.033 (0.052)	0.133 (0.197)
		Arcid	0.05 (0.058)	0 (0)	0 (0)	0.017 (0.041)
		Corbulid	0 (0)	0 (0)	0.017 (0.041)	0 (0)
		Crassatellid	0 (0)	0 (0)	0.033 (0.082)	0 (0)
		Cuspidariid	0 (0)	0 (0)	0 (0)	0.017 (0.041)
		Diplodontid	0 (0)	0.025 (0.05)	0 (0)	0 (0)
		Lucinid	0.225 (0.15)	0.075 (0.096)	0.117 (0.16)	0.667 (0.497)
		Mactrid	0.1 (0.2)	0.025 (0.05)	0.017 (0.041)	0.067 (0.082)
		Mesodesmatid	0 (0)	0 (0)	0 (0)	0.017 (0.041)
		Pandorid	0 (0)	0 (0)	0 (0)	0.017 (0.041)
		Solecurtid	0.05 (0.1)	0 (0)	0.017 (0.041)	0.033 (0.082)
		Tellinid	0.025 (0.05)	0.025 (0.05)	0.067 (0.082)	0.05 (0.084)
		Venerid	0.05 (0.058)	0.025 (0.05)	0.033 (0.052)	0.033 (0.052)
	Total	Bivalve	0.55 (0.265)	0.375 (0.34)	0.333 (0.151)	1.05 (0.532)
	Gastropod	Acteocinid	0 (0)	0 (0)	0.017 (0.041)	0 (0)
		Columbellid	0.025 (0.05)	0 (0)	0.05 (0.084)	0.083 (0.117)
		Nassariid	0 (0)	0.025 (0.05)	0 (0)	0 (0)
		Naticid	0.025 (0.05)	0.025 (0.05)	0 (0)	0.05 (0.084)
		Olivid	0.025 (0.05)	0.05 (0.1)	0.017 (0.041)	0.067 (0.082)
		Terebrid	0.025 (0.05)	0.05 (0.1)	0 (0)	0.017 (0.041)
	Total	Gastropod	0.1 (0.082)	0.15 (0.129)	0.083 (0.098)	0.217 (0.147)
	Opistobranch	Haminoeid	0.025 (0.05)	0 (0)	0.017 (0.041)	0.033 (0.052)
	Scaphopod		0 (0)	0 (0)	0.017 (0.041)	0.033 (0.052)
	Total	Mollusc	0.675 (0.33)	0.525 (0.32)	0.45 (0.176)	1.333 (0.427)

Table 2a cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
Crustacea	Amphipod	unident.	0 (0)	0.025 (0.05)	0 (0)	0.067 (0.121)
		Ampeliscid	0 (0)	0 (0)	0.017 (0.041)	0.05 (0.055)
		Aorid	0.025 (0.05)	0.025 (0.05)	0.017 (0.041)	0.017 (0.041)
		Caprellid	0 (0)	0 (0)	0.033 (0.052)	0 (0)
		Corophiid	0 (0)	0 (0)	0.017 (0.041)	0 (0)
		Gammerid	0.075 (0.05)	0.05 (0.1)	0.05 (0.122)	0.05 (0.055)
		Haustoriid	0.125 (0.096)	0.1 (0.141)	0.017 (0.041)	0.05 (0.084)
		Liljeborgiid	0.025 (0.05)	0.1 (0.141)	0.083 (0.117)	0.067 (0.103)
		Melitid	0 (0)	0.025 (0.05)	0.183 (0.402)	0 (0)
		Oedicerotid	0.175 (0.222)	0.2 (0.183)	0.05 (0.122)	0.033 (0.052)
		Phoxocephalid	0 (0)	0.025 (0.05)	0.017 (0.041)	0 (0)
		Stenothoid	0 (0)	0 (0)	0 (0)	0.017 (0.041)
	Total	Amphipod	0.425 (0.206)	0.55 (0.443)	0.483 (0.449)	0.35 (0.138)
	Copepoda		0 (0)	0 (0)	0.017 (0.041)	0 (0)
	Cumacean		0.075 (0.05)	0.075 (0.096)	0.083 (0.098)	0.05 (0.084)
	Decapod	unident.	0.025 (0.05)	0 (0)	0.017 (0.041)	0 (0)
		Pagurid	0 (0)	0.15 (0.238)	0.017 (0.041)	0.017 (0.041)
		Penacid	0.025 (0.05)	0 (0)	0 (0)	0.017 (0.041)
		Pinnotherid	0.1 (0.082)	0.075 (0.15)	0.083 (0.16)	0.233 (0.333)
		Sergestid	0.025 (0.05)	0 (0)	0 (0)	0.017 (0.041)
		Xanthid	0 (0)	0.025 (0.05)	0 (0)	0 (0)
	Isopod	Idoteid	0.05 (0.058)	0.025 (0.05)	0 (0)	0.05 (0.122)
		Sphaeromatid	0 (0)	0.025 (0.05)	0 (0)	0 (0)
	Isopod	total	0.05 (0.058)	0.05 (0.058)	0 (0)	0.05 (0.122)
	Mysid		0 (0)	0.1 (0.141)	0 (0)	0 (0)
	Ostracod		0 (0)	0.025 (0.05)	0 (0)	0.017 (0.041)
	Tanaid		0 (0)	0 (0)	0.017 (0.041)	0.017 (0.041)
	Total	Crustacea	0.725 (0.299)	1.05 (0.42)	0.717 (0.564)	0.767 (0.301)

Table 2a cont.

			Inshore				Offshore			
			Treatment		Control		Treatment		Control	
		Family	mean	SD	mean	SD	mean	SD	mean	SD
Annelid	Polychaete	unident.	0	(0)	0	(0)	0.017	(0.041)	0	(0)
		Acrocirrid	0	(0)	0	(0)	0.017	(0.041)	0	(0)
		Ampharetid	0.05	(0.1)	0	(0)	0.05	(0.084)	0.05	(0.084)
		Aphroditid	0	(0)	0.025	(0.05)	1.583	(2.402)	0.05	(0.122)
		Arabellid	0	(0)	0	(0)	0.033	(0.052)	0.033	(0.052)
		Capitellid	1.7	(1.417)	1.25	(0.839)	3.333	(2.856)	1.617	(0.717)
		Cerratulid	0	(0)	0.025	(0.05)	0.217	(0.325)	0.05	(0.084)
		Chaetopterid	0.05	(0.058)	0	(0)	0	(0)	0.117	(0.117)
		Dorvilleid	0	(0)	0	(0)	0.067	(0.103)	0.017	(0.041)
		Eunicid	0.1	(0.115)	0	(0)	0.1	(0.11)	0.017	(0.041)
		Glycerid	0.15	(0.129)	0.15	(0.1)	0.567	(0.656)	0.217	(0.194)
		Goniadid	0.5	(0.327)	0.625	(0.377)	0.733	(0.776)	0.717	(0.412)
		Hesionid	0.025	(0.05)	0.025	(0.05)	0.133	(0.197)	0.117	(0.147)
		Lumbrinerid	0	(0)	0	(0)	0.033	(0.052)	0.083	(0.098)
		Magelonid	0.575	(0.754)	0.3	(0.294)	0.05	(0.055)	0.35	(0.226)
		Maldanid	0.025	(0.05)	0.025	(0.05)	0.083	(0.16)	0.033	(0.052)
		Nephtyid	0.1	(0.082)	0.125	(0.05)	0.35	(0.493)	0.283	(0.133)
		Nereid	0	(0)	0.025	(0.05)	0.333	(0.28)	0.15	(0.152)
		Onuphid	0.175	(0.236)	0.125	(0.126)	0.067	(0.082)	0.2	(0.141)
		Opheliid	0.025	(0.05)	0.1	(0)	0.183	(0.16)	0.083	(0.204)
		Orbiniid	0.125	(0.05)	0.175	(0.096)	0.067	(0.121)	0.083	(0.16)
		Oweniid	0.025	(0.05)	0.05	(0.1)	0	(0)	0.233	(0.339)
		Paraonid	0.05	(0.1)	0	(0)	0.267	(0.378)	0.067	(0.082)
		Pectinarid	0.025	(0.05)	0	(0)	0	(0)	0.017	(0.041)
		Phyllodocid	0.025	(0.05)	0.025	(0.05)	0.183	(0.299)	0.017	(0.041)
		Pilargid	0	(0)	0	(0)	0.017	(0.041)	0	(0)
		Pisionid	0	(0)	0	(0)	0.067	(0.163)	0	(0)
		Polydontid	0	(0)	0	(0)	0.033	(0.082)	0	(0)
		Spionid	3.35	(3.018)	1.1	(0.688)	1.017	(0.527)	1.617	(0.527)
		Syllid	0.025	(0.05)	0.125	(0.189)	0.583	(0.791)	0.067	(0.121)
		Terebellid	0	(0)	0	(0)	0.067	(0.163)	0.017	(0.041)
	Total	Polychaetae	7.1	(3.746)	4.275	(1.603)	10.25	(6.078)	6.3	(0.863)

Table 2a cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
	Oligochaete		0 (0)	0 (0)	0.583 (0.861)	0 (0)
Aschelminthes	Nematode		0.125 (0.096)	0.125 (0.189)	0.433 (0.659)	0.15 (0.055)
Nemertean			0.325 (0.275)	0.4 (0.2)	0.683 (0.838)	0.25 (0.084)
Platyhelminthes	Polycladid		0.05 (0.1)	0.025 (0.05)	0.133 (0.207)	0 (0)
Echinoderm	Echiniod	Mellitid	0.025 (0.05)	0 (0)	0 (0)	0 (0)
		Schizasterid	0 (0)	0 (0)	0.033 (0.082)	0 (0)
	Echiniod	total	0.025 (0.05)	0 (0)	0.033 (0.082)	0 (0)
	Ophiuroid	Amphiurid	0.15 (0.058)	0.075 (0.05)	0.6 (0.906)	0.067 (0.082)
		unident.	0 (0)	0 (0)	0.017 (0.041)	0 (0)
	Ophiuroid	total	0.15 (0.058)	0.075 (0.05)	0.617 (0.926)	0.067 (0.082)
	Holothuroid	Cucumariid	0 (0)	0 (0)	0.017 (0.041)	0.017 (0.041)
		Synaptid	0.025 (0.05)	0 (0)	0.017 (0.041)	0.017 (0.041)
	Total	Echinoderm	0.2 (0.082)	0.075 (0.05)	0.683 (0.877)	0.1 (0.089)
Cnidaria	Actiniaria	Edwardsiid	0.125 (0.25)	0 (0)	0.017 (0.041)	0.05 (0.084)
		Halaclavid	0.05 (0.1)	0.025 (0.05)	0.05 (0.084)	0.033 (0.052)
		unident.	0 (0)	0 (0)	0 (0)	0.033 (0.082)
	Hydroid		0.05 (0.058)	0 (0)	0 (0)	0.033 (0.052)
Kamptozoa	(colonial)		0 (0)	0 (0)	0 (0)	0.05 (0.055)
Sipuncula		Golfingiid	0.025 (0.05)	0.025 (0.05)	0.017 (0.041)	0.05 (0.084)
		Sipunculid	0.05 (0.058)	0.025 (0.05)	0.05 (0.084)	0.05 (0.122)
	Sipuncula	total	0.075 (0.096)	0.05 (0.058)	0.067 (0.082)	0.1 (0.126)
Echiurida			0.075 (0.096)	0.025 (0.05)	0.033 (0.052)	0.05 (0.084)
Phoronida			0 (0)	0.025 (0.05)	0 (0)	0.017 (0.041)
Bryozoa	Ectoproct	Bugulid	0 (0)	0 (0)	0.017 (0.041)	0 (0)
Tunicate			0 (0)	0 (0)	0 (0)	0.017 (0.041)
Chaetognath			0.1 (0.141)	0.025 (0.05)	0 (0)	0 (0)
Amphioxis			0 (0)	0 (0)	0.017 (0.041)	0 (0)
		TOTAL	9.675 (3.902)	6.625 (1.696)	14.133 (8.786)	9.283 (1.436)

Table 2b. Mean (SD = standard deviation) abundance expressed as number m^{-2} of individuals by taxonomic family found in $76.4 cm^2$ core samples taken within (Treatment) and adjacent (Control) to inshore and offshore proposed sand borrow areas for the Bogue Banks beach renourshment. Statistics are calculated from the average of 10 cores taken from each of 6 sites sampled both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

			Inshore		Offshore	
			Treatment (n=4)	Control (n=4)	Treatment (n=6)	Control (n=6)
		Family	mean SD	mean SD	mean SD	mean SD
Mollusc	Bivalve	juv	6.54 (7.59)	26.18 (18.46)	4.32 (6.81)	17.41 (25.79)
		Arcid	6.54 (7.59)	0 (0)	0 (0)	2.23 (5.37)
		Corbulid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Crassatellid	0 (0)	0 (0)	4.32 (10.73)	0 (0)
		Cuspidariid	0 (0)	0 (0)	0 (0)	2.23 (5.37)
		Diplodontid	0 (0)	3.27 (6.54)	0 (0)	0 (0)
		Lucinid	29.45 (19.63)	9.82 (12.57)	15.31 (20.94)	87.3 (65.05)
		Mactrid	13.09 (26.18)	3.27 (6.54)	2.23 (5.37)	8.77 (10.73)
		Mesodesmatid	0 (0)	0 (0)	0 (0)	2.23 (5.37)
		Pandorid	0 (0)	0 (0)	0 (0)	2.23 (5.37)
		Solecurtid	6.54 (13.09)	0 (0)	2.23 (5.37)	4.32 (10.73)
		Tellinid	3.27 (6.54)	3.27 (6.54)	8.77 (10.73)	6.54 (10.99)
		Venerid	6.54 (7.59)	3.27 (6.54)	4.32 (6.81)	4.32 (6.81)
	Total	Bivalve	71.99 (34.69)	49.08 (44.5)	43.59 (19.76)	137.43 (69.63)
	Gastropod	Acteocinid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Columbellid	3.27 (6.54)	0 (0)	6.54 (10.99)	10.86 (15.31)
		Nassariid	0 (0)	3.27 (6.54)	0 (0)	0 (0)
		Naticid	3.27 (6.54)	3.27 (6.54)	0 (0)	6.54 (10.99)
		Olivid	3.27 (6.54)	6.54 (13.09)	2.23 (5.37)	8.77 (10.73)
		Terebrid	3.27 (6.54)	6.54 (13.09)	0 (0)	2.23 (5.37)
	Total	Gastropod	13.09 (10.73)	19.63 (16.88)	10.86 (12.83)	28.4 (19.24)
	Opistobranch	Haminoeid	3.27 (6.54)	0 (0)	2.23 (5.37)	4.32 (6.81)
	Scaphopod		0 (0)	0 (0)	2.23 (5.37)	4.32 (6.81)
	Total	Mollusc	88.35 (43.19)	68.72 (41.88)	58.9 (23.04)	174.48 (55.89)

Table 2b cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
Crustacea	Amphipod	unident.	0 (0)	3.27 (6.54)	0 (0)	8.77 (15.84)
		Ampeliscid	0 (0)	0 (0)	2.23 (5.37)	6.54 (7.2)
		Aorid	3.27 (6.54)	3.27 (6.54)	2.23 (5.37)	2.23 (5.37)
		Caprellid	0 (0)	0 (0)	4.32 (6.81)	0 (0)
		Corophiid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Gammerid	9.82 (6.54)	6.54 (13.09)	6.54 (15.97)	6.54 (7.2)
		Haustoriid	16.36 (12.57)	13.09 (18.46)	2.23 (5.37)	6.54 (10.99)
		Liljeborgiid	3.27 (6.54)	13.09 (18.46)	10.86 (15.31)	8.77 (13.48)
		Melitid	0 (0)	3.27 (6.54)	23.95 (52.62)	0 (0)
		Ocdicerotid	22.91 (29.06)	26.18 (23.95)	6.54 (15.97)	4.32 (6.81)
		Phoxocephalid	0 (0)	3.27 (6.54)	2.23 (5.37)	0 (0)
		Stenothoid	0 (0)	0 (0)	0 (0)	2.23 (5.37)
	Total	Amphipod	55.63 (26.96)	71.99 (57.98)	63.22 (58.77)	45.81 (18.06)
	Copepoda		0 (0)	0 (0)	2.23 (5.37)	0 (0)
	Cumacean		9.82 (6.54)	9.82 (12.57)	10.86 (12.83)	6.54 (10.99)
	Decapod	unident.	3.27 (6.54)	0 (0)	2.23 (5.37)	0 (0)
		Pagurid	0 (0)	19.63 (31.15)	2.23 (5.37)	2.23 (5.37)
		Penaeid	3.27 (6.54)	0 (0)	0 (0)	2.23 (5.37)
		Pinnotherid	13.09 (10.73)	9.82 (19.63)	10.86 (20.94)	30.5 (43.59)
		Sergestid	3.27 (6.54)	0 (0)	0 (0)	2.23 (5.37)
		Xanthid	0 (0)	3.27 (6.54)	0 (0)	0 (0)
	Isopod	Idoteid	6.54 (7.59)	3.27 (6.54)	0 (0)	6.54 (15.97)
		Sphaeromatid	0 (0)	3.27 (6.54)	0 (0)	0 (0)
	Isopod	total	6.54 (7.59)	6.54 (7.59)	0 (0)	6.54 (15.97)
	Mysid		0 (0)	13.09 (18.46)	0 (0)	0 (0)
	Ostracod		0 (0)	3.27 (6.54)	0 (0)	2.23 (5.37)
	Tanaid		0 (0)	0 (0)	2.23 (5.37)	2.23 (5.37)
	Total	Crustacea	94.9 (39.14)	137.43 (54.97)	93.85 (73.82)	100.39 (39.4)

Table 2b cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
Annelid	Polychaete	unident.	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Acrocirrid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Ampharetid	6.54 (13.09)	0 (0)	6.54 (10.99)	6.54 (10.99)
		Aphroditid	0 (0)	3.27 (6.54)	207.2 (314.4)	6.54 (15.97)
		Arabellid	0 (0)	0 (0)	4.32 (6.81)	4.32 (6.81)
		Capitellid	222.51 (185.47)	163.61 (109.82)	436.26 (373.82)	211.65 (93.85)
		Cerratulid	0 (0)	3.27 (6.54)	28.4 (42.54)	6.54 (10.99)
		Chaetopterid	6.54 (7.59)	0 (0)	0 (0)	15.31 (15.31)
		Dorvilleid	0 (0)	0 (0)	8.77 (13.48)	2.23 (5.37)
		Eunicid	13.09 (15.05)	0 (0)	13.09 (14.4)	2.23 (5.37)
		Glycerid	19.63 (16.88)	19.63 (13.09)	74.21 (85.86)	28.4 (25.39)
		Goniadid	65.45 (42.8)	81.81 (49.35)	95.94 (101.57)	93.85 (53.93)
		Hesionid	3.27 (6.54)	3.27 (6.54)	17.41 (25.79)	15.31 (19.24)
		Lumbrinerid	0 (0)	0 (0)	4.32 (6.81)	10.86 (12.83)
		Magelonid	75.26 (98.69)	39.27 (38.48)	6.54 (7.2)	45.81 (29.58)
		Maldanid	3.27 (6.54)	3.27 (6.54)	10.86 (20.94)	4.32 (6.81)
		Nephtyid	13.09 (10.73)	16.36 (6.54)	45.81 (64.53)	37.04 (17.41)
		Nereid	0 (0)	3.27 (6.54)	43.59 (36.65)	19.63 (19.9)
		Onuphid	22.91 (30.89)	16.36 (16.49)	8.77 (10.73)	26.18 (18.46)
		Opheliid	3.27 (6.54)	13.09 (0)	23.95 (20.94)	10.86 (26.7)
		Orbiniid	16.36 (6.54)	22.91 (12.57)	8.77 (15.84)	10.86 (20.94)
		Oweniid	3.27 (6.54)	6.54 (13.09)	0 (0)	30.5 (44.37)
		Paraonid	6.54 (13.09)	0 (0)	34.95 (49.48)	8.77 (10.73)
		Pectinarid	3.27 (6.54)	0 (0)	0 (0)	2.23 (5.37)
		Phyllodocid	3.27 (6.54)	3.27 (6.54)	23.95 (39.14)	2.23 (5.37)
		Pilargid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Pisionid	0 (0)	0 (0)	8.77 (21.34)	0 (0)
		Polydontid	0 (0)	0 (0)	4.32 (10.73)	0 (0)
		Spionid	438.48 (395.03)	143.98 (90.05)	133.12 (68.98)	211.65 (68.98)
		Syllid	3.27 (6.54)	16.36 (24.74)	76.31 (103.53)	8.77 (15.84)
		Terebellid	0 (0)	0 (0)	8.77 (21.34)	2.23 (5.37)
	Total	Polychaetae	929.32 (490.31)	559.55 (209.82)	1341.62 (795.55)	824.61 (112.96)

Table 2b cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
	Oligochaete		0 (0)	0 (0)	76.31 (112.7)	0 (0)
Aschelminthes	Nematode		16.36 (12.57)	16.36 (24.74)	56.68 (86.26)	19.63 (7.2)
Nemertean			42.54 (35.99)	52.36 (26.18)	89.4 (109.69)	32.72 (10.99)
Platyhelminthes	Polycladid		6.54 (13.09)	3.27 (6.54)	17.41 (27.09)	0 (0)
Echinoderm	Echiniod	Mellitid	3.27 (6.54)	0 (0)	0 (0)	0 (0)
		Schizasterid	0 (0)	0 (0)	4.32 (10.73)	0 (0)
	Echiniod	total	3.27 (6.54)	0 (0)	4.32 (10.73)	0 (0)
	Ophiuroid	Amphiurid	19.63 (7.59)	9.82 (6.54)	78.53 (118.59)	8.77 (10.73)
		unident.	0 (0)	0 (0)	2.23 (5.37)	0 (0)
	Ophiuroid	total	19.63 (7.59)	9.82 (6.54)	80.76 (121.2)	8.77 (10.73)
	Holothuroid	Cucumariid	0 (0)	0 (0)	2.23 (5.37)	2.23 (5.37)
		Synaptid	3.27 (6.54)	0 (0)	2.23 (5.37)	2.23 (5.37)
	Total	Echinoderm	26.18 (10.73)	9.82 (6.54)	89.4 (114.79)	13.09 (11.65)
Cnidaria	Actiniaria	Edwardsiid	16.36 (32.72)	0 (0)	2.23 (5.37)	6.54 (10.99)
		Halaclavid	6.54 (13.09)	3.27 (6.54)	6.54 (10.99)	4.32 (6.81)
		unident.	0 (0)	0 (0)	0 (0)	4.32 (10.73)
	Hydroid		6.54 (7.59)	0 (0)	0 (0)	4.32 (6.81)
Kamptozoa	(colonial)		0 (0)	0 (0)	0 (0)	6.54 (7.2)
Sipuncula		Golfingiid	3.27 (6.54)	3.27 (6.54)	2.23 (5.37)	6.54 (10.99)
		Sipunculid	6.54 (7.59)	3.27 (6.54)	6.54 (10.99)	6.54 (15.97)
	Sipuncula	total	9.82 (12.57)	6.54 (7.59)	8.77 (10.73)	13.09 (16.49)
Echiurida			9.82 (12.57)	3.27 (6.54)	4.32 (6.81)	6.54 (10.99)
Phoronida			0 (0)	3.27 (6.54)	0 (0)	2.23 (5.37)
Bryozoa	Ectoproct	Bugulid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
Tunicate			0 (0)	0 (0)	0 (0)	2.23 (5.37)
Chaetognath			13.09 (18.46)	3.27 (6.54)	0 (0)	0 (0)
Amphioxis			0 (0)	0 (0)	2.23 (5.37)	0 (0)
		TOTAL	1266.36 (510.73)	867.15 (221.99)	1849.87 (1150)	1215.05 (187.96)

Table 3a. Mean (SD = standard deviation) abundance of animals by family captured in a $10m^2$ tow of a benthic sled at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment. Statistics are calculated from the average of 2 samples taken from each of 6 sites both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

			Inshore				Offshore			
			Treatment		Control		Treatment		Control	
		Family	mean	SD	mean	SD	mean	SD	mean	SD
Mollusc	Bivalve	Mactrid	0	(0)	0.25	(0.289)	0	(0)	0	(0)
		Venerid	0	(0)	0.125	(0.25)	0	(0)	0	(0)
	Gastropod	Terebrid	2.25	(2.63)	0.875	(0.25)	0.0833333	(0.204)	0.4166667	(0.376)
	Scaphopod		0	(0)	0	(0)	0	(0)	0.0833333	(0.204)
Crustacea	Decapod	Calappid	0	(0)	0.125	(0.25)	0.0833333	(0.204)	0.0833333	(0.204)
		Pagurid	0.375	(0.25)	0.5	(0.408)	0.3333333	(0.408)	0.1666667	(0.258)
	offshore	Hippolythid	0	(0)	0	(0)	0	(0)	0.0833333	(0.204)
		Portunid	0.125	(0.25)	0.125	(0.25)	0	(0)	0	(0)
		Xanthid	0.125	(0.25)	0	(0)	0	(0)	0	(0)
Annelid	Polychaete	Glycerid	0	(0)	0	(0)	0.0833333	(0.204)	0.0833333	(0.204)
		Maldanid	0	(0)	0	(0)	0	(0)	0.0833333	(0.204)
		Onuphid	0.125	(0.25)	0	(0)	0.0833333	(0.204)	0	(0)
Echinoderm	Asteriod	Astropectinid	0	(0)	0	(0)	0.0833333	(0.204)	0.0833333	(0.204)
	Echinoid	Mellitid	0	(0)	0.75	(1.5)	0	(0)	0	(0)
Cnidaria	Anthozoa	Renillid	0.125	(0.25)	0	(0)	0	(0)	0	(0)
Sipuncula		Golfingiid	0	(0)	0	(0)	0	(0)	0.0833333	(0.204)
		TOTAL	3.125	(3.065)	2.75	(1.658)	0.75	(0.524)	1.1666667	(0.983)

Table 3b. Mean (SD = standard deviation) abundance expressed as number m^{-2} of animals by family captured in a $10m^2$ tow of a benthic sled at sites within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment. Statistics are calculated from the average of 2 samples taken from each of 6 sites both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

			Inshore				Offshore			
			Treatment		Control		Treatment		Control	
		Family	mean	SD	mean	SD	mean	SD	mean	SD
Mollusc	Bivalve	Mactrid	0	(0)	0.025	(0.029)	0	(0)	0	(0)
		Venerid	0	(0)	0.013	(0.025)	0	(0)	0	(0)
	Gastropod	Terebrid	0.225	(0.263)	0.088	(0.025)	0.008	(0.02)	0.042	(0.038)
	Scaphopod		0	(0)	0	(0)	0	(0)	0.008	(0.02)
Crustacea	Decapod	Calappid	0	(0)	0.013	(0.025)	0.008	(0.02)	0.008	(0.02)
		Pagurid	0.038	(0.025)	0.05	(0.041)	0.033	(0.041)	0.017	(0.026)
		Hippolythid	0	(0)	0	(0)	0	(0)	0.008	(0.02)
		Portunid	0.013	(0.025)	0.013	(0.025)	0	(0)	0	(0)
		Xanthid	0.013	(0.025)	0	(0)	0	(0)	0	(0)
Annelid	Polychaete	Glycerid	0	(0)	0	(0)	0.008	(0.02)	0.008	(0.02)
		Maldanid	0	(0)	0	(0)	0	(0)	0.008	(0.02)
		Onuphid	0.013	(0.025)	0	(0)	0.008	(0.02)	0	(0)
Echinoderm	Asteriod	Astropectinid	0	(0)	0	(0)	0.008	(0.02)	0.008	(0.02)
	Echinoid	Mellitid	0	(0)	0.075	(0.15)	0	(0)	0	(0)
Cnidaria	Anthozoa	Renillid	0.013	(0.025)	0	(0)	0	(0)	0	(0)
Sipuncula		Golfingiid	0	(0)	0	(0)	0	(0)	0.008	(0.02)
		TOTAL	0.313	(0.307)	0.275	(0.166)	0.075	(0.052)	0.117	(0.098)

Table 4a. Mean (SD = standard deviation) (n=2) abundances of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 11 November 1999.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	58.5	(70.004)	172	(237.588)	48	(53.74)	28.5	(2.121)
Atlantic cutlassfish	*Trichiurus lepturus*	8	(11.314)	15.5	(3.536)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	1	(1.414)	1.5	(2.121)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	40.5	(57.276)	84	(39.598)	23.5	(17.678)	39	(38.184)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	0	(0)	42	(59.397)	0	(0)	0	(0)
banded drum	*Larimus fasciatus*	0	(0)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0	(0)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	0	(0)
blackcheek tonguefish	*Symphurus plagiusa*	3	(4.243)	5	(7.071)	0	(0)	0	(0)
blackwing searobbin	*Prionotus rubio*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
bluefish	*Pomatomus saltatrix*	1.5	(2.121)	3	(1.414)	0	(0)	2	(2.828)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	2	(2.828)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	4.5	(3.536)	0.5	(0.707)	1	(1.414)	25	(32.527)
clearnose skate	*Raja ocellata*	3	(4.243)	7	(9.899)	0	(0)	0	(0)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	0	(0)	0	(0)	1.5	(2.121)	0	(0)
gray trout (weakfish)	*Cynoscion regalis*	14	(14.142)	3.5	(4.95)	1.5	(2.121)	0	(0)
harvestfish	*Peprilus alepidotus*	0	(0)	0	(0)	0	(0)	0	(0)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	1	(1.414)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0	(0)	0	(0)
lookdown	*Selene vomer*	6	(1.414)	5	(4.243)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	0	(0)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	21	(16.971)	15	(21.213)	0	(0)	8.5	(12.021)
northern puffer	*Sphoeroides maculatus*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
ocellated flounder	*Ancylopsetta quadrocellata*	0	(0)	0	(0)	0	(0)	0	(0)

Table 4a cont.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	9	(2.828)	1.5	(2.121)	42.5	(38.891)	27.5	(28.991)
pinfish	*Lagodon rhomboides*	34.5	(43.134)	26	(36.77)	68.5	(78.489)	189	(134.35)
planehead filefish	*Monacanthus hispidus*	0	(0)	0	(0)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	0	(0)	0	(0)	0	(0)	0	(0)
round herring	*Etrumeus teres*	0	(0)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0	(0)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	0	(0)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	0	(0)
silver perch	*Bairdiella chrysoura*	47	(14.142)	56	(62.225)	1	(1.414)	0	(0)
silver seatrout	*Cynoscion nothus*	0	(0)	0	(0)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	0	(0)	0	(0)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0.5	(0.707)	0	(0)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	0	(0)	0	(0)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	0	(0)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	0	(0)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	0	(0)
spiny box fish	*Lactophrys trigonus*	0.5	(0.707)	1.5	(2.121)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	18.5	(12.021)	13	(16.971)	302	(87.681)	290	(108.894)
spotted hake	*Urophycis regia*	0	(0)	0	(0)	0	(0)	0	(0)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0	(0)	0	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	0	(0)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0.5	(0.707)	0.5	(0.707)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	0	(0)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	3.5	(4.95)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	0	(0)	0	(0)	0	(0)	0	(0)
Average Abundance (n)		271.50	(183.14)	459.50	(392.44)	490.50	(127.99)	609.50	(290.62)
Average Species Diversity (H′)		1.99	(0.06)	1.57	(0.22)	1.13	(0.12)	1.31	(0.02)
Average Species Richness (S)		13.50	(3.54)	15.00	(9.90)	7.50	(2.12)	7.00	(1.41)

Table 4b. Mean (SD = standard deviation) (n=2) abundances expressed as number km-2 of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 11 November 1999.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	3547.17	(4244.72)	10429.3	(14406.26)	2910.5	(3258.55)	1728.11	(128.61)
Atlantic cutlassfish	*Trichiurus lepturus*	485.08	(686.03)	939.85	(214.41)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	60.64	(85.74)	90.95	(128.61)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	2455.74	(3472.96)	5093.38	(2401.04)	1424.93	(1071.91)	2364.78	(2315.3)
Atlantic stingray	*Dasyatis sabina*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	0	(0)	2546.69	(3601.56)	0	(0)	0	(0)
banded drum	*Larimus fasciatus*	0	(0)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0	(0)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	0	(0)
blackcheek tonguefish	*Symphurus plagiusa*	181.91	(257.28)	303.18	(428.75)	0	(0)	0	(0)
blackwing searobbin	*Prionotus rubio*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
bluefish	*Pomatomus saltatrix*	90.95	(128.61)	181.91	(85.74)	0	(0)	121.27	(171.48)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	272.86	(214.41)	30.32	(42.87)	60.64	(85.74)	1515.89	(1972.29)
clearnose skate	*Raja ocellata*	181.91	(257.28)	424.45	(600.23)	0	(0)	0	(0)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	0	(0)	0	(0)	90.95	(128.61)	0	(0)
gray trout (weakfish)	*Cynoscion regalis*	848.9	(857.51)	212.22	(300.15)	90.95	(128.61)	0	(0)
harvestfish	*Peprilus alepidotus*	0	(0)	0	(0)	0	(0)	0	(0)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	60.64	(85.74)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0	(0)	0	(0)
lookdown	*Selene vomer*	363.81	(85.74)	303.18	(257.28)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	0	(0)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	1273.34	(1029.04)	909.53	(1286.26)	0	(0)	515.4	(728.9)
northern puffer	*Sphoeroides maculatus*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
ocellated flounder	*Ancylopsetta quadrocellata*	0	(0)	0	(0)	0	(0)	0	(0)

Table 4b cont.

Species		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	545.72	(171.48)	90.95	(128.61)	2577.01	(2358.17)	1667.48	(1757.88)
pinfish	*Lagodon rhomboides*	2091.92	(2615.45)	1576.52	(2229.57)	4153.53	(4759.22)	11460.1	(8146.37)
planehead filefish	*Monacanthus hispidus*	0	(0)	0	(0)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	0	(0)	0	(0)	0	(0)	0	(0)
round herring	*Etrumeus teres*	0	(0)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0	(0)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	0	(0)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	0	(0)
silver perch	*Bairdiella chrysoura*	2849.87	(857.51)	3395.59	(3773.04)	60.64	(85.74)	0	(0)
silver seatrout	*Cynoscion nothus*	0	(0)	0	(0)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	0	(0)	0	(0)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	0	(0)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	30.32	(42.87)	0	(0)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	0	(0)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	0	(0)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	0	(0)
spiny box fish	*Lactophrys trigonus*	30.32	(42.87)	90.95	(128.61)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	1121.76	(728.9)	788.26	(1029.04)	18311.91	(5316.58)	17584.28	(6602.84)
spotted hake	*Urophycis regia*	0	(0)	0	(0)	0	(0)	0	(0)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0	(0)	0	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	0	(0)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	30.32	(42.87)	30.32	(42.87)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	0	(0)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	212.22	(300.15)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	0	(0)	0	(0)	0	(0)	0	(0)
Average Abundance (n)		16462.53	(11104.84)	27861.99	(23796.04)	29741.69	(7760.51)	36957.31	(17621.93)
Average Species Diversity (H′)		1.99	(0.06)	1.57	(0.22)	1.13	(0.12)	1.31	(0.02)
Average Species Richness (S)		13.50	(3.54)	15.00	(9.90)	7.50	(2.12)	7.00	(1.41)

Table 5a. Mean (SD = standard deviation) (n=2) abundances of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms^{-1} (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control).the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 4 February 2000 .

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
Atlantic cutlassfish	*Trichiurus lepturus*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	47	(18.385)	58	(77.782)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	56	(59.397)	43	(60.811)	16.5	(21.92)	4.5	(6.364)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	0.5	(0.707)	0	(0)	0	(0)	0	(0)
banded drum	*Larimus fasciatus*	0	(0)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	0	(0)
blackcheek tonguefish	*Symphurus plagiusa*	2	(1.414)	2	(1.414)	0	(0)	0	(0)
blackwing searobbin	*Prionotus rubio*	0	(0)	1.5	(2.121)	0	(0)	0	(0)
bluefish	*Pomatomus saltatrix*	0	(0)	0	(0)	0	(0)	0	(0)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	0	(0)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	0	(0)	0	(0)	0	(0)	0.5	(0.707)
clearnose skate	*Raja ocellata*	0	(0)	0	(0)	0.5	(0.707)	1.5	(0.707)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	0	(0)	0.5	(0.707)	0	(0)	0.5	(0.707)
gray trout (weakfish)	*Cynoscion regalis*	0	(0)	1	(1.414)	0.5	(0.707)	0	(0)
harvestfish	*Peprilus alepidotus*	0	(0)	0	(0)	0	(0)	0	(0)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	0	(0)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0.5	(0.707)	0	(0)
lookdown	*Selene vomer*	0	(0)	0	(0)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	0	(0)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	1	(1.414)	0.5	(0.707)	0	(0)	0	(0)
northern puffer	*Sphoeroides maculatus*	0	(0)	0	(0)	0	(0)	0	(0)
ocellated flounder	*Ancylopsetta quadrocellata*	0.5	(0.707)	0.5	(0.707)	0	(0)	0	(0)

Table 5a cont.

Species		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	0	(0)	0	(0)	0	(0)	0	(0)
pinfish	*Lagodon rhomboides*	38.5	(24.749)	15	(21.213)	3.5	(2.121)	9	(9.899)
planehead filefish	*Monacanthus hispidus*	0	(0)	0	(0)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	0	(0)	0	(0)	0	(0)	0	(0)
round herring	*Etrumeus teres*	0	(0)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0.5	(0.707)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	0	(0)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	0	(0)
silver perch	*Bairdiella chrysoura*	0	(0)	0	(0)	0	(0)	0	(0)
silver seatrout	*Cynoscion nothus*	0	(0)	0	(0)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	0	(0)	0	(0)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	0	(0)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	3	(4.243)	5	(7.071)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	0	(0)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	2.5	(3.536)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	0	(0)
spiny box fish	*Lactophrys trigonus*	0	(0)	0	(0)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	3	(2.828)	4	(5.657)	0	(0)	0	(0)
spotted hake	*Urophycis regia*	11	(1.414)	4	(5.657)	0.5	(0.707)	0.5	(0.707)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0.5	(0.707)	1	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	0	(0)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0	(0)	0	(0)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	0	(0)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	1	(1.414)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	0	(0)	0	(0)	0	(0)	0	(0)
Average Abundance (n)		162.50	(67.18)	139.50	(191.63)	22.50	(24.75)	18.00	(7.07)
Average Species Diversity (H′)		1.39	(0.02)	1.10	(0.76)	1.02	(0.44)	1.04	(0.15)
Average Species Richness (S)		8.00	(1.41)	9.00	(9.90)	4.50	(0.71)	5.50	(2.12)

Table 5b. Mean (SD = standard deviation) (n=2) abundances expressed as number km-2 of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 4 February 2000 .

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
Atlantic cutlassfish	*Trichiurus lepturus*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	2849.87	(1114.78)	3516.86	(4716.35)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	3395.59	(3601.56)	2607.32	(3687.3)	1000.49	(1329.13)	272.86	(385.88)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	30.32	(42.87)	0	(0)	0	(0)	0	(0)
banded drum	*Larimus fasciatus*	0	(0)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	0	(0)
blackcheek tonguefish	*Symphurus plagiusa*	121.27	(85.74)	121.27	(85.74)	0	(0)	0	(0)
blackwing searobbin	*Prionotus rubio*	0	(0)	90.95	(128.61)	0	(0)	0	(0)
bluefish	*Pomatomus saltatrix*	0	(0)	0	(0)	0	(0)	0	(0)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	0	(0)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	0	(0)	0	(0)	0	(0)	30.32	(42.87)
clearnose skate	*Raja ocellata*	0	(0)	0	(0)	30.32	(42.87)	90.95	(42.87)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	0	(0)	30.32	(42.87)	0	(0)	30.32	(42.87)
gray trout (weakfish)	*Cynoscion regalis*	0	(0)	60.64	(85.74)	30.32	(42.87)	0	(0)
harvestfish	*Peprilus alepidotus*	0	(0)	0	(0)	0	(0)	0	(0)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	0	(0)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	30.32	(42.87)	0	(0)
lookdown	*Selene vomer*	0	(0)	0	(0)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	0	(0)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	60.64	(85.74)	30.32	(42.87)	0	(0)	0	(0)
northern puffer	*Sphoeroides maculatus*	0	(0)	0	(0)	0	(0)	0	(0)
ocellated flounder	*Ancylopsetta quadrocellata*	30.32	(42.87)	30.32	(42.87)	0	(0)	0	(0)

Table 5b cont.

Species		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	0	(0)	0	(0)	0	(0)	0	(0)
pinfish	*Lagodon rhomboides*	2334.47	(1500.67)	909.53	(1286.26)	212.22	(128.61)	545.72	(600.23)
planehead filefish	*Monacanthus hispidus*	0	(0)	0	(0)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	0	(0)	0	(0)	0	(0)	0	(0)
round herring	*Etrumeus teres*	0	(0)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	30.32	(42.87)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	0	(0)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	0	(0)
silver perch	*Bairdiella chrysoura*	0	(0)	0	(0)	0	(0)	0	(0)
silver seatrout	*Cynoscion nothus*	0	(0)	0	(0)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	0	(0)	0	(0)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	0	(0)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	181.91	(257.28)	303.18	(428.75)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	0	(0)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	151.59	(214.41)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	0	(0)
spiny box fish	*Lactophrys trigonus*	0	(0)	0	(0)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	181.91	(171.48)	242.54	(343.01)	0	(0)	0	(0)
spotted hake	*Urophycis regia*	666.99	(85.74)	242.54	(343.01)	30.32	(42.87)	30.32	(42.87)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	30.32	(42.87)	60.64	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	0	(0)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0	(0)	0	(0)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	0	(0)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	60.64	(85.74)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	0	(0)	0	(0)	0	(0)	0	(0)
Average Abundance (n)		9853.26	(4073.2)	8458.65	(11619.33)	1364.3	(1500.65)	1091.44	(428.76)
Average Species Diversity (H′)		1.39	(0.02)	1.10	(0.76)	1.02	(0.44)	1.04	(0.15)
Average Species Richness (S)		8.00	(1.41)	9.00	(9.90)	4.50	(0.71)	5.50	(2.12)

Table 6a. Mean (SD = standard deviation) (n=2) abundances of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 11 May 2000 .

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	0	(0)	0	(0)	0	(0)	2	(2.828)
Atlantic cutlassfish	*Trichiurus lepturus*	0	(0)	12	(11.314)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	0	(0)	2	(2.828)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	556	(50.912)	1422	(347.897)	0	(0)	0	(0)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	748	(452.548)	284	(248.902)	0	(0)	2	(2.828)
banded drum	*Larimus fasciatus*	4	(5.657)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0	(0)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	2	(2.828)
blackcheek tonguefish	*Symphurus plagiusa*	4	(5.657)	16	(22.627)	0	(0)	2	(2.828)
blackwing searobbin	*Prionotus rubio*	358	(500.632)	464	(650.538)	0	(0)	8	(0)
bluefish	*Pomatomus saltatrix*	10	(2.828)	4	(0)	0	(0)	0	(0)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	0	(0)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	4	(5.657)	20	(16.971)	0	(0)	0	(0)
clearnose skate	*Raja ocellata*	10	(14.142)	24	(33.941)	0	(0)	2	(2.828)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	8	(11.314)	0	(0)	0	(0)	0	(0)
gray trout (weakfish)	*Cynoscion regalis*	0	(0)	0	(0)	0	(0)	0	(0)
harvestfish	*Peprilus alepidotus*	56	(79.196)	10	(14.142)	0	(0)	24	(33.941)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	0	(0)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0	(0)	0	(0)
lookdown	*Selene vomer*	0	(0)	0	(0)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	2	(2.828)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	12	(16.971)	20	(28.284)	0	(0)	0	(0)
northern puffer	*Sphoeroides maculatus*	2	(2.828)	2	(2.828)	0	(0)	2	(2.828)
ocellated flounder	*Ancylopsetta quadrocellata*	12	(16.971)	6	(2.828)	0	(0)	36	(50.912)

Table 6a cont.

species		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	38	(48.083)	0	(0)	0	(0)	394	(557.2)
pinfish	*Lagodon rhomboides*	0	(0)	18	(25.456)	0	(0)	0	(0)
planehead filefish	*Monacanthus hispidus*	0	(0)	2	(2.828)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	10	(14.142)	30	(36.77)	8	(5.657)	6	(8.485)
round herring	*Etrumeus teres*	2	(2.828)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0	(0)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	144	(203.647)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	2	(2.828)
silver perch	*Bairdiella chrysoura*	0	(0)	0	(0)	0	(0)	0	(0)
silver seatrout	*Cynoscion nothus*	20	(28.284)	52	(73.539)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	6	(8.485)	2	(2.828)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	2	(2.828)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	0	(0)	2	(2.828)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	4	(5.657)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	0	(0)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	2	(2.828)
spiny box fish	*Lactophrys trigonus*	0	(0)	0	(0)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	12	(11.314)	42	(14.142)	0	(0)	4	(5.657)
spotted hake	*Urophycis regia*	32	(39.598)	60	(79.196)	0	(0)	0	(0)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0	(0)	0	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	2	(2.828)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0	(0)	0	(0)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	2	(2.828)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	0	(0)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	68	(96.167)	40	(56.569)	0	(0)	0	(0)
Average Abundance (n)		1976.00	(203.65)	2542.00	(1632.00)	8.00	(5.66)	632.00	(848.53)
Average Species Diversity (H′)		1.44	(0.59)	1.19	(0.72)	0.00	0.00	1.29	(0.30)
Average Species Richness (S)		14.50	(4.95)	18.00	(8.49)	1.00	0.00	8.00	(4.24)

Table 6b. Mean (SD = standard deviation) (n=2) abundances expressed as number km-2 of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 11 May 2000 .

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	0	(0)	0	(0)	0	(0)	121.27	(171.48)
Atlantic cutlassfish	*Trichiurus lepturus*	0	(0)	727.63	(686.03)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	33713.32	(3087.07)	86223.62	(21094.89)	0	(0)	0	(0)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	45355.32	(27440.46)	17220.47	(15092.29)	0	(0)	121.27	(171.48)
banded drum	*Larimus fasciatus*	242.54	(343.01)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0	(0)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	121.27	(171.48)
blackcheek tonguefish	*Symphurus plagiusa*	242.54	(343.01)	970.17	(1372)	0	(0)	121.27	(171.48)
blackwing searobbin	*Prionotus rubio*	21707.49	(30356.05)	28134.85	(39445.67)	0	(0)	485.08	(0)
bluefish	*Pomatomus saltatrix*	606.35	(171.48)	242.54	(0)	0	(0)	0	(0)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	0	(0)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	242.54	(343.01)	1212.71	(1029.04)	0	(0)	0	(0)
clearnose skate	*Raja ocellata*	606.35	(857.51)	1455.25	(2058.03)	0	(0)	121.27	(171.48)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	485.08	(686.03)	0	(0)	0	(0)	0	(0)
gray trout (weakfish)	*Cynoscion regalis*	0	(0)	0	(0)	0	(0)	0	(0)
harvestfish	*Peprilus alepidotus*	3395.59	(4802.09)	606.35	(857.51)	0	(0)	1455.25	(2058.03)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	0	(0)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0	(0)	0	(0)
lookdown	*Selene vomer*	0	(0)	0	(0)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	727.63	(1029.04)	1212.71	(1715.01)	0	(0)	0	(0)
northern puffer	*Sphoeroides maculatus*	121.27	(171.48)	121.27	(171.48)	0	(0)	121.27	(171.48)
ocellated flounder	*Ancylopsetta quadrocellata*	727.63	(1029.04)	363.81	(171.48)	0	(0)	2182.88	(3087.07)

Table 6b cont.

Species		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	2304.15	(2915.53)	0	(0)	0	(0)	23890.37	(33786.08)
pinfish	*Lagodon rhomboides*	0	(0)	1091.44	(1543.54)	0	(0)	0	(0)
planehead filefish	*Monacanthus hispidus*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	606.35	(857.51)	1819.06	(2229.57)	485.08	(343.01)	363.81	(514.49)
round herring	*Etrumeus teres*	121.27	(171.48)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0	(0)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	8731.51	(12348.23)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	121.27	(171.48)
silver perch	*Bairdiella chrysoura*	0	(0)	0	(0)	0	(0)	0	(0)
silver seatrout	*Cynoscion nothus*	1212.71	(1715.01)	3153.04	(4459.07)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	363.81	(514.49)	121.27	(171.48)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	242.54	(343.01)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	0	(0)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	121.27	(171.48)
spiny box fish	*Lactophrys trigonus*	0	(0)	0	(0)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	727.63	(686.03)	2546.69	(857.51)	0	(0)	242.54	(343.01)
spotted hake	*Urophycis regia*	1940.33	(2401.04)	3638.13	(4802.09)	0	(0)	0	(0)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0	(0)	0	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0	(0)	0	(0)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	0	(0)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	4123.21	(5831.13)	2425.42	(3430.09)	0	(0)	0	(0)
Average Abundance (n)		119815.67	(12348.21)	154135.34	(98957.22)	485.08	(343.01)	38321.61	(51450.89)
Average Species Diversity (H′)		1.44	(0.59)	1.19	(0.72)	0.00	0.00	1.29	(0.30)
Average Species Richness (S)		14.50	(4.95)	18.00	(8.49)	1.00	0.00	8.00	(4.24)

Table 7. Results of gut content analysis for eight species of fish caught in trawl surveys conducted in November 1999.

Species	Location	% of fish stomachs empty *	Average weight of stomach contents	% clam**	% polychaete	% crab	% shrimp	% fish	% small crustaceans	% echindoerms
Croaker	Nearshore	50%	0.004	0%	0%	0%	70%	20%	10%	0%
Croaker	Offshore	40%	0.008	20%	25%	4%	10%	5%	1%	1%
Gray Trout	Nearshore	0%	0.006	0%	0%	0%	100%	0%	0%	0%
Gray Trout	Offshore	0%	0.107	0%	0%	5%	90%	5%	0%	0%
Pigfish	Offshore	33%	0.040	0%	90%	0%	5%	0%	5%	0%
Pinfish	Nearshore	20%	0.061	0%	50%	2%	20%	25%	1%	0%
Pinfish	Offshore	40%	0.019	0%	55%	3%	10%	25%	5%	0%
Sea Mullet	Offshore	40%	0.240	1%	37%	61%	1%	0%	0%	0%
Silver Perch	Nearshore	66%	0.002	0%	0%	0%	95%	0%	5%	0%
Silver Perch	Offshore	10%	0.005	0%	0%	0%	61%	0%	38%	0%
Silversides	Nearshore	nd	nd	0%	0%	0%	0%	0%	100%	0%
Silversides	Offshore	nd	nd	0%	0%	0%	0%	0%	100%	0%
Spot	Nearshore	56%	0.007	55%	20%	0%	0%	0%	20%	5%
Spot	Offshore	50%	0.010	5%	10%	0%	0%	65%	10%	0%

* Percentage calculated by dividing the number of fish examined whose stomach contents weighed 0.000 g by the number of fish examined.

** Percent of total diet made up by each group was calculated by summing the total stomach contents weights in that category of all fish examined and dividing that weight by the total wet weight of identifiable stomach contents off all fish within that species.

nd = not determined, stomach contents do not weigh enough to make a reasonable evaluation.

Table 8. Results of Sediment Analysis.

Sample Number	%Gravel	%Sand	%Fines	Mean	Std.Dev.	Mean (mm)	Description	Sorting
A1Ac	2.50	95.80	1.70	2.45	0.76	0.18	Fine Sand	Mod.Sorted
A1Bt	2.50	97.10	0.40	1.66	0.86	0.31	Medium Sand	Mod.Sorted
A1Ct	51.50	47.30	1.20	0.43	1.01	0.74	Coarse Sand	Poorly Sorted
A1Dt	41.10	58.60	0.30	0.16	0.73	0.90	Coarse Sand	Mod.Sorted
A1Ec	4.60	92.20	3.20	2.45	0.79	0.18	Fine Sand	Mod.Sorted
A2Fc	0.90	97.70	1.40	2.65	0.61	0.16	Fine Sand	Mod.Well Sorted
A2Gt	6.00	90.80	3.20	1.95	1.16	0.26	Medium Sand	Poorly Sorted
A2Ht	4.30	94.60	1.10	2.28	0.80	0.21	Fine Sand	Mod.Sorted
A2It	4.60	94.00	1.40	2.31	0.81	0.20	Fine Sand	Mod.Sorted
A2Jc	1.30	96.80	1.90	2.52	0.69	0.17	Fine Sand	Mod.Well Sorted
Anc	7.50	90.00	2.50	2.01	0.86	0.25	Fine Sand	Mod. Sorted
ASc	1.50	97.50	1.00	2.46	0.68	0.18	Fine Sand	Mod.Well Sorted
B1Ac	0.60	96.30	3.10	2.77	0.56	0.15	Fine Sand	Mod.Well Sorted
B1Bt	1.60	96.50	1.90	2.85	0.53	0.14	Fine Sand	Mod.Well Sorted
B1Ct	1.30	95.90	2.80	2.86	0.61	0.14	Fine Sand	Mod.Well Sorted
B1Dc	0.80	97.30	1.90	2.02	0.99	0.25	Fine Sand	Mod.Sorted
B2Ec	5.60	92.70	1.70	2.65	0.89	0.16	Fine Sand	Mod.Sorted
B2Ft	0.10	98.70	1.20	2.71	0.68	0.15	Fine Sand	Mod.Well Sorted
B2Gt	0.10	96.50	3.40	2.99	0.63	0.13	Fine Sand	Mod.Well Sorted
B2Hc	0.10	98.10	1.80	2.90	0.40	0.13	Fine Sand	Well Sorted

Table 9. Mean (SD = standard deviation) abundance m^{-2} of total infauna from this study compared with infauna abundances found in other studies from nearby locations.

Study			TOTAL INFAUNA m^{-2} mean SD
This study	Inshore Nov. 1999	Treatment	1266 (510.73)
	Inshore Nov. 1999	Control	867 (221.99)
	Offshore Nov. 1999	Treatment	1850 (1150)
	Offshore Nov. 1999	Control	1215 (187.96)
Day et al. (1971)[a]	Apr. 1965 - Jan. 1966	10m site	1005
	Apr. 1965 - Jan. 1966	20m site	936
Peterson et al. (1999)[b]	Dec. 1994	East Site	1597 (959)
		West Site	1170 (592)
Posey & Ambrose (1994)[c]	Jul.1990		3680 (900)
	Apr. 1991(1)		11030 (1281)
	Apr. 1991(2)		6880 (917)
Van Dolah et al. (1994)[d]	Winter 1990	Control site	2755
	Fall 1990	Control site	3527

[a] Day et al. (1971) took samples with a $0.2m^2$ van Veen grab and sieved them through a 1mm sieve. Infaunal abundances from samples taken from sites along a transect off Cape Lookout NC, were averaged over 5 sampling dates from Apr 1965 to Jan 1966. The two sites with depths closest to those of this study are presented.

[b] Peterson et al. (1999) present abundances of infauna (> 0.5mm) from 9.9cm diameter cores taken at sites about 1km SE (East Site) and SW (West Site) of Beaufort Inlet, Beaufort NC prior to any experimental disturbance. Replicate cores were taken from each of 9 stations on each side of the inlet.

[c] Posey and Ambrose (1994) present abundances of infauna (> 0.5mm) from 12cm diameter cores taken 12cm deep from stations along transects (1 & 2) perpendicular to "23 Mile Reef" 43.5km from Wilmington, NC. The 32m deep stations presented here are the stations 75m from the reef and least affected by the presence of the reef and associated fauna.

[d] Abundances of infauna (> 0.5mm) from 7.6cm diameter core samples 15cm deep taken by Van Dolah et al. (1994) are from an undisturbed control site 3km from Hilton Head I.

Table 10. Mean (SD = standard deviation) abundance expressed as number m^{-2} of infauna from major taxanomic groups from this study compared with abundances found in studies from nearby locations.

		Nearshore				Offshore				Day et al. (1971)[a]		Posey & Ambrose (1994)[b]			
		Treatment		Control		Treatment		Control		10m	20m	Jul.1990		Apr. 1991	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	mean	mean	SD	mean	SD
Mollusc	Bivalve	71.99	(34.69)	49.08	(44.5)	43.59	(19.76)	137.43	(69.63)	10.5	85	1220	(398.37)	1040	(519.62)
	Gastropod	13.09	(10.73)	19.63	(16.88)	10.86	(12.83)	28.4	(19.24)	16	6	0	(0)	110	(259.81)
	Scaphopod	0	(0)	0	(0)	2.23	(5.37)	4.32	(6.81)	0	0	150	(138.56)	0	(0)
Crustacea	Amphipod	55.63	(26.96)	71.99	(57.98)	63.22	(58.77)	45.81	(18.06)	336.5	113	70	(51.96)	340	(173.21)
	Isopod	6.54	(7.59)	6.54	(7.59)	0	(0)	6.54	(15.97)	-	-	700	(346.41)	560	(173.21)
Annelid	Polychaete (1)	929.32	(490.31)	559.55	(209.82)	1341.62	(795.55)	824.61	(112.96)	387	643	1230	(225.17)	8050	(1299.04)
	(2)											1000	(103.92)	4000	(398.37)
Echinoderm	Echiniod	3.27	(6.54)	0	(0)	4.32	(10.73)	0	(0)	66	4.5	100	(86.6)	-	-
	Ophiuroid	19.63	(7.59)	9.82	(6.54)	80.76	(121.2)	8.77	(10.73)	0	0	30	(34.64)	-	-
Sipuncula		9.82	(12.57)	6.54	(7.59)	8.77	(10.73)	13.09	(16.49)	4.5	13	-	-	-	-

[a] Day et al. (1971) took samples with a $0.2m^2$ van Veen grab and sieved them through a 1mm sieve. Infaunal abundances from samples taken from sites along a transect off Cape Lookout NC, were averaged over 5 sampling dates from Apr 1965 to Jan 1966. The two sites with depths closest to those of this study are presented.

[b] Posey and Ambrose (1994) present abundances of infauna (> 0.5mm) from 12cm diameter cores taken 12cm deep from stations along a transect (transects 1 & 2 for polychaetes) perpendicular to "23 Mile Reef" 43.5km from Wilmington, NC. The 32m deep stations presented here are the stations 75m from the reef and least affected by the presence of the reef and associated fauna.

Table 11. Mean (SD=standard deviation) abundance m^{-2} of echinoderms captured in a $10m^2$ belt transect (tow of a benthic sled) at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project compared with similar samples from other studies from nearby locations.

			This study								Dahlgren et al. (1994)[a]				Peterson et al (1999)[b]			
			Inshore				Offshore								December 1994			
			Treatment		Control		Treatment		Control		Spring 1993		Fall 1993		West Site		East Site	
			mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Mollusc	Bivalve		0	(0)	0.038	(0.048)	0	(0)	0	(0)	-	-	-	-	0.011	(0.047)	0	(0)
	Gastropod		0.225	(0.263)	0.088	(0.025)	0.008	(0.02)	0.042	(0.038)	-	-	-	-	0.072	(0.075)	0.65	(0.6)
	Scaphopod		0	(0)	0	(0)	0	(0)	0.008	(0.02)	-	-	-	-	0	(0)	0	(0)
Crustacea	Decapod	Pagurid	0.038	(0.025)	0.05	(0.041)	0.033	(0.041)	0.017	(0.026)	-	-	-	-	0.567	(0.49)	0.089	(0.132)
		total	0.063	(0.048)	0.075	(0.065)	0.042	(0.038)	0.033	(0.041)	-	-	-	-	0.617	(0.488)	0.1	(0.146)
Annelid	Polychaete		0.013	(0.025)	0	(0)	0.017	(0.041)	0.017	(0.026)	-	-	-	-	0	(0)	0.017	(0.038)
Echinoderm	Asteriod		0	(0)	0	(0)	0.008	(0.02)	0.008	(0.02)	0.053	(0.101)	0.007	(0.014)	0.017	(0.051)	0.006	(0.024)
	Echinoid		0	(0)	0.075	(0.15)	0	(0)	0	(0)	0.043	(0.048)	0.026	(0.055)	1.606	(1.273)	0.036	(0.094)
	Holothuroid		0	(0)	0	(0)	0	(0)	0	(0)	0.644	(0.948)	0.505	(0.728)	0.006	(0.024)	0.017	(0.038)
Cnidaria	Anthozoa	Renillid	0.013	(0.025)	0	(0)	0	(0)	0	(0)	-	-	-	-	0.017	(0.071)	0.006	(0.024)

[a] Dahlgren et al. (1994) present abundances of benthic fauna (> 1.5cm) from $10m^2$ belt transects taken by divers from 32m deep stations along a transect perpendicular to "23 Mile Reef" 43.5km from Wilmington, NC. The means presented here average samples from 1, 10, 25, 50, and 75 m from the reef. Tests among the transect stations showed no statistical difference in abundances relative to reef proximity.

[b] Peterson et al. (1999) present abundances of benthic fauna from (> 1.5cm) from $10m^2$ belt transects taken at sites about 1km SE (East Site) and SW (West Site) of Beaufort Inlet, Beaufort NC prior to any experimental disturbance. At the West Site transect were sampled by divers using visual and manual examination. Visibility was insufficient at the East Site for diver counts thus samples were taken using a benthic sled.

Table 12. Mean counts (standard error) of major taxa per transect for sampling conducted at six sites along Bogue Banks, NC. Sampling at each site was conducted along three transects oriented perpendicular to shore and spaced 50 m apart. Organisms were collected using a hand-operated aluminum corer with an internal diameter of 10.2 cm taken to a depth of 20 cm. Two cores were taken, seived on 1 mm mesh and pooled to form a single sample. Cores were collected every three meters along each transect and extended from just landward of mean high water to approximately 1 m deep in the surf zone. All sampling was conducted in the Spring and does not reflect relative abundances that may occur in other seasons.

SITE, DATE	**Ghost Crabs** *(Ocypode quadrata)*	**Donax spp.** *(D.variabilis, D. parvula)*	**Polychaetes** *(Scolelepis squamata)*	**Amphipods** (Talitridae, Haustoriidae)	**Mole Crab** *(Emerita talpoida)*
Emerald Isle Point, 5/30/97	7 (2.52)	89.7 (25.64)	172.3 (59.80)	36.3 (2.73)	0.3 (0.33)
Emerald Isle, 5/29/97	0	393.3 (161.99)	202.3 (56.68)	23 (8.14)	6.7 (3.33)
Salter Path, 5/27/97	6 (3.46)	219 (12.86)	179.3 (50.86)	17 (5.29)	7.3 (4.37)
Pine Knoll Shores, 5/28/97	0.3 (0.33)	269.7 (59.03)	171.7 (27.38)	66.7 (14.17)	0.6 (0.67)
Atlantic Beach, 5/20/97	0.3 (0.33)	68.7 (20.18)	141.3 (40.96)	18.7 (8.21)	0.6 (0.67)
Fort Macon, 5/22/97	1 (1.00)	14 (5.86)	239 (72.70)	10.3 (3.18)	1.7 (0.67)

APPENDICES

Appendix 1. Number of individuals by taxonomic family found in 76.4cm2 core samples taken at sites in (Treatment) and adjacent (Control) to inshore and offshore proposed sand borrow areas for the Bogue Banks beach renourishment. Ten cores were taken from each of 6 sites sampled both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

Year	Area	Treatment	sample number	Mollusc Bivalve juv	Arcid	Corbulid	Crassatellid	Cuspidariid	Diplodontid	Lucinid	Mactrid	Mesodesmatid	Pandorid
Nov-99	Offshore	Control	A1Ac-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ac-2	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A1Ac-3	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A1Ac-4	0	0	0	0	0	0	1	1	0	0
Nov-99	Offshore	Control	A1Ac-6	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A1Ac-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ac-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ac-11	0	0	0	0	0	0	3	0	0	0
Nov-99	Offshore	Control	A1Ac-12	0	0	0	0	0	0	1	1	0	0
Nov-99	Offshore	Control	A1Ac-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-8	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-8	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A1Ct-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-3	0	0	0	1	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-6	0	0	0	1	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-8	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-1	2	0	0	0	1	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-5	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A1Ec-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-14	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-1	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	A2Fc-2	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A2Fc-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-4	3	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-5	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-7	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	A2Fc-8	0	0	0	0	0	0	2	1	0	0
Nov-99	Offshore	Control	A2Fc-9	0	0	0	0	0	0	3	0	1	0
Nov-99	Offshore	Control	A2Fc-10	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-11	0	0	1	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-3	0	0	0	0	0	0	0	0	0	0

Appendix I cont.

sample number	Bivalve cont. Solecurtid	Tellinid	Venerid	Total Bivalve	Gastropod Acteocinid	Columbellid	Nassariid	Naticid	Olivid	Terebrid	Total Gastropod	Opistobranch Haminoeid	Scaphopod	Total Mollusc
A1Ac-1	0	1	1	2	0	0	0	0	0	0	0	0	0	2
A1Ac-2	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Ac-3	0	0	0	1	0	0	0	1	1	0	2	0	0	3
A1Ac-4	0	0	0	2	0	1	0	0	0	0	1	0	0	3
A1Ac-6	0	0	0	1	0	0	0	0	1	0	1	0	0	2
A1Ac-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-11	0	0	0	3	0	0	0	0	0	0	0	0	0	3
A1Ac-12	0	0	0	2	0	0	0	0	0	0	0	0	0	2
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-4	0	1	0	1	0	0	0	0	0	0	0	0	0	1
A1Bt-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	1	1	0	0	0	0	0	0	0	0	0	1
A1Bt-8	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-8	0	0	1	2	1	0	0	0	0	0	1	0	0	3
A1Ct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Dt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-6	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Dt-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-8	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Dt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-1	0	0	0	3	0	0	0	0	0	0	0	0	0	3
A1Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	1	0	0	2	0	2	0	0	0	0	2	0	0	4
A1Ec-6	1	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Ec-7	0	0	0	0	0	1	0	0	0	0	1	0	0	1
A1Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	2	0	0	0	0	0	0	0	0	0	2
A2Fc-2	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Fc-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-4	0	0	0	3	0	0	0	0	0	0	0	0	0	3
A2Fc-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	2	0	0	0	0	0	0	0	0	0	2
A2Fc-8	0	0	0	3	0	0	0	0	0	0	0	0	0	3
A2Fc-9	0	0	0	4	0	0	0	0	0	0	0	0	0	4
A2Fc-10	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	1	0	0	1	0	2	0	0	0	0	2	0	0	3
A2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0	1	0	1
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-11	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Amphipod unident.	Ampeliscid	Aorid	Caprellid	Corophiid	Gammarid	Haustoriid	Liljeborgiid	Melitid	Oedicerotid	Phoxocephalid	Stenothoid
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-3	0	0	0	0	0	1	0	0	0	0	0	0
A1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0.	0	0
A1Ac-8	0	1	0	0	0	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-11	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-12	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-5	0	0	0	0	0	0	0	1	0	0	0	0
A1Bt-6	0	1	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	0	-0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	0	0	0	0	0	0	1	0	0	0	0	0
A1Bt-13	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	1	0	0	0	0	0	0	0	0
A1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-10	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	0	0	1	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-6	0	0	0	0	0	0	0	1	0	0	0	0
A1Dt-7	0	0	0	1	0	0	0	0	0	0	0	0
A1Dt-8	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-9	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-10	0	0	0	0	0	0	0	0	4	0	0	0
A1Dt-12	0	0	0	0	0	0	0	0	6	0	0	0
A1Ec-1	0	0	0	0	0	0	0	1	0	0	0	0
A1Ec-2	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-8	0	0	0	0	0	0	0	1	0	0	0	0
A1Ec-9	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	0	1	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-2	0	1	0	0	0	0	0	0	0	0	0	0
A2Fc-3	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-4	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-5	1	0	0	0	0	0	0	0	0	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-8	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-9	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-10	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	1	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	0	0	3	0	0	0	0
A2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-11	0	0	0	0	0	0	0	0	0	0	1	0
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	1	0	0	0	0	0	0
A2Ht-3	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Total Amphipod	Copepoda	Cumacean	Decapod unident.	Pagurid	Penaeid	Pinnotherid	Sergestid	Xanthid	Isopod Idoteid	Sphaeromatid	Mysid	Ostracod	Tanaid
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-3	1	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Ac-4	0	0	0	0	0	0	2	0	0	0	0	0	0	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-4	0	0	0	0	0	0	1	0	0	0	0	0	0	1
A1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Dt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-9	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Dt-10	4	1	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-12	6	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-8	1	0	0	0	0	0	1	0	0	0	0	0	0	0
A1Ec-9	0	0	0	0	0	0	6	0	0	0	0	0	1	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-2	1	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Fc-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-8	0	0	0	0	1	0	0	0	0	0	0	0	0	1
A2Fc-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	2	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	0	0	0	1	1	0	0	0	0	0	0	0	0	0
A2Gt-11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	2	0	0	0	0	0	0	0
A2Ht-2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Total	Annelid Polychaete unident.	Polychaete cont. Acrocirrid	Ampharetid	Aphroditid	Arabellid	Capitellid	Cerratulid	Chaetopteridae	Dorvilleid	Euniced	Glycerid	Goniadid
A1Ac-1	0	0	0	0	0	0	1	0	0	0	0	1	0
A1Ac-2	0	0	0	0	0	0	6	0	0	0	0	0	0
A1Ac-3	2	0	0	0	0	0	4	1	0	0	0	0	0
A1Ac-4	2	0	0	0	0	0	5	0	0	0	0	1	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Ac-8	1	0	0	0	0	0	0	1	0	0	0	0	1
A1Ac-9	0	0	0	0	0	0	1	0	0	0	0	0	2
A1Ac-11	0	0	0	0	0	0	3	0	0	0	0	0	2
A1Ac-12	0	0	0	0	0	0	0	0	1	0	0	1	0
A1Ac-13	0	0	0	0	0	0	1	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	1	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	1	0	0	0	0	0	1
A1Bt-5	1	1	0	0	0	0	0	0	0	0	0	0	2
A1Bt-6	1	0	0	0	0	0	1	0	0	0	0	0	1
A1Bt-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	3	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	1	0	0	0	0	0	2
A1Bt-11	1	0	0	0	0	0	0	0	0	0	0	0	1
A1Bt-13	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	1	0	0	0	1	0	1	0	0	0	0	0	0
A1Ct-3	0	0	0	0	8	1	8	0	0	1	0	3	0
A1Ct-4	2	0	1	0	8	0	4	0	0	0	1	1	0
A1Ct-5	0	0	0	0	9	0	2	0	0	0	0	0	0
A1Ct-6	0	0	0	0	3	0	1	0	0	0	0	0	0
A1Ct-7	0	0	0	0	7	0	0	0	0	0	0	0	0
A1Ct-8	0	0	0	1	5	0	2	1	0	0	1	2	0
A1Ct-10	0	0	0	0	1	0	1	0	0	0	0	0	0
A1Ct-11	0	0	0	0	10	0	3	0	0	1	0	0	0
A1Ct-12	0	0	0	0	0	0	4	0	0	0	0	7	0
A1Dt-1	1	0	0	0	0	0	0	0	0	1	0	3	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	1	0	0	0	3	0	4	3	0	0	0	0	0
A1Dt-4	0	0	0	0	2	0	9	0	0	0	0	2	0
A1Dt-6	1	0	0	0	3	0	0	0	0	0	0	0	0
A1Dt-7	1	0	0	0	2	0	0	3	0	0	0	0	0
A1Dt-8	0	0	0	0	4	0	8	1	0	0	0	4	1
A1Dt-9	1	0	0	0	4	0	13	1	0	0	0	4	0
A1Dt-10	5	0	0	0	4	0	12	0	0	0	0	0	1
A1Dt-12	6	0	0	0	19	0	4	0	0	1	0	2	0
A1Ec-1	1	0	0	0	0	0	1	0	0	0	0	0	1
A1Ec-2	1	0	0	0	0	0	2	0	1	0	0	0	0
A1Ec-4	0	0	0	0	0	0	2	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	1	0	0	0	0	0	1	0	1	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-8	2	0	0	0	0	0	0	0	0	0	0	0	1
A1Ec-9	7	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	1	0	0	0	1
A1Ec-14	1	0	0	0	0	0	2	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	1	2	0	0	0	0	0	0
A2Fc-2	2	0	0	0	0	0	0	0	0	0	0	0	3
A2Fc-3	0	0	0	0	0	0	1	0	0	0	0	0	1
A2Fc-4	0	0	0	0	0	0	2	0	0	0	0	0	0
A2Fc-5	1	0	0	0	0	0	4	0	0	0	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	3	0	0	0	0	0	3
A2Fc-8	2	0	0	0	0	0	0	0	0	0	0	1	0
A2Fc-9	0	0	0	1	0	0	1	0	0	0	0	0	2
A2Fc-10	0	0	0	0	0	0	7	0	0	0	0	1	0
A2Gt-1	1	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	3	0	0	0	0	0	2	0	0	0	0	0	1
A2Gt-4	0	0	0	0	0	0	1	0	0	0	0	1	0
A2Gt-5	0	0	0	0	0	0	1	0	0	0	0	0	0
A2Gt-6	2	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	2	0	0	0	0	0	2	0	0	0	0	0	2
A2Gt-11	1	0	0	0	0	0	2	0	0	0	0	0	0
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	2	0	0	0	0	0	1	0	0	0	0	0	0
A2Ht-2	1	0	0	0	0	0	11	0	0	0	1	0	1
A2Ht-3	0	0	0	0	0	0	6	0	0	0	0	0	4

Appendix 1 cont.

sample number	Polychaete cont. Hesionid	Lumbrinerid	Magelonid	Maldanid	Nephtyid	Nereid	Onuphid	Opheliid	Orbiniid	Oweniid	Paraonid	Pectinarid	Phyllodocid	Pilargid
A1Ac-1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-3	0	0	0	0	1	0	1	0	0	0	0	0	0	0
A1Ac-4	0	0	0	0	0	1	0	0	0	1	0	0	0	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-8	0	0	3	0	0	0	1	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-11	0	0	1	0	0	1	0	0	0	1	0	0	0	0
A1Ac-12	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	1	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	0	2	0	0	0	0	0	0
A1Bt-5	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-13	0	0	0	0	11	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-3	3	0	0	0	0	1	0	0	0	0	0	0	0	0
A1Ct-4	1	0	0	0	0	1	0	0	0	0	3	0	0	0
A1Ct-5	0	0	0	0	0	0	0	0	0	0	5	0	1	0
A1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-8	1	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Ct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-11	0	1	0	0	0	0	0	0	0	0	0	0	1	0
A1Ct-12	0	0	0	1	0	1	0	0	0	0	0	0	1	0
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Dt-4	0	0	0	0	0	0	0	1	0	0	1	0	0	0
A1Dt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-7	0	0	0	0	0	0	0	1	0	0	0	0	1	0
A1Dt-8	0	0	0	0	1	0	0	1	0	0	1	0	1	0
A1Dt-9	0	0	0	3	0	0	0	0	0	0	1	0	1	0
A1Dt-10	0	0	0	0	0	2	0	1	0	0	4	0	2	0
A1Dt-12	0	0	0	1	0	0	0	0	0	0	0	0	1	0
A1Ec-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
A1Ec-2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-9	0	0	0	0	3	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	0	0	3	1	0	0	1	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-3	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Fc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-5	0	0	0	0	0	0	0	0	0	1	1	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	1	0	0	0	0	0	0	0	0	0	0
A2Fc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-9	1	1	0	0	1	0	0	0	0	0	0	0	0	0
A2Fc-10	0	1	0	0	0	1	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
A2Gt-4	0	0	0	0	0	2	1	0	0	0	0	0	0	0
A2Gt-5	2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	1	0	0	1	0	0	0	0	0
A2Gt-9	0	0	0	0	0	1	0	0	0	0	1	0	0	0
A2Gt-11	0	0	0	0	0	1	0	0	0	0	0	0	0	1
A2Gt-12	0	0	0	0	0	1	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Ht-3	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Polychaete cont. Pisionid	Polydontid	Spionid	Syllid	Terebellid	Polychaetae Total	Oligochaete	Aschelminthes Nematode	Nemertean	Platyhelminthes Polycladid	Echinoderma Echiniodea Mellitid
A1Ac-1	0	0	3	0	0	6	0	0	0	0	0
A1Ac-2	0	0	7	0	0	13	0	0	0	0	0
A1Ac-3	0	0	0	0	0	7	0	0	0	0	0
A1Ac-4	0	0	1	0	0	9	0	0	2	0	0
A1Ac-6	0	0	0	0	0	1	0	0	0	0	0
A1Ac-8	0	0	1	0	0	7	0	1	0	0	0
A1Ac-9	0	0	0	0	0	3	0	0	0	0	0
A1Ac-11	0	0	6	0	0	14	0	0	0	0	0
A1Ac-12	0	0	3	0	0	6	0	0	0	0	0
A1Ac-13	0	0	0	0	0	2	0	1	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	1	0	0	2	0	0	0	0	0
A1Bt-4	0	0	0	0	0	4	0	0	0	0	0
A1Bt-5	0	0	0	0	0	4	0	0	0	0	0
A1Bt-6	0	0	0	0	0	2	0	0	0	0	0
A1Bt-7	0	0	0	0	0	1	0	0	0	0	0
A1Bt-8	0	0	0	0	0	3	0	0	0	0	0
A1Bt-9	0	0	0	0	0	3	0	0	0	0	0
A1Bt-11	0	0	0	0	0	1	0	0	0	0	0
A1Bt-13	0	0	0	0	0	11	0	0	0	0	0
A1Ct-1	0	0	5	0	0	7	1	1	0	0	0
A1Ct-3	0	0	0	2	0	27	7	0	0	0	0
A1Ct-4	0	0	0	4	2	26	0	1	11	1	0
A1Ct-5	0	0	1	0	0	18	7	0	4	1	0
A1Ct-6	0	0	1	0	0	5	0	1	2	0	0
A1Ct-7	0	0	0	0	0	7	0	0	0	0	0
A1Ct-8	0	0	0	1	1	16	7	1	1	2	0
A1Ct-10	0	0	0	0	0	2	0	0	0	0	0
A1Ct-11	0	0	0	9	0	25	0	0	1	0	0
A1Ct-12	0	0	1	0	1	16	0	0	2	0	0
A1Dt-1	0	0	0	0	0	4	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	1	1	0	13	0	2	1	0	0
A1Dt-4	0	0	0	2	0	17	0	0	1	0	0
A1Dt-6	0	0	0	4	0	7	0	1	1	0	0
A1Dt-7	0	0	1	7	0	15	0	0	0	1	0
A1Dt-8	0	0	0	1	0	23	0	1	0	0	0
A1Dt-9	0	2	4	0	0	33	3	8	3	0	0
A1Dt-10	0	0	2	0	0	28	0	4	6	1	0
A1Dt-12	4	0	3	1	0	36	0	1	1	2	0
A1Ec-1	0	0	0	0	0	3	0	0	1	0	0
A1Ec-2	0	0	0	0	0	4	0	0	0	0	0
A1Ec-4	0	0	14	0	0	16	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	1	0	0
A1Ec-6	0	0	2	0	0	4	0	0	0	0	0
A1Ec-7	0	0	4	0	0	5	0	0	0	0	0
A1Ec-8	0	0	1	0	0	2	0	1	0	0	0
A1Ec-9	0	0	2	0	0	5	0	0	1	0	0
A1Ec-12	0	0	0	0	0	2	0	0	0	0	0
A1Ec-14	0	0	1	0	0	8	0	0	0	0	0
A2Fc-1	0	0	0	2	0	6	0	1	0	0	0
A2Fc-2	0	0	6	0	0	9	0	0	0	0	0
A2Fc-3	0	0	1	0	0	4	0	0	0	0	0
A2Fc-4	0	0	3	0	0	5	0	0	0	0	0
A2Fc-5	0	0	1	0	0	7	0	0	1	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	1	0	0	8	0	0	0	0	0
A2Fc-8	0	0	0	0	0	1	0	0	0	0	0
A2Fc-9	0	0	2	1	0	10	0	0	0	0	0
A2Fc-10	0	0	2	0	0	12	0	0	0	0	0
A2Gt-1	0	0	3	0	0	3	0	0	0	0	0
A2Gt-2	0	0	6	0	0	11	0	0	0	0	0
A2Gt-4	0	0	0	0	0	5	0	0	1	0	0
A2Gt-5	0	0	0	0	0	3	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	2	0	0	4	1	0	0	0	0
A2Gt-9	0	0	4	0	0	10	0	0	0	0	0
A2Gt-11	0	0	0	0	0	4	0	0	0	0	0
A2Gt-12	0	0	1	2	0	4	0	0	0	0	0
A2Gt-13	0	0	0	0	0	1	0	0	0	0	0
A2Ht-2	0	0	6	1	0	21	0	0	0	0	0
A2Ht-3	0	0	1	0	0	12	0	0	0	0	0

Appendix 1 cont.

sample number	Echinoderm cont. Schizasterid	Ophiuroid Amphiurid	unident	Holothuroid Cucumariid	Synaptid	Echinoderm Total	Cnidaria Actiniaria Edwardsiid	Halaclavid	unident	Hydroid	Kamptozoa (colonial)	Sipuncula Golfingiid	Sipuncula
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-3	0	0	0	0	0	0	1	0	0	0	0	0	0
A1Ac-4	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	1	0	0	0	0	0	0
A1Ac-11	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-12	0	0	0	1	0	1	0	0	0	1	0	1	0
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	1	0	0	0	0	1	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-13	1	0	0	0	0	1	0	0	0	0	0	0	0
A1Ct-1	0	1	0	0	0	1	0	0	0	0	0	0	0
A1Ct-3	0	4	0	0	0	4	0	0	0	0	0	0	0
A1Ct-4	0	2	0	0	0	2	0	1	0	0	0	0	0
A1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-6	0	1	0	0	0	1	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	1
A1Ct-8	0	5	1	0	0	6	0	0	0	0	0	0	0
A1Ct-10	0	1	0	0	0	1	0	0	0	0	0	0	0
A1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-12	0	1	0	0	0	1	0	0	0	0	0	0	1
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	2	0	0	0	2	0	0	0	0	0	0	0
A1Dt-4	0	1	0	0	0	1	0	0	0	0	0	0	0
A1Dt-6	0	2	0	0	0	2	0	0	0	0	0	0	0
A1Dt-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-8	0	4	0	0	0	4	0	0	0	0	0	0	0
A1Dt-9	0	5	0	0	0	5	1	0	0	0	0	0	0
A1Dt-10	0	3	0	0	0	3	0	0	0	0	0	0	0
A1Dt-12	0	3	0	0	0	3	0	0	0	0	0	1	0
A1Ec-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	1	0
A2Fc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-5	0	1	0	0	0	1	0	0	0	0	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-8	0	1	0	0	0	1	0	1	0	0	0	0	0
A2Fc-9	0	0	0	0	0	0	0	0	0	0	1	0	0
A2Fc-10	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-11	0	0	0	1	0	1	0	0	0	0	0	0	0
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-3	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Echiurida	Phoronida	Bryozoa Ectoproct Bugulid	Tunicate	Chaetognath	Amphioxis	TOTAL
A1Ac-1	0	0	0	0	0	0	8
A1Ac-2	0	0	0	0	0	0	14
A1Ac-3	0	0	0	0	0	0	13
A1Ac-4	0	0	0	0	0	0	17
A1Ac-6	0	0	0	0	0	0	3
A1Ac-8	0	1	0	0	0	0	10
A1Ac-9	0	0	0	0	0	0	4
A1Ac-11	0	0	0	0	0	0	17
A1Ac-12	0	0	0	0	0	0	11
A1Ac-13	0	0	0	0	0	0	3
A1Bt-2	0	0	0	0	0	0	0
A1Bt-3	0	0	0	0	0	0	4
A1Bt-4	0	0	0	0	0	0	5
A1Bt-5	0	0	0	0	0	0	5
A1Bt-6	0	0	0	0	0	0	3
A1Bt-7	0	0	0	0	0	0	2
A1Bt-8	0	0	0	0	0	0	4
A1Bt-9	0	0	0	0	0	0	3
A1Bt-11	0	0	0	0	0	0	2
A1Bt-13	0	0	0	0	0	0	12
A1Ct-1	0	0	0	0	0	0	11
A1Ct-3	0	0	0	0	0	0	38
A1Ct-4	0	0	0	0	0	0	44
A1Ct-5	0	0	0	0	0	0	30
A1Ct-6	0	0	0	0	0	0	9
A1Ct-7	0	0	0	0	0	0	8
A1Ct-8	0	0	0	0	0	0	36
A1Ct-10	0	0	0	0	0	0	3
A1Ct-11	0	0	0	0	0	0	26
A1Ct-12	0	0	0	0	0	1	21
A1Dt-1	0	0	0	0	0	0	5
A1Dt-2	0	0	0	0	0	0	0
A1Dt-3	0	0	0	0	0	0	20
A1Dt-4	0	0	0	0	0	0	19
A1Dt-6	0	0	0	0	0	0	13
A1Dt-7	0	0	0	0	0	0	17
A1Dt-8	0	0	0	0	0	0	29
A1Dt-9	0	0	0	0	0	0	54
A1Dt-10	0	0	0	0	0	0	47
A1Dt-12	0	0	0	0	0	0	50
A1Ec-1	0	0	0	0	0	0	8
A1Ec-2	0	0	0	0	0	0	5
A1Ec-4	0	0	0	0	0	0	16
A1Ec-5	0	0	0	0	0	0	5
A1Ec-6	0	0	0	0	0	0	6
A1Ec-7	0	0	0	0	0	0	6
A1Ec-8	0	0	0	0	0	0	5
A1Ec-9	0	0	0	0	0	0	13
A1Ec-12	0	0	0	0	0	0	2
A1Ec-14	0	0	0	0	0	0	9
A2Fc-1	0	0	0	0	0	0	9
A2Fc-2	0	0	0	0	0	0	13
A2Fc-3	0	0	0	0	0	0	4
A2Fc-4	1	0	0	0	0	0	9
A2Fc-5	0	0	0	0	0	0	11
A2Fc-6	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	10
A2Fc-8	0	0	0	0	0	0	8
A2Fc-9	0	0	0	0	0	0	15
A2Fc-10	0	0	0	0	0	0	13
A2Gt-1	0	0	0	0	0	0	4
A2Gt-2	0	0	0	0	0	0	17
A2Gt-4	0	0	0	0	0	0	6
A2Gt-5	0	0	0	0	0	0	3
A2Gt-6	0	0	0	0	0	0	3
A2Gt-8	0	0	0	0	0	0	5
A2Gt-9	0	0	0	0	0	0	12
A2Gt-11	0	0	0	0	0	0	7
A2Gt-12	0	0	0	0	0	0	4
A2Gt-13	0	0	0	0	0	0	3
A2Ht-2	1	0	0	0	0	0	23
A2Ht-3	0	0	1	0	0	0	13

Appendix 1 cont.

Year	Area	Treatment	sample number	Mollusc Bivalve juv	Arcid	Corbulid	Crassatellid	Cuspidariid	Diplodontid	Lucinid	Mactrid	Mesodesmatid	Pandorid
Nov-99	Offshore	Treatment	A2Ht-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-5	0	0	0	0	0	0	0	1	0	0
Nov-99	Offshore	Treatment	A2Ht-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-7	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A2Ht-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-11	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Treatment	A2Ht-13	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A2It-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-4	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A2It-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-7	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A2It-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-1	0	0	0	0	0	0	1	1	0	0
Nov-99	Offshore	Control	A2Jc-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-3	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A2Jc-4	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A2Jc-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-7	0	0	0	0	0	0	4	0	0	0
Nov-99	Offshore	Control	A2Jc-8	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A2Jc-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-12	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	ANc-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-3	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-5	0	0	0	0	0	0	0	0	0	1
Nov-99	Offshore	Control	ANc-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ASc-1	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	ASc-2	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	ASc-4	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	ASc-5	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	ASc-7	0	1	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ASc-9	0	0	0	0	0	0	3	0	0	0
Nov-99	Offshore	Control	ASc-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ASc-12	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	ASc-14	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	ASc-15	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-5	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-8	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Control	B1Ac-13	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-14	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-1	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B1Bt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-4	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B1Bt-6	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B1Bt-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-5	0	1	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-8	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample		Bivalve cont.		Total	Gastropod						Total	Opistobranch	Scaphopod	Total
number	Solecurtid	Tellinid	Venerid	Bivalve	Acteocinid	Columbellid	Nassariid	Naticid	Olivid	Terebrid	Gastropod	Haminoeid		Mollusc
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Ht-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-7	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Ht-8	0	1	0	1	0	0	0	0	0	0	0	0	0	1
A2Ht-9	0	0	0	0	0	0	0	0	0	0	0	0	1	1
A2Ht-11	0	0	0	2	0	0	0	0	0	0	0	0	0	2
A2Ht-13	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2It-1	0	0	0	0	0	0	0	0	1	0	1	0	0	1
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	1	0	2	0	0	0	0	0	0	0	0	0	2
A2It-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-7	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	1	0	1	0	0	0	0	0	0	0	0	0	1
A2It-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	1	0	0	0	0	1	0	0	1
A2Jc-1	0	0	0	2	0	0	0	0	0	0	0	1	0	3
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-3	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Jc-4	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	0	0	0	4	0	0	0	0	0	0	0	0	0	4
A2Jc-8	0	0	0	1	0	0	0	0	1	0	1	0	0	2
A2Jc-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-12	0	0	0	1	0	0	0	0	0	0	0	0	0	1
ANc-2	0	0	1	1	0	0	0	0	0	0	0	0	0	1
ANc-3	0	0	0	1	0	0	0	1	0	0	1	0	0	2
ANc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
ANc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-9	0	0	0	0	0	1	0	0	0	0	1	0	0	1
ANc-11	0	0	0	0	0	0	0	1	0	0	1	0	0	1
ANc-12	0	0	0	0	0	0	0	0	0	0	0	1	1	2
ANc-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
ASc-2	0	0	0	2	0	0	0	0	0	0	0	0	0	2
ASc-4	0	1	0	3	0	0	0	0	0	1	1	0	0	4
ASc-5	0	0	0	1	0	0	0	0	0	0	0	0	1	2
ASc-7	0	1	0	2	0	0	0	0	0	0	0	0	0	2
ASc-9	0	0	0	3	0	0	0	0	1	0	1	0	0	4
ASc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-12	0	0	0	1	0	0	0	0	0	0	0	0	0	1
ASc-14	0	0	0	2	0	0	0	0	0	0	0	0	0	2
ASc-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	1	1	0	0	1
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	1	1	0	0	0	0	0	0	0	0	0	1
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-7	0	1	0	1	0	0	0	0	0	0	0	0	0	1
B1Ac-8	0	0	0	1	0	0	0	0	0	1	1	0	0	2
B1Ac-13	0	0	0	1	0	0	1	0	0	0	1	0	0	2
B1Ac-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-4	0	0	0	1	0	0	0	0	0	1	1	0	0	2
B1Bt-6	0	0	1	2	0	0	0	0	0	0	0	0	0	2
B1Bt-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-11	0	1	0	1	0	0	0	0	0	0	0	0	0	1
B1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Amphipod unident.	Amphipod cont. Ampeliscid	Aorid	Caprellid	Corophiid	Gammerid	Haustorid	Liljeborgiid	Melitid	Oedicerotid	Phoxocephalid	Stenothoid
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-6	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-7	0	0	0	0	0	1	0	0	0	0	0	0
A2Ht-8	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-9	0	0	0	0	0	1	0	0	0	0	0	0
A2Ht-11	0	0	0	0	0	0	0	0	0	3	0	0
A2Ht-13	0	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	0	0	0	0	0	0	0	0	0	0	0
A2It-6	0	0	0	0	0	0	0	0	1	0	0	0
A2It-7	0	0	0	0	0	0	0	0	0	0	0	0
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	0	0	0	0	0	0	0	0	0	0	0
A2It-11	0	0	0	0	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-3	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-4	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	3	0	0	0	0	0	0	0	0	0	0	0
A2Jc-8	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-9	0	0	0	0	0	1	0	0	0	0	0	0
A2Jc-12	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0
ANc-3	0	0	0	0	0	0	1	1	0	0	0	1
ANc-4	0	0	0	0	0	0	0	0	0	0	0	0
ANc-5	0	0	0	0	0	0	0	0	0	0	0	0
ANc-7	0	0	0	0	0	0	0	0	0	1	0	0
ANc-8	0	0	0	0	0	0	0	0	0	0	0	0
ANc-9	0	0	0	0	0	0	0	0	0	0	0	0
ANc-11	0	0	0	0	0	0	0	0	0	0	0	0
ANc-12	0	0	0	0	0	0	0	1	0	0	0	0
ANc-13	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	0	0	0	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0
ASc-4	0	0	0	0	0	0	0	0	0	0	0	0
ASc-5	0	0	0	0	0	0	0	0	0	0	0	0
ASc-7	0	0	0	0	0	0	0	0	0	0	0	0
ASc-9	0	0	1	0	0	0	0	0	0	0	0	0
ASc-11	0	0	0	0	0	0	0	0	0	0	0	0
ASc-12	0	0	0	0	0	0	1	0	0	0	0	0
ASc-14	0	0	0	0	0	0	1	0	0	1	0	0
ASc-15	0	0	0	0	0	1	0	0	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-7	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-8	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-14	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-3	0	0	0	0	0	0	0	0	0	1	0	0
B1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-7	0	0	0	0	0	1	0	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-6	0	0	0	0	0	0	0	0	0	1	0	0
B1Ct-7	0	0	0	0	0	0	0	0	0	2	0	0
B1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0

Appendix I cont.

sample number	Total Amphipod	Copepoda	Cumacean	Decapod unident.	Pagurid	Penaeid	Pinnotherid	Sergestid	Xanthid	Isopod Idoteid	Sphaeromatid	Mysid	Ostracod	Tanaid
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-7	1	0	1	0	0	0	0	0	0	0	0	0	0	0
A2Ht-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-9	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-11	3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-13	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-3	0	0	2	0	0	0	0	0	0	0	0	0	0	0
A2Jc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-9	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-5	0	0	0	0	0	0	0	0	0	2	0	0	0	0
ANc-7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-9	0	0	0	0	0	0	1	0	0	0	0	0	0	0
ANc-11	0	0	0	0	0	0	0	0	0	1	0	0	0	0
ANc-12	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-9	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-12	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-14	2	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-15	1	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ac-1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	0	0	0	0	0	0	0	0	0	1	0	0
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
B1Ac-6	0	0	0	0	0	0	0	0	0	1	0	0	0	0
B1Ac-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-8	0	0	0	0	0	0	0	0	0	0	0	2	0	0
B1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Total	Annelid Polychaeta unident.	Polychaeta cont. Acrocirrid	Ampharetid	Aphroditid	Arabellid	Capitellid	Cerratulid	Chaetopteridae	Dorvilleid	Eunicid	Glycerid	Goniadid
A2Ht-4	0	0	0	0	0	0	7	0	0	0	0	1	2
A2Ht-5	0	0	0	0	0	0	14	0	0	0	0	0	1
A2Ht-6	0	0	0	0	0	0	12	2	0	0	1	0	1
A2Ht-7	2	0	0	0	0	0	13	2	0	0	0	0	3
A2Ht-8	0	0	0	0	0	0	8	0	0	0	0	0	2
A2Ht-9	1	0	0	0	0	0	6	0	0	0	0	0	4
A2Ht-11	3	0	0	0	0	1	0	0	0	0	0	0	2
A2Ht-13	1	0	0	0	0	0	5	0	0	0	0	1	1
A2It-1	0	0	0	2	0	0	3	0	0	0	0	1	1
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	2	0	0	0	0	0	1
A2It-4	0	0	0	0	1	0	3	0	0	0	0	0	3
A2It-6	1	0	0	0	0	0	4	0	0	0	1	0	1
A2It-7	0	0	0	0	1	0	3	0	0	0	0	0	1
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	2
A2It-9	0	0	0	0	0	0	8	0	0	0	1	0	0
A2It-11	0	0	0	0	0	0	0	0	0	0	0	1	1
A2It-12	0	0	0	0	0	0	4	0	0	0	0	1	1
A2Jc-1	1	0	0	0	0	0	2	0	1	0	0	0	1
A2Jc-2	0	0	0	0	0	0	1	0	0	0	0	0	0
A2Jc-3	2	0	0	0	0	0	1	0	1	0	0	0	1
A2Jc-4	0	0	0	0	0	0	2	0	0	0	0	0	2
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	1
A2Jc-6	0	0	0	0	0	0	6	0	0	0	0	0	2
A2Jc-7	3	0	0	0	0	0	2	0	0	0	0	1	2
A2Jc-8	0	0	0	0	0	0	3	0	0	0	0	0	2
A2Jc-9	1	0	0	0	0	0	5	0	0	0	0	0	2
A2Jc-12	0	0	0	0	0	0	4	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	3	0	0	0	0	0	0
ANc-3	3	0	0	0	1	0	0	0	1	0	0	0	2
ANc-4	0	0	0	0	0	0	0	0	0	0	0	1	0
ANc-5	2	0	0	0	0	0	2	0	0	1	0	0	1
ANc-7	1	0	0	0	2	0	1	0	0	0	0	0	2
ANc-8	0	0	0	0	0	0	0	0	0	0	1	0	1
ANc-9	1	0	0	0	0	0	3	0	0	0	0	0	0
ANc-11	1	0	0	0	0	0	0	0	0	0	0	0	1
ANc-12	1	0	0	0	0	0	1	0	0	0	0	0	2
ANc-13	0	0	0	0	0	0	2	0	0	0	0	0	1
ASc-1	1	0	0	0	0	0	1	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	3	0	0	0	0	1	1
ASc-4	0	0	0	0	0	0	2	0	0	0	0	1	1
ASc-5	0	0	0	0	0	0	0	0	0	0	0	0	1
ASc-7	0	0	0	0	0	0	2	0	0	0	0	0	0
ASc-9	1	0	0	2	0	0	2	0	0	0	0	0	0
ASc-11	0	0	0	0	0	0	0	0	0	0	0	1	0
ASc-12	1	0	0	0	0	1	0	0	0	0	0	1	0
ASc-14	2	0	0	0	0	0	0	0	0	0	0	0	0
ASc-15	2	0	0	0	0	0	0	1	0	0	0	1	0
B1Ac-1	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	1	0
B1Ac-3	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-4	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ac-5	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-6	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-7	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Ac-8	2	0	0	0	0	0	2	0	0	0	0	0	0
B1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	1
B1Ac-14	0	0	0	0	0	0	4	0	0	0	0	0	1
B1Bt-1	0	0	0	0	0	0	1	0	0	0	2	0	0
B1Bt-2	0	0	0	0	0	0	5	0	0	0	0	0	0
B1Bt-3	1	0	0	0	0	0	7	0	0	0	0	0	0
B1Bt-4	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-6	0	0	0	2	0	0	5	0	0	0	0	0	0
B1Bt-7	1	0	0	0	0	0	5	0	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	5	0	0	0	0	0	1
B1Bt-9	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	7	0	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-3	0	0	0	0	0	0	1	0	0	0	0	0	1
B1Ct-4	0	0	0	0	0	0	2	0	0	0	0	0	1
B1Ct-5	0	0	0	0	0	0	2	0	1	0	0	0	1
B1Ct-6	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	2	0	0	0	0	0	6	0	0	0	0	0	0
B1Ct-8	0	0	0	0	0	0	1	0	0	0	0	1	2

Appendix 1 cont.

sample number	Hesionid	Lumbrinerid	Polychaete cont. Magelonid	Maldanid	Nephtyid	Nereid	Onuphid	Opheliid	Orbiniid	Owenid	Paraonid	Pectinarid	Phyllodocid	Pilargid
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	0	0	0	0	0	2	0	0	0	0	0
A2Ht-6	0	0	0	0	0	0	0	0	1	0	0	0	0	0
A2Ht-7	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A2Ht-8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-9	0	0	1	0	2	2	0	2	0	0	0	0	0	0
A2Ht-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-13	0	0	0	0	0	0	0	1	0	0	0	0	0	0
A2It-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A2It-3	0	1	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	0	0	0	1	1	0	0	0	0	0	0	0	0
A2It-6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2It-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	0	0	0	1	2	0	2	0	0	0	0	0	0
A2It-11	0	0	1	0	0	1	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-3	0	0	1	0	1	0	0	0	0	0	0	0	0	0
A2Jc-4	0	0	4	0	0	0	0	0	0	0	0	0	0	0
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	1	0	0	0	0	0	0	0	0	1	0	0	0	0
A2Jc-8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-9	1	0	0	0	1	0	0	0	1	1	0	0	0	0
A2Jc-12	0	0	2	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-3	0	0	1	0	0	0	2	0	0	0	0	0	0	0
ANc-4	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ANc-5	0	1	0	0	1	0	0	0	0	0	0	0	0	0
ANc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-8	0	0	0	0	1	0	0	0	1	0	0	0	0	0
ANc-9	0	0	1	0	0	0	1	0	0	0	0	0	0	0
ANc-11	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ANc-12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
ANc-13	0	0	0	0	1	0	0	0	3	0	0	0	0	0
ASc-1	0	0	0	0	1	0	0	0	0	0	1	0	0	0
ASc-2	1	0	0	0	2	0	1	0	0	0	0	0	0	0
ASc-4	0	0	1	0	0	0	0	0	0	0	0	0	0	0
ASc-5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
ASc-7	0	1	1	0	0	0	0	1	0	0	0	0	0	0
ASc-9	0	0	0	0	0	4	2	0	0	3	0	0	0	0
ASc-11	0	0	1	0	1	0	0	0	0	3	0	0	0	0
ASc-12	1	0	1	0	0	0	0	3	0	2	0	0	0	0
ASc-14	1	0	0	0	1	0	0	0	0	0	0	0	0	0
ASc-15	0	1	0	0	0	0	1	0	0	1	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	1	0	0	0	0	0	1	0	0	0	0	0
B1Ac-6	0	0	0	0	0	0	0	0	0	1	0	0	0	0
B1Ac-7	0	0	0	0	0	1	0	0	0	1	0	0	0	0
B1Ac-8	0	0	2	0	0	0	0	0	0	0	0	0	0	0
B1Ac-13	0	0	0	0	2	0	0	0	0	0	0	0	0	0
B1Ac-14	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Bt-1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	1	0	1	0	0	0
B1Bt-3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-7	0	0	0	0	1	0	0	0	0	0	0	0	0	0
B1Bt-8	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-3	0	0	1	0	0	0	1	0	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Ct-5	0	0	0	1	0	0	0	0	0	0	0	0	0	0
B1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Ct-8	0	0	0	0	0	0	1	1	1	0	0	0	0	0

Appendix 1 cont.

sample number	Pisionid	Polydontid	Polychaete cont. Spionid	Syllid	Terebellid	Polychaetae Total	Oligochaete	Aschelminthes Nematode	Nemertean	Platyhelminthes Polycladid	Echinoderm Echiniodea Mellitid
A2Ht-4	0	0	0	0	0	10	0	0	0	0	0
A2Ht-5	0	0	1	0	0	18	0	0	0	0	0
A2Ht-6	0	0	0	0	0	17	0	0	0	0	0
A2Ht-7	0	0	2	0	0	21	0	0	0	0	0
A2Ht-8	0	0	0	0	0	11	0	0	2	0	0
A2Ht-9	0	0	2	0	0	19	0	0	0	0	0
A2Ht-11	0	0	1	0	0	4	0	0	0	0	0
A2Ht-13	0	0	1	0	0	9	0	0	0	0	0
A2It-1	0	0	1	0	0	9	6	0	1	0	0
A2It-2	0	0	3	0	0	4	0	0	0	0	0
A2It-3	0	0	0	0	0	4	0	0	0	0	0
A2It-4	0	0	3	0	0	12	0	0	0	0	0
A2It-6	0	0	2	0	0	9	0	0	0	0	0
A2It-7	0	0	0	0	0	5	0	0	0	0	0
A2It-8	0	0	0	0	0	2	0	0	1	0	0
A2It-9	0	0	1	0	0	15	1	0	1	0	0
A2It-11	0	0	0	0	0	4	0	0	0	0	0
A2It-12	0	0	1	0	0	8	2	5	1	0	0
A2Jc-1	0	0	2	0	0	6	0	1	0	0	0
A2Jc-2	0	0	0	0	0	1	0	0	0	0	0
A2Jc-3	0	0	2	0	0	7	0	0	1	0	0
A2Jc-4	0	0	0	0	0	8	0	0	0	0	0
A2Jc-5	0	0	0	0	0	1	0	0	0	0	0
A2Jc-6	0	0	2	0	0	10	0	0	0	0	0
A2Jc-7	0	0	1	0	0	8	0	0	1	0	0
A2Jc-8	0	0	1	0	0	7	0	1	0	0	0
A2Jc-9	0	0	1	0	0	12	0	0	1	0	0
A2Jc-12	0	0	2	0	0	8	0	0	0	0	0
ANc-2	0	0	3	0	0	6	0	1	1	0	0
ANc-3	0	0	0	0	0	7	0	0	1	0	0
ANc-4	0	0	1	0	0	3	0	0	0	0	0
ANc-5	0	0	1	0	0	7	0	0	0	0	0
ANc-7	0	0	0	0	0	5	0	0	0	0	0
ANc-8	0	0	3	0	0	7	0	0	0	0	0
ANc-9	0	0	2	0	0	7	0	0	1	0	0
ANc-11	0	0	2	0	0	4	0	0	0	0	0
ANc-12	0	0	0	0	0	4	0	0	0	0	0
ANc-13	0	0	0	1	0	8	0	0	0	0	0
ASc-1	0	0	0	0	0	3	0	0	0	0	0
ASc-2	0	0	0	0	0	9	0	0	0	0	0
ASc-4	0	0	6	0	0	11	0	0	0	0	0
ASc-5	0	0	0	0	0	2	0	0	0	0	0
ASc-7	0	0	1	0	0	6	0	0	1	0	0
ASc-9	0	0	3	0	1	17	0	0	0	0	0
ASc-11	0	0	0	0	0	6	0	0	1	0	0
ASc-12	0	0	2	0	0	11	0	0	0	0	0
ASc-14	0	0	0	0	0	2	0	0	1	0	0
ASc-15	0	0	1	0	0	6	0	2	0	0	0
B1Ac-1	0	0	1	0	0	1	0	0	0	0	0
B1Ac-2	0	0	0	0	0	1	0	1	0	0	0
B1Ac-3	0	0	0	0	0	1	0	0	2	0	0
B1Ac-4	0	0	1	0	0	2	0	0	0	0	0
B1Ac-5	0	0	1	0	0	3	0	0	0	0	0
B1Ac-6	0	0	1	0	0	2	0	0	0	0	0
B1Ac-7	0	0	0	4	0	7	0	1	0	0	0
B1Ac-8	0	0	1	0	0	5	0	0	1	0	0
B1Ac-13	0	0	0	0	0	3	0	2	0	0	0
B1Ac-14	0	0	1	0	0	7	0	0	0	0	0
B1Bt-1	0	0	11	0	0	16	0	0	1	0	0
B1Bt-2	0	0	3	0	0	10	0	0	1	0	0
B1Bt-3	0	0	2	0	0	10	0	0	1	0	0
B1Bt-4	0	0	9	0	0	9	0	1	0	0	1
B1Bt-6	0	0	9	0	0	16	0	0	0	0	0
B1Bt-7	0	0	9	0	0	15	0	1	1	0	0
B1Bt-8	0	0	4	0	0	11	0	0	0	0	0
B1Bt-9	0	0	1	0	0	2	0	0	0	0	0
B1Bt-10	0	0	6	0	0	14	0	0	1	0	0
B1Bt-11	0	0	4	0	0	5	0	0	0	0	0
B1Ct-3	0	0	0	1	0	5	0	0	0	0	0
B1Ct-4	0	0	4	0	0	8	0	0	0	0	0
B1Ct-5	0	0	6	0	0	11	0	0	0	0	0
B1Ct-6	0	0	13	0	0	13	0	0	0	0	0
B1Ct-7	0	0	7	0	0	14	0	0	0	0	0
B1Ct-8	0	0	8	0	0	15	0	0	0	0	0

Appendix 1 cont.

sample number	Schizasterid	Ophiuroid Amphiurid	unident.	Holothuroid Cucumariid	Synaptid	Echinoderm Total	Cnidaria Actiniaria Edwardsiid	Halaclavid	unident.	Hydroid	Kamptozoa (colonial)	Sipuncula Golfingiid	Sipuncula
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-7	0	1	0	0	0	1	0	1	0	0	0	0	0
A2Ht-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-9	0	0	0	0	1	1	0	0	0	0	0	0	1
A2Ht-11	0	0	0	0	0	0	0	1	0	0	0	0	0
A2Ht-13	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-11	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	1	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-9	0	1	0	0	0	1	0	0	0	0	0	0	0
A2Jc-12	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-5	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-7	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-8	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-9	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-11	0	0	0	0	0	0	0	0	0	0	1	0	0
ANc-12	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-13	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	0	1	1	0	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-4	0	0	0	0	0	0	0	0	0	0	0	0	1
ASc-5	0	0	0	0	0	0	0	0	0	0	0	0	1
ASc-7	0	0	0	0	0	0	1	0	0	0	0	0	1
ASc-9	0	1	0	0	0	1	0	0	2	0	0	0	0
ASc-11	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-12	0	0	0	0	0	0	0	1	0	0	0	0	0
ASc-14	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-15	0	0	0	0	0	0	0	0	0	1	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	0	0	0	0	0	0	0	0	0	1	0
B1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-7	0	1	0	0	0	1	0	0	0	0	0	0	0
B1Ac-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-14	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	1	0	0	1	2	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-4	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-7	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	1
B1Bt-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Ct-3	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	0	2	0	0	0	2	0	0	0	1	0	0	0
B1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Echiurida	Phoronida	Bryozoa Ectoproct Bugulid	Tunicate	Chaetognath	Amphioxis	TOTAL
A2Ht-4	0	0	0	0	0	0	10
A2Ht-5	0	0	0	0	0	0	19
A2Ht-6	0	0	0	0	0	0	17
A2Ht-7	0	0	0	0	0	0	26
A2Ht-8	0	0	0	0	0	0	14
A2Ht-9	0	0	0	0	0	0	23
A2Ht-11	0	0	0	0	0	0	10
A2Ht-13	0	0	0	0	0	0	11
A2It-1	0	0	0	0	0	0	17
A2It-2	0	0	0	0	0	0	4
A2It-3	0	0	0	0	0	0	4
A2It-4	0	0	0	0	0	0	14
A2It-6	0	0	0	0	0	0	10
A2It-7	0	0	0	0	0	0	6
A2It-8	0	0	0	0	0	0	3
A2It-9	0	0	0	0	0	0	18
A2It-11	0	0	0	0	0	0	4
A2It-12	1	0	0	0	0	0	18
A2Jc-1	0	0	0	0	0	0	11
A2Jc-2	0	0	0	0	0	0	2
A2Jc-3	0	0	0	0	0	0	11
A2Jc-4	0	0	0	0	0	0	9
A2Jc-5	0	0	0	0	0	0	1
A2Jc-6	0	0	0	0	0	0	10
A2Jc-7	0	0	0	0	0	0	16
A2Jc-8	0	0	0	0	0	0	10
A2Jc-9	0	0	0	1	0	0	16
A2Jc-12	0	0	0	0	0	0	9
ANc-2	0	0	0	0	0	0	9
ANc-3	0	0	0	0	0	0	13
ANc-4	0	0	0	0	0	0	3
ANc-5	0	0	0	0	0	0	10
ANc-7	0	0	0	0	0	0	6
ANc-8	0	0	0	0	0	0	7
ANc-9	0	0	0	0	0	0	10
ANc-11	0	0	0	0	0	0	7
ANc-12	0	0	0	0	0	0	7
ANc-13	0	0	0	0	0	0	8
ASc-1	0	0	0	0	0	0	6
ASc-2	0	0	0	0	0	0	11
ASc-4	0	0	0	0	0	0	16
ASc-5	0	0	0	0	0	0	5
ASc-7	0	0	0	0	0	0	11
ASc-9	0	0	0	0	0	0	25
ASc-11	0	0	0	0	0	0	7
ASc-12	2	0	0	0	0	0	16
ASc-14	0	0	0	0	0	0	7
ASc-15	0	0	0	0	0	0	11
B1Ac-1	0	0	0	0	0	0	3
B1Ac-2	0	0	0	0	0	0	2
B1Ac-3	0	0	0	0	0	0	5
B1Ac-4	0	0	0	0	0	0	2
B1Ac-5	0	0	0	0	0	0	6
B1Ac-6	0	0	0	0	0	0	3
B1Ac-7	0	0	0	0	1	0	11
B1Ac-8	0	0	0	0	0	0	10
B1Ac-13	0	0	0	0	0	0	7
B1Ac-14	0	0	0	0	0	0	7
B1Bt-1	0	0	0	0	0	0	20
B1Bt-2	0	0	0	0	0	0	11
B1Bt-3	0	0	0	0	0	0	12
B1Bt-4	0	0	0	0	0	0	14
B1Bt-6	1	0	0	0	0	0	19
B1Bt-7	0	0	0	0	0	0	19
B1Bt-8	0	0	0	0	1	0	12
B1Bt-9	0	0	0	0	0	0	3
B1Bt-10	1	0	0	0	0	0	16
B1Bt-11	0	0	0	0	0	0	7
B1Ct-3	0	0	0	0	0	0	6
B1Ct-4	0	0	0	0	0	0	8
B1Ct-5	0	0	0	0	0	0	12
B1Ct-6	0	0	0	0	1	0	15
B1Ct-7	0	0	0	0	0	0	19
B1Ct-8	1	0	0	0	0	0	16

Appendix 1 cont.

Year	Area	Treatment	sample number	Mollusc Bivalve juv	Arcid	Corbulid	Crassatellid	Cuspidariid	Diplodontid	Lucinid	Mactrid	Mesodesmatid	Pandorid
Nov-99	Inshore	Treatment	B1Ct-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-12	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-3	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-3	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-6	0	1	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-7	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B2Ft-8	1	0	0	0	0	0	2	0	0	0
Nov-99	Inshore	Treatment	B2Ft-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-3	0	0	0	0	0	0	2	0	0	0
Nov-99	Inshore	Treatment	B2Gt-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-6	0	0	0	0	0	0	0	1	0	0
Nov-99	Inshore	Treatment	B2Gt-9	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B2Gt-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-11	0	0	0	0	0	0	0	3	0	0
Nov-99	Inshore	Treatment	B2Gt-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-1	2	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-2	0	0	0	0	0	0	0	1	0	0
Nov-99	Inshore	Control	B2Hc-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-4	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Control	B2Hc-6	0	0	0	0	0	1	1	0	0	0
Nov-99	Inshore	Control	B2Hc-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-10	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-11	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-12	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Solecurtid	Bivalve cont. Tellinid	Venerid	Total Bivalve	Gastropod Acteocinid	Columbellid	Nassariid	Naticid	Olivid	Terebrid	Total Gastropod	Opistobranch Haminoeid	Scaphopod	Total Mollusc
B1Ct-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-10	0	0	0	0	0	0	0	0	1	0	1	0	0	1
B1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-12	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-3	0	0	0	1	0	0	0	0	1	0	1	0	0	2
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	1	0	1	0	0	1
B1Dc-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	1	0	0	1	0	0	1
B2Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	1	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Ft-6	1	0	0	2	0	0	0	0	0	0	0	0	0	2
B2Ft-7	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Ft-8	0	0	0	3	0	0	0	0	0	0	0	0	0	3
B2Ft-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-2	0	0	1	1	0	0	0	0	0	0	0	0	0	1
B2Gt-3	0	0	0	2	0	0	0	0	0	0	0	0	0	2
B2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-5	0	0	0	0	0	0	0	1	0	0	1	0	0	1
B2Gt-6	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Gt-9	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Gt-10	0	0	0	0	0	1	0	0	0	0	1	0	0	1
B2Gt-11	0	0	0	3	0	0	0	0	0	0	0	0	0	3
B2Gt-12	0	0	0	0	0	0	0	0	0	0	0	1	0	1
B2Hc-1	0	0	0	2	0	0	0	0	0	0	0	0	0	2
B2Hc-2	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Hc-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-4	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Hc-6	0	0	0	2	0	0	0	0	0	0	0	0	0	2
B2Hc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-10	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Hc-11	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Amphipod unident.	Amphipod cont. Ampeliscid	Aorid	Caprellid	Corophiid	Gammarid	Haustoriid	Liljeborgiid	Melitid	Oedicerotid	Phoxocephalid	Stenothoid
B1Ct-9	0	0	0	0	0	0	0	0	0	1	0	0
B1Ct-10	0	0	0	0	0	1	1	0	0	0	0	0
B1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-12	0	0	0	0	0	0	0	0	0	1	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	1	0	0	0	0	0	0	0	0	1	0	0
B1Dc-3	0	0	0	0	0	0	0	1	0	0	1	0
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	0	0	0	0	0	2	0	0	0	1	0	0
B2Ec-10	0	0	0	0	0	0	2	0	0	2	0	0
B2Ec-11	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-12	0	0	0	0	0	0	1	0	0	0	0	0
B2Ec-13	0	0	1	0	0	0	0	0	0	1	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	0	0	0	0	0	0	0	1	0	0	0	0
B2Ft-6	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-7	0	0	0	0	0	0	2	0	0	0	0	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-9	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	0	0	0	0	0	0	0	0	0	1	0	0
B2Gt-1	0	0	0	0	0	1	0	0	0	0	0	0
B2Gt-2	0	0	1	0	0	0	0	0	0	0	0	0
B2Gt-3	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-5	0	0	0	0	0	0	1	0	0	0	0	0
B2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-9	0	0	0	0	0	0	1	0	0	0	0	0
B2Gt-10	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-11	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-3	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-6	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-7	0	0	0	0	0	0	1	3	1	2	0	0
B2Hc-8	0	0	0	0	0	0	0	0	0	1	0	0
B2Hc-10	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-11	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Total Amphipod	Copepoda	Cumacean	Decapod unident.	Pagurid	Penaeid	Pinnotherid	Sergestid	Xanthid	Isopod Idoteid	Sphaeromatid	Mysid	Ostracod	Tanaid
B1Ct-9	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-10	2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-11	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Ct-12	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	1	0	1	0	0	0	0	0	0	0
B1Dc-2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-3	2	0	0	0	0	0	2	0	1	0	0	0	0	0
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	3	0	0	0	0	0	0	0	1	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	1	0	0	0
B1Dc-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-12	0	0	0	0	1	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	3	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-10	4	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ec-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-12	1	0	1	0	0	0	0	0	0	0	0	1	0	0
B2Ec-13	2	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	1	0	0	0	0	0	1	0	0	0	0	0	0	0
B2Ft-6	0	0	0	1	0	1	0	0	0	1	0	0	0	0
B2Ft-7	2	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-9	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
B2Gt-2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-9	1	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Gt-10	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B2Gt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-7	7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Total	Annelid Polychaete unident.	Polychaete cont. Acrocirrid	Ampharetid	Aphroditid	Arabellid	Capitellid	Cerratulid	Chaetopteridae	Dorvilleid	Eunicid	Glycerid	Goniadid
B1Ct-9	1	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-10	2	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-11	1	0	0	0	0	0	3	0	0	0	0	0	0
B1Ct-12	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	2	0	0	0	0	0	0	0	0	0	0	0	1
B1Dc-2	2	0	0	0	0	0	0	0	0	0	0	1	0
B1Dc-3	5	0	0	0	0	0	1	0	0	0	0	0	0
B1Dc-4	0	0	0	0	0	0	1	0	0	0	0	0	1
B1Dc-5	4	0	0	0	0	0	0	0	0	0	0	0	3
B1Dc-8	0	0	0	0	0	0	5	0	0	0	0	0	2
B1Dc-9	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Dc-12	1	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	2	0	0	0	0	0	0
B2Ec-3	0	0	0	0	0	0	0	0	0	0	0	1	1
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	3	0	0	0	1	0	2	0	0	0	0	0	1
B2Ec-10	5	0	0	0	0	0	0	0	0	0	0	0	1
B2Ec-11	0	0	0	0	0	0	3	0	0	0	0	0	1
B2Ec-12	3	0	0	0	0	0	2	0	0	0	0	0	0
B2Ec-13	2	0	0	0	0	0	0	0	0	0	0	0	1
B2Ft-1	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	3	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0	3
B2Ft-4	2	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-6	3	0	0	0	0	0	0	0	0	0	0	0	1
B2Ft-7	3	0	0	0	0	0	1	0	0	0	0	0	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0	1
B2Ft-9	1	0	0	0	0	0	0	0	0	0	0	0	2
B2Ft-10	0	0	0	0	0	0	2	0	0	0	0	2	2
B2Ft-13	1	0	0	0	0	0	1	0	0	0	0	0	0
B2Gt-1	2	0	0	0	0	0	0	0	0	0	0	2	0
B2Gt-2	1	0	0	0	0	0	1	0	0	0	0	0	1
B2Gt-3	0	0	0	0	0	0	0	0	1	0	0	0	0
B2Gt-4	0	0	0	0	0	0	0	0	0	0	0	1	0
B2Gt-5	1	0	0	0	0	0	0	0	0	0	1	0	1
B2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0	1
B2Gt-9	2	0	0	0	0	0	3	0	0	0	0	0	1
B2Gt-10	1	0	0	0	0	0	0	0	0	0	1	0	0
B2Gt-11	0	0	0	0	0	0	2	0	0	0	0	0	0
B2Gt-12	1	0	0	0	0	0	0	0	0	0	0	0	1
B2Hc-1	0	0	0	0	0	0	4	0	0	0	0	0	1
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0	1
B2Hc-3	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Hc-6	0	0	0	0	0	0	3	0	0	0	0	0	6
B2Hc-7	7	0	0	0	0	0	0	0	0	0	0	0	1
B2Hc-8	1	0	0	0	0	0	5	0	0	0	0	0	1
B2Hc-10	0	0	0	0	0	0	5	0	0	0	0	3	0
B2Hc-11	0	0	0	0	0	0	4	0	0	0	0	0	1
B2Hc-12	0	0	0	0	0	0	2	0	0	0	0	0	0

Appendix 1 cont.

sample number	Hesionid	Lumbrinerid	Magelonid	Maldanid	Nephtyid	Nereid	Onuphid	Opheliid	Orbiniid	Oweniid	Paraonid	Pectinarid	Phyllodocid	Pilargid
	Polychaete cont.													
B1Ct-9	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Ct-10	0	0	1	0	0	0	1	0	0	0	0	0	0	0
B1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-3	0	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	0	0	1	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	2	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-10	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ec-11	0	0	0	1	0	0	1	1	1	0	0	0	0	0
B2Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-13	0	0	0	0	1	0	0	0	2	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	1	0	0	0	1	0	0	0	0	0
B2Ft-3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-6	0	0	0	0	1	0	1	0	0	0	0	0	0	0
B2Ft-7	0	0	0	0	0	0	1	0	0	0	0	0	1	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	1	0	0	0	0	0	0	1	0	0	0	0
B2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-3	0	0	1	0	0	0	0	0	0	0	0	1	0	0
B2Gt-4	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Gt-5	0	0	2	0	0	0	0	0	0	0	0	0	0	0
B2Gt-6	0	0	2	0	0	0	0	0	0	0	0	0	0	0
B2Gt-9	0	0	2	0	1	0	0	0	0	0	0	0	0	0
B2Gt-10	0	0	4	0	0	0	0	0	1	0	0	0	0	0
B2Gt-11	0	0	3	0	0	0	0	0	0	0	0	0	0	0
B2Gt-12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Hc-3	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B2Hc-7	0	0	3	0	1	0	0	0	0	0	0	0	0	0
B2Hc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-10	0	0	4	0	0	0	0	0	0	0	0	0	1	0
B2Hc-11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Pisionid	Polydontid	Polychaete cont. Spionid	Syllid	Terebellid	Polychaetae Total	Oligochaete	Aschelminthes Nematode	Nemertean	Platyhelminthes Polycladid	Echinoderm Echiniodea Mellitid
B1Ct-9	0	0	1	0	0	3	0	0	0	0	0
B1Ct-10	0	0	5	0	0	8	0	0	1	0	0
B1Ct-11	0	0	11	0	0	14	0	1	1	0	0
B1Ct-12	0	0	6	0	0	6	0	0	0	0	0
B1Dc-1	0	0	0	0	0	1	0	0	0	0	0
B1Dc-2	0	0	2	0	0	3	0	0	0	0	0
B1Dc-3	0	0	2	0	0	4	0	1	2	1	0
B1Dc-4	0	0	0	0	0	2	0	0	0	0	0
B1Dc-5	0	0	0	0	0	4	0	0	0	0	0
B1Dc-8	0	0	1	0	0	8	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	1	0	0	3	0	0	1	0	0
B1Dc-11	0	0	1	0	0	3	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	1	0	0	4	0	0	0	0	0
B2Ec-3	0	0	1	0	0	3	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	4	0	0	6	0	0	0	0	0
B2Ec-8	0	0	1	0	0	1	0	0	0	0	0
B2Ec-9	0	0	6	0	0	10	0	0	0	0	0
B2Ec-10	0	0	3	0	0	5	0	0	3	0	0
B2Ec-11	0	0	2	0	0	10	0	0	0	0	0
B2Ec-12	0	0	0	0	0	2	0	0	0	0	0
B2Ec-13	0	0	3	0	0	7	0	0	0	0	0
B2Ft-1	0	0	0	0	0	1	0	0	0	0	0
B2Ft-2	0	0	1	0	0	6	0	0	0	0	0
B2Ft-3	0	0	0	0	0	4	0	0	0	0	0
B2Ft-4	0	0	1	0	0	1	0	0	0	0	0
B2Ft-6	0	0	0	0	0	3	0	0	0	0	0
B2Ft-7	0	0	0	0	0	3	0	0	0	0	0
B2Ft-8	0	0	1	0	0	2	0	0	0	0	0
B2Ft-9	0	0	0	0	0	2	0	0	0	0	0
B2Ft-10	0	0	1	0	0	7	0	0	0	0	0
B2Ft-13	0	0	0	0	0	1	0	0	0	0	0
B2Gt-1	0	0	1	0	0	5	0	0	2	0	0
B2Gt-2	0	0	0	0	0	2	0	1	1	0	0
B2Gt-3	0	0	0	0	0	3	0	0	0	1	0
B2Gt-4	0	0	0	0	0	2	0	0	0	0	0
B2Gt-5	0	0	1	0	0	5	0	0	0	0	0
B2Gt-6	0	0	0	0	0	3	0	0	0	0	0
B2Gt-9	0	0	2	0	0	9	0	1	0	0	0
B2Gt-10	0	0	3	0	0	9	0	0	0	0	0
B2Gt-11	0	0	3	0	0	8	0	0	0	0	0
B2Gt-12	0	0	1	0	0	3	0	0	3	1	0
B2Hc-1	0	0	3	0	0	8	0	0	0	0	0
B2Hc-2	0	0	0	1	0	3	0	0	1	0	0
B2Hc-3	0	0	0	0	0	2	0	0	2	0	0
B2Hc-4	0	0	0	0	0	1	0	0	1	0	0
B2Hc-6	0	0	1	0	0	11	0	0	0	0	0
B2Hc-7	0	0	2	0	0	7	0	0	0	0	0
B2Hc-8	0	0	1	0	0	7	0	0	1	0	0
B2Hc-10	0	0	2	0	0	15	0	0	1	0	0
B2Hc-11	0	0	0	0	0	6	0	0	1	0	0
B2Hc-12	0	0	1	0	0	3	0	0	0	0	0

Appendix I cont.

sample number	Schizasterid	Ophiuroid Amphiurid	unident.	Holothuroid Cucumariid	Synaptid	Echinoderm Total	Cnidaria Actiniaria Edwardsiid	Halacarid	unident.	Hydroid	Kamptozoa (colonial)	Sipuncula Golfingiid	Sipuncula
B1Ct-9	0	0	0	0	0	0	2	0	0	0	0	0	0
B1Ct-10	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-11	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-11	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-13	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-9	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-4	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-6	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Gt-9	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-11	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-12	0	0	0	0	0	0	0	0	0	1	0	1	1
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-6	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Hc-7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-8	0	0	0	0	0	0	0	0	0	0	0	0	1
B2Hc-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-11	0	0	0	0	0	0	0	1	0	0	0	0	0
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Echiurida	Phoronida	Bryozoa Ectoproct Bugulid	Tunicate	Chaetognath	Amphioxus	TOTAL
B1Ct-9	0	0	0	0	0	0	6
B1Ct-10	0	0	0	0	0	0	13
B1Ct-11	0	0	0	0	1	0	19
B1Ct-12	0	0	0	0	1	0	9
B1Dc-1	0	0	0	0	0	0	3
B1Dc-2	0	0	0	0	0	0	5
B1Dc-3	0	0	0	0	0	0	15
B1Dc-4	0	0	0	0	0	0	2
B1Dc-5	0	0	0	0	0	0	8
B1Dc-8	0	0	0	0	0	0	8
B1Dc-9	0	0	0	0	0	0	2
B1Dc-10	0	0	0	0	0	0	4
B1Dc-11	0	0	0	0	0	0	3
B1Dc-12	0	0	0	0	0	0	1
B2Ec-2	1	0	0	0	0	0	5
B2Ec-3	0	0	0	0	0	0	5
B2Ec-6	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	6
B2Ec-8	0	0	0	0	0	0	2
B2Ec-9	0	0	0	0	0	0	13
B2Ec-10	0	1	0	0	0	0	14
B2Ec-11	0	0	0	0	0	0	10
B2Ec-12	0	0	0	0	0	0	5
B2Ec-13	0	0	0	0	0	0	9
B2Ft-1	0	0	0	0	0	0	1
B2Ft-2	0	0	0	0	0	0	7
B2Ft-3	0	0	0	0	0	0	4
B2Ft-4	0	0	0	0	0	0	4
B2Ft-6	0	0	0	0	0	0	8
B2Ft-7	0	0	0	0	0	0	7
B2Ft-8	0	0	0	0	0	0	5
B2Ft-9	0	0	0	0	0	0	3
B2Ft-10	0	0	0	0	0	0	7
B2Ft-13	0	0	0	0	0	0	2
B2Gt-1	0	0	0	0	0	0	9
B2Gt-2	0	0	0	0	0	0	6
B2Gt-3	0	0	0	0	0	0	6
B2Gt-4	0	0	0	0	0	0	3
B2Gt-5	0	0	0	0	0	0	7
B2Gt-6	0	0	0	0	0	0	5
B2Gt-9	0	0	0	0	0	0	13
B2Gt-10	0	0	0	0	0	0	11
B2Gt-11	0	0	0	0	0	0	11
B2Gt-12	0	0	0	0	0	0	12
B2Hc-1	0	0	0	0	0	0	10
B2Hc-2	0	0	0	0	0	0	5
B2Hc-3	0	0	0	0	0	0	4
B2Hc-4	0	0	0	0	0	0	3
B2Hc-6	0	0	0	0	0	0	14
B2Hc-7	0	0	0	0	0	0	14
B2Hc-8	0	0	0	0	0	0	10
B2Hc-10	0	0	0	0	0	0	17
B2Hc-11	0	0	0	0	0	0	9
B2Hc-12	0	0	0	0	0	0	3

Appendix 2. Number of individuals by taxonomic family captured in a $10m^2$ tow of a benthic sled at sites in (Treatment) and adjacent (Control) to inshore and offshore proposed sand borrow areas for the Bogue Banks beach renourishment. Two tows were taken from each of 6 sites sampled both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

				Mollusc Bivalve							Gastropod						Crustacea Decapod		
Year	Area	Treatment	sample number	Cardiid	Corbulid	Diplodontid	Lucinid	Mactrid	Tellinid	Venerid	Cerithid	Columbellid	Naticid	Olivid	Terebrid	scaphopod	Callanassid	Pagurid	Penaeid
Nov-99	Offshore	Control	A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Nov-99	Offshore	Treatment	A1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nov-99	Offshore	Treatment	A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nov-99	Offshore	Control	A1Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Nov-99	Offshore	Control	A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Nov-99	Offshore	Treatment	A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Nov-99	Offshore	Treatment	A2It-1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Offshore	Treatment	A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Offshore	Control	A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ASc-1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Offshore	Control	ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0
Nov-99	Inshore	Control	B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-2	0	0	0	0	0	0	0	0	0	0	0	10	0	0	1	0
Nov-99	Inshore	Control	B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-2	0	0	0	0	1	0	1	0	0	0	0	1	0	0	2	0
Nov-99	Inshore	Control	B2Ec-1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Inshore	Control	B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nov-99	Inshore	Treatment	B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0
Nov-99	Inshore	Treatment	B2Gt-2	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
Nov-99	Inshore	Control	B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nov-99	Inshore	Control	B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

Appendix 2 cont.

sample number	Pinnotherid	Sergestid	Calappid	Hippolythid	Portunid	Xanthid	Annelid Polychaete Chaetopteridae	Cossurid	Glycerid	Goniadid	Hesionid	Maldanid	Nephtyid	Nereid	Onuphid	Pilargid	Sabellariid	Terebellid
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-2	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
A1Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
ASc-1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
B2Gt-2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2 cont.

sample number	Echinoderm Echiniodea Arbaciid	Mellitid	Schizasterid	Ophiuroid Amphiurid	Ophiothricid	unident.	Holothuroid Cucumariid	Synaptid	Stelleroidea Astropectinid	Cnidaria Actiniaria Edwardsiid	Halaclavid	Anthozoa Renillid	Sipuncula Golfingiid	Bryozoa Ectoproct Bugulid
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	6	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3. Numbers of individuals of species captured 12.3m^{-1} otter trawl towed for 20 minutes at a speed of 1.1 ms^{-1} (2.5mph) and covering an estimated 0.016 km^2 at estimated 0.016 km^2 at sites within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 29 November 1999, 4 February 2000, and 11 May 2000.

				Atlantic croaker	Atlantic cutlassfish	Atlantic menhaden	Atlantic silverside	Atlantic stingray	Atlantic thread herring	banded drum	black drum	black sea bass	blackcheek tonguefish
Date	Area	Treatment	Trawl	*Micropogonias undulatus*	*Trichiurus lepturus*	*Brevoortia tyrannus*	*Menidia menidia*	*Dasyatis sabina*	*Opisthonema oglinum*	*Larimus fasciatus*	*Pogonias cromis*	*Centropristis striata*	*Symphurus plagiusa*
29-Nov-99	Offshore	Control	A1c	27	0	0	66	0	0	0	0	0	0
29-Nov-99	Offshore	Control	A2c	30	0	0	12	0	0	0	0	0	0
29-Nov-99	Offshore	Treatment	A1t	86	0	0	36	0	0	0	0	0	0
29-Nov-99	Offshore	Treatment	A2t	10	0	0	11	0	0	0	0	0	0
29-Nov-99	Inshore	Control	B1c	340	18	3	112	1	0	0	0	0	10
29-Nov-99	Inshore	Control	B2c	4	13	0	56	0	84	0	0	0	0
29-Nov-99	Inshore	Treatment	B1t	108	16	2	81	0	0	0	0	0	0
29-Nov-99	Inshore	Treatment	B2t	9	0	0	0	0	0	0	0	0	6
4-Feb-00	Offshore	Control	A1c	0	0	0	9	0	0	0	0	0	0
4-Feb-00	Offshore	Control	A2c	0	0	0	0	0	0	0	0	0	0
4-Feb-00	Offshore	Treatment	A1t	0	0	0	32	0	0	0	0	0	0
4-Feb-00	Offshore	Treatment	A2t	0	0	0	1	0	0	0	0	0	0
4-Feb-00	Inshore	Control	B1c	1	0	113	86	0	0	0	1	0	3
4-Feb-00	Inshore	Control	B2c	0	0	3	0	0	0	0	0	0	1
4-Feb-00	Inshore	Treatment	B1t	0	0	34	98	0	1	0	0	0	4
4-Feb-00	Inshore	Treatment	B2t	0	0	60	14	0	0	0	0	0	0
11-May-00	Offshore	Control	A1c	0	0	0	0	0	4	0	0	0	4
11-May-00	Offshore	Control	A2c	4	0	0	0	0	0	0	0	4	0
11-May-00	Offshore	Treatment	A1t	0	0	0	0	0	0	0	0	0	0
11-May-00	Offshore	Treatment	A2t	0	0	0	0	0	0	0	0	0	0
11-May-00	Inshore	Control	B1c	0	4	4	1668	0	460	0	0	0	32
11-May-00	Inshore	Control	B2c	0	20	0	1176	0	108	0	0	0	0
11-May-00	Inshore	Treatment	B1t	0	0	0	520	0	428	8	0	0	8
11-May-00	Inshore	Treatment	B2t	0	0	0	592	0	1068	0	0	0	0

Appendix 3 cont.

Date	Trawl	blackwing searobbin *Prionotus rubio*	bluefish *Pomatomus saltatrix*	brown shrimp *Farfantepenaeus aztecus*	butterfish *Peprilus triacanthus*	clearnose skate *Raja ocellata*	cownose ray *Rhinoptera bonasus*	fringed flounder *Etropus crossotus*	gray trout (weakfish) *Cynoscion regalis*	harvestfish *Peprilus alepidotus*	inshore lizardfish *Synodus foetens*	longfin squid *Loligo pealeii*	lookdown *Selene vomer*
29-Nov-99	A1c	0	4	0	2	0	0	0	0	0	0	0	0
29-Nov-99	A2c	0	0	0	48	0	0	3	0	0	0	0	0
29-Nov-99	A1t	0	0	0	2	0	0	0	3	0	0	0	0
29-Nov-99	A2t	0	0	0	0	0	0	0	0	0	2	0	0
29-Nov-99	B1c	1	2	4	1	14	0	0	7	0	0	0	2
29-Nov-99	B2c	0	4	0	0	6	0	0	0	0	0	0	8
29-Nov-99	B1t	0	3	0	2	0	0	0	4	0	0	0	5
29-Nov-99	B2t	0	0	0	7	0	0	0	24	0	0	0	7
4-Feb-00	A1c	0	0	0	0	1	0	0	0	0	0	0	0
4-Feb-00	A2c	0	0	0	1	2	0	0	0	0	0	0	0
4-Feb-00	A1t	0	0	0	0	1	0	0	1	0	0	0	0
4-Feb-00	A2t	0	0	0	0	0	0	0	0	0	0	1	0
4-Feb-00	B1c	3	0	0	0	0	0	1	2	0	0	0	0
4-Feb-00	B2c	0	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B1t	0	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B2t	0	0	0	0	0	0	0	0	0	0	0	0
11-May-00	A1c	8	0	0	0	0	0	0	0	0	0	0	0
11-May-00	A2c	8	4	0	0	0	4	0	0	0	48	0	0
11-May-00	A1t	0	0	0	0	0	0	0	0	0	0	0	0
11-May-00	A2t	0	0	0	0	0	0	0	0	0	0	0	0
11-May-00	B1c	924	4	0	32	48	0	0	0	0	0	0	0
11-May-00	B2c	4	4	0	8	0	0	0	0	20	0	0	0
11-May-00	B1t	712	8	0	0	20	0	16	0	0	0	0	0
11-May-00	B2t	4	12	0	8	0	0	0	0	112	0	0	0

Appendix 3 cont.

Date	Trawl	mantis shrimp *Squilla empusa*	northern kingfish *Menticirrhus saxatilis*	northern puffer *Sphoeroides maculatus*	ocellated flounder *Ancylopsetta quadrocellata*	pigfish *Orthopristis chrysoptera*	pinfish *Lagodon rhomboides*	planehead filefish *Monacanthus hispidus*	portunid crab *Portunus gibbesii*	round herring *Etrumeus teres*	sand seatrout *Cynoscion arenarius*
29-Nov-99	A1c	0	17	0	0	48	284	0	0	0	0
29-Nov-99	A2c	0	0	0	0	7	94	0	0	0	0
29-Nov-99	A1t	0	0	0	0	15	13	0	0	0	0
29-Nov-99	A2t	0	0	0	0	70	124	0	0	0	0
29-Nov-99	B1c	0	30	1	0	3	52	0	0	0	0
29-Nov-99	B2c	0	0	0	0	0	0	0	0	0	0
29-Nov-99	B1t	0	33	0	0	7	65	0	0	0	0
29-Nov-99	B2t	0	9	0	0	11	4	0	0	0	0
4-Feb-00	A1c	0	0	0	0	0	2	0	0	0	0
4-Feb-00	A2c	0	0	0	0	0	16	0	0	0	1
4-Feb-00	A1t	0	0	0	0	0	5	0	0	0	0
4-Feb-00	A2t	0	0	0	0	0	2	0	0	0	0
4-Feb-00	B1c	0	1	0	1	0	30	0	0	0	0
4-Feb-00	B2c	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B1t	0	2	0	1	0	56	0	0	0	0
4-Feb-00	B2t	0	0	0	0	0	21	0	0	0	0
11-May-00	A1c	0	0	0	0	0	0	0	12	0	0
11-May-00	A2c	0	0	0	0	72	788	0	0	0	0
11-May-00	A1t	0	0	0	0	0	0	0	12	0	0
11-May-00	A2t	0	0	0	0	0	0	0	4	0	0
11-May-00	B1c	4	40	4	8	0	36	4	56	0	0
11-May-00	B2c	0	0	0	4	0	0	0	4	0	0
11-May-00	B1t	0	24	4	24	72	0	0	0	0	0
11-May-00	B2t	0	0	0	0	4	0	0	20	4	0

Appendix 3 cont.

Date	Trawl	scup *Stenotomus chrysops*	sheepshead *Archosargus probatocephalus*	silver perch *Bairdiella chrysoura*	silver seatrout *Cynoscion nothus*	smooth butterfly ray *Gymnura altavela*	smooth dogfish *Mustelus canis*	southern flounder *Paralichthys lethostigma*	spadefish *Chaetodipterus faber*	speckled crab *Arenaeus cribrarius*	spider crab *Libinia dubia*	spiny box fish *Lactophrys trigonus*
29-Nov-99	A1c	0	0	0	0	0	0	0	0	0	0	0
29-Nov-99	A2c	0	0	0	0	0	0	0	0	0	0	0
29-Nov-99	A1t	0	0	2	0	0	0	0	0	0	0	0
29-Nov-99	A2t	0	0	0	0	0	0	0	0	0	0	0
29-Nov-99	B1c	0	0	100	0	0	0	0	0	0	0	0
29-Nov-99	B2c	0	0	12	0	0	0	0	0	0	0	3
29-Nov-99	B1t	0	0	57	0	0	0	0	0	0	0	0
29-Nov-99	B2t	0	0	37	0	0	0	0	0	0	0	1
4-Feb-00	A1c	0	0	0	0	0	0	1	0	0	0	0
4-Feb-00	A2c	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	A1t	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	A2t	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B1c	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B2c	0	0	0	0	0	0	10	0	5	0	0
4-Feb-00	B1t	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B2t	0	0	0	0	0	0	0	0	0	0	0
11-May-00	A1c	0	0	0	0	0	0	6	0	0	0	0
11-May-00	A2c	288	4	0	0	0	0	0	0	0	4	0
11-May-00	A1t	0	0	0	0	0	0	0	0	0	0	0
11-May-00	A2t	0	0	0	0	0	0	0	0	0	0	0
11-May-00	B1c	0	0	0	104	4	4	4	0	0	0	0
11-May-00	B2c	0	0	0	0	0	0	0	0	0	0	0
11-May-00	B1t	0	0	0	40	12	0	0	8	0	0	0
11-May-00	B2t	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 cont.

		spot	spotted hake	spotted whiff	striped burrfish	striped cusk-eel	summer flounder	white shrimp	windowpane
Date	Trawl	*Leiostomus xanthurus*	*Urophycis regia*	*Citharichthys macropos*	*Chilomycterus schoepfi*	*Ophidion marginatum*	*Paralichthys dentatus*	*Litopenaeus setiferus*	*Scopthalmus aquosus*
29-Nov-99	A1c	367	-0	0	0	0	0	0	0
29-Nov-99	A2c	213	0	0	0	0	0	0	0
29-Nov-99	A1t	240	0	0	0	0	0	0	0
29-Nov-99	A2t	364	0	0	0	0	0	0	0
29-Nov-99	B1c	25	0	0	0	1	0	5	0
29-Nov-99	B2c	1	0	0	0	0	0	0	0
29-Nov-99	B1t	10	0	0	0	1	0	0	0
29-Nov-99	B2t	27	0	0	0	0	0	0	0
4-Feb-00	A1c	0	0	1	0	0	0	0	0
4-Feb-00	A2c	0	1	1	0	1	0	0	0
4-Feb-00	A1t	0	1	0	0	0	0	0	0
4-Feb-00	A2t	0	0	1	0	0	0	0	0
4-Feb-00	B1c	8	8	0	0	0	0	2	0
4-Feb-00	B2c	0	0	0	0	0	0	0	0
4-Feb-00	B1t	5	12	0	0	0	0	0	0
4-Feb-00	B2t	1	10	0	0	0	0	0	0
11-May-00	A1c	0	0	0	0	0	0	0	0
11-May-00	A2c	8	0	0	0	0	0	0	0
11-May-00	A1t	0	0	0	0	0	0	0	0
11-May-00	A2t	0	0	0	0	0	0	0	0
11-May-00	B1c	52	116	0	0	0	4	0	80
11-May-00	B2c	32	4	0	4	0	0	0	0
11-May-00	B1t	20	60	0	0	0	0	0	136
11-May-00	B2t	4	4	0	0	0	0	0	0

APPENDIX D

APPENDIX D
BIOLOGICAL ASSESSMENT

BOGUE BANKS BEACH NOURISHMENT PROJECT
CARTERET COUNTY, NORTH CAROLINA

February 2000

1.00 INTRODUCTION

Bogue Banks is a barrier island with a southward facing ocean shoreline stretching some 26 miles between two large tidal inlets, Bogue Inlet to the west and Beaufort Inlet to the east. The Banks are surrounded by Bogue Sound on the north and Onslow Bay of the Atlantic Ocean on the south. Bogue Banks is an important resource to Carteret County, both economically and ecologically. From an economic perspective, the need for the proposed Bogue Banks beach nourishment project is to protect the largest portion of the county's overall economy; tourism. Environmentally, beaches, high dunes, and maritime forests harbor a wide range of wildlife resources. However, severe storms and associated erosion results in the increasing loss of this valuable resource. Therefore, this project proposes to nourish a large section of Bogue Banks with 4.5 million cubic yards of sand taken from borrow areas offshore. The project area includes the beaches reaching from the town limits of Pine Knoll Shores and Atlantic Beach to the western end of Emerald Isle, approximately 1 mile east of Bogue Inlet. The total project length is 16.8 miles of shoreline.

2.00 PROPOSED PROJECT

The Bogue Banks nourishment project proposes to widen the beach area from the town limits of Pine Knoll Shores and Atlantic Beach to the western end of Emerald Isle, approximately 1 mile east of Bogue Inlet. The total project length is 16.8 miles of shoreline. The sand will be supplied by dredging from one or more of four possible borrow areas and bringing this material to shore via hydraulic or hopper dredge. These proposed actions are planned to occur between November of 2000 and April of 2001.

3.00 PRIOR CONSULTATIONS

No previous Section 7 consultations exist for the proposed beach nourishment project. However, consultations have been performed for beach nourishment projects on nearby beaches such as Atlantic Beach and address similar issues as this biological assessment.

4.00 LIST OF SPECIES

Species to be considered in this biological assessment were provided by USFWS and the NMFS and are listed in the following table.

Common Name	Scientific Name	Status	Habitat present?	Known observation*
Mammals				
Eastern cougar	*Felis concolor couguar*	E	no	no
Finback whale	*Balaenoptera physalus*	E	no	no
Humpback whale	*Megaptera novaeangliae*	E	yes	yes**
Right whale	*Eubaleana glacialis*	E	yes	yes**
Sei whale	*Baleanoptera borealis*	E	no	no
Sperm whale	*Physeter catodon*	E	no	no
West Indian manatee	*Trichechus manatus*	E	yes	no
Birds				
Piping plover	*Charadrius melodus*	T	yes	no
Red-cockaded woodpecker	*Picoides borealis*	E	no	no
Roseate tern	*Sterna douglallii*	E	yes	no
Reptiles				
American alligator	*Alligator mississippiensis*	T(S/A)	no	no
Green sea turtle	*Chelonia mydas*	T	yes	yes**
Hawksbill sea turtle	*Eretmochelys imbricata*	E	yes	yes**
Kemp's ridley sea turtle	*Lepidochelys kempi*	E	ycs	yes**
Leatherback sea turtle	*Dermochelys coriacea*	E	yes	yes**
Loggerhead sea turtle	*Caretta caretta*	T	yes	yes
Fish				
Shortnose sturgeon	*Acipenser brevirostrum*	E	yes	no
Plants				
Rough-leaf loosestrife	*Lysimachia asperulaefolia*	E	no	no
Seabeach amaranth	*Amaranthus pumilus*	T	yes	yes

KEY

Status	Definition
E	A taxon "in danger of extinction throughout all or a significant portion of its range."
T	A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."
T(S/A)	Threatened due to similarity of appearance - a species that is threatened due to similarity of appearance with other rare species and is listed for its protection. These species are not biologically endangered or threatened and are not subject to Section 7 consultation.

* According to NC Natural Heritage Program data.

** Species known to migrate along the coast of NC (Wynne, 1999).

5.00 SURVEY AND ANALYSIS METHODS

Impacts to the natural environment of the project area were determined by information obtained from literature sources and consultation with informed individuals.

6.00 GENERAL EFFECTS ON LISTED SPECIES

The presence of these species in the project area depends on the availability and abundance of appropriate habitat. Since the Bogue Banks nourishment project area does not contain any freshwater or forested areas, the eastern cougar, American alligator, red-cockaded woodpecker, and roughleaf loosestrife are not likely to be found at this site and will not be affected by the proposed actions.

Listed species that could potentially be located at Bogue Banks during the proposed action are the finback whale, humpback whale, right whale, sei whale, sperm whale, West Indian manatee, piping plover, roseate tern, green sea turtle, hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, loggerhead sea turtle, and seabeach amaranth.

7.00 SPECIES ASSESSMENTS

7.01 Right Whale, Finback Whale, Humpback Whale, Sei Whale, and Sperm Whale

a. Status and Natural History of the Species in the Project Area

These whale species all occur infrequently in the ocean off the coast of North Carolina. Of these, only the right whale and the humpback whale routinely come close enough inshore to encounter the project area. Humpback whales are often found in protected waters over shallow banks and shelf waters for breeding and feeding. They migrate toward the poles in summer and toward the tropics in winter and visit the North Carolina coast during seasonal migrations, especially between December and April (Conant, 1993). They eat schooling fish such as herring and can consume up to 1.5 tons per day of krill. Right whales swim very close to the shoreline and are often noted only a few hundred meters offshore (Schmidly, 1981). They feed primarily on copepods and euphausids. While it usually winters in the waters between Georgia and Florida, the right whale can on occasion be found in the waters off North Carolina. Sighting data provided by the Right Whale Program of the New England Aquarium indicates that 93% of all North Carolina sightings between 1976 and 1992 occurred between mid-October and mid-April (Chris Slay, 1993). The number of right whales documented in the vicinity of Morehead City during a single season ranges from 2 to 25 (USACOE, 1989).

b. Effect Determination

Of the five species of whales being considered, only the right whale and humpback whale would normally be expected to occur within the project area during the construction period. While some food resources may be initially affected by either dredging activities or burial associated with the beach nourishment, most invertebrates will quickly reestablish from adjacent unaffected areas or through recruitment processes. Furthermore, the presence of a dredge in this area should pose no more of a collision threat to migrating whales than normal commercial ship traffic. However, if hopper dredges are used, ACOE and NMFS hopper dredge protocol will be followed to reduce potential impacts to whales. A whale observer with at-sea large whale identification experience will be present on the hopper dredge from the beginning of hopper dredge use through March 31 to conduct daytime observations in order to reduce the potential for accidental collision. Since habitat conditions and food supplies will be maintained in their current states and the potential for accidental collisions with dredges will be minimized, it has been determined that the proposed project is not likely to adversely affect these whale species.

7.02 West Indian Manatee

a. Status and Natural History of the Species in the Project Area

The manatee is an occasional summer resident off the North Carolina coast. The species can be found in shallow (5 feet to usually less than 20 feet), slow-moving rivers, estuaries, saltwater bays, canals, and coastal areas (USFWS, 1991). The West Indian manatee is herbivorous and eats aquatic plants such as hydrilla, eelgrass, and water lettuce (USFWS, 1999). During winter months, the United States' manatee population confines itself to the coastal waters of the southern half of peninsular Florida and to springs and warm water outfalls as far north as southeast Georgia. They are sighted frequently in southeastern North Carolina with most records occurring in July, August, and September, as they migrate up and down the coast (Clark, 1993). However, scattered records of this species in the region span all seasons. Based on these data, the manatee is considered a year-round resident with a maximum population in the late summer months. Manatee population trends are poorly understood, but deaths have increased steadily. A large percent of mortality is due to collisions with water crafts, especially of calves. Another closely related factor in their decline has been the loss of suitable habitat through incompatible coastal development, particularly destruction of sea grass beds by boating facilities.

b. Effect Determination

Since the proposed dredging work is currently scheduled to occur during the time of year when manatee populations are expected to be minimal, it is unlikely that there will be any manatees in the project area during the proposed project. Therefore, it has been determined that the dredging of the borrow areas and the subsequent beach nourishment are not likely to adversely affect the West Indian manatee.

7.03 Piping Plover

a. Status and Natural History of the Species in the Project Area

The Atlantic Coast piping plover population breeds on coastal beaches from Newfoundland to North Carolina (and occasionally in South Carolina) and winters along the Atlantic Coast from North Carolina south, along the Gulf Coast, and in the Caribbean USFWS, 1996). Since being listed as threatened in 1986, the population has increased from approximately 800 pairs to almost 1350 pairs in 1995, although most of this increase may be attributable to an increase in surveying intensity. Piping plovers nest above the high tide line on coastal beaches, sand flats at the ends of sand spits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, sparsely vegetated dunes, and washover areas cut into or between dunes (USFWS, 1996). Feeding areas include intertidal portions of ocean beaches, washover areas, mud flats, sand flats, wrack lines, and shorelines of coastal ponds, lagoons, or salt marshes. Loss and degradation of habitat due to development and shoreline stabilization have been major contributors to the species' decline.

Most piping plovers at Bogue Banks have been observed at the west end of Emerald Isle as predominantly a migratory and winter resident (D. Allen, pers. comm.). During a 1991 U.S. Fish and Wildlife Service International Piping Plover Census (winter), 4 piping plovers were observed and during a 1996 winter census, 1 individual was observed. However, both Bogue and Beaufort inlets contain intertidal flats exposed at low tide that are prime feeding and roosting habitat for a variety of shorebirds and colonial waterbirds including pelicans, cormorants, terns, and gulls. These areas may be used by piping plovers as well.

b. Effect Determination

Within Bogue Banks, only the west end of Emerald Isle has been documented to support piping plovers. This area is not located within the project boundaries and will not be affected by beach nourishment or dredging activities. However, one proposed borrow area is located within Bogue Inlet, which contains feeding and roosting habitat for a variety of colonial waterbirds and shorebirds. If this area is chosen for dredging, potential plover feeding habitat may be lost. However, there is sufficient intertidal flat habitat elsewhere in the area to compensate for this potential loss. Therefore, the proposed project will not adversely affect the piping plover.

7.04 Roseate Tern

a. Status and Natural History of the Species in the Project Area

Roseate terns breed primarily on small offshore islands, rocks, cays, and islets. Rarely do they breed on large islands. They have been reported nesting near vegetation or jagged rock, on open sandy beaches, close to the waterline on narrow ledges of emerging rocks, or among coral rubble (USFWS, 1999). This species is primarily observed south of Cape Hatteras, particularly at Cape Point within Cape Hatteras National Seashore, during the months of July and August.

b. Effect Determination

The roseate tern has never been observed within the project site. Bogue Banks is most likely too large and too developed an island to provide appropriate habitat for the roseate tern. Additionally, when the tern is observed in North Carolina, it is mostly during summer months, when the project is not scheduled to occur. Therefore, the project is not likely to affect the roseate tern.

7.05 Hawksbill, Leatherback, Kemp's Ridley, and Green Sea Turtles

a. Status and Natural History of the Species in the Project Area

In North Carolina, the green sea turtle and the Kemp's ridley sea turtle are known from estuarine and oceanic waters, whereas the hawksbill and leatherback sea turtles are normally associated solely with oceanic waters (Schwartz, 1977; Lee and Palmer, 1981). All of these species are found in North Carolina waters throughout the year and can be present in inshore waters April through December (Epperly et al., 1995).

Neither the hawksbill or leatherback sea turtle is observed in North Carolina with much frequency. Their nesting is generally restricted to Florida and these species are only occasionally observed migrating through North Carolina waters. The Kemp's ridley sea turtle is commonly observed migrating within North Carolina inshore waters during the spring and fall, but has been documented to nest only once in North Carolina. The entire population nests on approximately 15 miles of beach in Mexico between the months of April and June (USFWS, 1991). Green sea turtle nesting is primarily limited to Florida's east coast (300 to 1000 nests reported annually) but has been observed as far north as North Carolina. Although turtle crawls have been documented at Emerald Isle Beach (R. Boettcher, pers. comm.), no nests have been observed within the project site and the green sea turtle is not considered to be a regular nester within the project area. Like the Kemp ridley, greens are commonly observed migrating within North Carolina inshore waters during the spring and fall. The principal food sources for these sea turtle species are crustaceans, mollusks, other invertebrates, fish, and plant material (Schwartz, 1977).

b. Effect Determination

The hawksbill, leatherback, and Kemp's ridley sea turtles do not regularly nest along North Carolina coasts. The green sea turtle nests sporadically in North Carolina but has not been observed nesting in the project area. Therefore, beach nourishment activities will not affect any of these sea turtle species. However, all of these species migrate within North Carolina waters throughout the year, mostly between April and December.

Hydraulic or hopper dredges will be used to dredge material from borrow areas located within these migratory waters and transport it to the shore. Although the majority of construction activities is planned to occur between November and April to avoid nesting and migrating turtles, dredging activities may begin as early as October and may continue into the spring months in order to complete the project in one season. Therefore, dredging activities may occur during moderate levels of sea turtle migration.

Hopper dredges move rapidly over the bottom sediments and can injure or kill juvenile turtles lying on the sea bottom. If a hopper dredge is used, the proposed project will follow NMFS and ACOE hopper dredge protocol to reduce potential impacts to migrating sea turtles. An observer will be present on the hopper dredge, except when water temperatures are cold enough to ensure that turtles will not be present (January and February) to document any takes of turtle species and to ensure that turtle deflector dragheads are used properly. If two sea turtle takes occur within 24 hours, work will cease upon a subsequent take, and will only resume if concurred in by the ACOE. If three takes occur, a risk assessment and appropriate risk management plan will be developed and submitted to the ACOE. Should a total take of five sea turtles occur, all work will be terminated. If a total of two endangered species of sea turtles are taken during a project, work will be suspended until further guidance from the ACOE has been given. Despite these precautions, the chance of impacting migrating sea turtles with a hopper dredge still exists. Therefore, it has been determined that the proposed project may adversely affect the hawksbill, leatherback, Kemp's ridley, and green sea turtles.

7.09 Loggerhead Sea Turtle

a. Status and Natural History of the Species in the Project Area

The loggerhead turtle utilizes the Bogue Banks upper beach for its seasonal (March-October) nesting events. Off the Carolina coast these turtles commonly occur at the edge of the continental shelf when they forage around coral reefs, artificial reefs, and boat wrecks. They feed on benthic invertebrates including mollusks, crustaceans, and sponges (Morrimen, 1982). They have also been found to eat fish, clams, oysters, sponges, jellyfish, shrimp, and crabs when near shore. Research has shown that the turtle populations have greatly declined in the last 20 years due to a loss of nesting habitat along the beachfront and by incidental drowning in shrimp trawl nets. It appears that the combination of poorly placed nests coupled with unrestrained human use of the beach by auto and foot traffic has impacted this species greatly. Eroding steep beach escarpments, lights, sand fences, and other physical barriers (debris) often cause the mature females to select poor nesting sites at the dune toes which causes higher nestling mortality rates. Loggerhead turtles are known to regularly nest from Bogue Inlet to Beaufort Inlet, including the entire stretch of the project site. Between 1995 and 1999, an average of 28 nests/year were recorded within the project area (Ruth Boettcher, pers. comm.). Like the Kemp's ridley and green sea turtles, loggerheads are known to frequently use coastal waters as travel corridors (Wynne, 1999) and have been observed migrating along the North Carolina coast (Epperly et al, 1995).

b. Effect Determination

The proposed project could potentially affect loggerhead sea turtles in two ways. First, dredging activities proposed to occur offshore may occur in areas used by migrating juveniles. The act of dredging material with a hopper dredge may adversely affect juvenile turtles. If a hopper dredge is used, NMFS and ACOE hopper dredge protocol will be followed to reduce these impacts (see Hawksbill, Leatherback, Kemp's Ridley, and Green Sea Turtles' Effect Determination). Second, nourishing the beach with the fill material may affect nesting activities by altering nesting habitat. If the beach becomes too hard through the compaction of deposited nourishment sediments by construction equipment, it could present a physical barrier to turtle nest digging. Furthermore, beach nourishment may influence physical characteristics of beaches such as sand-grain size and shape, silt-clay content, sand compaction, moisture content, porosity/water retention, gas diffusion rates, and color of sand grains which could alter the temperature of the beach. These factors could reduce reproductive success of nests laid in nourished areas (Crain et al., 1995; Ackerman, 1996). To alleviate impacts to nesting sea turtles in the project area, the following steps will be taken:

1. Only beach quality sand suitable for sea turtle nesting, successful incubation, and hatchling emergence shall be used for beach nourishment on the project site. Furthermore, sand of similar grain size to the existing beach will be used to reduce any changes in physical characteristics of the beach that may affect nest survival.

2. Immediately after completion of the beach nourishment project and prior to the next three nesting seasons, beach compaction shall be monitored and tilling shall be conducted as required to reduce the likelihood of impacting sea turtle nesting and hatching activities.

3. Immediately after completion of this project and prior to the next three nesting seasons, monitoring shall be conducted to determine if escarpments are present and escarpments shall be leveled as required to reduce the likelihood of impacting sea turtle nesting and hatching activities.

4. Carteret County will ensure that contractors doing the beach nourishment and dredging work fully understand sea turtle protection measures.

5. Beach nourishment and dredging activities are planned to begin after November 1 and be completed before May 1. If any filling occurs before March 1, the pipeline will be placed along the landward edge of the berm.

6. If any beach nourishment or dredging activities take place during the period from March 1 through November 15, a standardized nest monitoring and relocation plan will be implemented in addition to the monitoring that already occurs. The plan incorporates monitoring of the beach disposal area each morning from the beginning of the nesting season until all equipment is removed from the beach and the relocation of any nests laid within the project area. Using standard nest relocation

techniques, all nests will be located to a suitable nursery beach, agreed to prior to the start of relocation effort by the U.S. Fish and Wildlife Service and the North Carolina Wildlife Resources Commission. Hatching success of relocated nests will be monitored and reported.

7. Immediately after completion of this project and prior to March 1 for three subsequent years, sand compaction will be monitored in the area of restoration in accordance with a protocol agreed to by the Service, the State regulatory agency, and Carteret County. At a minimum, the protocol provided under 7a and 7b below will be followed. If required, the area will be tilled to a depth of 36 inches. All tilling activity must be completed prior to March 1. A report on the results of compaction monitoring will be submitted to the Service prior to any tilling actions being taken. An annual summary of compaction surveys and the actions taken will be submitted to the Service. This condition will be evaluated annually and may be modified if necessary to address sand compaction problems identified during the previous year.

   7a. Compaction sampling stations shall be located at 500-foot intervals along the project area. One station will be at the seaward edge of the dune/berm line (when material is place in this area); one station will be midway between the dune line and the high water line; and one station will be located just landward of the high water line. At each station, the cone penetrometer shall be pushed to a depth of 6, 12, and 18 inches three times (three replicates). Material may be removed from the hole if necessary to ensure accurate readings of successive levels of sediment. Replicates will be located as close to each other as possible, without interacting with the previous hole and/or disturbed sediments. The three replicate compaction values for each depth will be averaged to produce final values for each depth at each station. Reports will include all 27 values for each transect line, and the final 9 averaged compaction values.

   7b. If the average value for any depth exceeds 500 psi for any two or more adjacent stations, then that area will be tilled prior to March 1 of the following year. If values exceeding 500 psi are distributed throughout the project area but in no case do those values exist at two adjacent stations at the same depth, then consultation with the Fish and Wildlife Service will be sought to determine if tilling is required. If a few values exceeding 500 psi are present randomly within the project area, tilling will not occur.

8. Visual surveys for escarpments along the project area shall be made immediately after completion of the beach nourishment project and prior to March 1 for three subsequent years. Results of the surveys will be submitted to the Service prior to any action being taken. Escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet will be leveled to the natural beach contour by March 1. The Service will be contacted immediately if subsequent reformation of escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet occurs during the nesting and hatching season to determine the appropriate action to be taken. If it is determined that

escarpment leveling is required during the nesting or hatching season, the Service will provide a brief written authorization that describes methods to be used to reduce the likelihood of impacting existing nests. An annual summary of escarpment surveys and actions taken will be submitted to the Service.

9. From March 1 through April 30 and November 1 through November 15, staging areas for construction equipment will be located off the beach to the maximum extent practicable. Nighttime storage of construction equipment not in use will be off the beach to minimize disturbance to sea turtle nesting and hatching activities. In addition, all construction pipes that are placed on the beach will be located as far landward as possible without compromising the integrity of the dune system. Temporary storage of pipes on the beach will be in such a manner so as to impact the least amount of nesting habitat and shall likewise not compromise the integrity of the dune systems.

By planning to perform the majority of the project during off-season months, monitoring beach hardness, and relocating nests found in unsuitable habitat if project completion delays occur, impacts to nesting loggerhead sea turtles will be minimized. In addition, NMFS and ACOE hopper dredge protocol will be followed to minimize impacts to migrating loggerheads caused by dredges. However, because of the possibility of missing a sea turtle nest during the nest monitoring program, inadvertently breaking eggs during relocation, or injuring a migrating loggerhead with a hopper dredge, it has been determined that the project may affect the loggerhead sea turtle.

7.10 Shortnose Sturgeon

a. Status and Natural History of the Species in the Project Area

This species ranges along the Atlantic seaboard from southern Canada to northeastern Florida (USFWS, 1999). The shortnose sturgeon feeds on invertebrates and stems and leaves of macrophytes. From historical accounts, it appears that this species was once fairly abundant throughout North Carolina waters, however, many of these early records are unreliable due to confusion between this species and the Atlantic sturgeon (*Acipenser oxyrhynchus*). Because of the lack of suitable freshwater spawning areas in the project area and the requirement of low salinity waters by juveniles, any shortnose sturgeons present would most likely be non-spawning adults.

b. Effect Determination

It is unlikely that the shortnose sturgeon occurs in the project area (F. Rohde, pers. comm.). However, should it occur, its habitat would be only minimally altered by project construction and maintenance. This species feeds on a wide variety of invertebrates and while some food resources may be initially affected by either burial associated with beach nourishment or excavation in borrow areas, most invertebrates will quickly reestablish from adjacent unaffected areas or through recruitment processes. Although dredges have been known to impact shortnose sturgeons, this species is not likely to be present in the project area and, therefore, impacts from dredges are not anticipated to occur. Because of the unlikelihood of shortnose sturgeon being present in the project area and because of the precautions being taken with the dredges, it has been determined that the actions of the proposed project are not likely to affect the shortnose sturgeon.

7.11 Seabeach Amaranth

a. Status and Natural History of the Species in the Project Area

Seabeach amaranth is an annual herb that occurs on beaches, lower foredunes, and overwash flats (Fussell, 1996). Weakley (1986) found that in North Carolina the plant is most common on overwash flats on accreting ends of barrier islands. This species occupies elevations ranging from 0.2 to 1.5 m above mean high tide (Weakley and Bucher, 1992). Historically, seabeach amaranth was found from Massachusetts to South Carolina. But according to recent surveys (U.S. Army Corps of Engineers, 1992-1995), its distribution is now restricted to North and South Carolina with several populations on Long Island, New York. The decline of this species is caused mainly by development of its habitat, such as inlet areas and barrier islands, and increased ORV and human traffic which tramples individuals (Fussell, 1996). Seed dispersal of seabeach amaranth is achieved in a number of ways, including water and wind dispersal (USFWS, 1995). Between 1992 and 1995, annual surveys of amaranth were conducted at Bogue Banks (NCNHP, 1995). The results are as follows:

	# Plants Observed at Bogue Banks	**# Plants Observed within Project Area**
1992	2556	159
1993	3762	232
1994	1181	182
1995	14776	391

No survey was conducted in 1996 because of early summer hurricanes that washed away or buried most of the plants. In 1997, certain sections of Bogue Banks were surveyed, but were found to support very low numbers of amaranth. Because no survey has been conducted since 1997, the size of recent populations are currently unknown. Several hurricanes that hit the North Carolina coast in 1999 may have buried plants and seeds under sand or heavy winds associated with the storms may have dispersed seeds along the project area and into the ocean.

b. Effect Determination

Since dredging of the borrow areas will be done offshore, no impacts to amaranth plants will occur from this action. Furthermore, since beach nourishment will occur in winter months, when amaranth exists as seeds, immediate impacts from filling will be reduced. However, deeply burying existing seeds could negatively affect the amaranth population in later seasons. Assuming that seeds are located in the general position of former parent plants observed in past surveys, they may be covered by proposed beach nourishment activities. Research on the consequences of beach nourishment to amaranth seeds is somewhat inconclusive. The U.S. Army Corps of Engineers (1995) found that amaranth at Masonboro Inlet was more abundant in areas that recently received dredged material. In addition, 1995 survey data from the NC Natural Heritage Program found a section of Bogue Banks that was used as a disposal zone in 1994 had an increase in population from 100 to 7300 plants. Dredging activities could uncover buried seeds and allow them to germinate in deposited areas. (This benefit is unlikely to occur during this project if dredged material is supplied from areas offshore that do not contain amaranth seeds.) In contrast, Hancock (1995) concluded that amaranth seedlings generally do not emerge from depths of sand greater than 1 cm. Therefore, the added sand may be detrimental if placed on top of seeds. However, the beach nourishment that is to take place along the coast of Bogue Banks will occur on areas suffering from erosion and should ultimately expand potential habitat for the plant species.

The U.S. Army Corps of Engineers has instituted a long-term seabeach amaranth monitoring program at every beach in North Carolina which routinely receives dredged material from federally funded projects. The program is to be conducted until such a time that enough data are available to allow a reasonable prediction of the actual impacts of each planned disposal action on the species in the future. After this beach nourishment project is complete, the project area will be monitored by the applicant to see if and where seeds survived. Within a few monitoring seasons, these data will help predict ultimate impacts of beach nourishment on amaranth at Bogue Banks and will be made available to the Corps' monitoring program. Because known amaranth habitat will be filled, it has been determined that the proposed project may affect seabeach amaranth.

8.00 SUMMARY EFFECT DETERMINATION

This assessment has examined the potential impacts of the proposed project on listed species of plants and animals which are, or may be, present in the project area. Both primary and secondary impacts to habitat have been considered. Based on this analysis, it has been determined that the project may affect the hawksbill sea turtle, leatherback sea turtle, Kemp's ridley sea turtle, green sea turtle, loggerhead sea turtle, and seabeach amaranth.

9.00 SUMMARY OF PROTECTIVE MEASURES

To minimize impacts to nesting sea turtles and vegetative-stage seabeach amaranth, work is planned to occur during the winter months with contingencies in place for project completion beyond this period. Furthermore, sand will be placed in areas suffering from erosion, minimizing impacts to suitable sea turtle nesting habitat and expanding potential habitat for seabeach amaranth. All material will be monitored to determine beach hardness, and areas will be tilled where the postdisposal beach is harder than 500 CPUs.

If any work on the project occurs between May 1, a beach monitoring and nest relocation program for sea turtles will be implemented. This program will include daily patrols of disposal areas at sunrise, relocation of any nests laid in areas to be impacted by fill placement, and monitoring of hatching success of the relocated nests. Sea turtle nests will be relocated to an area suitable to both the USFWS and the NC Wildlife Resources Commission's Sea Turtle Coordinator.

If hopper dredges are used to dredge and transport material to the shoreline during the proposed project, NMFS and ACOE hopper dredge protocol will be followed to reduce impacts to whales, fish, and sea turtles that may be in the area. An observer will be present on the hopper dredge to document any takes of sea turtle species, except when water temperatures are cold enough to ensure that sea turtles will not be present (during January and February), to watch for and alert the dredge operator of whales in the area (from the beginning of hopper dredge use through March 31 for daytime observations), and to ensure that turtle deflector dragheads are used properly. Limits on take set by the ACOE will be strictly followed.

REFERENCES

Ackerman, R.A. 1996. The nest environment and the embryonic development of sea turtles. Pp. 83-106 in The Biology of Sea Turtles (Lutz, P.L. and J.A. Musick, eds.) Boca Raton, FL, CRC Press.

Allen, D. 2000. North Carolina Wildlife Resources Commission. Personal communication regarding the occurrence and distribution of piping plovers and other rare birds in the Bogue Banks area. February, 2000.

Boettcher, R. 2000. North Carolina Sea Turtle Coordinator, North Carolina Wildlife Resources Commission. Personal communication regarding the number of loggerhead sea turtle nests found in the project area between 1995 and 1999.

Clark, M.K. 1993. Curator of Mammals, North Carolina State Museum of Natural Sciences. Personal communication regarding seasonal distribution of manatees in the Cape Fear region; p.6, In: Biological Assessment: Channel Realignment Masonboro Inlet, New Hanover County, NC. August 1995. USACOE.

Conant, T. 1993. Humpback whale: *Megaptera novaeangliae*. In *Wildlife Profiles*. Division of Conservation Education, North Carolina Wildlife Resources Commission, Raleigh, NC.

Crain, D.A., A.B. Bolten, and K.A. Bjorndal. 1995. Effects of beach nourishment on sea turtles: Review and research initiatives. *Restoration Ecology* 3(2): 95-104.

Epperly, S.P., J. Braun, & A. Veishlow. 1995. Sea turtles in North Carolina waters. *Conservation Biology* 9(2): 384-394.

Fussell, J. 1996. Comments about Piping Plover, Beach Amaranth, and Other Declining Species on South Spit of Figure Eight Island. December, 1996.

Hancock, T.E. 1995. Ecology of the threatened species seabeach amaranth (*Amaranthus pumilus* Rafinesque). M.S. Thesis, University of North Carolina at Wilmington.

Morrimen, J. 1982. Feeding ecology of sea turtles, Biology and Conservation of Sea Turtles. Smithsonian Institute, Press, Washington, D.C.

Moser, M.L. and S.W. Ross. 1995. Habitat use and movements of shortnose and Atlantic sturgeons in the Low Cape Fear River, North Carolina. Transactions of the American Fisheries Society. 124 (2): 225-235.

NCNHP, 1995. Seabeach amaranth survey, July 13-14, 1995. For Figure Eight Island. North Carolina Natural Heritage Program, Raleigh. Unpublished data.

Rohde, F. 2000. Biological Supervisor, North Carolina Division of Marine Fisheries. Personal communication about the occurrence of shortnose sturgeon within the project area. February 17, 2000.

Schmidly, D.J. 1981. Marine mammals of the southeastern United States coast and the Gulf of Mexico. U.S. Fish and Wildlife Service- Office of Biological Services Report No. 80/41. 165pp.

Schwartz, F.J. 1977. *Caretta caretta caretta* (Linnaeus), Atlantic loggerhead; *Chelonia mydas* (Linnaeus), Altantic green turtle; *Eretmochelys imbricata imbricata* (Linnaeus), Atlantic hawksbill; *Lepidochelys kempi* (Garman), Atlantic ridley; *Dermochelys coriacea coriacea* (Linnaeus), Atlantic leatherback; p. 303-308 In: Cooper, J.E. S.S. Robinson, and J.B. Funderburg (Eds.). 1977 Endangered and threatened plants and animals of North Carolina. N.C. State Museum of Natural History, Raleigh, N.C. 444 pages.

Slay, C. 1993. Right Whale Research Project, New England Aquarium. Personal communication regarding seasonal occurrence of right whales of the Cape Fear region; p.5, In: Biological Assessment: Channel Realignment Masonboro Inlet, New Hanover County, NC. August 1995. USACOE.

U.S. Army Corps of Engineers. 1989. Supplemental biological assessment: Operation and Maintenance of Morehead City Harbor. Carteret County, North Carolina. July, 1989; pp. 5.

U.S. Army Corps of Engineers. Wilmington District seabeach amaranth surveys. 1992-1995. Unpublished data.

U.S. Army Corps of Engineers. 1995. Environmental Assessment: Channel Realignment Maintenance Dredging, Masonboro Inlet, New Hanover County, North Carolina; pp. 9-15.

USFWS, 1991. *Endangered and Threatened Species of the Southeast United States.*

USFWS, 1992. Threatened and Endangered Species of Texas. Endangered Species Office, Albuquerque, New Mexico.

USFWS, 1995. September 1995 Seabeach Amaranth Technical/Agency Draft Recovery Plan, U.S. Fish and Wildlife Service, Atlanta, GA. 75 pp.

USFWS, 1996. Piping Plover (Charadrius melodus), Atlantic Coast Population, Revised Recovery Plan. Hadley, MA. 258 pp.

USFWS, 1999. Roseate Terns in North Carolina, http:/web.ral.r4.fws.gov/birds/rosetern.html.

USFWS, 1999. Shortnose Sturgeon in North Carolina http: //web.ral.r4.fws.gov/fish/shortst.html.

USFWS, 1999. West Indian Manatees in North Carolina, http://web.ral.r4.fws.gov/mammal/manatee.html.

Weakley, A.S. 1986. Summary of Information on Seabeach Amaranth (*Amaranthus pumilus*). NCDHENR, Natural Heritage Program, Raleigh.

Weakley , A.S. and M.A. Bucher. 1992. Status survey of seabeach amaranth (*Amaranthus pumilus* Rafinesque) in North and South Carolina. Report to the North Carolina Plant Conservation Program, and Endangered Species Field Office. 178p.

Wynne, B. 1999. Scoping information to be used in preparing an environmental document for the dredging of Mason Inlet, New Hanover County. North Carolina Wildlife Resources Commission, Raleigh.

APPENDIX E

APPENDIX E — SEDIMENT SURVEYS

APPENDIX E1. PREVIOUS STUDIES

Numerous scientific studies address the geology, geomorphic history, and sediments of the North Carolina coast (Table E1). In contrast, relatively few reports present field data on these topics for the area of Bogue Banks and immediate offshore zone (Table E2). The salient points of these studies with respect to nourishment planning and identification of viable borrow areas include:

- Bogue Banks is a Holocene barrier island within the less exposed western "limits" of the Cape Lookout cuspate foreland with strikingly different topography and profile compared to the northeastern-limit barriers, Core Banks and Portsmouth Island (Heron et al., 1984).

- During Quaternary times, the shoreline off Bogue Banks was transgressive under the influence of deglaciation and rapid sea-level rise across the gently sloping continental shelf of the Carolinas.

- Whether or not Bogue Banks existed as a single or series of subaerial barriers prior to 4000 years ago, only a thin sediment cover remains offshore--most of the inner continental shelf consists of outcropping Tertiary hard bottom (Fig. E1) (Hine and Snyder, 1985).

- As sea-level rise slowed and approached its present elevation about 4000 ago, Bogue Banks began to accumulate sediment from reworked paleo-inlet deltas and littoral sources (Hine and Snyder, 1985).

- Bogue Banks became a "regressive barrier" accreting seaward and vertically via build-up of the shoreface for several thousand years up to this century.

- Accumulation of littoral sediments in the area of present-day Bogue Banks, infilled paleochannels (inlets), the most recent of which were (Fisher, 1962):

  - Prehistoric relict inlet near the causeway to Atlantic Beach.
  - Two relict inlets (noted on Fig. E-5 as #1 and #2) in eastern Emerald Isle, approximately 0.1 and 2.0 miles west of Indian Beach, respectively.
  - Relict Cheeseman Inlet (closed sometime between 1860 and 1886) along west Atlantic Beach about one mile east of Pine Knoll Shores.

- With the exception of a short-term breach in the low area of eastern Emerald Isle during Hurricane *Donna* (1960), Bogue Banks has existed as a contiguous ~25-mile-long barrier island for almost 150 years.

- Bogue Inlet to the west and Beaufort Inlet to the east constitute the primary boundaries of the Bogue Banks littoral cell.

- Bogue Banks's bounding inlets contain huge reservoirs of littoral sand in the form of ebb- and flood-tidal deltas.

- Bogue Banks' positional stability allowed accretion of high dune ridges--in some areas, exceeding 40 feet (ft) above sea level and along most of the shoreline reaching 20 ft. Relief and absolute elevations across Bogue Banks are much greater than Core Banks and Portsmouth Island.

- High relief along Bogue Banks inhibits formation of washovers. Low longshore transport rates lessen the rate of sand loss to the inlets compared to east-facing barrier islands in other parts of Carteret County. Average erosion rates have been low (0-5 ft/yr) since 1939 according to available published reports.

- Subaerial sediments range from medium to coarse sand along the upper beach to fine sand in the dunes to mixtures of sand, coarse shells, and mud in back-barrier areas. The foreshore sediments coarsen toward the step (inshore breakpoint), then fine to the inner trough and bar. Seaward of a shore-parallel bar situated about 400 ft offshore, sediments fine along the lower shoreface.

TABLE E1. Selected references providing background information on the geology, geomorphic history, and sediments of the North Carolina coast (not specific to Bogue Banks).

NOTE: While by no means a complete list, these references provide an excellent overview of geologic processes, landforms, and sediments along the North Carolina coast. Their authors tend to be the researchers who frequently appear in the literature. Many remain active in the profession and continue to offer new insights regarding shoreline evolution. The list focuses on publications having relatively wide distribution. We particularly recommend *Geology of Holocene Barrier Island Systems* (R.A. Davis, editor, Springer-Verlag, 1994) for its collection of synthesis papers under one cover.

Blackwelder, B.W., I.G. MacIntyre, and O.H. Pilkey. 1982. Geology of the continental shelf, Onslow Bay, North Carolina, as revealed by submarine outcrops. Bull. AAPG, Vol. 66, pp. 44-56.

Cleary, W.J., and P.E. Hosier. 1979. Geomorphology, washover history, and inlet zonation: Cape Lookout, NC, to Bird Island, NC. In S.P. Leatherman (ed), *Barrier Islands*, Academic Press, New York, NY, pp. 237-271.

Hayes, M.O. 1994. The Georgia Bight barrier system. Chap. 7 in R. Davis (ed), *Geology of Holocene Barrier Island Systems*, Springer-Verlag, Berlin, pp. 233-304.

Langfelder, L.J., P.B. Stuffard, and M. Amein. 1970. Coastal erosion in North Carolina. Jour. Waterways and Harbors Div., Proc. ASCE, Vol. 96(NWW2), pp. 531-545.

Luternauer, J.L., and O.H. Pilkey. 1967. Phosphorite grains: their application to the interpretation of North Carolina shelf sedimentation. *Marine Geology*, Vol. 5, pp. 4, 314-320.

Meisburger, E.P. 1979. Reconnaissance geology of the inner continental shelf, Cape Fear region, North Carolina. CERC, Tech. Paper 79-3, 135 pp.

Moslow, T.F., and S.D. Heron, Jr. 1979. Quaternary evolution of Core Banks, North Carolina: Cape Lookout to New Drum Inlet. In S.P. Leatherman (ed), *Barrier Islands*, Academic Press, New York, NY, pp. 211-236.

Moslow, T.F., and S.D. Heron, Jr. 1981. Holocene depositional history of a microtidal cuspate foreland cape: Cape Lookout, North Carolina. *Marine Geology*, Vol. 41, pp. 251-270.

Moslow, T., and D. Heron. 1994. The Outer Banks of North Carolina. Chap. 2 in R. Davis (ed), *Geology of Holocene Barrier Island Systems*, Springer-Verlag, Berlin, pp. 47-74.

Pearson, D., and S. Riggs. 1981. Relationship of surface sediments on the lower forebeach and nearshore shelf to beach nourishment at Wrightsville Beach, North Carolina. Shore & Beach, Vol. 49, pp. 26-31.

Pierce, J.W., and D.J. Colquhoun. 1970. Holocene evolution of a portion of the North Carolina coast. Geol. Soc. Amer. Bull. Vol. 81, pp. 3697-3714.

Pilkey, O.H., L. Blackwelder, E. Doyle, and M. Terlecky. 1969. Aspects of carbonate sedimentation on the Atlantic Continental Shelf off of southern United States. Jour. Sed. Petrol., Vol. 39(2), pp. 744-769.

Riggs, S., W. Cleary, and S. Snyder. 1995. Influence of inherited geologic framework on barrier shoreface morphology and dynamics. *Marine Geology*, Vol. 126, pp. 213-234.

Susman, K.R., and S.D. Heron, Jr. 1979. Evolution of a barrier island, Shackleford Banks, Carteret County, North Carolina. Geol. Soc. Amer. Bull., Vol. 90, pp. 205-215.

Swift, D.J.P. 1975. Barrier-island genesis: evidence from the central Atlantic shelf, eastern U.S.A. *Sed. Geology*, Vol. 14, pp. 1-43.

Swift, D.J.P., J.W. Kofoed, F.P. Saulsbury, and P. Sears. 1972. Holocene evolution of the shelf surface, central and southern Atlantic shelf of North America. In Swift et al. (eds), *Shelf Sediment Transport, Process and Pattern*, Dowden, Hutchinson and Ross, Stroudsburg, PA, pp. 499-574.

Thieler, R., W. Cleary, C. Hobbs, and R. Gammisch. 1995. Geology of the Wrightsville Beach, North Carolina, shoreface: implications for the concept of shoreface profile equilibrium. *Marine Geology*, Vol. 1126, pp. 271-287.

TABLE E2. Reports and publications containing site-specific data and relating to geology and sediments in the Bogue Banks section of the North Carolina coast. The papers by Hine and Snyder (1985) and Heron et al. (1985) along with the thesis by Reed (1997) were particularly helpful during the planning of the 1999 field survey.

Batten, W. 1962. The sediments of the Beaufort Inlet area, North Carolina. *Southeastern Geology*, Vol. 2, pp. 191-205.

Fisher, J.J. 1967. Development pattern of relict beach ridges, Outer Banks barrier chain, NC. Unpublished dissertation, Univ. North Carolina, Chapel Hill.

Goff, T.W. 1977. Sedimentation in a modern tidal inlet: Bogue Inlet, North Carolina. Unpublished thesis, Univ. North Carolina, Chapel Hill.

Heron, D., T. Moslow, W. Berelson, J. Herbert, K, Steele, and K. Susman. 1984. Holocene sedimentation of a wave-dominated barrier island shoreline: Cape Lookout, North Carolina. *Marine Geology*, Vol. 60, pp. 413-434.

Hine, A., and S. Snyder. 1985. Coastal lithosome preservation: evidence from the shoreface and inner continental shelf off Bogue Banks, North Carolina. *Marine Geology*, Vol. 63, pp. 307-330.

Mixon, R.B., and O.H. Pilkey. 1976. Reconnaissance of the submerged and emerged coastal plain province: Cape Lookout quadrangle, North Carolina. U.S. Geol. Survey Paper 859, 45 pp.

Reed, A. 1997. Sediment distribution patterns offshore of a replenished beach: Atlantic Beach and Fort Macon State Park, North Carolina. M.S. Thesis, Dept. Geology, Univ. North Carolina, Chapel Hill, 74 pp. + app.

Sarle, L.L. 1977. Processes and resulting morphology of sand deposits within Beaufort Inlet, Carteret County, North Carolina. M.S. Thesis, Dept. Geol., Duke Univ., Durham, NC, 149 pp.

Steele, G.A. 1980. Stratigraphy and depositional history of Bogue Banks, North Carolina. Ph.D. Thesis, Duke Univ., Durham, NC, 201 pp.

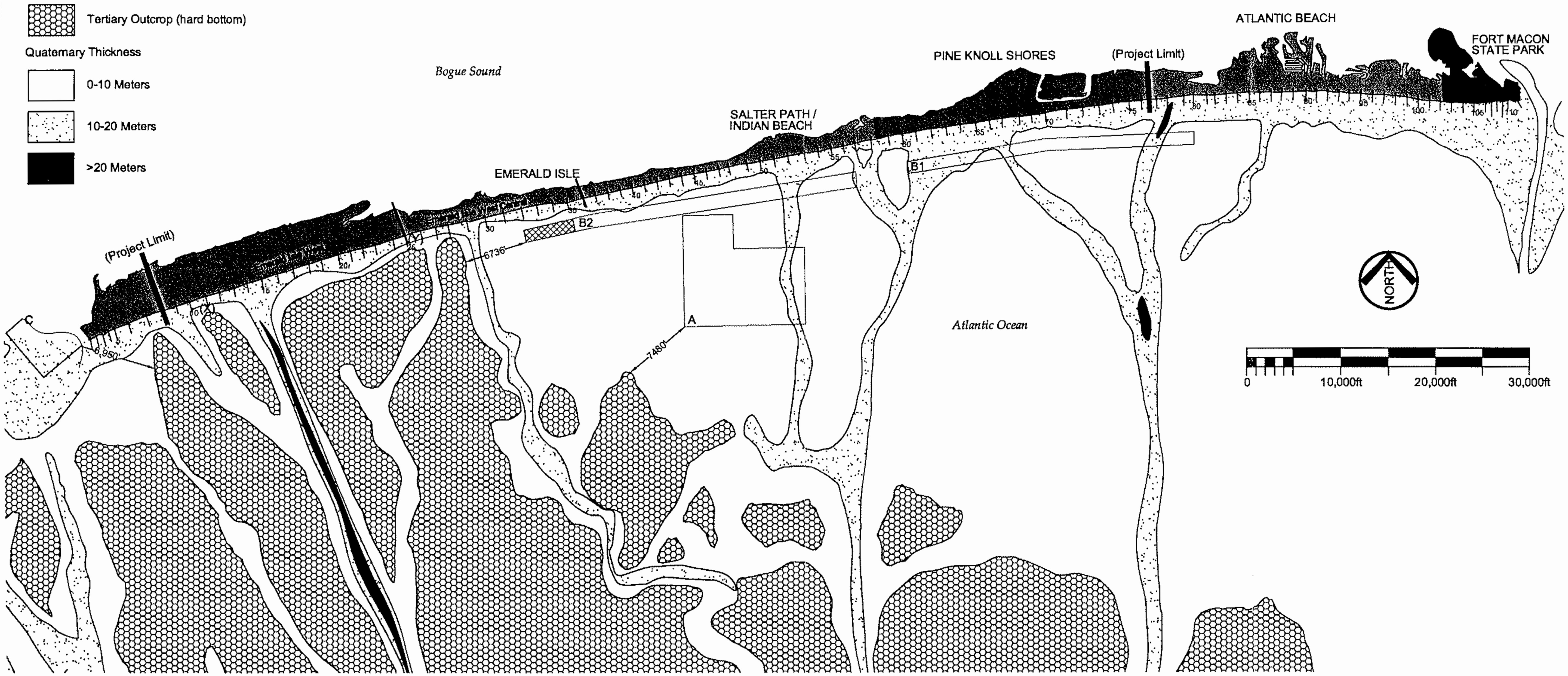
Thieler, R. 1996. Shoreface processes in Onslow Bay. Carolina Geological Survey, 1996 Fieldtrip Guidebook, pp. 23-32.

USACE. 1976. Morehead City Harbor, NC. General Design Memorandum, U.S. Army Corps of Engineers, Dept. Army, Wilmington Dist., NC, 327 pp.

USACE. 1990. Feasibility report and environmental assessment. Morehead City Harbor improvement, Morehead City, NC, 79 pp.

USACE. 1993. Environmental assessment and findings of no significant impact. Disposal of dredged material on the ocean reach of Bogue Banks from combined maintenance — dredging and deepening of Morehead City Harbor inner navigation channels and pumpout of Brandt Island upland diked disposal site, Carteret County, NC, 37 pp.

USACE. 1994. Environmental assessment: designation and use of a placement area for underwater nearshore berm. Morehead City Harbor project, Morehead City, NC, 50 pp.



Interpretation of Tertiary (hard bottom) outcrops and estimated Quaternary layer thickness (of unconsolidated sediments) based on Hine and Snyder (1985, Figure 6). Infilled paleochannels comprise the thickest deposits but have limited areal extent and highly variable sediment texture including high percentages of fines. Potential borrow areas A, B1, B2, & C identified in the present study are superimposed.

Closest distance to Tertiary outcrop

- Borrow area A..................7500ft
- Borrow area B2................6700ft
- Borrow area C..................6,950ft

Project Reach

- Emerald Isle West (Y)........1600ft (from outer bar)
- Emerald Isle Central (X).....1600ft (from outer bar)

STROUD ENGINEERING

CSE Coastal Science & Engineering, LLC

Figure E1

Interpretation of Tertiary (hard bottom) outcrops and estimated Quartemary thickness

APPENDIX E2. SURVEY DESIGN

Despite a limited supply of beach-quality sand offshore of Bogue Banks as inferred from the literature (see Table E2), more detailed confirmation was required before ruling out alternative borrow areas. The study team recommended a reconnaissance-level survey during initial planning of the Bogue Banks restoration project based on the following desirable criteria:

- Viable sand deposits closer to the project areas than Beaufort or Bogue Inlets could potentially yield very large cost savings for the project.

- Sediments that are somewhat coarser (on average) than the native beach and coarser than the material typically available from channel maintenance would improve the durability of the nourishment projects.

- Deposits with lower mud/fine-sand content than previously used in Corps disposal projects would reduce the rate of fill losses and minimize turbidity in nearshore waters.

- If broad, shallow areas (at least 1-2 ft thick) could be confirmed, hopper dredges or alternate equipment could be used for excavations, and the rate of environmental recovery might be more rapid based on experience elsewhere (Jutte et al., 1999).

The sediment survey encompassed the following field sampling over two phases between June and November 1999:

- **Beach sampling and textural analysis** (June 1999) to quantify native material — 20 samples divided among dune (2), berm (6), beach face (6), and low-tide terrace (6) at CSE-Stroud transect 10 (west Emerald Isle), transect 30 (central Emerald Isle), transect 50 (Indian Beach), transect 70 (Pine Knoll Shores east), transect 90 (Atlantic Beach), transect 110 (Coast Guard Station); spacing of transects was approximately 20,000 ft.

- **Phase I borrow source sampling** (June 1999)
  - *Offshore reconnaissance* — 53 short cores by divers in a regional grid pattern encompassing a 16-mile length of coast from central Atlantic Beach to central Emerald Isle and extending between ~0.25 and 3 miles offshore. Generally consisted of shore-perpendicular transects of 3-5 boring locations at approximate two-mile intervals in the longshore direction. Additional, more closely spaced cores were collected 0.5-1 mile from the most promising sites. Cores average about 2 ft long.

  - *Bogue Inlet* — eight surface grab samples at five stations over intertidal shoals in the middle of Bogue Inlet.
  - *Bogue Sound* — three diver borings at accessible back-barrier areas adjacent to access channels.
  - *Corps disposal area (Brandt Island)* — four supratidal grab samples.

- **Phase II confirmation** sampling (November 1999)
  - *Borrow area A (western half)* — 46 borings (averaging ~2.3 ft) at ~1200-1500 ft spacing; eight vibracores (3-9 ft) at ~3000 ft spacing.
  - *Borrow area B1* — four diver borings (~2.8 ft); three vibracores (7.5-11 ft).
  - *Borrow area B2* — seven diver borings (~2.9 ft); three vibracores (~9-10 ft).
  - *Bogue Inlet intertidal shoals, borrow area "C"* — six short cores (~4 ft).

CSE Baird performed all Phase I sampling and the diver sampling for Phase II. Athena Technologies, Inc. (Columbia, SC) performed the vibracore sampling under subcontract to CSE Baird. Positioning was via Garmin Model Map215 differential GPS navigation system which provided ~10-15 meter accuracy after considerations of boat swing over each coring site.

The only known borings prior to the 1999 survey in the primary offshore region (central Bogue Banks) were those collected in the early 1980s by university researchers (Dr. S.R. Riggs and Dr. A.C. Hine, principal investigators, as reported in Hine and Snyder, 1985) (Fig. E2). That regional survey of Onslow Bay included approximately 20 vibracores on the inner shelf inside the 20-meter depth contour off Bogue Banks. The Hine and Snyder (1985) borings generally describe a shore-parallel line about 3-3.5 miles offshore. Several borings were made closer to shore in presumed paleochannels off the western end of Atlantic Beach and western Emerald Isle (Fig. E2). Hine and Snyder noted for the area thin layers of Holocene sands and crushed shell overlying more heterogeneous Pleistocene sediments. Paleo-channels (Fig. E2) reportedly contained admixtures of mud, sand, shells, and phosphatic material.

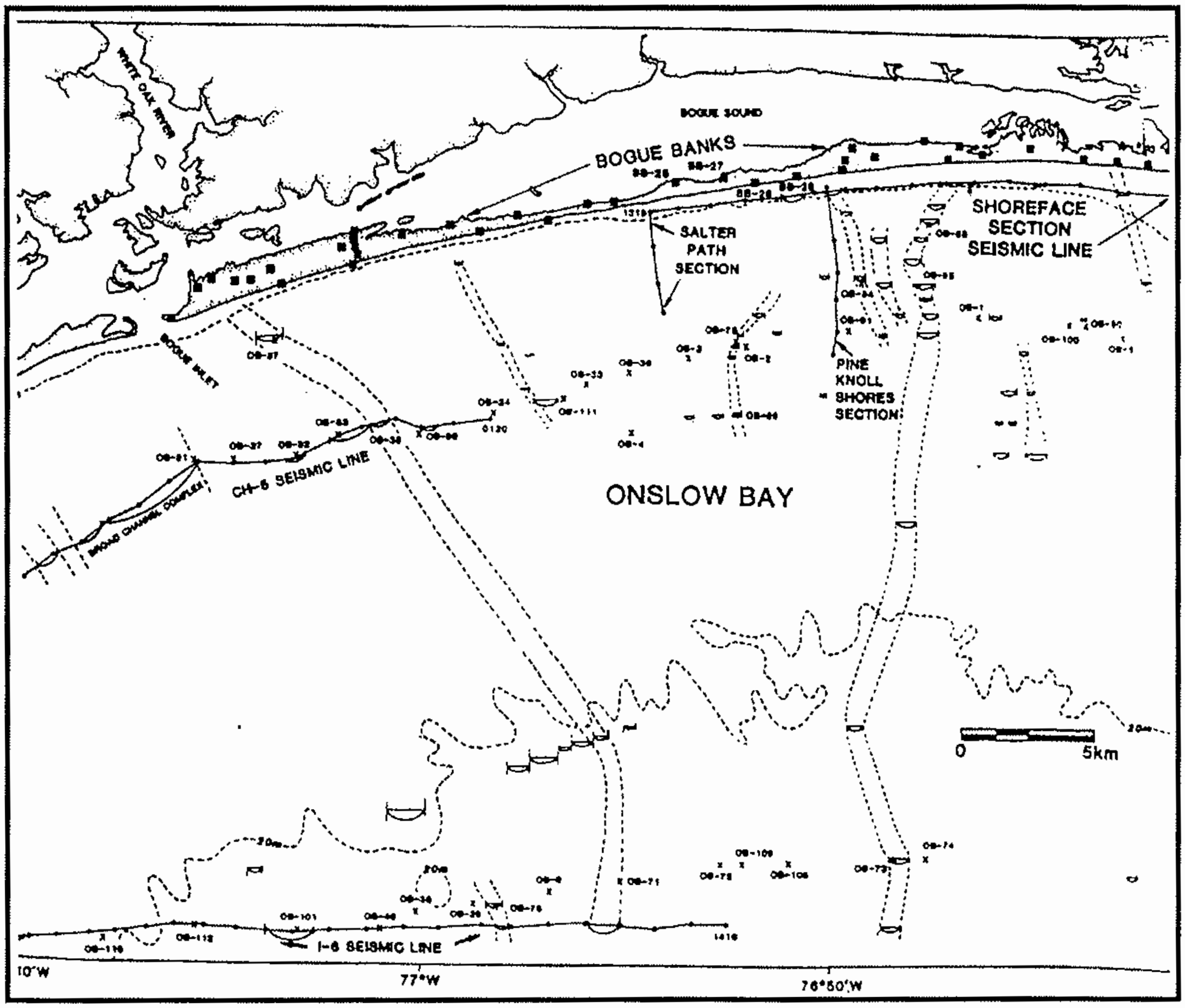


FIGURE E2. Vibracore locations and inferred positions of buried paleochannels (dashed lines perpendicular to the shoreline) offshore of Bogue Banks. Outer depth contour is 20 meters (~65 ft). [From Hine and Snyder, 1985; Fig. 2]

The present study focused on the uppermost ~2-3 ft layer for three reasons:

1) Preliminary evidence suggested that the "Holocene" section was more likely to contain beach-quality sediments.

2) Hopper dredges reportedly work most efficiently in borrow areas where the depth of cut is of the order 1-2 ft (E. Elefson, Aug. 1999, Weeks Marine, pers. comm.).

3) Given a fixed budget for offshore surveys, many more shallow borings could be obtained by divers working out of small craft compared to the number of vibracores possible using much larger equipment.

The study design provided for a two-phased search whereby preliminary borrow areas would be defined using a coarse regional grid of samples, then refined in Phase II by a more detailed search. Phase II also provided for a representative sampling of thicker sections using a large vibracore rig sufficient to recover ~10-ft samples.

In total, the 1999 surveys accomplished the following:

- Characterized the upper 2-3 ft of sediments in an approximate 50 square mile area off Bogue Banks.
- Identified potential offshore borrow areas representing approximately 10 square miles.
- Confirmed sediment in potential borrow areas in sufficient detail to develop isopach maps of textural properties.
- Obtained ~90 percent of the borings in the most promising six square miles, yielding an average 15 borings per square mile in the potential borrow areas.

The reader is also referred to sediment quality data from ten environmental sampling sites around the offshore borrow areas, reported by University of North Carolina investigators in Appendix C of this document. Those data apply to the upper 2 centimeters (0.07 ft).

APPENDIX E3. LABORATORY ANALYSIS

Sediment samples were collected and stored as follows.

Diver cores — two-inch aluminum barrels driven by hammer to refusal, cut, and temporarily capped in situ; then decanted, cut to sediment level, and recapped in the field noting penetration depth and recovery thickness; stored vertically for transport to the lab.

Vibracores — 2½-inch steel barrels driven remotely via large-scale vibrator to the depth of refusal; removed, cut, capped, and measured for penetration depth and recovery thickness.

Grab samples (beach) — hand samples from the upper three inches placed in sample bags.

Grab samples (Bogue Inlet)
- *Phase I* — hand samples in the upper six inches on the bar surface and in two vertical sections along steep slip faces adjacent to the channel.
- *Phase II* — on the subaerial bar surface by posthole excavations and short core tubes to achieve a representative 4-ft section; stored in plastic bags.

Samples were logged, split, and analyzed as follows.

1) **Diver and vibracore cores** — split by saw, logged, and one-half sampled as a single or multiple composite; the remaining core half was sealed in plastic in its half barrel and archived.

   Phase I samples — visual estimates of mud percentages; then washed, dried, and dry-sieved using 0.25 phi (ϕ) intervals from -1ϕ to 4ϕ – that is, granule (2 mm) to very fine sand (0.0625 mm); fractions retained >2 mm and <0.0625 mm were noted.

   Phase II samples — same handling and grain-size analysis procedures as Phase I samples except nearly all tested for percent mud and percent carbonate via subsampling.

   - *Percent mud* was determined by drying an undisturbed sample (composite from the length of the core), weighing it, rewetting and disagregating the sample, decanting the mud fraction until the water ran clear, redrying the sample, then reweighing it. Percent mud is computed from the difference in dry weight of the unwashed and washed samples.
   - *Percent carbonate* was determined from a 20-gram subsample that had been washed and dried, then treated with repeated quantities of 10 percent dilute HCL for several hours until all reactions stopped. Samples were redried and reweighed for comparison with the untreated sample weight, and the percentage of carbonate material is computed.

2) **Native beach samples, Bogue Inlet samples (Phase I and Phase II) and other miscellaneous samples** — representative splits were obtained, washed, dried, and dry-sieved at 0.25ϕ intervals. No mud analyses were performed because the grab samples were generally void of mud. Percent carbonate was determined via the same procedure for Phase II cores, for the Bogue Inlet (Phase II) samples, and groupings of native beach samples (i.e., physical composites of multiple berm, beach face, etc., samples).

Raw data were entered into spreadsheets and analyzed via custom software (CSE's BPAS system) which automates computation of standard statistical parameters [including moment measures and the graphic parameters of Inman (1952) and Folk and Ward (1957)]. Grain-size distributions (GSDs) were graphed as frequency and cumulative frequency distributions using phi (ϕ) and millimeter (mm) axes for cross-reference. To facilitate evaluation and comparison with other engineering sieve sizes, Figure E3 shows the general relationships of grain size (mm), phi value, sediment classification, and ASTM sieve mesh sizes.

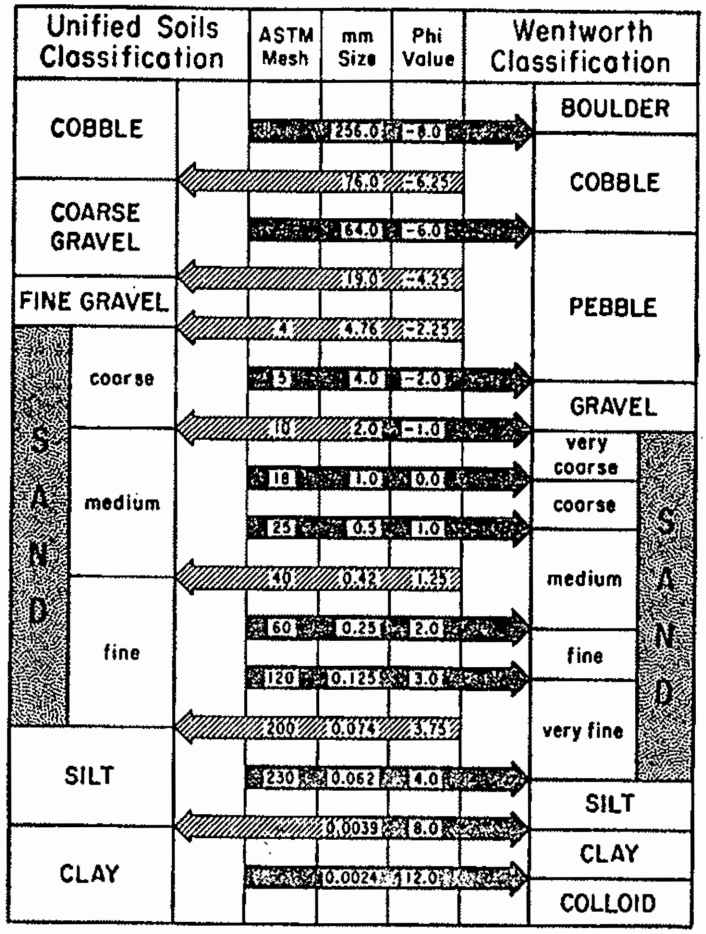


FIGURE E3. Grain-size scales (soil classification).

Sediment quality and compatibility for beach nourishment were based on the technique of James (1975) (CERC, 1984), whereby a population of potential borrow area samples is compared statistically with the native beach size distribution. James (1975) presents methodology for computing the "overfill ratio," R_A, which represents how similar a particular size distribution of sediments is compared to the native population of sediments. R_As of nearly 1.0 suggest the sample will perform more or less equal to the native population. Higher R_As represent the ratio of non-native "borrow" material required to perform as 1.0 unit of native material. Thus, an R_A equal to 2.0 suggests it will take twice as much material to equal 1.0 unit of native sediment.

The concept of overfill ratios is not a perfect predictor of nourishment performance, but it remains perhaps the most useful and proven technique for comparing nourishment sediments (NAS, 1995). The primary factors considered are mean grain size and sorting (standard deviation measure of the size distribution). Experience has shown that borrow sources at least as coarse as the native beach (Dean, 1991; CERC, 1984) or having significant coarse fractions (Kana and Mohan, 1998) perform equal to or better than native sediments (as measured by durability of the dry beach). Borrow sediments that are finer than native or that contain high percentages of fine material perform worse (NAS, 1995). This response is related to profile adjustment (function of wave energy and wave steepness) as well as the background erosion rate. Obviously, the concept of R_A as a predictor of performance assumes that the scale of the nourishment is relatively large and covers a reasonable length of shoreline. Short projects do no perform as well for another reason--because end losses cause spreading away from the nourishment "bulge" (NAS, 1995).

For purposes of the 1999 study, we determined R_As using the James (1975) nomogram in CERC (1984) (Fig. E4). The resulting R_As were revised based on the percent mud in each sample and reported as a revised overfill ratio. Mud is assumed to winnow out quickly, thus increasing the R_A in direct proportion to the mud percentage. Mud is defined as those sediments testing in the silt-clay range (mean size <0.0625 mm or >4.0ϕ).

Sediment quality and borrow area suitability was based on the R_As, mean grain size and sorting parameters, percent mud, percent carbonate, percent coarser than 2 mm (i.e., granule, or larger), and proximity to the project area.

Where data were sufficiently dense, we prepared isopach maps of various sediment size/quality parameters and R_As, and present them in the results section.

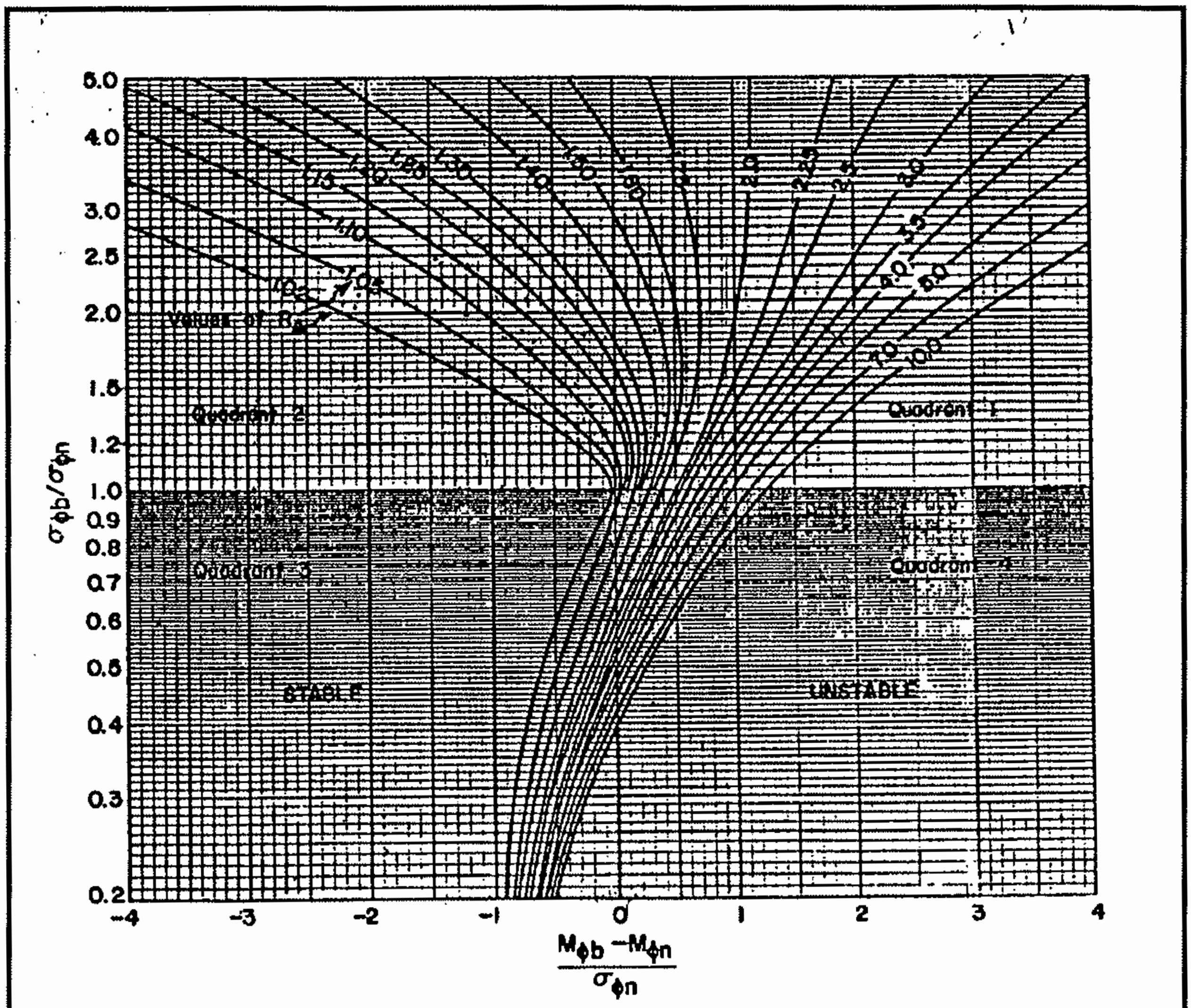


FIGURE E4. Isolines of the adjusted overfill factor for values of phi mean difference and phi sorting ratio (from James, 1975).

APPENDIX E4. SEDIMENT RESULTS

This section provides a summary of results and refers to data sets contained in Annex E1. Information on core and sample locations and summary statistics are given in Annex E1 as follows:

Table E1-A. Core locations in latitude/longitude and North Carolina State Plane System (NAD'83) (Phases I and II).

Table E1-B. Beach sample locations (CSE-Stroud transect numbers), grain-size statistics (mean, standard deviation, and skewness), sediment description.

Table E1-C. Bogue Inlet, Bogue Sound, and Corps spoil island samples — June 1999 Phase I sediment characteristics.

Table E1-D. Offshore core sediment characteristics — June 1999 Phase I samples.

Table E1-E. Offshore core sediment characteristics — November 1999 Phase II samples.

Grain-size distributions, size frequency curves, and textural classifications are contained in Annex E2. Because of the large number of individual samples, results are grouped by phase and sample area with divider pages between phases as follows:

Phase I	Beach	BB series	21 samples
	Bogue Inlet	BI series	8 samples
	Bogue Sound	BS series	3 samples
	Corps Disposal Area	BD series	4 samples
	Offshore Cores	C(MILE) series	53 samples
Phase II	Borrow area A	A series	59 samples
	Borrow area B1	B-1 series	7 samples
	Borrow area B2	B-2 series	13 samples
	Borrow area C	C series	6 samples

NOTE: Selected core locations were sampled by vibracore. These are given on sample sheets as ATH series or cross-referenced with A, B-1, and B-2 series. In some cases, two samples were processed for a core, in which case the samples are given as "S1" and "S2" in the suffix of the sample label. The sample thickness or interval (in the case of multiple samples) is given in Tables E1-D and E1-E. Core logs are given for the vibracores at the back of Annex E-2.

E4.1 Beach Composites

Native-beach size distributions were established using statistical composites of physical composite results of individual samples. Table E3 contains the individual sample results (primary statistics) from 21 dune/beach/low-tide terrace samples distributed in six transects along Bogue Banks. Of the three dune samples, only two were considered representative of natural dunes, which tend to have finer sediment than beach-face samples. At stations CSE-Stroud 30, CSE-Stroud 50, and CSE-Stroud 70, repeated dune scraping has introduced anomalously coarse sands from the berm. Therefore, these stations were not sampled at the dune. At station 110 (Coast Guard station), nourishment via Corps spoil projects has introduced a coarse sediment which similarly does not reflect native dune sands, therefore it was eliminated from the composites.

Table E3. Beach Sediment Characteristics and Composites

Bogue Banks — Beach Sediment Characteristics

Profile # - Locality	Sample	ID	Grain Size Distributions Mean (mm)	Std Dev. (m	Skewness	Sediment Description*
10 - Emerald Isle	Berm	BB10B	**0.365**	0.630	-0.299	MS,mws,sym
10	MBF	BB10C	**0.290**	0.622	-0.496	MS,mws,sc-s
10	LTT	BB10D	**0.380**	0.525	-0.482	MS,ms,sc-s
30 - Emerald Isle	Dune	BB30A	**0.246**	**0.740**	-0.034	FS,ws,sym
30	Berm	BB30B	**0.384**	**0.619**	-0.149	MS,mws,sym
30	MBF	BB30C	**0.312**	**0.714**	-0.495	MS,ws,sym
30	LTT	BB30D	**0.270**	**0.709**	-0.646	MS,ws,sym
50 - Indian Beach	Berm	BB50B	**0.418**	0.544	-0.439	MS,ms,sc-s
50	MBF	BB50C	**0.302**	0.760	-0.455	MS,ws,sym
50	LTT	BB50D	**0.215**	0.693	-0.683	FS,ws,c-s
70 - Pine Knoll Shores	Berm	BB70B	**0.338**	0.566	-0.733	MS,ms,sc-s
70	UBF	BB70C	**0.475**	0.517	-0.288	MS,ms,c-s
70	LTT	BB70D	**0.288**	0.669	-0.744	MS,mws,c-s
90 - Atlantic Beach	Dune***	BB90A	**0.234**	0.750	0.074	FS,ws,sym
90	Berm***	BB90B	**0.228**	0.708	-0.830	FS,ws,c-s
90	UBF	BB90C	**0.244**	0.630	-0.614	FS,mws,c-s
90	LTT	BB90D	**0.243**	0.636	-0.569	FS,mws,c-s
10 - Coast Guard Statio	Dune**	BB110A	**0.801**	0.432	-0.090	CS,ps,sym
110	Berm**	BB110B	**0.541**	0.514	-0.169	CS,ms,c-s
110	MBF	BB110B	**0.457**	0.472	-0.347	MS,ps,c-s
110	LTT	BB110B	**0.200**	0.599	-1.247	FS,mws,c-s
Composites	Dune	(2)	**0.240**	0.745	0.390	FS,ws,sym
Composites	Berm	(6)	**0.368**	0.552	-0.460	MS,ms,c-s
Composites	each Fac	(6)	**0.357**	0.574	-0.634	MS,ms,c-s
Composites	LTT	(6)	**0.265**	0.602	-0.717	MS,mws,c-s
All	ll Sample	(20)	**0.302**	0.585	-0.648	MS,mws,c-s

**CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical dist.
MBF-mid beachface; UBF-upper beach face; LTT-Low Tide Terrace

Note: Scraped Dunes At Stations 30, 50, & 70 Not Representative
Spoil At Station 110 Dune·Contains non-natural coarse material

Native Composite (20 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)
Mean=1.725 phi (Mn) Std dev=0.773 phi (SDn Skewness=-0.648
Mean=0.302 mm Std dev=.585 mm Skewness=-0.648

Native Composite (12 Samples @ Berm, Beach Face)
Mean=1.466 phi (Mn) Std dev=0.830 phi (SDn Skewness=-0.542
Mean=0.362 mm Std dev=.563 mm Skewness=-0.542

** Spoil Section   **Nourished Section

Sets of composites were computed as follows:

1) Composite "20" based on 20 samples (2 dune, 6 berm, 6 beach face, and 6 low-tide terrace).
2) Composite "12" based on 12 samples (6 berm and 6 beach face).
3) Composite "Dune" based on 2 dune samples.
4) Composite "Berm" based on 6 berm samples taken from the dry beach.
5) Composite "Beach Face" based on 6 beach face samples taken from the middle of the upper beach face.
6) Composite "LTT" based on 6 low-tide terrace samples.

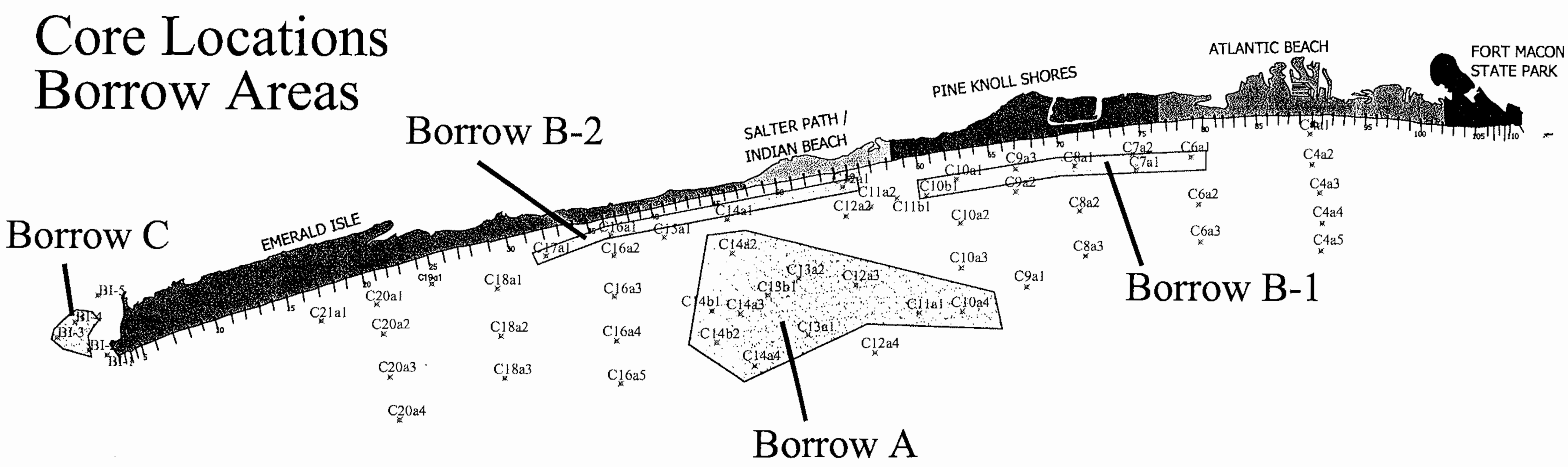
The composite results are given at the bottom of Table E3 (statistics and frequency curves in Annex E3). Review of the results confirmed coarsest sediments tend to reside on the berm and beach face (medium sand, moderately sorted, coarse-skewed) with finer sediments occurring along undisturbed dunes and low-tide terrace (typically fine sand, well sorted). Composite "12" yielded a mean grain size of 0.362 mm along the beach face and berm, whereas composite "20" yielded a mean size of 0.302 mm. Considering that the proposed nourishment is designed to widen the recreational beach including part of the under-water profile, we elected to use the composite "20" as a "native" beach. This weights the composite toward the coarse sizes common along the beach face, berm. and low-tide terrace where the majority of the nourishment sand will be placed. We also elected not to include samples over the outer bar or further offshore (even if these areas are part of the littoral zone), because they tend to be much finer than the beach face and would weight the "result" toward less stable sediment sizes. Similarly, we elected to only include two dune samples in composite "20" because a relatively small percentage of nourishment sediments will be subject to aeolian processes or contribute to dune building after construction.

The "native" composite selected for a baseline in the 1999 study is considerably coarser than the native sediment distribution used by the USACE (1976) in planning for potential disposal projects along Atlantic Beach. The Corps sampled at 2 ft intervals from the berm to -30 ft mean low water (MLW) along four transects at the eastern end of Bogue Banks. Their statistical composites yielded a mean grain size of 0.17 mm (2.52ϕ) and standard deviation of 0.77ϕ. The Corps results confirm the fining of sediments offshore but tend to weight the result toward less stable material. The native composite we chose is much more conservative for beach nourishment planning because it eliminates from consideration certain fine deposits that characterize the area seaward of the bar. Use of a coarser "native" size distribution lowers the amount of potentially beach-compatible material in our search areas. At the same time, it better distinguishes good sediment from marginally acceptable sediment.

E4.2 Phase I Core Samples

The Phase I sediment test results are summarized in Figures E5 and E6. Figure E5 shows the general locations of diver cores (C## series) obtained in June 1999. The ## (i.e., 10a, 14b, etc.) corresponds approximately to the distance in miles west of Beaufort Inlet of a particular transect. The subscript "a" relates to whole-mile distances and "b" to one-half mile distances. Therefore, core C12a(#) is from a transect approximately 12 statue miles from Beaufort Inlet and C14b(#) is approximately 14.5 miles from the inlet. Also shown on Figure E-5 are the locations of shore profiles. Beach samples were collected at transects 10, 30, 50, 70, 90, and 110.

Grain-size isopachs developed for the Phase I cores are shown at the bottom of Figure E5. Also, superimposed are paleochannels inferred by Hine and Snyder (1985), largely from seismic records (limited number of cores as shown on Figure E2).



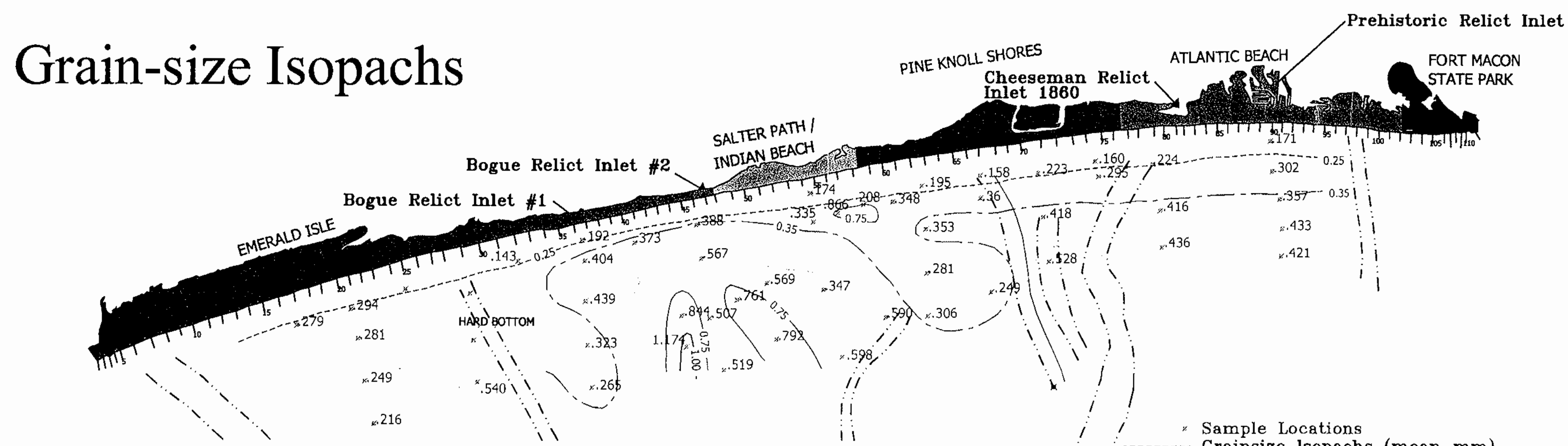


FIGURE E5. Sand search data showing the location of potential new borrow areas for Bogue Banks identified during the present surveys.

CSE
Coastal Science & Engineering, LLC

STROUD ENGINEERING
101A HIGHWAY 24
MOREHEAD CITY, N.C. 28557
(252) 247-7479

Surveyed By:
Drawn By: PAM TWK
Checked By: TWK
Approved By: TEW

REVISIONS:
Addition of Borrow Areas 8/2/99
Date

PROJECT NORTH
0 5000 10000

Bogue Banks
Beach Nourishment
North Carolina

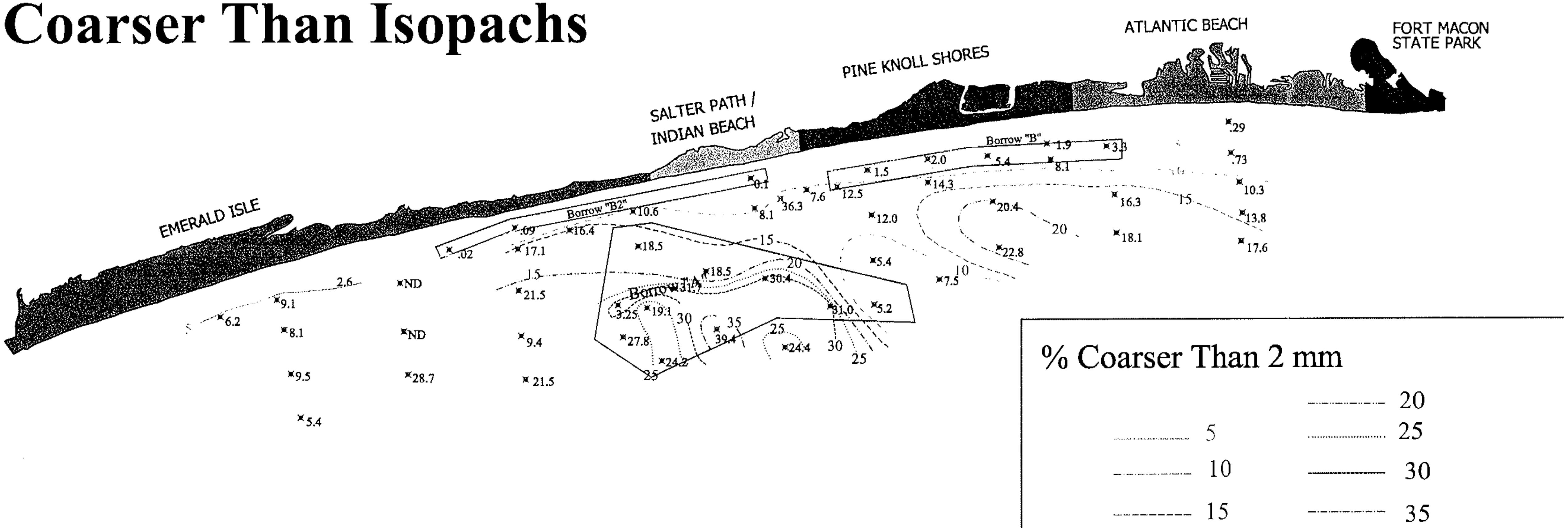
Prepared For:
Carteret County
North Carolina

Drawing Title:

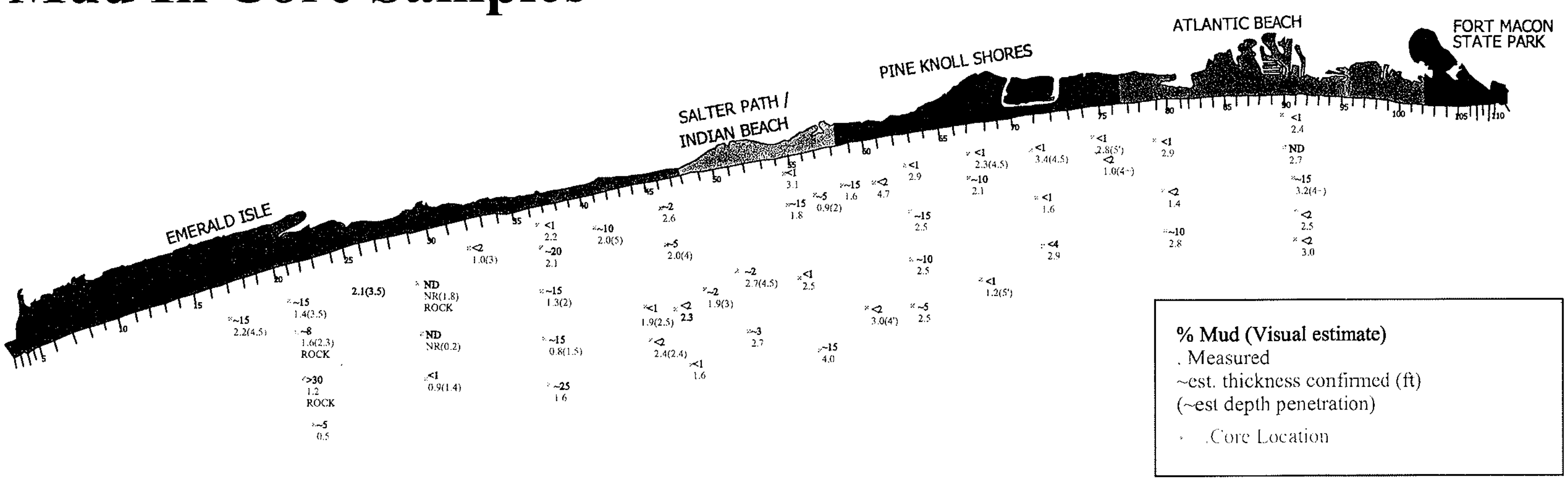
Fig E5

CSE Project Number: 9863-04
Date: February 2000
Printed: 2/11/00
Drawing Number: Fig_05-1.dwg
Sheet Number:

% Coarser Than Isopachs



% Mud In Core Samples



CSE
Coastal Science & Engineering, LLC

STROUD ENGINEERING
151A HIGHWAY 24
MOREHEAD CITY, N.C. 28557
(252) 247-7479

Surveyed By:
Drawn By: PAM TWK
Checked By: TWK
Approved By: TEW

REVISIONS:

Date

PROJECT NORTH

0 5000 10000

Bogue Banks
Beach Nourishment
North Carolina

Prepared For:
Carteret County
North Carolina

Drawing Title:
Fig E6
Borrow Areas
% Coarser than Isopacs
% Mud

CSE Project Number: 9803-04
Date: February 2000
Printed: 2/11/00
Drawing Number: Fig_E6-1.dwg
Sheet Number:

Figure E6 contains isopachs and sample data relating to the percentage of coarse material in each location (>2 mm mean diameter). The lower half of Figure E6 shows the approximate thickness sampled and confirmed, along with a visual estimate of mud percentages.

These preliminary results were used to identify three potential borrow areas: A, B1, and B2. Area A (Fig. E5, upper), represented by 12 cores, tended to contain the coarsest material and the least mud. Areas B1 and B2 were identified as promising because of their proximity to shore and reasonable uniformity of sediment with low mud content. B1 is represented by seven cores and B2 by four cores collected during Phase I.

E4.3 Phase I Sediment Compatibility

Groups of samples for each potential borrow area (including Bogue Inlet, Bogue Sound, and Corps spoil island samples) were compared with the native beach. Using the method of James (1975), borrow composites were compared with native beach composites to yield an overfill (R_A) factor for each borrow area (Table E4). The results--using beach composite 12 as well as beach composite 20--show a significant range with borrow areas A and C containing sediment that most closely matches the native beach. R_As for borrow area A were 1.10 on composite 20 and 1.13 on composite 12. Borrow areas B1 and B2 had finer sands on average, yielding R_As of 1.62 to 1.80 on composite 20. Samples from Bogue Sound yielded R_As >10, meaning only a small fraction of those deposits would provide stable nourishment sediments along the ocean beach. Most of the sediments in Bogue Sound are believed to be fine sand, silt, or clay.

On the basis of the preliminary results, CSE Baird recommended further sampling to refine borrow areas A, B1, B2, and C. Sediment quality and compatibility for nourishment as reflected by R_As in each deposit served as a basis for preliminary project formulation (CSE Baird-Stroud, 1999).

E4.4 Phase II Core Samples

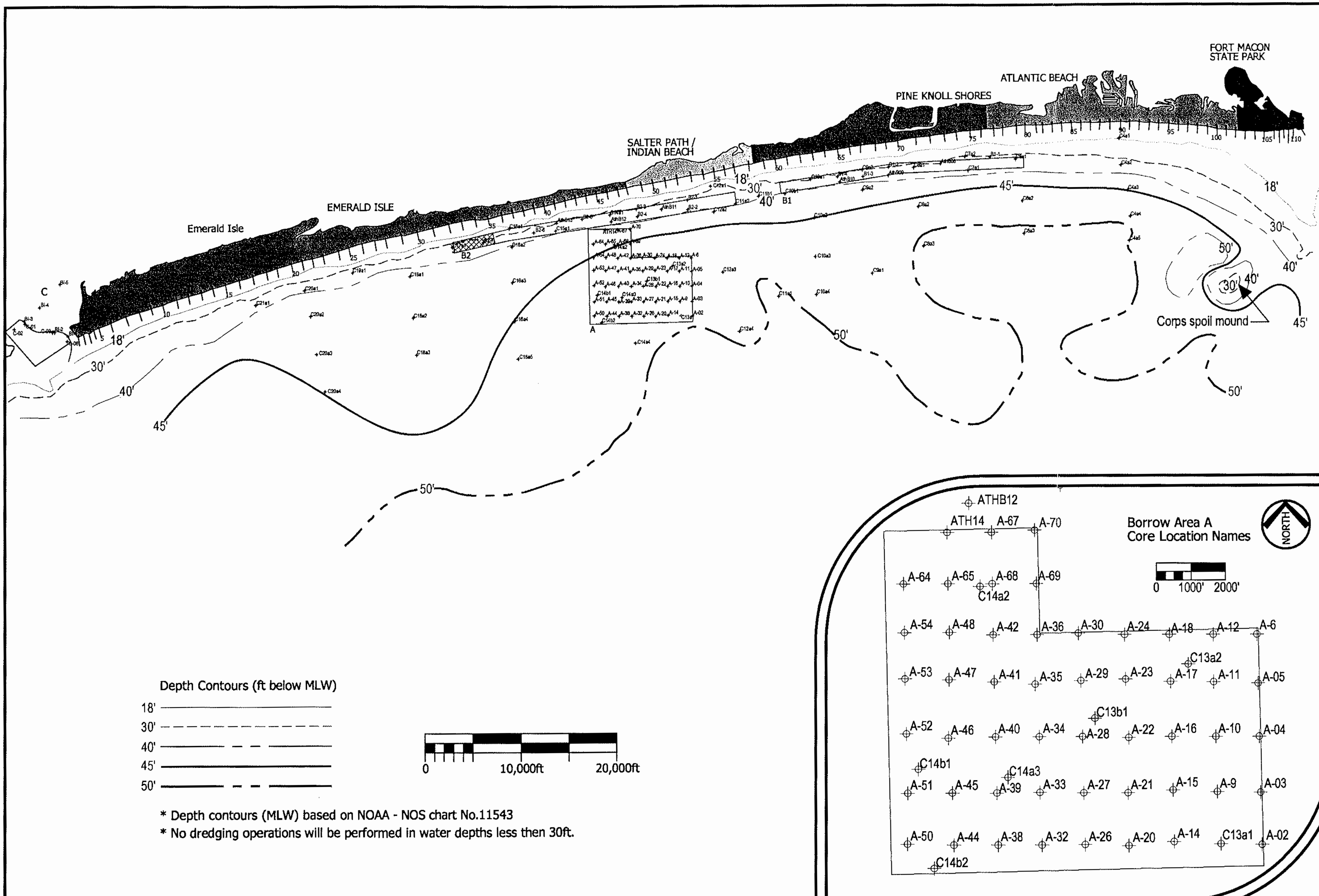
The Phase II sampling strategy consisted of establishing a grid of closely spaced samples over the most promising section of area A and filling in gaps along areas B1 and B2. Approximately 60 additional borings were made by CSE Baird divers, and 14 vibracores were obtained by subcontract to Athena Technologies, Inc. (c/o Dr. Walter J. Sexton, P.G.). The western half of borrow A was targeted because of its slightly coarser sediments than the eastern half. Prior to sampling, we prepared a 15-second grid which yielded sampling "nodes" spaced ~1200x1500 ft apart in the longshore and cross-shore directions, respectively. Revised borrow area A (target) is an L-shaped grid ~12,000x12,000 ft (Fig. E7). Typical water depth is 45-50 ft, and its closest edge to the shoreline is ~2500 ft offshore. Because not every node was sampled (or was sampled during Phase I or by Athena Technologies in Phase II), station (sample) numbering is not in continuous sequence.

Revised isopach maps of various sample parameters were prepared over the target borrow areas where data provided relatively dense coverage. Figures E8 through E12 show the following:

Figure E8	Mean grain size (mm)
Figure E9	Percent mud
Figure 10	Percent carbonate
Figure E11	Percent coarser than 2 mm
Figure E12	Confirmed thickness (ft) based on the recovery length of cores or sample interval (as noted)

Table E4. Sediment compatibility for nourishment based on RAs comparing native and borrow composites. Based on the method of James (1975).

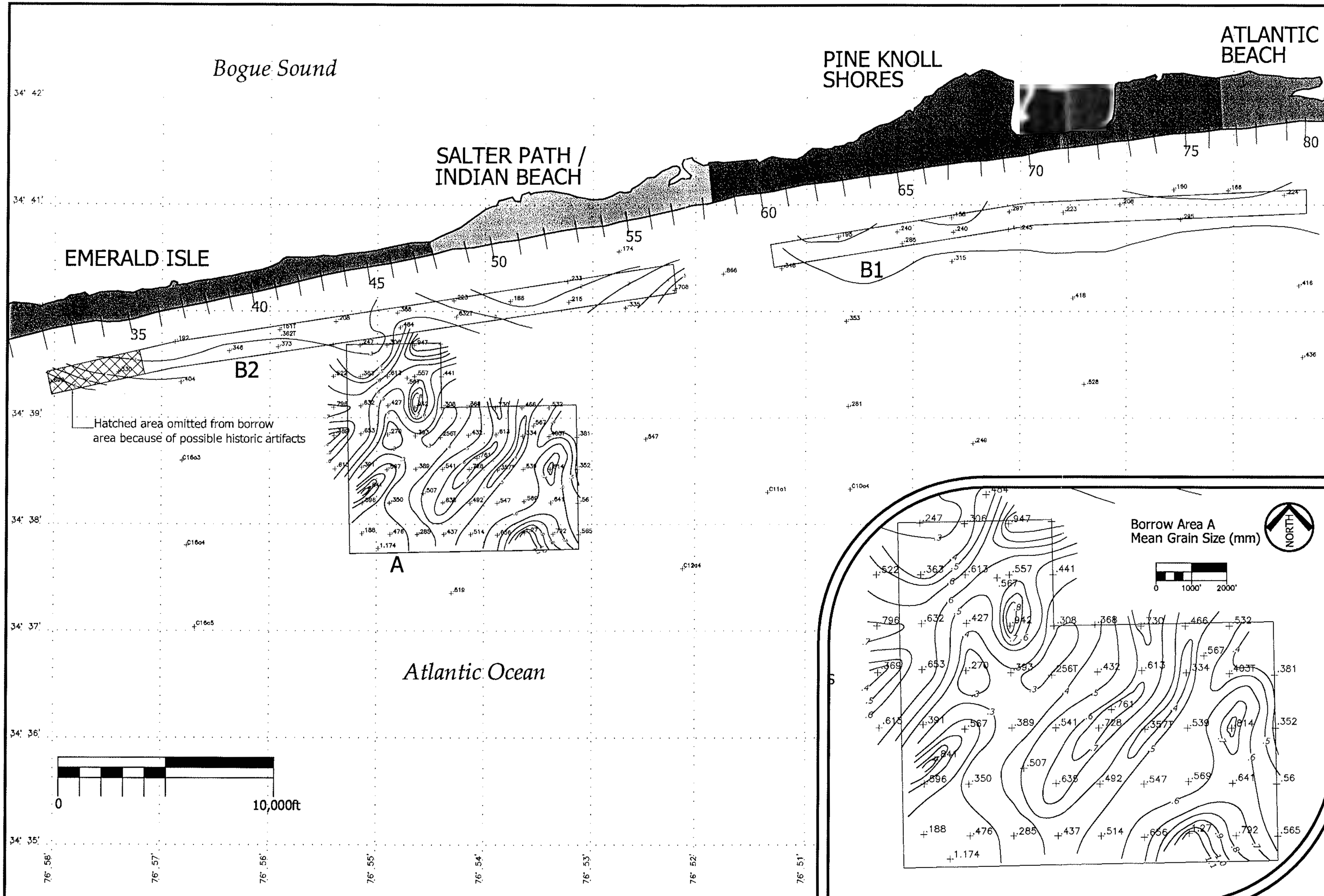
Bogue Banks			Sediment Compatibility						
		Potential Borrow Areas vs Overall Beach Composites (incl dune & LTT samples)							
	Note:	*Native Composite (20 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)*							
		Mean=1.725 phi (Mn)		*Std dev=0.773 phi (SDn)*		*Skewness=-0.648*		MS,mws,c-s	
		Mean=0.302 mm		*Std dev=.585 mm*		*Skewness=-0.648*			
									Overfill
Composite	# Samples	Type	Interval	Sediment	Moment Measures		X	Y	RA
			(feet)	Description*	M-phi-b	Sigma-b	(Mb-Mn)/SDn	(SDb/SDn)	(SPM '84)
Borrow A	12	Offshore	Top to ~-2.5	CS,ps,sym	.822	1.568	-1.17	2.03	**1.10**
Borrow B1	7	Inshore	Top to ~-2.5	FS,ps,sc-s	2.182	1.230	0.59	1.59	**1.62**
Borrow B2	4	Inshore	Top to ~-2.5	FS,ps,sc-s	2.263	1.081	0.70	1.40	**1.80**
Borrow C	6	Inlet	Top to ~-2.5	MS,ms,sc-s	1.738	.978	0.02	1.27	**1.15**
Bogue Sound	3	Lagoon	Top to ~-4	FS,ws,c-s	2.141	0.463	0.54	0.60	**>10**
Corps Spoil Island	4	Spoil	Top to -2	FS,ms,c-s	2.292	.903	0.73	1.17	**2.35**
Corps Spoil Island									
	**CS-Coarse Sand; MS-Medium Sand; FS-fine sand*								
	ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted								
	c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution								
		Potential Borrow Areas vs Berm & Beachface Composites							
	Note:	*Native Composite (12 Samples @ Berm, Beach Face)*							
		Mean=1.466 phi (Mn)		*Std dev=0.830 phi (SDn)*		*Skewness=-0.542*		MS,ms,c-s	
		Mean=0.362 mm		*Std dev=.563 mm*		*Skewness=-0.542*			
									Overfill
Composite	# Samples	Type	Interval	Sediment	Moment Measures		X	Y	RA
			(feet)	Description*	M-phi-b	Sigma-b	(Mb-Mn)/SDn	(SDb/SDn)	(SPM '84)
Borrow A	12	Offshore	Top to ~-2.5	CS,ps,sym	.822	1.568	-0.78	1.89	**1.13**
Borrow B1	7	Inshore	Top to ~-2.5	FS,ps,sc-s	2.182	1.230	0.86	1.48	**2.00**
Borrow B2	4	Inshore	Top to ~-2.5	FS,ps,sc-s	2.263	1.081	0.96	1.30	**2.75**
Borrow C	6	Inlet	Top to ~-2.5	MS,ms,sc-s	1.738	.978	0.33	1.18	**1.45**
Bogue Sound	3	Lagoon	Top to ~-4	FS,ws,c-s	2.141	0.463	0.81	0.56	**>10**
Corps Spoil Island	4	Spoil	Top to -2	FS,ms,c-s	2.292	.903	1.00	1.09	**4.20**



STROUD ENGINEERING

CSE Coastal Science & Engineering, LLC

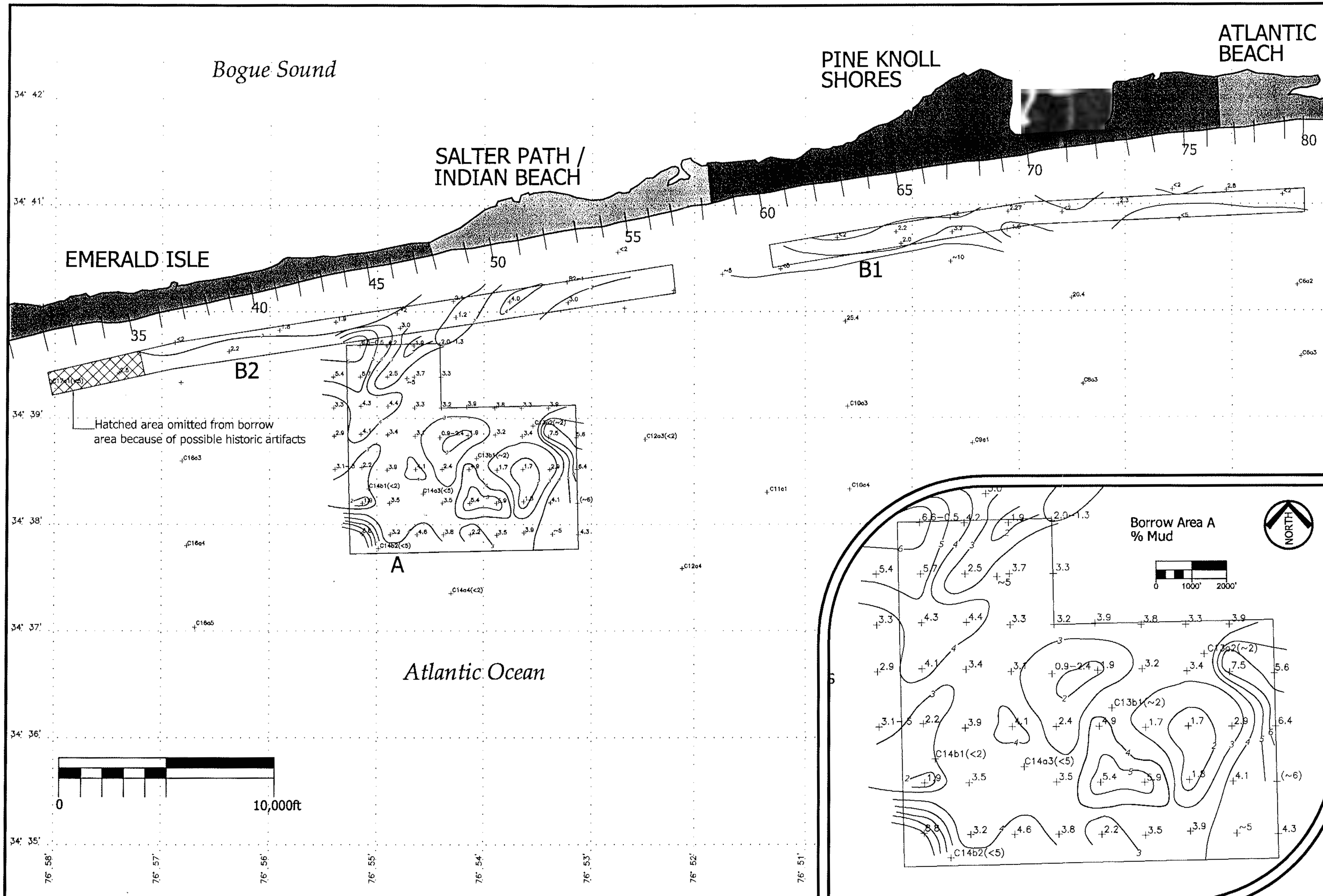
Figure E7
Core locations and target borrow areas - Phase I and Phase II



STROUD ENGINEERING

CSE
Coastal Science & Engineering, LLC

Figure E8
Mean grain size in potential borrow areas off Bogue Banks



STROUD ENGINEERING

CSE Coastal Science & Engineering, LLC

Figure E9
Percentage of mud in potential Borrow areas off Bogue Banks

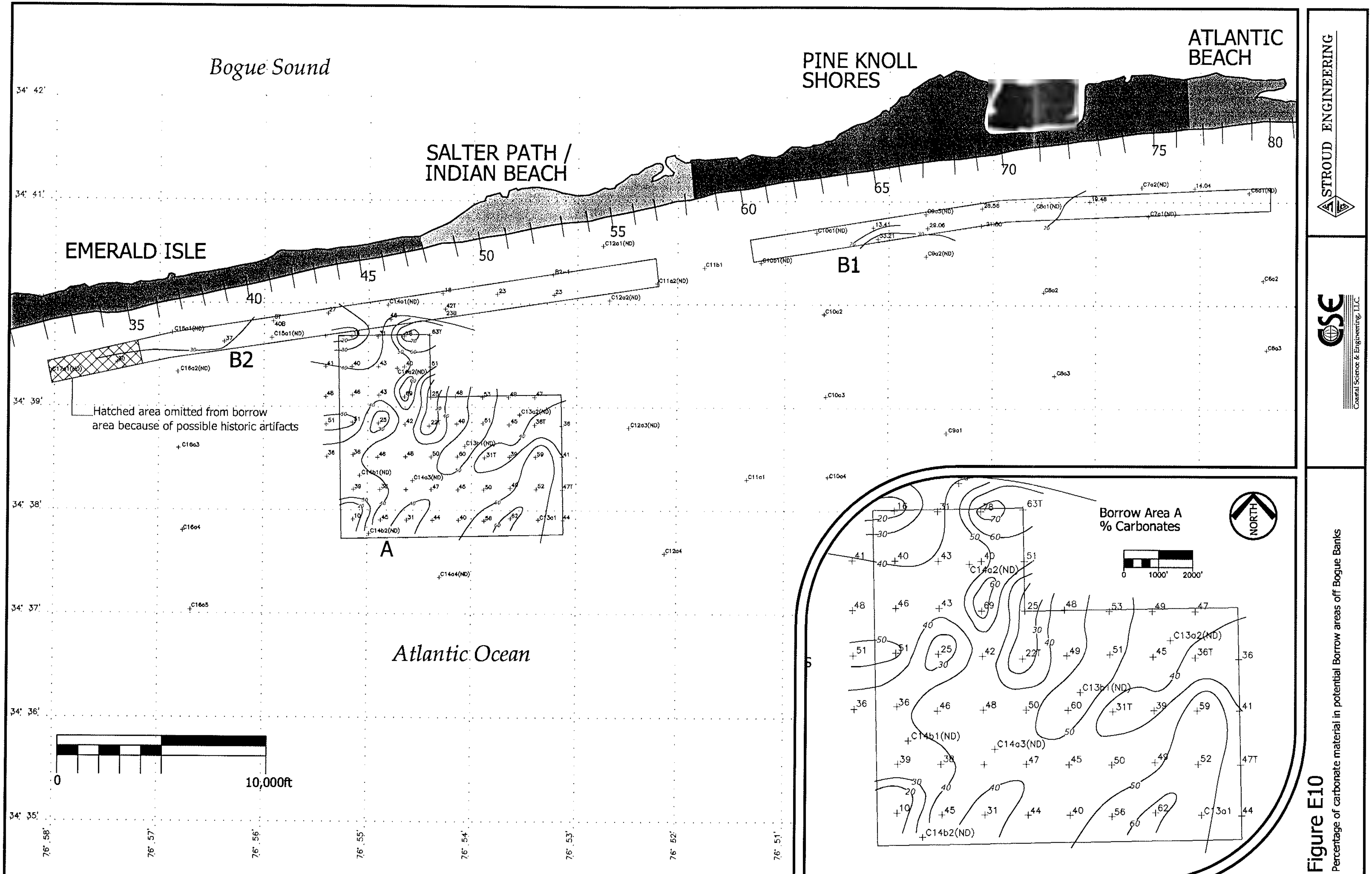
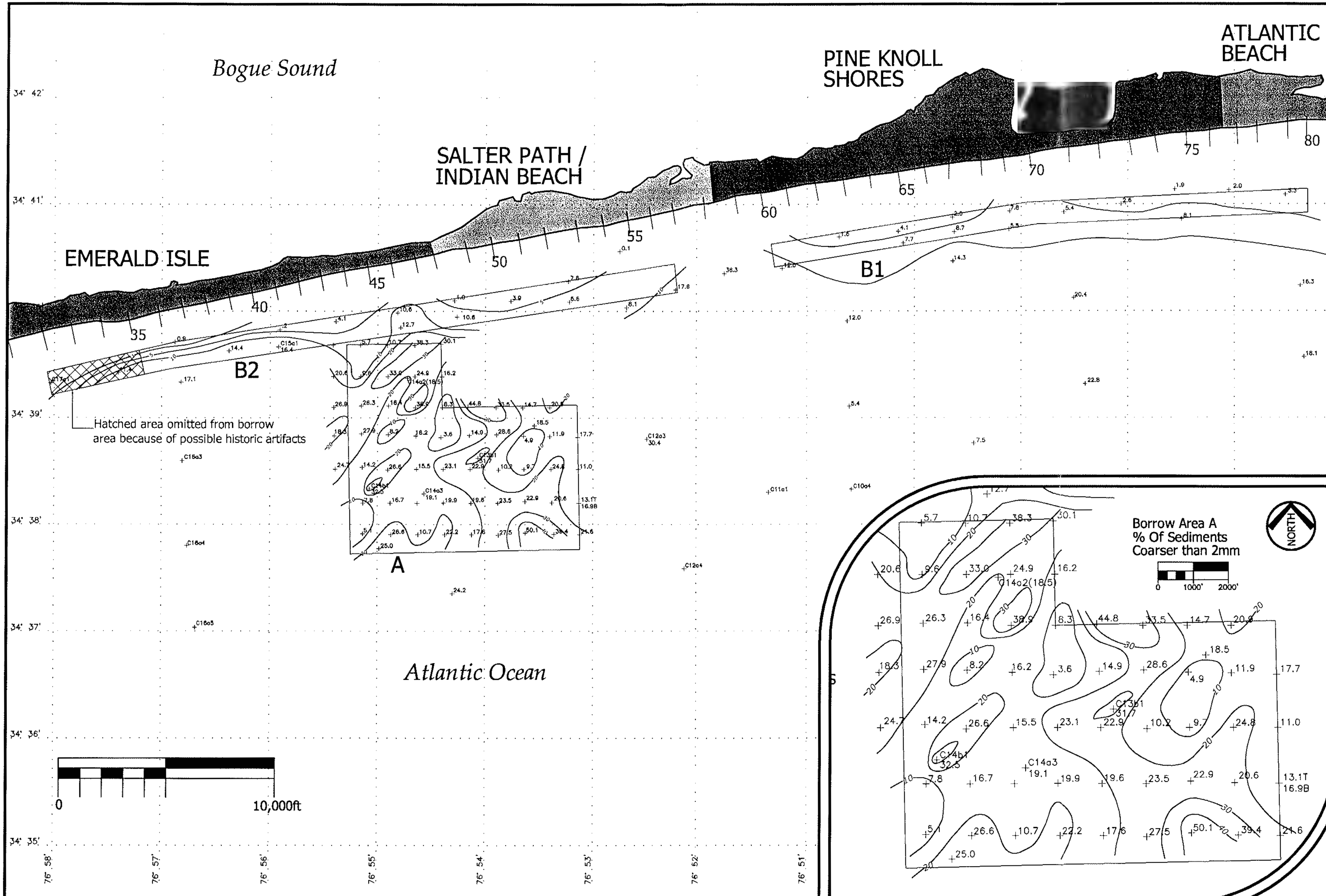


Figure E10
Percentage of carbonate material in potential Borrow areas off Bogue Banks



STROUD ENGINEERING

CSE Coastal Science & Engineering, LLC

Figure E11
Percentage of sediments coarser than 2mm diameter in borrow areas off Bogue Banks

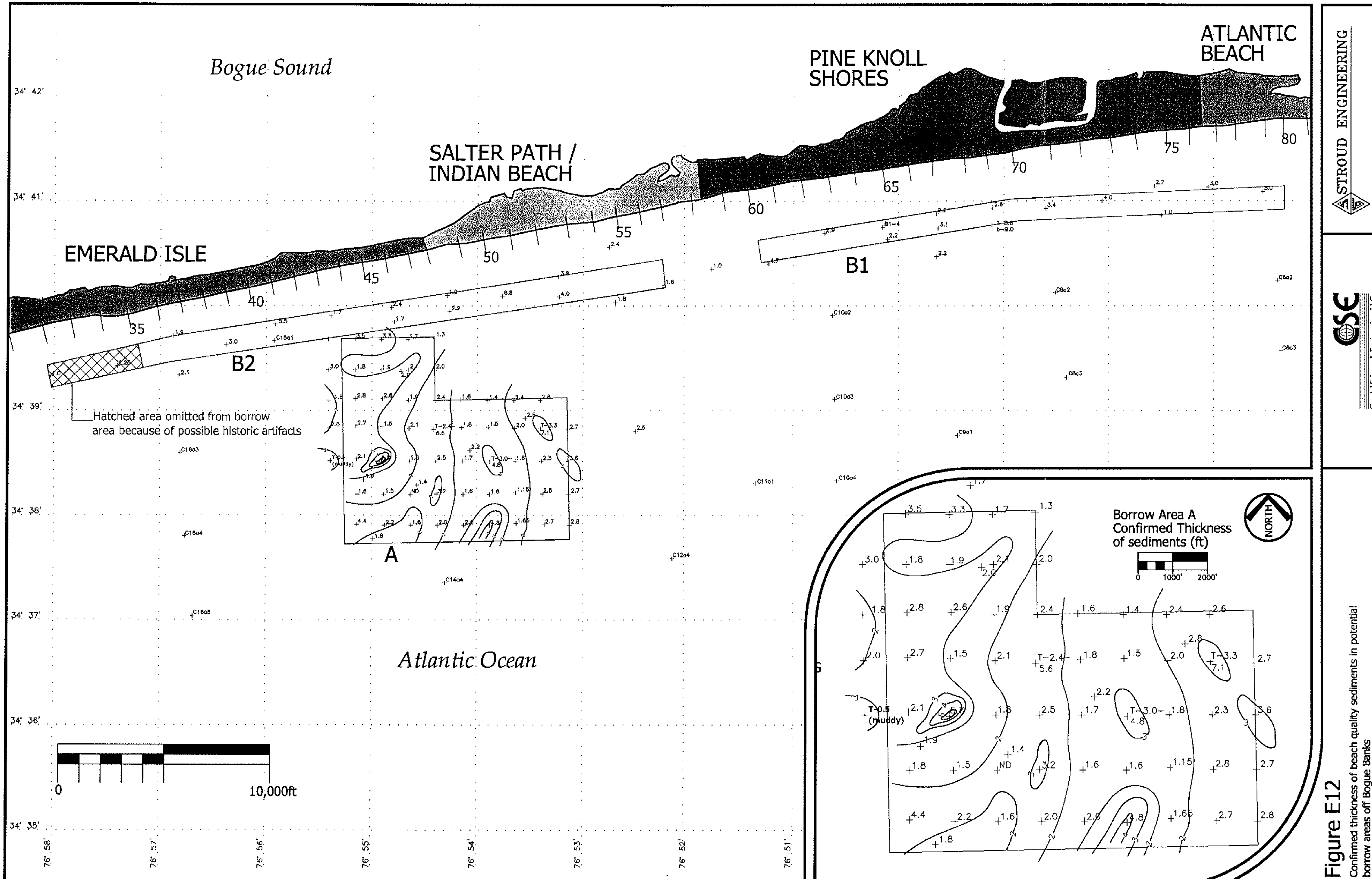


Figure E12
Confirmed thickness of beach quality sediments in potential borrow areas off Bogue Banks

Table E5 contains sediment compatibility calculations (R_As) for all samples (Phases I and II) compared against the beach 20 composite. (Note: Sample statistics for skewness, percent carbonate, and percent coarser than 2 mm are given in Annex E1 through Annex E3.) Two R_As were computed during Phase II—the first on washed samples (mud eliminated) and the second factoring in the mud percentage. In the latter, mud adds an incremental volume of nonbeach-compatible material which increases each R_A in direct proportion to the sample mud fraction. This "revised" R_A is given on the summary map in Figure E13 and used as a basis for developing isopachs of sediment compatibility. Note that in some of the figures, nonlinear isopach spacing is used to simplify the graphic.

Table E6 summarizes the results for each borrow area and provides nonweighted averages for key sediment parameters. All values are approximate because percent mud for June samples was visually estimated. Nevertheless, the results reflect the typical character of sediments in each borrow area. During Phase II, the boundaries for borrow area A were revised to a much smaller area, and the boundaries for B1 and B2 were shifted to fit the sample distribution and to stay within the 30-40 ft depth contour.

The revised borrow areas yield revised R_As (factoring in mud percentage) of 1.16 at borrow area A, 1.57 at borrow area C, 1.97 at borrow area B1, and 2.19 at borrow area B2. Overall, borrow area A (revised) provides the deposit likely to perform the best for nourishment because its sediments are slightly coarser than the native beach. Carbonate material (mostly broken or crushed shell) comprises about 44 percent of the sediment in the confirmed section (versus 15-20 percent on the existing beach) and about 20 percent of the deposit is coarser than 2.0 mm. Mud percentage in borrow area A averaged ~4 percent in the applicable sections.

Borrow area C had the next lowest average R_A at 1.57, meaning ~35 percent more material would have to be placed to yield the same performance as borrow area A. Area B2, while averaging close to the native beach in mean grain size (composite 20), has areas of poor-quality material. As noted in Table E7, certain samples were omitted from the statistics under the assumption that these areas would not be dredged. Other sections of the EIS for the project provide refined borrow area criteria and suggest revisions in the areas to avoid marginal sections. The confirmed borrow volumes indicate borrow area A alone could potentially provide sufficient quantities for the present project. Similarly, borrow areas B1 and B2 could provide sufficient volumes, although 70-90 percent more sand would have to be pumped compared to borrow area A to yield comparable performance. Borrow area C is not sufficient by itself to provide the necessary project volume but could serve to supplement borrow areas A, B1, and B2. Further considerations addressed elsewhere in the EIS are the economics of borrowing from multiple areas based on proximity to the project sections.

Table E5. Potential Borrow Area Sediment Quality and Compatibility Factors (RA).

Bogue Banks		Sediment Compatibility								Prepared January 2000		
		Individual Samples vs Overall Beach Composites (incl dune & LTT samples)										
	Note:	*Native Composite (20 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)*										
		Mean=1.725 phi (Mn)		*Std dev=0.773 phi (SDn)*				*Skewness=-0.648*		MS,mws,c-s		
		Mean=0.302 mm		*Std dev=.585 mm*				*Skewness=-0.648*				
											Overfill	**Revised**
Borrow Area	**Sample ID**	**Type**	Recovery	**Interval**	**Sediment**	**% Mud**	**Moment Measures**		**X**	**Y**	RA	**Overfill**
			Length(ft)	(feet)	**Description****	to indicated	M-phi-b	Sigma-b	(Mb-Mn)/SDn	(SDb/SDn)	(SPM '84)	incl/ mud %
A						samp interval						
Preliminary	10A-4	Core	2.5	0-2.5	MS,ps,sc-s	~5	1.717	1.125	-0.01	1.46	**1.20**	**~1.25**
Jun-99	11A-1	Core	3.0	0-3.0	CS,ps,sym	<5	0.761	1.662	-1.25	2.15	**1.10**	**~1.13**
Samples	12A-3	Core	2.5	0-2.5	CS,ps,sym	<2	0.871	1.707	-1.10	2.21	**1.14**	**~1.15**
•	13A-2	Core	2.7	0-2.7	CS,ps,sym	~2	0.819	1.501	-1.17	1.94	**1.08**	**~1.10**
	13A-1	Core	2.7	0-2.7	CS,ps,sf-s	~5	0.337	1.554	-1.80	2.01	**1.04**	**~1.09**
	13B-1	Core	1.9	0-1.9	CS,ps,f-s	~2	0.394	1.396	-1.72	1.81	**1.02**	**~1.04**
	14A-2	Core	2.0	0-2.0	CS,ps,sym	~5	0.819	1.501	-1.17	1.94	**1.08**	**~1.13**
	14A-3	Core	2.3	0-2.3	CS,ps,c-s	<5	0.979	1.518	-0.97	1.96	**1.11**	**~1.15**
	14A-4	Core	1.6	0-1.6	CS,ps,c-s	<2	0.945	1.627	-1.01	2.10	**1.13**	**~1.14**
	14B-1	Core	1.9	0-1.9	CS,ps,sf-s	<2	0.244	1.338	-1.92	1.73	**<1.02**	**~1.02**
	14B-2a	Core	2.4	0-1.8	MS,ps,sc-s	<5	1.161	1.645	-0.73	2.13	**1.18**	**~1.15***
	14B-2b	Core		1.8-2.4	VCS,vws,c-s	<5	-0.927	0.166	-3.43	0.21	**<<1.02**	**composite*
A	A-02	Core	2.8	2.8	CS,ps,sym	4.3	0.824	1.497	-1.17	1.94	**1.09**	1.13
Supplementary	A-03s1	Core	2.7	0-1.0	CS,ps,c-s	<1	0.852	1.235	-1.13	1.60	**1.03**	1.04
	A-03s2	Core		1.0-2.7	CS,ps,f-s	21.5	0.814	1.465	-1.18	1.90	**1.08**	1.29
Nov-99	A-04	Core	3.6	3.6	MS,ps,sc-s	6.4	1.506	1.416	-0.28	1.83	**1.21**	1.27
Samples	A-05	Core	2.7	2.7	MS,ps,sc-s	5.6	1.392	1.554	-0.43	2.01	**1.22**	1.28
	A-09	Core	2.8	2.8	CS,ps,sym	4.1	0.641	1.390	-1.40	1.80	**1.04**	1.08
	A-10	Core	2.3	2.3	CS,ps,f-s	2.9	0.297	1.224	-1.85	1.58	**<1.02**	1.03
	A-11s-1	Core	7.1	0-3.3	MS,ps,sc-s	7.5	1.312	1.407	-0.53	1.82	**1.15**	1.22
	A-11s-2	Core		3.3-7.1	CS,ps,sym	3.0	0.660	1.543	-1.38	2.00	**1.07**	1.10
	A-12	Core	2.6	2.6	CS,ps,c-s	3.9	0.911	1.506	-1.05	1.95	**1.10**	1.14
	A-14	Core	1.7	1.7	CS,ps,sf-s	3.9	-0.172	1.233	-2.45	1.60	**<1.02**	1.04
	A-15	Core	1.2	1.2	CS,ps,sym	1.8	0.813	1.480	-1.18	1.91	**1.08**	1.10
	A-16	Core	1.8	1.8	CS,ps,c-s	1.7	0.892	1.128	-1.08	1.46	**1.02**	1.04
	A-17	Core	2.0	2.0	MS,ps,sc-s	3.4	1.584	1.201	-0.18	1.55	**1.16**	1.19
	A-18	Core	2.4	2.4	MS,ps,c-s	3.3	1.103	1.439	-0.80	1.86	**1.12**	1.15
•	A-20	Core	8.8	0-4.8	CS,ps,f-s	3.5	0.608	1.504	-1.45	1.95	**1.05**	1.09
	A-21	Core	1.6	1.6	CS,ps,c-s	5.9	0.871	1.527	-1.10	1.98	**1.09**	1.15
	A-22s-1	Core	5.8	0-3.0	MS,ps,sc-s	1.7	1.488	1.337	-0.31	1.73	**1.18**	1.20
•	A-22s-2	Core		3.0-4.8	CS,ps,sf-s	2.9	0.291	1.489	-1.86	1.93	**1.03**	1.06
	A-23	Core	1.5	1.5	CS,ps,sym	3.2	0.705	1.539	-1.32	1.99	**1.07**	1.10
	A-24	Core	1.4	1.4	CS,ps,sf-s	3.8	0.454	1.551	-1.64	2.01	**1.04**	1.08

Table E5 (con't)

Table E5. Potential Borrow Area Sediment Quality and Compatibility Factors (RA).

	A-26	Core	2.0	2.0	CS,ps,c-s	2.2	0.961	1.380	-0.99	1.79	**1.08**	**1.10**
	A-27	Core	1.6	1.6	CS,ps,c-s	5.4	1.022	1.497	-0.91	1.94	**1.11**	**1.16**
	A-28	Core	1.8	1.8	CS,ps,f-s	4.9	0.457	1.308	-1.64	1.69	**1.02**	**1.07**
	A-29	Core	1.8	1.8	MS,ps,sc-s	2.0	1.212	1.410	-0.66	1.82	**1.13**	**1.15**
	A-30	Core	1.6	1.6	CS,ps,sf-s	3.9	0.103	1.441	-2.10	1.86	**1.02**	**1.06**
	A-32	Core	2.0	2.0	MS,ps,sc-s	3.8	1.194	1.615	-0.69	2.09	**1.18**	**1.22**
	A-33	Core	3.2	3.2	CS,ps,sym	3.4	0.655	1.330	-1.38	1.72	**1.04**	**1.07**
	A-34	Core	2.5	2.5	CS,ps,c-s	2.4	0.887	1.501	-1.08	1.94	**1.09**	**1.11**
	A-35s-1	Core	5.6	0-2.4	FS,ms,sc-s	0.9	1.964	0.999	0.31	1.29	**1.35**	**1.36**
	A-35s-2	Core		2.4-5.6	CS,ps,f-s	3.6	0.512	1.508	-1.57	1.95	**1.04**	**1.08**
	A-36	Core	2.4	2.4	MS,ps,sc-s	3.2	1.701	1.244	-0.03	1.61	**1.30**	**1.33**
	A-38	Core	1.6	1.6	MS,ps,sc-s	4.6	1.813	1.377	0.11	1.78	**1.34**	**1.39**
	A-40	Core	1.8	1.8	MS,ps,sc-s	4.1	1.361	1.519	-0.47	1.97	**1.20**	**1.24**
	A-41	Core	2.1	2.1	MS,ps,sc-s	3.0	1.349	1.484	-0.49	1.92	**1.19**	**1.22**
	A-42	Core	1.9	1.9	CS,ps,sf-s	3.3	0.086	1.329	-2.12	1.72	**<1.02**	**1.03**
	A-44	Core	2.2	2.2	MS,ps,sc-s	3.2	1.070	1.682	-0.85	2.18	**1.17**	**1.20**
	A-45	Core	1.5	1.5	MS,ps,sc-s	3.5	1.515	1.569	-0.27	2.03	**1.27**	**1.30**
	A-46	Core	5.7	5.7	CS,ps,sym	3.9	0.819	1.603	-1.17	2.07	**1.10**	**1.14**
	A-47	Core	1.5	1.5	MS,ps,sc-s	3.4	1.889	1.283	0.21	1.66	**1.35**	**1.38**
	A-48	Core	2.6	2.6	MS,ps,sc-s	4.4	1.228	1.547	-0.64	2.00	**1.17**	**1.21**
*	A-50	Core	4.4	0-3.0	FS,ms,sc-s	8.8	2.413	1.160	0.89	1.50	**1.03**	**1.12**
*	A-51	Core	1.8	0-1.3	CS,ps,c-s	1.9	0.746	1.499	-1.27	1.94	**1.07**	**1.09**
	A-52	Core	2.1	2.1	MS,ps,sc-s	2.2	1.355	1.461	-0.48	1.89	**1.18**	**1.20**
	A-53	Core	2.7	2.7	CS,ps,f-s	4.1	0.614	1.545	-1.44	2.00	**1.06**	**1.10**
	A-54	Core	2.8	2.8	CS,ps,f-s	4.3	0.662	1.560	-1.38	2.02	**1.07**	**1.11**
*	A-58	Core	4.1	0.0-.5;2-4.1	CS,ps,sym	~23	0.701	1.491	-1.32	1.93	**1.06**	**~1.30**
	A-59	Core	2.0	2.0	MS,ps,sc-s	3.0	1.437	1.552	-0.37	2.01	**1.23**	**1.26**
	A-60	Core	1.8	1.8	CS,ps,sym	3.3	0.330	1.201	-1.80	1.55	**<<1.02**	**1.03**
*	A-61	Core	3.0	0-2.5	CS,ps,c-s	5.4	0.937	1.515	-1.02	1.96	**1.10**	**1.15**
*	A-63	Core	3.5	0-.5	FS,ps,sc-s	6.6	2.020	1.269	0.38	1.64	**1.47**	**1.54**
	A-64	Core	1.8	1.8	MS,ps,sc-s	5.7	1.462	1.393	-0.34	1.80	**1.20**	**1.26**
	A-65	Core	1.9	1.9	CS,ps,f-s	2.5	0.706	1.649	-1.32	2.13	**1.09**	**1.12**
	A-66	Core	3.3	3.3	MS,ps,sc-s	4.2	1.707	1.509	-0.02	1.95	**1.33**	**1.37**
	A-67	Core	1.7	1.7	CS,ps,sf-s	1.9	0.078	1.315	-2.13	1.70	**<<1.02**	**1.02**
	A-68	Core	2.1	2.1	CS,ps,sym	3.7	0.845	1.581	-1.14	2.05	**1.10**	**1.14**
	A-69	Core	2.0	2.0	MS,ps,sc-s	3.3	1.182	1.428	-0.70	1.85	**1.13**	**1.16**
	A-70T	Core	2.8	0-1.25	VCS,ps,f-s	2.0	0.000	1.056	-2.23	1.37	**<<1.02**	**1.02**
	A-70B	Core		2.05-2.8	CS,ps,f-s	~30	0.481	1.367	-1.61	1.77	**1.02**	**~1.30**
B1	6A-1	Core	2.9	0-2.9	FS,ps,sc-s	<2	2.157	1.077	0.56	1.39	**1.62**	~1.64
Preliminary	7A-2	Core	2.8	0-2.8	FS,mws,c-s	<2	2.648	0.829	1.19	1.07	**7.00**	~7.02
Jun-99	7A-1	Core	1.0	0-1.0	MS,ps,sc-s	<5	1.761	1.442	0.05	1.87	**1.34**	~1.39
Samples	8A-1	Core	3.4	0-3.4	FS,ps,sc-s	<2	2.165	1.209	0.57	1.56	**1.60**	~1.62

Table E5. Potential Borrow Area Sediment Quality and Compatibility Factors (RA).

	9A-3	Core	2.3	0-2.3	FS,mws,c-s	<2	2.660	.830	1.21	1.07	6.50	~6.52
	10A-1	Core	2.9	0-2.9	FS,ms,sc-s	<2	2.355	1.018	0.82	1.32	2.20	~2.22
*	10B-1	Core	4.7	0-3.6	MS,ps,sc-s	<5	1.522	1.537	-0.26	1.99	1.26	~1.26
B1	B1-1	Core	2.9	2.9	FS,mws,c-s	2.8	2.594	0.894	1.12	1.16	4.50	4.53
Supplementary	B1-2	Core	2.6	2.6	MS,ps,sc-s	2.3	1.753	1.326	0.04	1.72	1.30	1.32
Nov-99	B1-3	Core	3.1	3.1	FS,ps,sc-s	3.2	2.058	1.349	0.43	1.75	1.50	1.53
Samples	B1-4	Core	2.5	2.5	FS,ps,sc-s	2.2	2.233	1.144	0.66	1.48	1.75	1.77
*	ATHB08	Core	11.2	0-4.0	FS,ps,sc-s	2.2	2.262	1.066	0.69	1.38	1.80	1.82
	ATH-9s1	Core	9.0	0-3.8	FS,ps,sc-s	1.6	2.03	1.284	0.39	1.66	1.48	1.50
	ATH-9s2	Core	2.9	3.8-9	FS,mws,c-s	0.9	2.711	0.734	1.28	0.95	>10	>10
	ATHB10	Core	7.5	0-2.2	MS,ps,sc-s	2.0	1.813	1.402	0.11	1.81	1.34	1.36
B2	11A-2	Core	1.6	0-1.6	CS,ps,c-s	~10	0.498	1.098	-1.59	1.42	<1.02	~1.10
Preliminary	12A-1	Core	3.1	0-3.1	FS,mws,c-s	<2	2.523	.662	1.03	0.86	10.00	~10
Jun-99	12A-2	Core	1.8	0-1.8	MS-ps,sc-s	~10	1.577	1.438	-0.19	1.86	1.25	~1.35
Samples	14A-1	Core	2.4	0-2.4	MS,ps,c-s	~2	1.367	1.438	-0.46	1.86	1.18	~1.2
	15A-1	Core	2.0	0-2.0	MS,ps,sc-s	~10	1.422	1.626	-0.39	2.10	1.25	~1.35
	16A-1	Core	1.9	0-1.9	FS,mws,sc-s	<2	2.378	.833	0.84	1.08	3.70	~3.72
	17A-1	Core	1.0	0-1.0	FS,ws,sym	<5	2.807	.523	1.40	0.68	>10.0	>10
B2	B2-1	Core	3.7	3.7	FS,ps,sc-s	8.7	2.099	1.347	0.48	1.74	1.15	1.24
Supplementary	B2-2	Core	4.0	4.0	FS,ps,sc-s	3.0	2.216	1.312	0.64	1.70	1.11	1.14
Nov-99	B2-3	Core	1.9	0-1.9	FS,ps,sc-s	2.1	2.101	1.068	0.49	1.38	1.05	1.07
Samples	B-2-4s1	Core	2.2	0-0.9	CS,ps,c-s	1.2	.661	.992	-1.38	1.28	<<1.02	1.01
	B-2-4s2	Core		.9-2.2	MS,ps,sc-s	3.4	1.866	1.416	0.18	1.83	1.38	1.41
	B2-5	Core	1.8	1.8	FS,ps,sc-s	1.9	2.264	1.214	0.70	1.57	1.75	1.77
	B2-6	Core	3.1	3.1	MS,ps,sc-s	2.2	1.532	1.552	-0.25	2.01	1.27	1.29
	B2-7	Core	2.3	2.3	MS,ps,sc-s	2.5	1.598	1.470	-0.16	1.90	1.27	1.30
*	ATHB11	Core	10.0	0-6.8	FS,ps,sc-s	4.1	2.423	1.168	0.90	1.51	2.05	2.09
*	ATHB12	Core	10.2	0-1.7	CS,ps,c-s	3.0	1.047	1.322	-0.88	1.71	1.07	1.10
*	ATH13s1	Core	9.6	0-2.0	FS,ws,sym	1.8	2.727	.539	1.30	0.70	>10	>10
*	ATH13s2	Core		2.0-5.6	MS,ps,sc-s	2.5	1.618	1.504	-0.14	1.95	1.28	1.30
											Overfill	
Borrow Area	Sample ID	Type		Interval	Sediment		Moment Measures		X	Y	RA	
				(feet)	Description*		M-phi-b	Sigma-b	(Mb-Mn)/SDn	(SDb/SDn)	(SPM '84)	
C	BI-2	Grab		upper 0-5 ft	CS,ms,c-s	0	.269	.837	-1.88	1.08	<<1.02	<1.02
Preliminary	BI-3A	Grab		upper 0-5 ft	FS,mws,c-s	0	2.001	.521	0.36	0.67	4.10	4.10
Jun-99	BI-3B	Grab		upper 0-5 ft	FS,ms,sym	0	1.276	.953	-0.58	1.23	1.02	1.02
Samples	BI-3C	Grab		upper 0-5 ft	FS,ws,c-s	0	2.217	.571	0.64	0.74	6.70	6.70
	BI-4A	Grab		upper 0-5 ft	FS,vws,sym	0	2.484	.274	0.98	0.35	>>10	>>10
	BI-4B	Grab		upper 0-5 ft	FS,vws,sym	0	2.358	.367	0.82	0.47	>>10	>>10

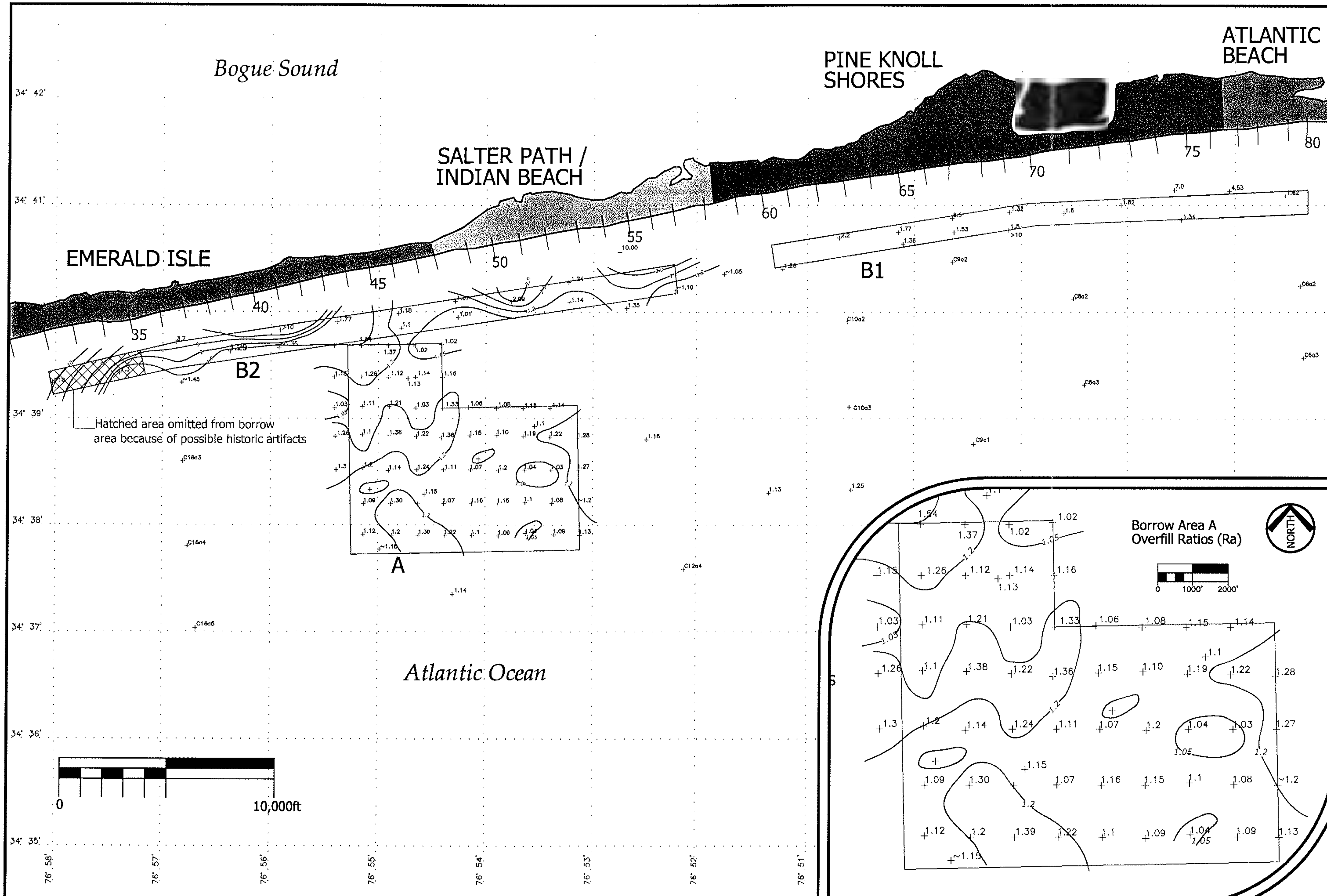
Table ʳ⁻ ʼᵔon't)

Table E5. Potential Borrow Area Sediment Quality and Compatibility Factors (RA).

B1 -	C-01	Grab/Hole		upper 0-5 ft	MS,mws,sc-s	0	1.857	.747	0.17	0.97	1.25	1.25
Supplementary	C-02	Grab/Hole		upper 0-5 ft	FS,mws,sc-s	0	1.946	.629	0.29	0.81	2.00	2.00
Nov-99	C-03	Grab/Hole		upper 0-5 ft	CS,ps,c-s	0	.356	1.025	-1.77	1.33	< < 1.02	< < 1.02
Samples	C-04	Grab/Hole		upper 0-5 ft	CS,ps,c-s	0	.568	.994	-1.50	1.29	< 1.02	< 1.02
	C-05	Grab/Hole		upper 0-5 ft	MS,mws,sc-s	0	1.769	.803	0.06	1.04	1.10	1.10
	C-06	Grab/Hole		upper 0-5 ft	FS,vws,sym	0	2.417	.297	0.90	0.38	> > 10	> > 10
Bogue Sound	BS1	Grab		upper 2 ft	FS,vws,sym		2.346	.356	0.80	0.46	> > 10.0	> 10
	BS2	Grab		upper 2 ft	FS,vws,c-s		2.049	.440	0.42	0.57	> 10.0	> 10
	BS3	Grab		upper 2 ft	FS,ws,c-s		2.078	.510	0.46	0.66	5.50	5.50
Corps Disposal	BD1	Grab		upper 2 ft	MS,cs,c-s		1.204	1.117	-0.67	1.45	1.04	1.04
	BD2	Grab		upper 2 ft	FS,ws,sym		2.607	.451	1.14	0.58	> > 10.0	> > 10.0
	BD3	Grab		upper 2 ft	FS,ws,sym		2.672	.413	1.23	0.53	> > 10.0	> > 10.0
	BD4	Grab		upper 2 ft	FS,ws,sym		2.597	.500	1.13	0.65	> 10.0	> 10.1

***CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution

** These samples have a limiting acceptable depth for excavation based on recovered cores*
(ie. Underlying material is considered less suitable for nourishment).



STROUD ENGINEERING

CSE Coastal Science & Engineering, LLC

Figure E13
Borrow area sediment capability based on revised overfill factors Ra (including mud%)

Table E6. Summary RAs and representative statistics for revised borrow areas A, B1, B2 & C.
Based on Phase II samples plus applicable Phase I samples.
See Figure E7 for Phase II revised Borrow Area Delineations.

Borrow Area	**# Samples**	**Mean Grain Size** (mm)	**Mean Grain Size** (phi)	**%mud**	**RAs** revised
A	61	0.51	0.974	4.0	**1.16**
B1	13	0.23	2.105	2.6	**2.19**
B2	17	0.30	1.729	4.1	**1.97**
C	8	0.42	1.255	<1	**1.57**
Native Beach	20	0.302	1.725	<1	**1**

Borrow Area	**Area** Acres	**%carbonate**	**% >2mm**	Confirmed **Thickness** (Ft)	Confirmed **Borrow Volume** (Cubic Yards)
A	2850	~44	~20.5	2.2	10+ million
B1	645	~20	~4.5	2.9	~3 million
B2	760	~22	~7.5	2.8	3+ million
C	370	ND	~5	~5	~3 million
Native Beach		~15-20	~5	NA	

Notes: Phase I & II samples omitted from the above statistics because they are outside the revised borrow area or represent sections below the confirmed thickness.
Area A: C10A4, C11A1, C12A3, C14B2b (lower unit below 1.8 ft), A-11s2 (lower unit below 3.3 ft), A-22s2 (lower unit below 3.0 ft), A-35s2 (lower unit below 2.4 ft), A-58, A-70B (below 1.25 ft).
Area B1: C7A2, ATH 9s2 (lower unit below 3.8 ft).
Area B2: C12A2, C17A1
Area C: Sample BI-4A, BI-4B, BI-3C, C-06

The confirmed borrow volume represents the potential maximum volume of material that could be obtained from the indicated borrow areas. In actuality, shallower cuts over a more select area will be planned during final design, with the idea of optimizing the area for best fill performance, and lowest cost of dredging. The final borrow areas will be revised to avoid any cultural artifacts, or unique biological habitats identified in other sections of the present EIS.

APPENDIX E5. REFERENCES CITED

CERC. 1984. *Shore Protection Manual.* 4th Edition, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Vir.; U.S. Government Printing Office, Washington, D.C., 2 vols.

CSE Baird/Stroud. 1999. Shoreline assessment and preliminary beach restoration plan: Bogue Banks. Executive Summary Report, 38 pp.

Dean, R.G. 1991. Equilibrium beach profiles: characteristics and applications. Jour. Coastal Research, Vol. 7(1), pp. 53-84.

Fisher, J.J. 1962. Geomorphic expression of former inlets along the Outer Banks of North Carolina. M.S. Thesis, Univ. North Carolina, Chapel Hill, 120 pp.

Folk, R.L., and W.C. Ward. 1957. Brazos River bar: a study in significance of grain-size parameters. Jour. Sed. Petrology, Vol. 27, pp. 3-26.

Heron, S.D., T.F. Moslow, W.M. Berelson, J.R. Herbert, G.A. Steele, and K.R. Susman. 1984. Holocene sedimentation of a wave-dominated barrier-island shoreline: Cape Lookout, North Carolina. *Marine Geology*, Vol. 60, pp. 413-434.

Hine, A.C., and S.W. Snyder. 1985. Coastal lithosome preservation: evidence form the shoreface and inner continental shelf off Bogue Banks, North Carolina. *Marine Geology*, Vol. 63, pp. 307-330.

Inman, D.L.. 1952. Measures for describing the size distribution of sediments. Jour. Sed. Petrology, Vol. 22, pp. 125-145.

James, W.R. 1975. Techniques in evaluating suitability of borrow material for beach nourishment. Rept. No. TM-60, CERC, U.S. Army Waterways Experiment Station, Vicksburg, Miss.

Jutte, P.C., R.F. Van Dolah, and M.V. Levisen. 1999a. An environmental monitoring study of the Myrtle Beach renourishment project: interitdal benthic community assessment — Phase II, Myrtle Beach. Final Report, SC Dept. Natural Resources, Charleston, 34 pp. + app.

Jutte, P.C., et al. 1999b. An environmental monitoring study of the Myrtle Beach renourishment project: physical and biological assessment of offshore sand borrow sites: Phase I, Cherry Grove borrow area. Final Report, SC Dept. Natural Resrouces, Charleston, 79 pp. + app.

Kana, T.W., and R.K. Mohan. 1998. Analysis of nourished profile stability following the fifth Hunting Island (SC) beach nourishment project. Jour. Coastal Engineering, Vol. 33, pp. 117-136.

NAS. 1995. *Beach Nourishment and Protection.* Committee on Beach Nourishment and Protection, Marine Board, Commission on Engineering and Technical Systems, National Research Council; National Academy Press, National Academy of Sciences, Washington, DC, 334 pp.

USACE. 1976. General design memorandum: Morehead City Harbor, North Carolina. Wilmington District, USACE, 41 pp. + app.

ANNEX E-1

Bogue Banks, North Carolina 1999 Core Locations

Date	Station Grid Node	Latitude DDMMSS.sss	Longitude DDMMSS.sss	NORTH Nad 83 (Y ft.)	EAST Nad 83 (X ft.)	Equivalent Station
8-Nov-99	A-02	343844.996	765314.962	332797.1391	2635325.2657	
8-Nov-99	A-03	343900.042	765314.962	334317.8248	2635292.9003	
8-Nov-99	A-04	343914.981	765314.962	335827.6936	2635260.7644	
8-Nov-99	A-05	343930.026	765314.962	337348.2776	2635228.4022	
	A-08	See below for coordinates @ C13a1				C13a1
8-Nov-99	A-09	343900.256	765329.967	334312.8051	2634039.1831	ATH-01
4-Nov-99	A-10	343915.008	765329.935	335803.8320	2634010.1870	
8-Nov-99	A-11	343929.785	765330.290	337296.7028	2633948.8123	ATH-02
8-Nov-99	A-12	343944.963	765330.064	338831.1286	2633935.1017	
9-Nov-99	A-14	343845.931	765345.134	332838.1070	2632803.0873	
9-Nov-99	A-15	343900.817	765344.940	334342.9659	2632787.3950	
4-Nov-99	A-16	343915.008	765344.940	335777.2408	2632756.9915	
4-Nov-99	A-17	343929.999	765344.940	337292.3688	2632724.8688	
8-Nov-99	A-18	343944.963	765345.036	338804.5965	2632684.7900	
8-Nov-99	A-19	343844.622	765400.171	332679.2093	2631549.8917	ATH-04
4-Nov-99	A-21	343859.989	765359.944	334232.7395	2631535.9941	
8-Nov-99	A-22	343914.606	765359.233	335711.3255	2631564.1175	ATH-03
9-Nov-99	A-23	343930.774	765359.944	337344.1568	2631470.1640	
9-Nov-99	A-24	343944.963	765359.944	338778.2316	2631439.8196	
8-Nov-99	A-26	343844.996	765414.949	332690.9186	2630314.7277	
4-Nov-99	A-27	343859.989	765414.949	334206.2500	2630282.7329	
8-Nov-99	A-28	343914.981	765414.949	335721.4829	2630250.7349	
9-Nov-99	A-29	343930.319	765415.111	337271.3976	2630204.4751	
9-Nov-99	A-30	343945.470	765415.661	338801.7323	2630126.2106	
4-Nov-99	A-32	343844.996	765429.922	332664.5341	2629064.0748	
8-Nov-99	A-33	343900.095	765430.213	334190.0722	2629007.6115	ATH-05
4-Nov-99	A-34	343915.008	765429.922	335697.8314	2629000.1509	
8-Nov-99	A-35	343929.197	765430.924	337130.1444	2628886.2500	ATH-06
9-Nov-99	A-36	343944.963	765429.890	338725.4232	2628939.0223	
5-Nov-99	A-38	343844.996	765444.959	332638.0938	2627808.0741	
	A-39	See below for coordinates @ C14a3				C14a3
4-Nov-99	A-40	343915.008	765444.927	335671.4501	2627746.9521	
4-Nov-99	A-41	343929.999	765444.927	337186.5814	2627715.0853	
5-Nov-99	A-42	343944.989	765444.959	338701.5584	2627680.5512	
	A-43	See below for coordinates @ C14b2				C14b2
8-Nov-99	A-44	343844.996	765459.899	332611.8734	2626560.1772	
4-Nov-99	A-45	343859.989	765459.931	334127.1555	2626525.6955	
8-Nov-99	A-46	343914.633	765500.869	335605.5741	2626416.2894	ATH-07
9-Nov-99	A-47	343930.747	765500.190	337235.4003	2626438.8156	
9-Nov-99	A-48	343945.871	765459.705	338764.8294	2626447.2343	
9-Nov-99	A-50	343845.397	765515.518	332625.0492	2625254.7113	
4-Nov-99	A-51	343859.989	765514.936	334100.8760	2625272.4311	
9-Nov-99	A-52	343916.076	765514.936	335726.7848	2625238.3727	
9-Nov-99	A-53	343931.067	765515.033	337241.7520	2625198.5302	
9-Nov-99	A-54	343945.818	765514.839	338732.9692	2625183.5039	
8-Nov-99	A-59	343930.026	765530.071	337110.2559	2623944.8392	

Date	Station Grid Node	Latitude DDMMSS.sss	Longitude DDMMSS.sss	NORTH Nad 83 (Y ft.)	EAST Nad 83 (X ft.)	Equivalent Station
8-Nov-99	A-60	343944.963	765530.071	338619.9344	2623913.2808	
8-Nov-99	A-61	344000.006	765530.071	340140.3281	2623881.4961	
8-Nov-99	A-63	344015.048	765514.969	341687.0079	2625110.7612	
8-Nov-99	A-64	344000.006	765514.969	340166.7192	2625142.6083	
5-Nov-99	A-65	344000.006	765459.964	340192.9921	2626395.6201	
5-Nov-99	A-66	344014.995	765459.931	341707.9823	2626366.5781	ATH-14
5-Nov-99	A-67	344014.995	765444.959	341734.2520	2627616.7684	
9-Nov-99	A-68	344000.006	765444.991	340219.2651	2627645.9580	
9-Nov-99	A-69	344000.006	765429.890	340245.8104	2628906.9816	
9-Nov-99	A-70	344015.689	765430.180	341830.3740	2628849.3635	
5-Nov-99	ATHB08	344112.459	764807.783	348257.9134	2660652.7231	
5-Nov-99	ATHB09	344110.295	764910.680	347923.3924	2655406.6470	
7-Nov-99	ATHB10	344056.671	765010.765	346436.6732	2650420.4823	
5-Nov-99	ATHB11	344033.723	765350.631	343722.8281	2632113.1562	
5-Nov-99	ATHB12	344022.529	765452.364	342482.7100	2626982.4377	
7-Nov-99	ATHB13	344022.609	765559.531	342373.4843	2621373.8255	
5-Nov-99	B1-1	344117.855	764707.116	348915.8497	2665705.2461	
5-Nov-99	B1-2	344102.041	764911.295	347088.0545	2655373.6253	
5-Nov-99	B1-3	344101.427	764942.113	346969.5932	2652802.0833	
5-Nov-99	B1-4	344102.121	765013.416	346982.6706	2650187.1490	
5-Nov-99	B2-1	344042.379	765318.519	344654.6030	2634775.7743	
5-Nov-99	B2-2	344032.788	765318.164	343685.8793	2634826.0367	
5-Nov-99	B2-3			343745.8136	2629483.9501	
5-Nov-99	B2-4	344027.018	765420.835	342991.8406	2629605.5282	
5-Nov-99	B2-5	344025.895	765528.227	342760.1444	2623980.7677	
18-Nov-99	B2-6			341383.5630	2619032.8773	
18-Nov-99	B2-7	344004.307	765729.527	340368.1627	2613897.1818	
19-Nov-99	C-01	343851.570	770649.461	332091.1450	2567278.4613	
19-Nov-99	C-02	343846.546	770702.299	331562.9921	2566215.7480	
19-Nov-99	C-03	343842.590	770613.307	331241.0466	2570315.7021	
19-Nov-99	C-06	343833.022	770558.238	330298.0512	2571592.9495	
5-Jun-99	C04A-1	344133.561	764427.075	350804.2979	2679029.5636	
5-Jun-99	C04A-2	344106.476	764425.458	348070.0066	2679226.8635	
5-Jun-99	C04A-3	344041.017	764417.632	345511.8602	2679938.8451	
5-Jun-99	C04A-4	344014.380	764415.466	342823.8944	2680181.0499	
5-Jun-99	C04A-5	343949.799	764417.277	340336.1549	2680086.4469	
5-Jun-99	C06A-1	344115.211	764635.587	348707.4770	2668343.3301	
5-Jun-99	C06A-2	344033.082	764628.408	344463.0807	2669038.1168	
5-Jun-99	C06A-3	343959.872	764627.179	341108.9633	2669216.0007	
11-Jun-99	C07A-1	344105.033	764734.280	347569.4587	2663466.3615	
11-Jun-99	C07A-2	344118.924	764737.838	348966.7749	2663138.1135	
6-Jun-99	C08A-1	344109.547	764840.283	347903.6483	2657945.9908	
6-Jun-99	C08A-2	344029.716	764835.626	343886.6142	2658423.6056	
6-Jun-99	C08A-3	343949.532	764830.290	339835.1640	2658958.8156	

Date	Station Grid Node	Latitude DDMMSS.sss	Longitude DDMMSS.sss	NORTH Nad 83 (Y ft.)	EAST Nad 83 (X ft.)	Equivalent Station
8-Jun-99	C09A-1	343923.211	764933.446	337058.9764	2653743.0938	
11-Jun-99	C09A-2	344047.936	764943.245	345604.0223	2652737.4016	
11-Jun-99	C09A-3	344108.238	764942.954	347656.4304	2652716.8110	
6-Jun-99	C10A-1	344100.225	765046.466	346731.0433	2647432.0538	
6-Jun-99	C10A-2	344021.193	765043.005	342792.4245	2647806.6437	
6-Jun-99	C10A-3	343941.569	765042.715	338788.2316	2647917.7986	
6-Jun-99	C10A-4	343903.008	765042.520	334891.2992	2648018.6975	
11-Jun-99	C10B-1	344046.360	765118.480	345271.8537	2644789.5505	
8-Jun-99	C11A-1	343902.474	765128.667	334753.9009	2644165.6102	
11-Jun-99	C11A-2	344044.436	765151.077	345018.7073	2642072.1424	
11-Jun-99	C11B-1	344037.410	765218.791	344258.8976	2639773.4482	
6-Jun-99	C12A-1	344055.843	765249.609	346066.8406	2637160.5184	
6-Jun-99	C12A-2	344029.743	765246.440	343434.5965	2637481.4534	
6-Jun-99	C12A-3	343928.475	765236.609	337259.8622	2638434.7703	
7-Jun-99	C12A-4	343827.864	765217.109	331168.8714	2640194.6752	
8-Jun-99	C13A-1	343845.156	765329.158	332788.0971	2634139.1765	
8-Jun-99	C13A-2	343935.824	765338.925	337891.7487	2633214.7178	
7-Jun-99	C13B-1	343921.234	765410.681	336360.9974	2630593.8419	
6-Jun-99	C14A-1	344029.449	765453.852	343179.5013	2626843.4974	
6-Jun-99	C14A-2	343959.097	765449.131	340120.1214	2627302.1719	
6-Jun-99	C14A-3	343905.227	765441.175	334689.4816	2628081.1155	
7-Jun-99	C14A-4	343818.670	765426.429	330009.9311	2629411.9357	
8-Jun-99	C14B-1	343908.113	765511.379	334928.1923	2625552.3130	
8-Jun-99	C14B-2	343840.185	765506.723	332113.6680	2626000.3806	
11-Jun-99	C15A-1	344014.754	765600.695	341577.5558	2621293.1594	
7-Jun-99	C16A-1	344018.067	765657.771	341813.5564	2616520.2559	
7-Jun-99	C16A-2	343959.311	765654.829	339922.9593	2616805.0951	
7-Jun-99	C16A-3	343922.864	765655.055	336238.8583	2616862.3556	
7-Jun-99	C16A-4	343843.366	765653.309	332249.7999	2617090.7054	
7-Jun-99	C16A-5	343805.359	765649.655	328414.7310	2617475.3675	
11-Jun-99	C17A-1	344000.113	765807.234	339879.6654	2610757.1030	
7-Jun-99	C18A-1	343931.709	765859.783	336919.3570	2606427.2113	
7-Jun-99	C18A-2	343849.512	765856.711	332659.6785	2606770.4626	
7-Jun-99	C18A-3	343811.961	765853.445	328869.9081	2607120.4462	
11-Jun-99	C19A-1	343936.759	770009.536	337311.9751	2600591.4797	
7-Jun-99	C20A-1	343919.497	770108.747	335468.1759	2595681.3287	
7-Jun-99	C20A-2	343853.094	770101.762	332811.2270	2596318.0217	
7-Jun-99	C20A-3	343814.580	770055.359	328929.2388	2596930.6791	
7-Jun-99	C20A-4	343736.383	770045.917	325084.3865	2597796.7356	
11-Jun-99	C21A-1	343905.708	770208.185	333975.8333	2590744.6752	

Bogue Banks **Beach Sediment Characteristics**

Profile # - Locality	Sample	ID	Grain Size Distributions			Sediment
			Mean (mm)	***Std Dev. (mm)***	***Skewness***	**Description***
10 - Emerald Isle	Berm	BB10B	**0.365**	0.630	-0.299	MS,mws,sym
10	MBF	BB10C	**0.290**	0.622	-0.496	MS,mws,sc-s
10	LTT	BB10D	**0.380**	0.525	-0.482	MS,ms,sc-s
30 - Emerald Isle	Dune	BB30A	**0.246**	0.740	-0.034	FS,ws,sym
30	Berm	BB30B	**0.384**	0.619	-0.149	MS,mws,sym
30	MBF	BB30C	**0.312**	0.714	-0.495	MS,ws,sym
30	LTT	BB30D	**0.270**	0.709	-0.646	MS,ws,sym
50 - Indian Beach	Berm	BB50B	**0.418**	0.544	-0.439	MS,ms,sc-s
50	MBF	BB50C	**0.302**	0.760	-0.455	MS,ws,sym
50	LTT	BB50D	**0.215**	0.693	-0.683	FS,ws,c-s
70 - Pine Knoll Shores	Berm	BB70B	**0.338**	0.566	-0.733	MS,ms,sc-s
70	UBF	BB70C	**0.475**	0.517	-0.288	MS,ms,c-s
70	LTT	BB70D	**0.288**	0.669	-0.744	MS,mws,c-s
90 - Atlantic Beach	Dune***	BB90A	**0.234**	0.750	0.074	FS,ws,sym
90	Berm***	BB90B	**0.228**	0.708	-0.830	FS,ws,c-s
90	UBF	BB90C	**0.244**	0.630	-0.614	FS,mws,c-s
90	LTT	BB90D	**0.243**	0.636	-0.569	FS,mws,c-s
110 - Coast Guard Station	Dune**	BB110A	**0.801**	0.432	-0.090	CS,ps,sym
110	Berm**	BB110B	**0.541**	0.514	-0.169	CS,ms,c-s
110	MBF	BB110B	**0.457**	0.472	-0.347	MS,ps,c-s
110	LTT	BB110B	**0.200**	0.599	-1.247	FS,mws,c-s
Composites	Dune	(2)	**0.240**	0.745	0.390	FS,ws,sym
Composites	Berm	(6)	**0.368**	0.552	-0.460	MS,ms,c-s
Composites	Beach Face	(6)	**0.357**	0.574	-0.634	MS,ms,c-s
Composites	LTT	(6)	**0.265**	0.602	-0.717	MS,mws,c-s
All	All Samples	(20)	**0.302**	0.585	-0.648	MS,mws,c-s

**CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical dist.
MBF-mid beachface; UBF-upper beach face; LTT-Low Tide Terrace

Note: Scraped Dunes At Stations 30, 50, & 70 Not Representative
Spoil At Station 110 Dune Contains non-natural coarse material

Native Composite (20 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)
Mean=1.725 phi (Mn) Std dev=0.773 phi (SDn) Skewness=-0.648
Mean=0.302 mm Std dev=.585 mm Skewness=-0.648

Native Composite (12 Samples @ Berm, Beach Face)
Mean=1.466 phi (Mn) Std dev=0.830 phi (SDn) Skewness=-0.542
Mean=0.362 mm Std dev=.563 mm Skewness=-0.542

** Spoil Section **Nourished Section

Bogue Banks — Bogue Inlet, Bogue Sound & Corps Spoil Island Samples

Locality	~Water Depth (Ft)	ID	Recovery Lgth (Ft)	Grain Size Distributions Mean (mm)	Std Dev. (mm)	Skewness	%Coarser Than 2 mm	%Mud	Sediment Description*
Bogue Inlet	Intertidal	BI1	Grab	**0.191**	0.776	-1.869	0.1	0	FS,vws,sym
" "	Intertidal	BI2	Grab	**0.830**	0.560	-0.063	12.6	0	CS,ms,c-s
" "	Intertidal	BI3A	Grab	**0.250**	0.697	-0.424	0.0	0	FS,mws,c-s
" "	Intertidal	BI3B	Grab	**0.413**	0.517	-0.263	3.1	0	MS,ms,sym
" "	Intertidal	BI3C	Grab	**0.215**	0.673	-1.204	0.3	0	FS,ws,sc-s
" "	36	BI4A	Grab	**0.179**	0.827	-0.071	0.0	0	FS,vws,sym
" "	48	BI4B	Grab	**0.195**	0.775	-1.539	0.1	0	FS,vws,sym
" "	50	BI5	Grab	**0.180**	0.775	-1.807	0.1	0	FS,vws,sym
Bogue Sound	<5	BS1	Grab	**0.197**	0.792	-0.552	0.0	ND	FS,vws,sym
" "	<5	BS2	Grab	**0.242**	0.737	-1.374	0.3	ND	FS,vws,c-s
" "	<5	BS3	Grab	**0.237**	0.702	-0.599	0.1	ND	FS,ws,c-s
Corps Disposal Area	Supratidal	BD1	Grab	**0.434**	0.461	-0.147	5.5	ND	MS,ps,c-s
" " "	Supratidal	BD2	Grab	**0.164**	0.732	-1.153	0.1	ND	FS,ws,sym
" " "	Supratidal	BD3	Grab	**0.157**	0.751	-0.681	0.0	ND	FS,ws,sym
" " "	Supratidal	BD4	Grab	**0.165**	0.707	-0.618	0.0	ND	FS,ws,sym
Beach Composites	Dune	(2)		**0.240**	0.745	0.390	0.00	0	FS,ws,sym
Composites	Berm	(6)		**0.368**	0.552	-0.460	2.07	0	MS,ms,c-s
Composites	Beach Face	(6)		**0.357**	0.574	-0.634	2.54	0	MS,ms,c-s
Composites	LTT	(6)		**0.265**	0.602	-0.717	0.87	0	MS,mws,c-s
All	All Samples	(20)		**0.302**	0.585	-0.648	1.37	0	MS,mws,c-s

**CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution
MBF-mid beachface; UBF-upper beach face; LTT-Low Tide Terrace

Native Composite (20 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)
Mean=1.725 phi (Mn) Std dev=0.773 phi (SDn) Skewness=-0.648
Mean=0.302 mm Std dev=.585 mm Skewness=-0.648
Native Composite (12 Samples @ Berm, Beach Face)
Mean=1.466 phi (Mn) Std dev=0.830 phi (SDn) Skewness=-0.542
Mean=0.362 mm Std dev=.563 mm Skewness=-0.542

Bogue Banks

Offshore Sediment Characteristics

Locality *(Distance To Beaufort Inlet)*	~Water Depth (Ft)	ID	Recovery Lgth (Ft)	Grain Size Distributions *Mean (mm)*	*Std Dev. (mm)*	*Skewness*	*%Coarser Than 2 mm*	*%Mud*	Sediment Description*
Atlantic Beach (4 mi)	16	C4A-1	2.2	**0.171**	0.505	-1.168	2.9	<2	FS,ms,sc-s
(4 mi)	37	C4A-2	2.7	**0.302**	0.398	-0.430	7.3		MS,ps,sc-s
(4 mi)	48	C4A-3	3.2	**0.357**	0.372	-0.322	10.8	~15	MS,ps,sc-s
(4 mi)	51	C4A-4	2.5	**0.433**	0.361	-0.192	13.8	<5	MS,ps,sc-s
(4 mi)	52	C4A-5	3.0	**0.421**	0.347	-0.234	17.6	<5	MS,ps,sc-s
Atlantic Beach (6 mi)	36	C6A-1	2.9	**0.224**	0.474	-0.728	3.3	<2	FS,ps,sc-s
(6 mi)	48	C6A-2	1.4	**0.416**	0.361	-0.266	16.3	<5	MS,ps,sc-s
(6 mi)	50	C6A-3	2.8	**0.436**	0.363	-0.320	18.1	~10	MS,ps,sc-s
Pine Knoll Shores (7 mi)	30	C7A-2	2.8	**0.160**	0.563	-1.340	1.9	<2	FS,mws,c-s
(7 mi)	40	C7A-1	1.0	**0.295**	0.368	-0.369	8.1	<5	MS,ps,sc-s
Pine Knoll Shores (8 mi)	30	C8A-1	3.4	**0.223**	0.433	-0.751	5.4	<2	FS,ps,sc-s
(8 mi)	42	C8A-2	1.6	**0.418**	0.343	-0.257	20.4	<2	MS,ps,sc-s
(8 mi)	48	C8A-3	2.9	**0.528**	0.340	-0.051	22.8	<5	CS,ps,c-s
Pine Knoll Shores (9 mi)	29	C9A-3	2.3	**0.158**	0.563	-1.376	2.0	<2	FS,mws,sc-s
(9 mi)	42	C9A-2	2.1	**0.315**	0.357	-0.486	14.3	~10	MS,ps,sc-s
(9 mi)	48	C9A-1	1.2	**0.249**	0.423	-0.690	7.5	<2	FS,ps,sc-s
Pine Knoll Shores (10 mi)	32	C10A-1	2.9	**0.195**	0.494	-0.836	1.5	<2	FS,ms,sc-s
(10 mi)	48	C10A-2	2.5	**0.353**	0.370	-0.294	12.0	~15	MS,ps,sc-s
(10 mi)	48	C10A-3	2.5	**0.281**	0.429	-0.555	5.4	~10	MS,ps,sc-s
(10 mi)	50	C10A-4	2.5	**0.306**	0.459	-0.619	5.2	~5	MS,ps,sc-s
Pine Knoll Shores (10.5 mi)	40	C10B-1	4.7	**0.348**	0.345	-0.268	12.5	<5	MS,ps,sc-s
Pine Knoll Shores (11 mi)	39	C11A-2	1.6	**0.708**	0.467	-0.012	17.6	~15	CS,ps,c-s
(11 mi)	47	C11A-1	3.0	**0.590**	0.316	0.470	31.1	<5	CS,ps,sym
Pine Knoll Shores (11.5 mi)	40	C11B-1	0.9	**0.866**	0.610	0.331	36.3	~5	CS,ps,sf-s
Salter Path (12 mi)	20	C12A-1	3.1	**0.174**	0.632	-0.715	0.1	<2	FS,mws,c-s
(12 mi)	44	C12A-2	1.8	**0.335**	0.369	-0.287	8.1	~15	MS,ps,sc-s
(12 mi)	49	C12A-3	2.5	**0.547**	0.306	-0.004	30.4	<2	CS,ps,sym
(12 mi)	50	C12A-4	4.0	**0.598**	0.339	0.089	24.5	~15	CS,ps,sym
Salter Path (13 mi)	47	C13A-2	2.7	**0.567**	0.353	0.140	18.5	~2	CS,ps,sym
(13 mi)	49	C13A-1	2.7	**0.792**	0.341	0.244	39.4	~5	CS,ps,sc-s
Salter Path (13.5 mi)	49	C13B-1	1.9	**0.761**	0.380	0.173	31.7	~2	CS,ps,f-s
Indian Beach (14 mi)	37	C14A-1	2.6	**0.388**	0.369	-0.174	10.6	~2	MS,ps,c-s
(14 mi)	47	C14A-2	2.0	**0.567**	0.353	0.140	18.5	~5	CS,ps,sym
(14 mi)	48	C14A-3	2.3	**0.507**	0.349	-0.067	19.1	<5	CS,ps,c-s
(14 mi)	49	C14A-4	1.6	**0.519**	0.324	-0.056	24.2	<2	CS,ps,c-s

Offshore Samples

Locality	~Water	ID	Recovery	Grain Size Distributions			%Coarser	%Mud	Sediment
(Distance To Beaufort Inlet)	Depth (Ft)		Lgth (Ft)	*Mean (mm)*	*Std Dev. (mm)*	*Skewness*	*Than 2 mm*		Description*
Indian Beach (14.5 mi)	48	C14B-1	1.9	**0.844**	0.396	0.252	32.5	<2	CS,ps,sf-s
(14.5 mi)	48	C14B-2	2.4	**1.174**	0.606	-0.123	25.0	<5	MS,ps,sc-s
Emerald Isle (15 mi)	36	C15A-1	2.0	**0.373**	0.324	-0.225	16.4	~10	MS,ps,sc-s
Emerald Isle (16 mi)	19	C16A-1	2.2	**0.192**	0.561	-1.011	0.9	<2	FS,mws,sc-s
(16 mi)	40	C16A-2	2.1	**0.404**	0.338	-0.224	17.1	~20	MS,ps,sc-s
(16 mi)	44	C16A-3	2.0	**0.439**	0.327	-0.189	21.5	~15	MS,ps,sc-s
(16 mi)	44	C16A-4	1.5	**0.328**	0.392	-0.462	9.5	~15	MS,ps,sc-s
(16 mi)	48	C16A-5	2.0	**0.265**	0.446	-0.754	21.5	~25	MS,ps,sc-s
Emerald Isle (17 mi)	30	C17A-1	1.0	**0.143**	0.696	-1.345	0.2	<5	FS,ws,sym
Emerald Isle (18 mi)	42	C18A-1	NR	ND	ND	ND	ND	ND	ND
(18 mi)	45	C18A-2	NR	ND	ND	ND	ND	ND	ND
(18 mi)	46	C18A-3	1.4	**0.540**	0.326	-0.073	28.7	<2	CS,ps,c-s
Emerald Isle (19 mi)	35	C19A-1	2.1	**0.204**	0.509	-0.916	2.6	~15	FS,ms,sc-s
Emerald Isle (20 mi)	40	C20A-1	1.4	**0.294**	0.401	-0.538	9.1	~15	MS,ps,sc-s
(20 mi)	46	C20A-2	1.6	**0.284**	0.428	-0.686	8.1	~8	MS,ps,sc-s
(20 mi)	48	C20A-3	1.2	**0.249**	0.434	-0.869	9.5	~25	FS,ps,sc-s
(20 mi)	49	C20A-4	0.5	**0.216**	0.503	-1.155	5.4	~5	FS,ms,sc-s
Emerald Isle (21 mi)	37	C21A-1	2.2	**0.279**	0.433	-0.545	6.2	~15	MS,ps,sc-s
Composites	Dune	(2)		**0.240**	0.745	0.390	0.00	0	FS,ws,sym
Composites	Berm	(6)		**0.368**	0.552	-0.460	2.07	0	MS,ms,c-s
Composites	Beach Face	(6)		**0.357**	0.574	-0.634	2.54	0	MS,ms,c-s
Composites	LTT	(6)		**0.265**	0.602	-0.717	0.87	0	MS,mws,c-s
All	All Samples	(20)		**0.302**	0.585	-0.648	1.37	0	MS,mws,c-s

**CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution
MBF-mid beachface; UBF-upper beach face; LTT-Low Tide Terrace

Native Composite (20 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)
Mean=1.725 phi (Mn) *Std dev=0.773 phi (SDn)* *Skewness=-0.648*
Mean=0.302 mm *Std dev=.585 mm* *Skewness=-0.648*

Native Composite (12 Samples @ Berm, Beach Face)
Mean=1.466 phi (Mn) *Std dev=0.830 phi (SDn)* *Skewness=-0.542*
Mean=0.362 mm *Std dev=.563 mm* *Skewness=-0.542*

Bogue Banks Offshore Sediment Characteristics Nov 1999 Survey

Locality *(Borrow Area)*	~Water Depth (Ft)	ID	Recovery Lgth (Ft)	Interval (Ft)	Grain Size Distributions Mean (mm)	*Std Dev. (mm)*	Skewness	*%Coarser Than 2 mm*	% *Mud*	% *Carbonate*	Sediment Description*
Borrow A	51.1	A-02	2.8	2.8	**0.565**	0.354	-0.006	21.6	4.3	43.9	CS,ps,sym
Borrow A	52.6	A-03s1	2.7	0-.1.0	**0.554**	0.425	-0.073	13.1	<1	47.5	CS,ps,c-s
Borrow A		A-03s2		1.0-2.7	**0.569**	0.362	0.127	16.8	21.5	53.9	CS,ps,f-s
Borrow A	52.0	A-04	3.6	3.6	**0.352**	0.375	-0.334	11.0	6.4	40.6	MS,ps,sc-s
Borrow A	51.4	A-05	2.7	2.7	**0.381**	0.341	-0.290	17.7	5.6	35.5	MS,ps,sc-s
Borrow A	49.0	A-09	2.8	2.8	**0.641**	0.382	0.095	20.6	4.1	51.8	CS,ps,sym
Borrow A	47.9	A-10	2.3	2.3	**0.814**	0.428	0.227	24.8	2.9	59.3	CS,ps,f-s
Borrow A	46.0	A-11s-1	7.1	0-3.3	**0.403**	0.377	0.248	11.9	7.5	36.5	MS,ps,sc-s
Borrow A		A-11s-2		3.3-7.1	**0.633**	0.345	0.069	27.9	3.0	47.1	CS,ps,sym
Borrow A	50.3	A-12	2.6	2.6	**0.532**	0.352	0.048	20.9	3.9	46.8	CS,ps,c-s
Borrow A	51.4	A-14	1.7	1.7	**1.127**	0.425	0.502	50.1	3.9	61.8	CS,ps,sf-s
Borrow A	50.8	A-15	1.2	1.2	**0.569**	0.358	0.013	22.9	1.8	49.0	CS,ps,sym
Borrow A	47.7	A-16	1.8	1.8	**0.539**	0.458	0.185	9.7	1.7	39.3	CS,ps,c-s
Borrow A	48.9	A-17	2.0	2.0	**0.334**	0.435	0.345	5.0	3.4	44.8	MS,ps,sc-s
Borrow A	49.9	A-18	2.4	2.4	**0.466**	0.369	0.136	14.6	3.3	48.7	MS,ps,c-s
Borrow A	50.0	A-20	8.8	0-4.8	**0.656**	0.353	0.087	27.5	3.5	56.0	CS,ps,f-s
Borrow A		A-21	1.6	1.6	**0.547**	0.347	0.017	23.5	5.9	49.9	CS,ps,c-s
Borrow A	48.0	A-22s-1	5.8	0-3.0	**0.357**	0.396	-0.396	10.2	1.7	30.6	MS,ps,sc-s
Borrow A		A-22s-2		3.0-4.8	**0.817**	0.356	0.247	38.0	2.9	52.6	CS,ps,sf-s
Borrow A		A-23	1.5	1.5	**0.613**	0.344	0.033	28.6	3.2	50.9	CS,ps,sym
Borrow A	52.4	A-24	1.4	1.4	**0.730**	0.341	0.188	33.6	3.8	52.5	CS,ps,sf-s
Borrow A	51.7	A-26	2.0	2.0	**0.514**	0.384	0.146	17.6	2.2	39.8	CS,ps,c-s
Borrow A		A-27	1.6	1.6	**0.492**	0.354	-0.120	19.6	5.4	45.4	CS,ps,c-s
Borrow A	51.3	A-28	1.8	1.8	**0.728**	0.404	0.191	22.9	4.9	59.7	CS,ps,f-s
Borrow A	52.3	A-29	1.8	1.8	**0.432**	0.376	-0.255	15.0	2.0	49.3	MS,ps,sc-s
Borrow A	52.4	A-30	1.6	1.6	**0.931**	0.368	0.380	44.8	3.9	47.5	CS,ps,sf-s
Borrow A	48.4	A-32	2.0	2.0	**0.437**	0.326	-0.203	22.2	3.8	43.9	MS,ps,sc-s
Borrow A	47.0	A-33	3.2	3.2	**0.635**	0.398	0.035	19.9	3.4	47.0	CS,ps,sym
Borrow A	47.6	A-34	2.5	2.5	**0.541**	0.353	-0.054	23.2	2.4	49.8	CS,ps,c-s
Borrow A	49.0	A-35s-1	5.6	0-2.4	**0.256**	0.500	-0.839	3.6	0.9	22.0	FS,ms,sc-s
Borrow A		A-35s-2		2.4-5.6	**0.701**	0.352	0.150	30.4	3.6	55.5	CS,ps,f-s
Borrow A	51.9	A-36	2.4	2.4	**0.308**	0.422	-0.582	8.3	3.2	24.6	MS,ps,sc-s

Locality (Borrow Area)	~Water Depth (Ft)	ID	Recovery Lgth (Ft)	Interval (Ft)	Grain Size Distributions Mean (mm)	*Std Dev. (mm)*	*Skewness*	*%Coarser Than 2 mm*	% *Mud*	% *Carbonate*	Sediment Description*
Borrow A	50.0	A-38	1.6	1.6	**0.285**	0.385	-0.597	10.7	4.6	31.1	MS,ps,sc-s
Borrow A	48.3	A-40	1.8	1.8	**0.389**	0.349	-0.273	15.5	4.1	47.9	MS,ps,sc-s
Borrow A	47.8	A-41	2.1	2.1	**0.393**	0.357	-0.292	16.1	3.0	42.4	MS,ps,sc-s
Borrow A	46.0	A-42	1.9	1.9	**0.942**	0.398	0.376	39.0	3.3	68.7	CS,ps,sf-s
Borrow A	51.7	A-44	2.2	2.2	**0.476**	0.312	-0.127	26.6	3.2	45.2	MS,ps,sc-s
Borrow A	50.4	A-45	1.5	1.5	**0.350**	0.337	-0.365	16.7	3.5	37.6	MS,ps,sc-s
Borrow A	47.0	A-46	5.7	5.7	**0.567**	0.329	0.000	26.6	3.9	46.3	CS,ps,sym
Borrow A	47.8	A-47	1.5	1.5	**0.270**	0.411	-0.659	8.2	3.4	24.7	MS,ps,sc-s
Borrow A	46.4	A-48	2.6	2.6	**0.427**	0.342	-0.178	16.4	4.4	43.4	MS,ps,sc-s
Borrow A	50.2	A-50	4.4	0-3.0	**0.188**	0.448	-0.999	5.1	8.8	10.2	FS,ms,sc-s
Borrow A	50.6	A-51	1.8	0-1.3	**0.596**	0.354	0.013	7.8	1.9	38.7	CS,ps,c-s
Borrow A	48.2	A-52	2.1	2.1	**0.391**	0.363	-0.299	14.2	2.2	36.1	MS,ps,sc-s
Borrow A	48.0	A-53	2.7	2.7	**0.653**	0.343	0.107	28.0	4.1	50.9	CS,ps,f-s
Borrow A	47.0	A-54	2.8	2.8	**0.632**	0.339	0.092	26.3	4.3	46.2	CS,ps,f-s
Borrow A	49.7	A-58	4.1	0.0-.5;2-4.1	**0.615**	0.356	0.046	24.7	3.1	36.4	CS,ps,sym
Borrow A	49.0	A-59	2.0	2.0	**0.369**	0.341	-0.346	18.3	3.0	51.3	MS,ps,sc-s
Borrow A	47.4	A-60	1.8	1.8	**0.796**	0.435	0.086	26.9	3.3	47.6	CS,ps,sym
Borrow A	46.9	A-61	3.0	0-2.5	**0.522**	0.350	-0.056	20.6	5.4	41.4	CS,ps,c-s
Borrow A	42.9	A-63	3.5	0-.5	**0.247**	0.415	-0.610	5.7	6.6	16.3	FS,ps,sc-s
Borrow A	46.8	A-64	1.8	1.8	**0.363**	0.381	-0.296	9.6	5.7	40.0	MS,ps,sc-s
Borrow A	45.0	A-65	1.9	1.9	**0.613**	0.319	0.063	33.0	2.5	43.3	CS,ps,f-s
Borrow A	43.0	A-66	3.3	3.3	**0.306**	0.351	-0.395	10.7	4.2	30.9	MS,ps,sc-s
Borrow A	44.0	A-67	1.7	1.7	**0.947**	0.402	0.404	38.3	1.9	77.6	CS,ps,sf-s
Borrow A	50.6	A-68	2.1	2.1	**0.557**	0.334	0.019	24.9	3.7	40.3	CS,ps,sym
Borrow A	50.7	A-69	2.0	2.0	**0.441**	0.372	-0.228	16.2	3.3	51.4	MS,ps,sc-s
Borrow A	47.9	A-70T	2.8	0-1.25	**1.000**	0.481	0.300	30.1	2.0	63.4	VCS,ps,f-s
Borrow A		A-70B		2.05-2.8	**0.716**	0.388	0.174	24.2	5.4	38.2	CS,ps,f-s
Borrow B-1	35.0	B1-1	2.9	2.9	**0.166**	0.553	-1.510	2.0	2.8	14.0	FS,mws,c-s
Borrow B-1	38.0	B1-2	2.6	2.6	**0.297**	0.399	-0.468	7.8	2.3	28.6	MS,ps,sc-s
Borrow B-1	37.0	B1-3	3.1	3.1	**0.240**	0.393	-0.655	8.7	3.2	29.1	FS,ps,sc-s
Borrow B-1	32.5	B1-4	2.5	2.5	**0.213**	0.453	-0.778	4.1	2.2	13.4	FS,ps,sc-s
Borrow B-1	35.0	ATHB08	11.3	0-4.0	**0.208**	0.478	-0.751	2.6	2.2	19.5	FS,ps,sc-s
Borrow B-1	32.0	ATH-9s1	9.0	0-3.8	**0.245**	0.411	-0.607	5.5	1.6	21.8	FS,ps,sc-s
Borrow B-1		ATH-9s2		3.8-9	**0.153**	0.601	-1.392	1.0	0.9	11.8	FS,mws,c-s
Borrow B-2	37.0	ATHB10	7.5	2.2	**0.285**	0.378	-0.420	7.7	2.0	33.2	MS,ps,sc-s

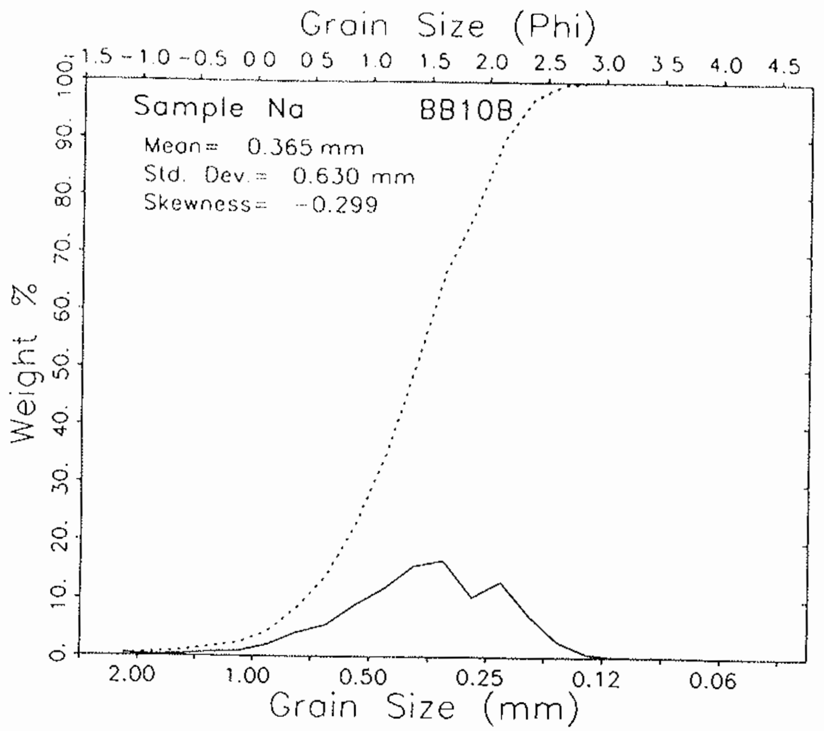
Locality	~Water	ID	Recovery	Interval	Grain Size Distributions			%Coarser	%	%	Sediment
(Borrow Area)	Depth (Ft)		Lgth (Ft)	(Ft)	Mean (mm)	*Std Dev. (mm)*	*Skewness*	*Than 2 mm*	*Mud*	*Carbonate*	Description*
Borrow B-2	31.0	B2-1	3.7	3.7	**0.233**	0.393	-0.638	7.8	8.7	27.9	FS,ps,sc-s
Borrow B-2	38.0	B2-2	4.0	4.0	**0.215**	0.403	-0.639	5.6	3.0	22.9	FS,ps,sc-s
Borrow B-2	32.0	B2-3	2.6	0-1.9	**0.223**	0.477	-0.425	1.0	2.1	18.1	FS,ps,sc-s
Borrow B-2	38.0	B-2-4s1	2.2	0-0.9	**0.632**	0.503	-0.112	10.6	1.2	41.8	CS,ps,c-s
Borrow B-2		B-2-4s2		.9-2.2	**0.274**	0.375	-0.376	7.8	3.4	22.8	MS,ps,sc-s
Borrow B-2	30.0	B2-5	1.8	1.8	**0.208**	0.431	-0.794	4.4	1.9	26.7	FS,ps,sc-s
Borrow B-2	35.7	B2-6	3.1	3.1	**0.346**	0.341	-0.304	14.4	2.2	36.6	MS,ps,sc-s
Borrow B-2	35.8	B2-7	2.3	2.3	**0.330**	0.361	-0.360	11.4	2.5	29.8	MS,ps,sc-s
Borrow B-2	35.0	ATHB11	10.0	0-6.8	**0.186**	0.445	-0.786	3.9	4.1	23.0	FS,ps,sc-s
Borrow B-2	37.0	ATHB12	10.3	0-1.7	**0.484**	0.400	-0.088	12.7	3.0	45.6	CS,ps,c-s
Borrow B-2	29.0	ATH13s	9.6	0-2.0	**0.151**	0.688	-1.546	0.2	1.8	8.1	FS,ws,sym
Borrow B-2		ATH13s2		2.0-5.6	**0.326**	0.353	-0.291	9.3	2.5	39.5	MS,ps,sc-s
Bogue Inlet	Grab	C-01	4'		**0.276**	0.596	-0.713	1.3	0.0		MS,mws,sc-s
Bogue Inlet	Grab	C-02	4'		**0.260**	0.647	-0.925	0.5	0.0		FS,mws,sc-s
Bogue Inlet	Grab	C-03	4'		**0.781**	0.491	-0.019	18.6	0.0		CS,ps,c-s
Bogue Inlet	Grab	C-04	4'		**0.675**	0.502	-0.104	12.0	0.0		CS,ps,c-s
Bogue Inlet	Grab	C-05	4'		**0.293**	0.573	-0.925	2.0	0.0		MS,mws,sc-s
Bogue Inlet	Grab	C-06	4'		**0.187**	0.814	-0.987	0.0	0.0		FS,ws,sym
Composites	Berm	(6)			**0.368**	0.552	-0.460			16.1	MS,ms,c-s
Composites	Beach Face	(6)			**0.357**	0.574	-0.634			11.8	MS,ms,c-s
Composites	LTT	(6)			**0.265**	0.602	-0.717			17.0	MS,mws,c-s

**CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution
MBF-mid beachface; UBF-upper beach face; LTT-Low Tide Terrace

Native Composite (20 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)
Mean=1.725 phi (Mn) Std dev=0.773 phi (SDn) Skewness=-0.648
Mean=0.302 mm Std dev=.585 mm Skewness=-0.648

ANNEX E-2
Part 1

Phase I — June 1999
Sedimert Sample Results



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB10B	060699						
Bogue Banks Beach Samples BB10B Berm							
		-1.125	.410		.412	-1.000	.412
		-.875	.200		.201	-.750	.613
		-.625	.310		.312	-.500	.925
		-.375	.620		.624	-.250	1.549
		-.125	.770		.774	.000	2.323
		.125	1.930		1.941	.250	4.264
		.375	4.020		4.043	.500	8.307
		.625	5.390		5.421	.750	13.728
		.875	8.840		8.891	1.000	22.619
		1.125	11.660		11.727	1.250	34.346
		1.375	15.440		15.529	1.500	49.874
		1.625	16.480		16.574	1.750	66.449
		1.875	10.250		10.309	2.000	76.758
		2.125	12.900		12.974	2.250	89.731
		2.375	7.050		7.090	2.500	96.822
		2.625	2.550		2.565	2.750	99.387
		2.875	.500		.503	3.000	99.889
		3.125	.070		.070	3.250	99.960
		3.375	.020		.020	3.500	99.980
		3.625	.010		.010	3.750	99.990
		3.875	.010		.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.430

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

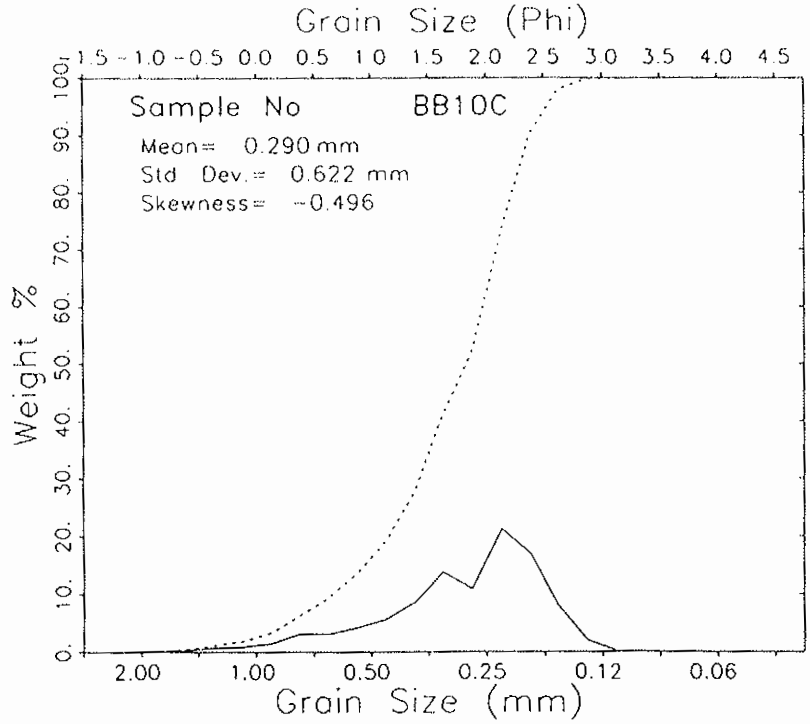
MOMENT MEASURES:

MEAN = 1.455 STANDARD DEVIATION = .667 SKEWNESS = -.299 KURTOSIS = .711
DISPERSION = .421 STANDARD DEVIATION = .638 DEVIATION FROM NORMAL DISTR. = -4.29%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.470	.295	.814	1.051	1.502	1.957	2.140	2.436	2.712

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.477	1.485	MEDIUM SAND
STANDARD DEVIATION	.663	.656	MODERATELY WELL SORTED
SKEWNESS(1)	-.038	-.083	NEAR SYMMETRICAL
SKEWNESS(2)	-.206		
KURTOSIS	.614	.968	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB10C	060699					
Bogue Banks Beach Samples BB10C MBF						
		-1.125	.070	.068	-1.000	.068
		-.875	.130	.125	-.750	.193
		-.625	.230	.222	-.500	.415
		-.375	.640	.617	-.250	1.032
		-.125	.800	.771	.000	1.803
		.125	1.430	1.379	.250	3.182
		.375	3.200	3.086	.500	6.268
		.625	3.210	3.095	.750	9.364
		.875	4.290	4.137	1.000	13.500
		1.125	5.760	5.554	1.250	19.055
		1.375	8.660	8.351	1.500	27.406
		1.625	14.210	13.703	1.750	41.109
		1.875	11.200	10.800	2.000	51.909
		2.125	22.000	21.215	2.250	73.124
		2.375	17.590	16.962	2.500	90.087
		2.625	8.080	7.792	2.750	97.878
		2.875	1.970	1.900	3.000	99.778
		3.125	.180	.174	3.250	99.952
		3.375	.040	.039	3.500	99.990
		3.625	.000	.000	3.750	99.990
		3.875	.010	.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.700

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

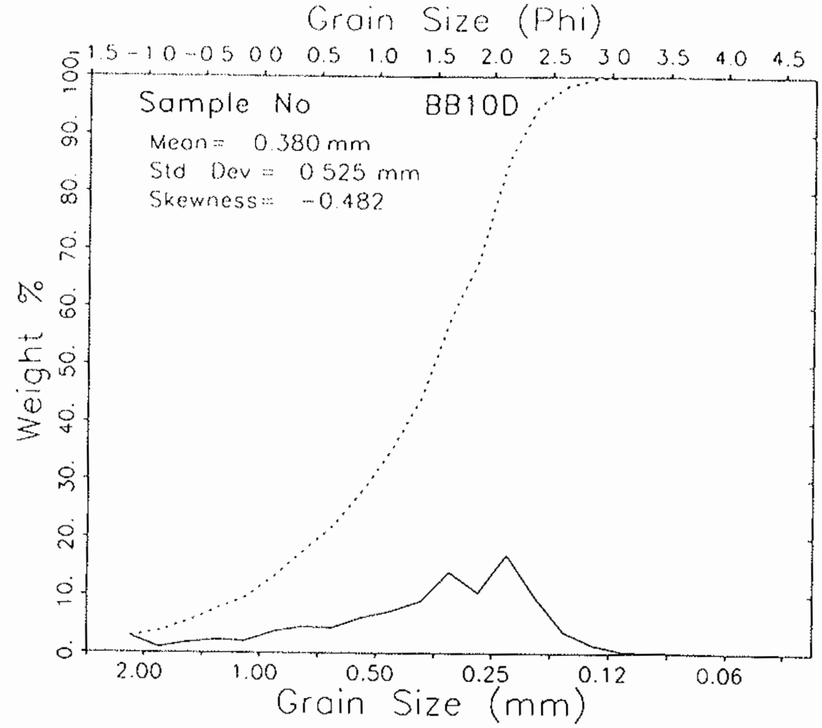
MEAN = 1.785 STANDARD DEVIATION = .684 SKEWNESS = -.496 KURTOSIS = .862

DISPERSION = .397 STANDARD DEVIATION = .604 DEVIATION FROM NORMAL DISTR. = -11.69%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.263	.397	1.113	1.428	1.956	2.278	2.410	2.658	2.898

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.761	1.826	MEDIUM SAND
STANDARD DEVIATION	.649	.667	MODERATELY WELL SORTED
SKEWNESS(1)	-.300	-.339	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.660		
KURTOSIS	.742	1.090	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB10D	060699						
Bogue Banks Beach Samples BB10D LTT							
		-1.125	3.210		2.797	-1.000	2.797
		-.875	1.000		.871	-.750	3.668
		-.625	1.940		1.690	-.500	5.359
		-.375	2.500		2.178	-.250	7.537
		-.125	2.270		1.978	.000	9.515
		.125	4.160		3.625	.250	13.139
		.375	5.120		4.461	.500	17.600
		.625	4.910		4.278	.750	21.879
		.875	6.910		6.021	1.000	27.899
		1.125	8.160		7.110	1.250	35.009
		1.375	10.130		8.826	1.500	43.835
		1.625	16.030		13.967	1.750	57.803
		1.875	11.970		10.430	2.000	68.232
		2.125	19.510		16.999	2.250	85.231
		2.375	10.990		9.576	2.500	94.807
		2.625	4.040		3.520	2.750	98.327
		2.875	1.480		1.290	3.000	99.617
		3.125	.300		.261	3.250	99.878
		3.375	.110		.096	3.500	99.974
		3.625	.030		.026	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 114.770

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

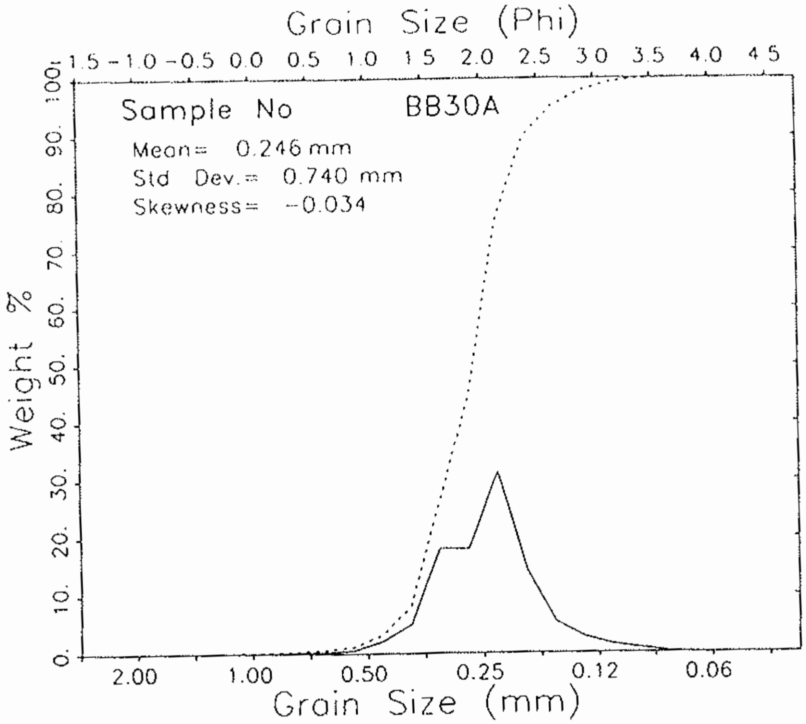
MOMENT MEASURES:

MEAN = 1.395 STANDARD DEVIATION = .930 SKEWNESS = -.452 KURTOSIS = .272
DISPERSION = .515 STANDARD DEVIATION = .791 DEVIATION FROM NORMAL DISTR. = -14.93%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.161	-.553	.410	.880	1.610	2.100	2.232	2.514	2.880

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.321	1.418	MEDIUM SAND
STANDARD DEVIATION	.911	.920	MODERATELY SORTED
SKEWNESS(1)	-.318	-.364	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.692		
KURTOSIS	.684	1.030	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB30A	060699						
Bogue Banks Beach Samples BB30A Dune							
		-1.125	.000		.000	-1.000	.000
		-.875	.010		.010	-.750	.010
		-.625	.040		.040	-.500	.050
		-.375	.030		.030	-.250	.079
		-.125	.010		.010	.000	.089
		.125	.090		.089	.250	.179
		.375	.190		.189	.500	.368
		.625	.230		.229	.750	.596
		.875	.500		.497	1.000	1.093
		1.125	2.100		2.086	1.250	3.179
		1.375	4.930		4.898	1.500	8.077
		1.625	18.220		18.102	1.750	26.180
		1.875	18.080		17.963	2.000	44.143
		2.125	31.490		31.287	2.250	75.430
		2.375	14.380		14.287	2.500	89.717
		2.625	5.320		5.286	2.750	95.002
		2.875	2.740		2.722	3.000	97.725
		3.125	1.420		1.411	3.250	99.136
		3.375	.710		.705	3.500	99.841
		3.625	.150		.149	3.750	99.990
		3.875	.010		.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.650

PERCENT FINER THAN 4.00 PHI = .01 PERCENT COARSER THAN -1.00 PHI = .00

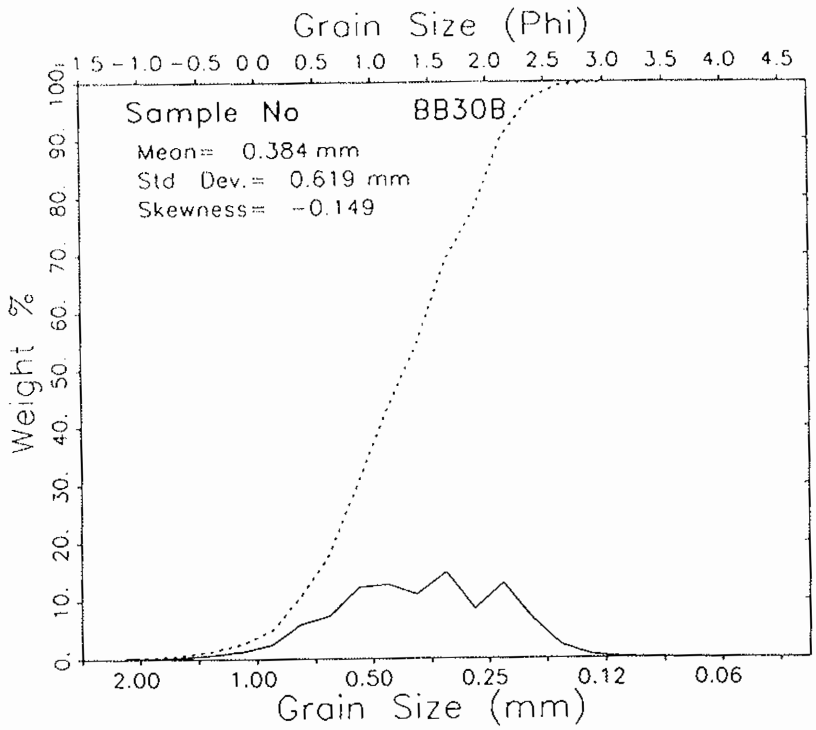
MOMENT MEASURES:

MEAN = 2.023 STANDARD DEVIATION = .435 SKEWNESS = -.034 KURTOSIS = 2.226
DISPERSION = .229 STANDARD DEVIATION = .410 DEVIATION FROM NORMAL DISTR. = -5.83%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.953	1.343	1.609	1.734	2.047	2.247	2.400	2.750	3.226

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.005	2.019	FINE SAND
STANDARD DEVIATION	.395	.411	WELL SORTED
SKEWNESS(1)	-.107	-.054	NEAR SYMMETRICAL
SKEWNESS(2)	-.001		
KURTOSIS	.780	1.124	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB30B	060699						
Bogue Banks Beach Samples BB30B Berm							
		-1.125	.200		.200	-1.000	.200
		-.875	.150		.150	-.750	.350
		-.625	.340		.340	-.500	.689
		-.375	.640		.639	-.250	1.329
		-.125	1.200		1.199	.000	2.528
		.125	2.350		2.348	.250	4.876
		.375	5.860		5.855	.500	10.730
		.625	7.310		7.303	.750	18.034
		.875	12.270		12.259	1.000	30.293
		1.125	12.710		12.699	1.250	42.991
		1.375	11.070		11.060	1.500	54.051
		1.625	14.790		14.777	1.750	68.828
		1.875	8.520		8.512	2.000	77.340
		2.125	12.870		12.858	2.250	90.199
		2.375	6.820		6.814	2.500	97.013
		2.625	2.260		2.258	2.750	99.271
		2.875	.530		.530	3.000	99.800
		3.125	.150		.150	3.250	99.950
		3.375	.050		.050	3.500	100.000
		3.625	.000		.000	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.090

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

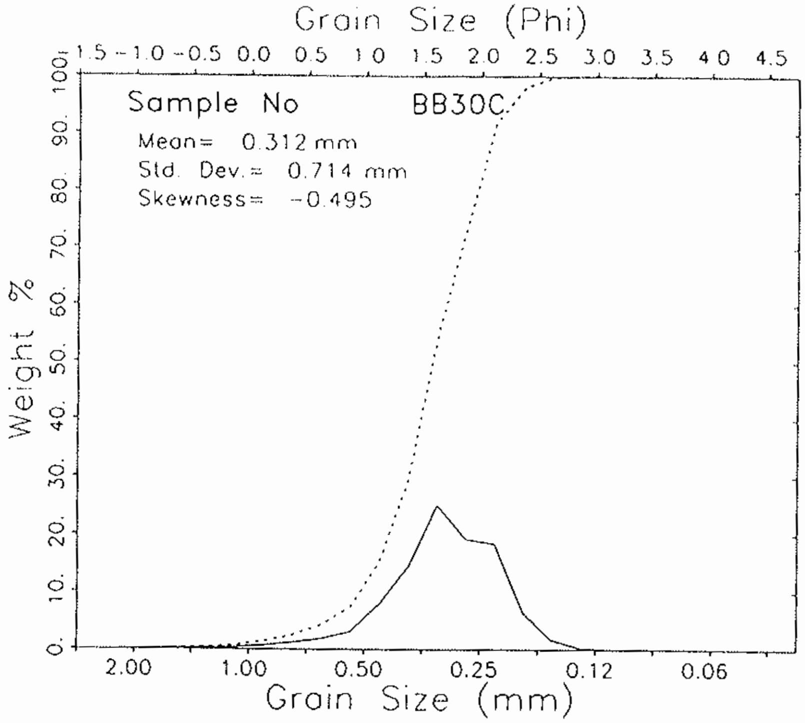
MOMENT MEASURES:

MEAN = 1.379 STANDARD DEVIATION = .693 SKEWNESS = -.149 KURTOSIS = -.139
DISPERSION = .441 STANDARD DEVIATION = .667 DEVIATION FROM NORMAL DISTR. = -3.64%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.379	.255	.680	.892	1.408	1.931	2.129	2.426	2.720

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.405	1.406	MEDIUM SAND
STANDARD DEVIATION	.725	.691	MODERATELY WELL SORTED
SKEWNESS(1)	-.005	-.034	NEAR SYMMETRICAL
SKEWNESS(2)	-.093		
KURTOSIS	.498	.856	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB30C	060699						
Bogue Banks Beach Samples BB30C MBF							
		-1.125	.070		.067	-1.000	.067
		-.875	.060		.058	-.750	.125
		-.625	.100		.096	-.500	.221
		-.375	.200		.192	-.250	.413
		-.125	.300		.288	.000	.700
		.125	.640		.614	.250	1.314
		.375	1.160		1.113	.500	2.427
		.625	1.870		1.794	.750	4.221
		.875	3.140		3.012	1.000	7.233
		1.125	8.150		7.818	1.250	15.052
		1.375	14.700		14.102	1.500	29.154
		1.625	26.100		25.038	1.750	54.192
		1.875	19.970		19.158	2.000	73.350
		2.125	19.120		18.342	2.250	91.692
		2.375	6.680		6.408	2.500	98.101
		2.625	1.730		1.660	2.750	99.760
		2.875	.230		.221	3.000	99.981
		3.125	.010		.010	3.250	99.990
		3.375	.000		.000	3.500	99.990
		3.625	.000		.000	3.750	99.990
		3.875	.010		.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.240

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

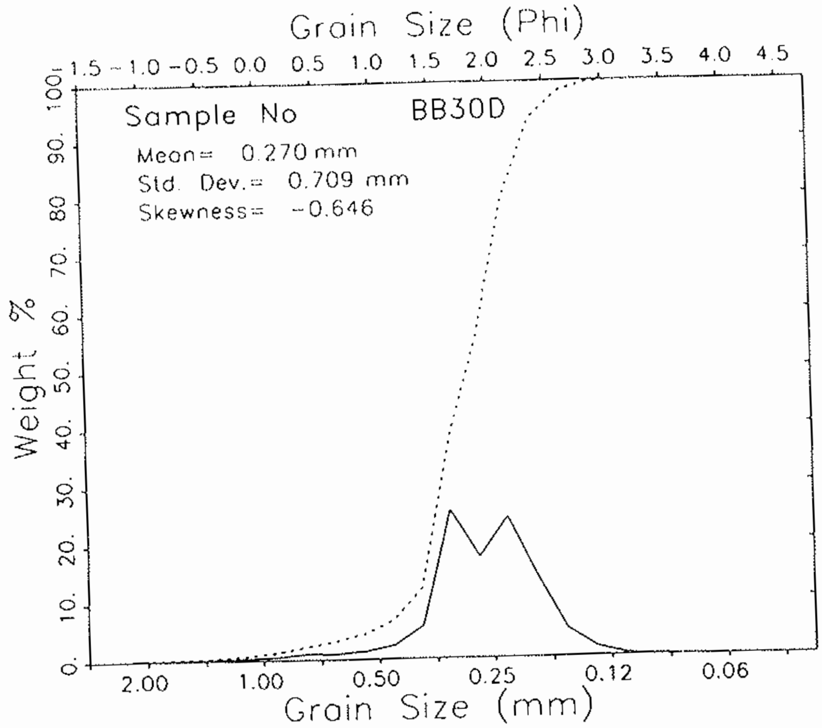
MOMENT MEASURES:

MEAN = 1.680 STANDARD DEVIATION = .486 SKEWNESS = -.495 KURTOSIS = 2.608
DISPERSION = .272 STANDARD DEVIATION = .453 DEVIATION FROM NORMAL DISTR. = -6.80%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.122	.815	1.267	1.426	1.708	2.022	2.145	2.379	2.635

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.706	1.707	MEDIUM SAND
STANDARD DEVIATION	.439	.457	WELL SORTED
SKEWNESS(1)	-.005	-.074	NEAR SYMMETRICAL
SKEWNESS(2)	-.253		
KURTOSIS	.781	1.076	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB30D	060699					
Bogue Banks Beach Samples BB30D LTT						
		-1.125	.100	.099	-1.000	.099
		-.875	.080	.079	-.750	.178
		-.625	.120	.119	-.500	.296
		-.375	.190	.188	-.250	.484
		-.125	.280	.277	.000	.761
		.125	.500	.494	.250	1.255
		.375	.960	.949	.500	2.204
		.625	.860	.850	.750	3.053
		.875	1.340	1.324	1.000	4.377
		1.125	2.360	2.332	1.250	6.709
		1.375	5.600	5.534	1.500	12.243
		1.625	25.900	25.593	1.750	37.836
		1.875	17.630	17.421	2.000	55.257
		2.125	24.560	24.269	2.250	79.526
		2.375	13.980	13.814	2.500	93.340
		2.625	4.790	4.733	2.750	98.073
		2.875	1.570	1.551	3.000	99.625
		3.125	.320	.316	3.250	99.941
		3.375	.060	.059	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.200

PERCENT FINER THAN 4.00 PHI = .00   PERCENT COARSER THAN -1.00 PHI = .00

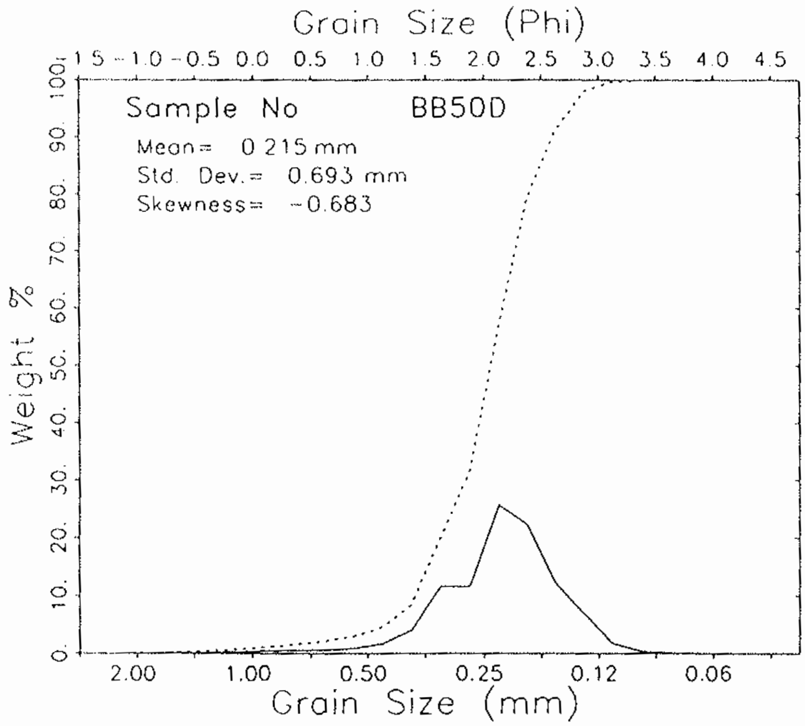
MOMENT MEASURES:

MEAN = 1.887 STANDARD DEVIATION = .497 SKEWNESS = -.646 KURTOSIS = 4.591
DISPERSION = .252 STANDARD DEVIATION = .432 DEVIATION FROM NORMAL DISTR. = -12.98%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.121	1.067	1.537	1.625	1.925	2.203	2.331	2.588	2.899

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.934	1.931	MEDIUM SAND
STANDARD DEVIATION	.397	.429	WELL SORTED
SKEWNESS(1)	.023	-.052	NEAR SYMMETRICAL
SKEWNESS(2)	-.245		
KURTOSIS	.915	1.077	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB50D	060699						
Bogue Banks Beach Samples BB50D LTT							
		-1.125	.100		.083	-1.000	.083
		-.875	.100		.083	-.750	.166
		-.625	.190		.158	-.500	.323
		-.375	.190		.158	-.250	.481
		-.125	.250		.207	.000	.688
		.125	.430		.357	.250	1.045
		.375	.600		.498	.500	1.543
		.625	.640		.531	.750	2.074
		.875	.970		.805	1.000	2.878
		1.125	1.900		1.576	1.250	4.454
		1.375	4.680		3.882	1.500	8.336
		1.625	13.960		11.579	1.750	19.915
		1.875	13.930		11.554	2.000	31.470
		2.125	30.880		25.614	2.250	57.084
		2.375	26.810		22.238	2.500	79.322
		2.625	14.510		12.036	2.750	91.357
		2.875	8.060		6.685	3.000	98.042
		3.125	1.990		1.651	3.250	99.693
		3.375	.340		.282	3.500	99.975
		3.625	.030		.025	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 120.560

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

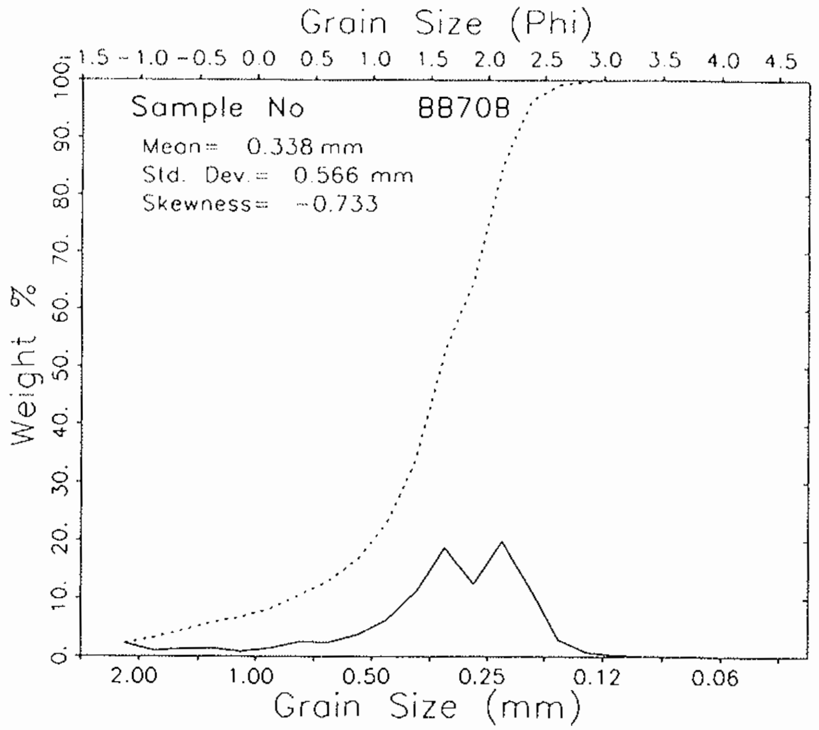
MOMENT MEASURES:

MEAN = 2.128 STANDARD DEVIATION = .529 SKEWNESS = -.683 KURTOSIS = 4.778
DISPERSION = .290 STANDARD DEVIATION = .472 DEVIATION FROM NORMAL DISTR. = -10.75%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.218	1.285	1.665	1.860	2.181	2.451	2.597	2.886	3.145

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.131	2.148	FINE SAND
STANDARD DEVIATION	.466	.476	WELL SORTED
SKEWNESS(1)	-.106	-.113	COARSE-SKEWED
SKEWNESS(2)	-.204		
KURTOSIS	.718	1.110	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB70B	060699						
Bogue Banks Beach Samples BB70B Berm							
		-1.125	2.780		2.235	-1.000	2.235
		-.875	1.250		1.005	-.750	3.241
		-.625	1.520		1.222	-.500	4.463
		-.375	1.730		1.391	-.250	5.854
		-.125	1.050		.844	.000	6.698
		.125	1.750		1.407	.250	8.105
		.375	3.030		2.436	.500	10.542
		.625	2.980		2.396	.750	12.938
		.875	4.640		3.731	1.000	16.669
		1.125	7.720		6.208	1.250	22.877
		1.375	13.510		10.864	1.500	33.741
		1.625	23.290		18.728	1.750	52.469
		1.875	15.440		12.416	2.000	64.884
		2.125	24.590		19.773	2.250	84.657
		2.375	14.500		11.660	2.500	96.317
		2.625	3.510		2.822	2.750	99.140
		2.875	.790		.635	3.000	99.775
		3.125	.230		.185	3.250	99.960
		3.375	.050		.040	3.500	100.000
		3.625	.000		.000	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 124.360

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

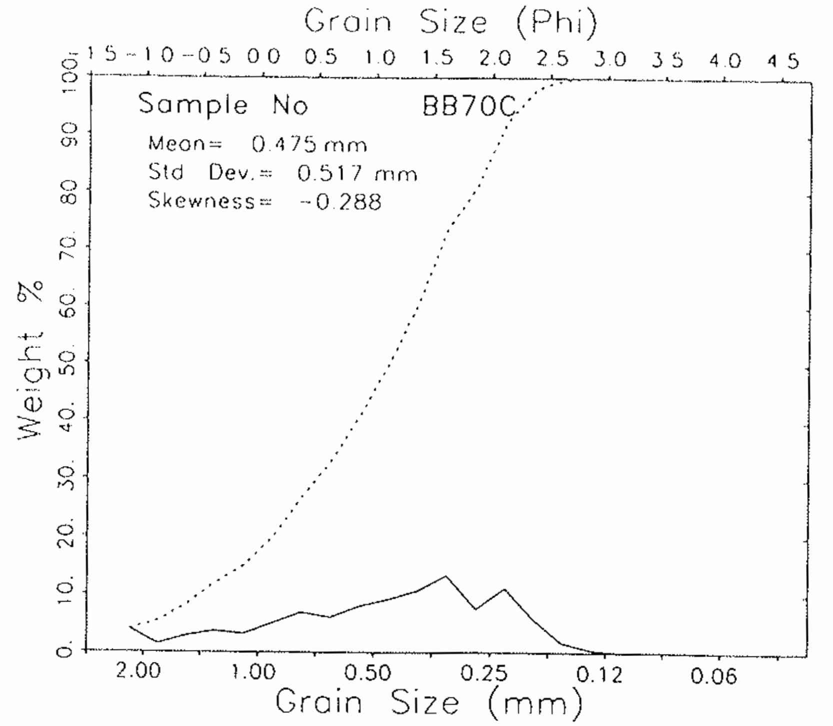
MOMENT MEASURES:

MEAN = 1.564 STANDARD DEVIATION = .821 SKEWNESS = -.733 KURTOSIS = 2.158
DISPERSION = .420 STANDARD DEVIATION = .636 DEVIATION FROM NORMAL DISTR. = -22.59%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.138	-.403	.955	1.299	1.717	2.128	2.242	2.472	2.738

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.598	1.638	MEDIUM SAND
STANDARD DEVIATION	.643	.757	MODERATELY SORTED
SKEWNESS(1)	-.184	-.330	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.062		
KURTOSIS	1.235	1.421	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT (PHI)	CLASS LIMITS	CUM PERCENT
BB70C	060699						
Bogue Banks Beach Samples BB70C UBF							
		-1.125	4.350	3.966	-1.000	3.966	
		-.875	1.560	1.422	-.750	5.388	
		-.625	3.040	2.771	-.500	8.159	
		-.375	4.020	3.665	-.250	11.824	
		-.125	3.400	3.100	.000	14.924	
		.125	5.570	5.078	.250	20.002	
		.375	7.520	6.856	.500	26.858	
		.625	6.650	6.063	.750	32.920	
		.875	8.770	7.995	1.000	40.915	
		1.125	10.040	9.153	1.250	50.068	
		1.375	11.540	10.521	1.500	60.589	
		1.625	14.500	13.219	1.750	73.808	
		1.875	8.180	7.457	2.000	81.265	
		2.125	12.110	11.040	2.250	92.306	
		2.375	6.260	5.707	2.500	98.013	
		2.625	1.780	1.623	2.750	99.635	
		2.875	.400	.365	3.000	100.000	
		3.125	.000	.000	3.250	100.000	
		3.375	.000	.000	3.500	100.000	
		3.625	.000	.000	3.750	100.000	
		3.875	.000	.000	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 109.690

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

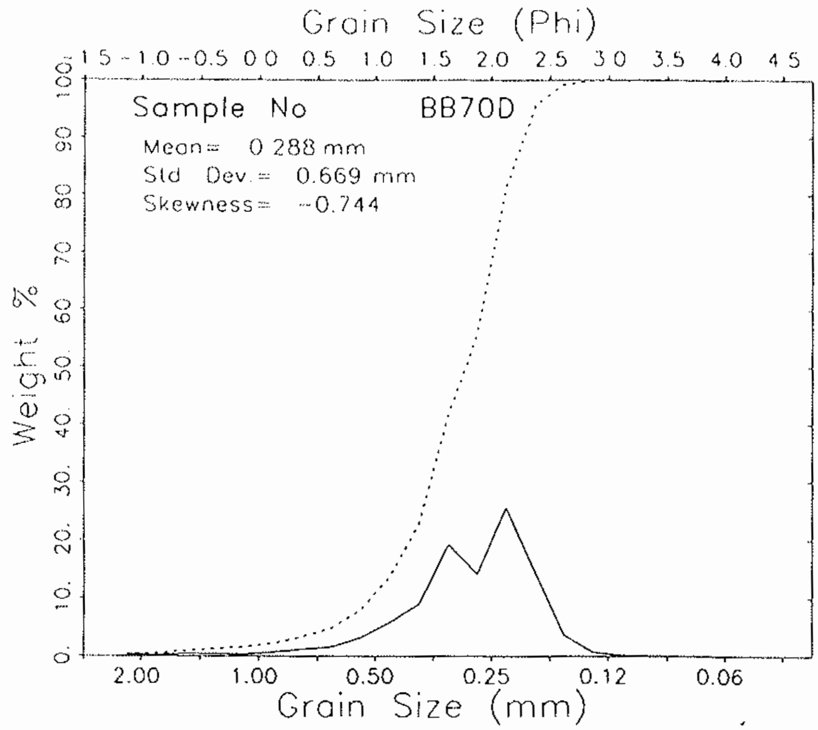
MOMENT MEASURES:

MEAN = 1.073 STANDARD DEVIATION = .953 SKEWNESS = -.288 KURTOSIS = -.432
DISPERSION = .542 STANDARD DEVIATION = .843 DEVIATION FROM NORMAL DISTR. = -11.57%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.187	-.818	.053	.432	1.248	1.790	2.062	2.368	2.652

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.057	1.121	MEDIUM SAND
STANDARD DEVIATION	1.004	.985	MODERATELY SORTED
SKEWNESS(1)	-.190	-.243	COARSE-SKEWED
SKEWNESS(2)	-.471		
KURTOSIS	.586	.962	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB70D	060699						
Bogue Banks Beach Samples BB70D							
		-1.125	.390		.310	-1.000	.310
		-.875	.280		.222	-.750	.532
		-.625	.440		.350	-.500	.882
		-.375	.460		.365	-.250	1.247
		-.125	.390		.310	.000	1.557
		.125	.760		.604	.250	2.161
		.375	1.430		1.136	.500	3.297
		.625	1.920		1.526	.750	4.823
		.875	3.930		3.123	1.000	7.945
		1.125	7.230		5.744	1.250	13.690
		1.375	11.050		8.780	1.500	22.469
		1.625	24.170		19.204	1.750	41.673
		1.875	17.720		14.079	2.000	55.752
		2.125	32.250		25.624	2.250	81.376
		2.375	17.970		14.278	2.500	95.654
		2.625	4.490		3.567	2.750	99.221
		2.875	.770		.612	3.000	99.833
		3.125	.150		.119	3.250	99.952
		3.375	.050		.040	3.500	99.992
		3.625	.010		.008	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 125.860

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

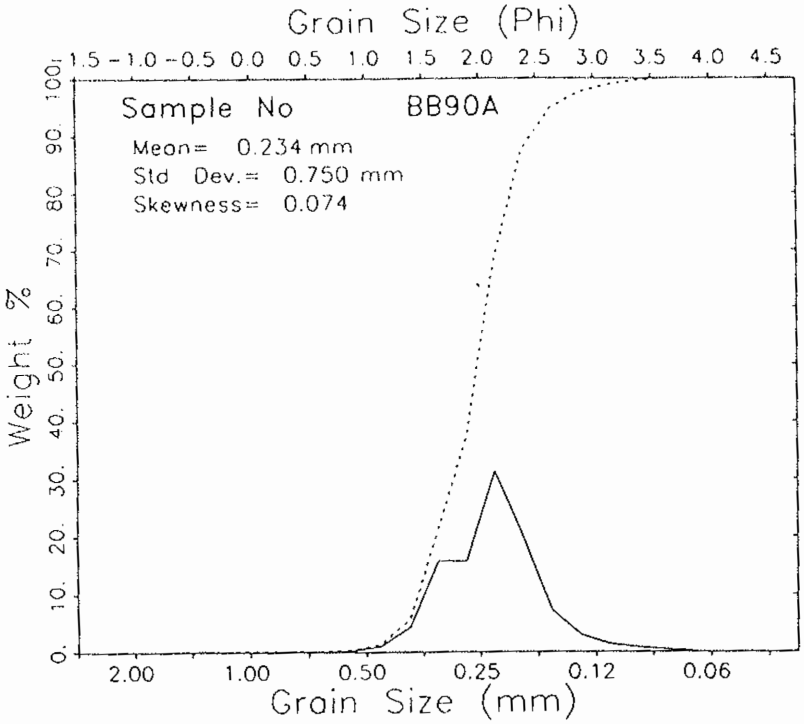
MOMENT MEASURES:

MEAN = 1.794 STANDARD DEVIATION = .581 SKEWNESS = -.744 KURTOSIS = 3.952
DISPERSION = .311 STANDARD DEVIATION = .495 DEVIATION FROM NORMAL DISTR. = -14.69%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.419	.764	1.316	1.533	1.898	2.188	2.296	2.489	2.734

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.806	1.837	MEDIUM SAND
STANDARD DEVIATION	.490	.506	MODERATELY WELL SORTED
SKEWNESS(1)	-.188	-.251	COARSE-SKEWED
SKEWNESS(2)	-.554		
KURTOSIS	.759	1.079	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB90A	060699					
Bogue Banks Beach Samples BB90A Dune						
		-1.125	.000	.000	-1.000	.000
		-.875	.000	.000	-.750	.000
		-.625	.000	.000	-.500	.000
		-.375	.100	.097	-.250	.097
		-.125	.000	.000	.000	.097
		.125	.010	.010	.250	.106
		.375	.020	.019	.500	.126
		.625	.040	.039	.750	.164
		.875	.200	.193	1.000	.358
		1.125	.990	.957	1.250	1.314
		1.375	4.310	4.165	1.500	5.479
		1.625	16.300	15.750	1.750	21.229
		1.875	16.200	15.654	2.000	36.883
		2.125	32.380	31.288	2.250	68.171
		2.375	20.230	19.548	2.500	87.719
		2.625	7.260	7.015	2.750	94.734
		2.875	2.900	2.802	3.000	97.536
		3.125	1.360	1.314	3.250	98.850
		3.375	.770	.744	3.500	99.594
		3.625	.380	.367	3.750	99.961
		3.875	.040	.039	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.490

PERCENT FINER THAN 4.00 PHI = .01 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

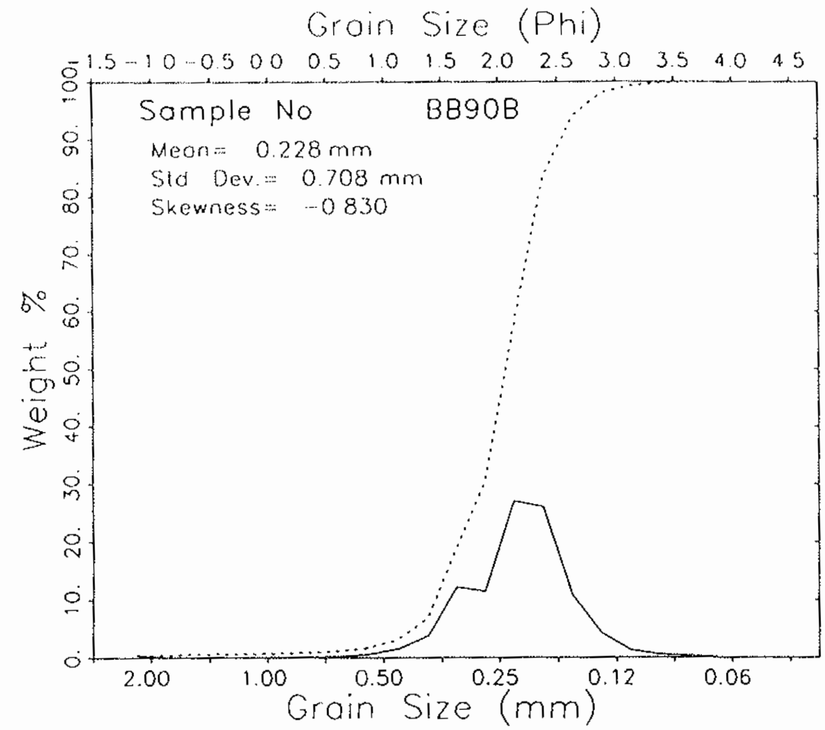
MEAN = 2.094 STANDARD DEVIATION = .415 SKEWNESS = .074 KURTOSIS = 2.041
DISPERSION = .210 STANDARD DEVIATION = .392 DEVIATION FROM NORMAL DISTR. = -5.42%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.168	1.471	1.667	1.810	2.105	2.337	2.452	2.774	3.300

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.060	2.075	FINE SAND
STANDARD DEVIATION	.393	.394	WELL SORTED
SKEWNESS(1)	-.115	-.044	NEAR SYMMETRICAL
SKEWNESS(2)	.045		
KURTOSIS	.658	1.013	MESOKURTIC

R LANGUAGE-PCL3GUI



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB90B	060699					
Bogue Banks Beach Sample BB90B Dune						
		-1.125	.390	.386	-1.000	.386
		-.875	.090	.089	-.750	.475
		-.625	.070	.069	-.500	.544
		-.375	.080	.079	-.250	.624
		-.125	.040	.040	.000	.663
		.125	.110	.109	.250	.772
		.375	.150	.148	.500	.921
		.625	.210	.208	.750	1.128
		.875	.570	.564	1.000	1.693
		1.125	1.450	1.435	1.250	3.128
		1.375	3.670	3.633	1.500	6.760
		1.625	12.270	12.145	1.750	18.905
		1.875	11.520	11.403	2.000	30.308
		2.125	27.240	26.962	2.250	57.270
		2.375	26.290	26.022	2.500	83.292
		2.625	10.700	10.591	2.750	93.883
		2.875	4.150	4.108	3.000	97.991
		3.125	1.200	1.188	3.250	99.178
		3.375	.510	.505	3.500	99.683
		3.625	.280	.277	3.750	99.960
		3.875	.040	.040	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.030

PERCENT FINER THAN 4.00 PHI = .02 PERCENT COARSER THAN -1.00 PHI = .00

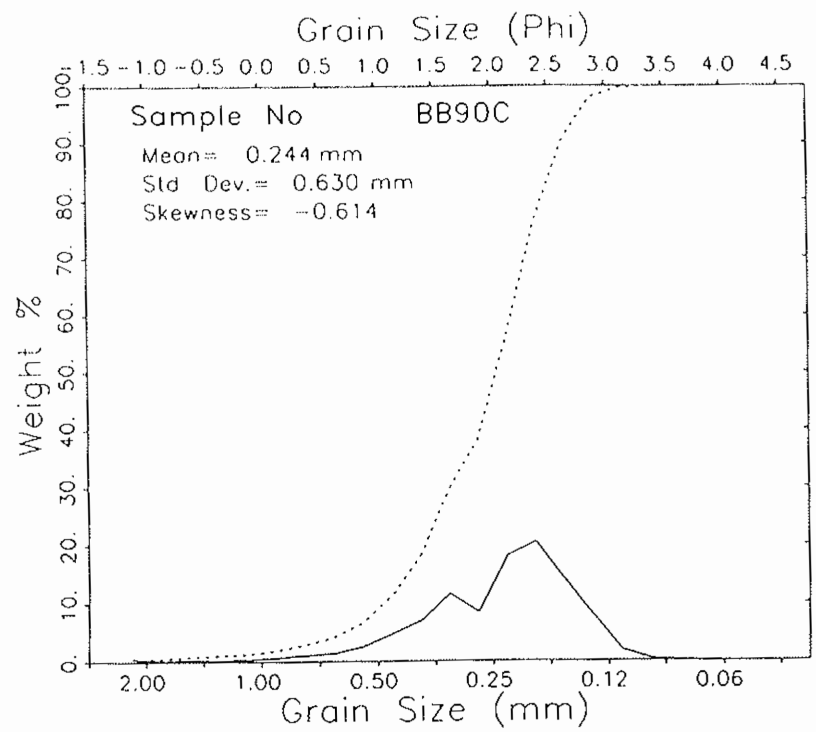
MOMENT MEASURES:

MEAN = 2.131 STANDARD DEVIATION = .499 SKEWNESS = -.830 KURTOSIS = 8.976
DISPERSION = .248 STANDARD DEVIATION = .428 DEVIATION FROM NORMAL DISTR. = -14.14%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.596	1.379	1.690	1.884	2.183	2.420	2.517	2.818	3.212

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.103	2.130	FINE SAND
STANDARD DEVIATION	.413	.425	WELL SORTED
SKEWNESS(1)	-.191	-.154	COARSE-SKEWED
SKEWNESS(2)	-.204		
KURTOSIS	.741	1.099	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB90C	060699						
Bigue Banks Beach Sample BB90C UBF							
		-1.125	.390		.365	-1.000	.365
		-.875	.150		.141	-.750	.506
		-.625	.230		.216	-.500	.722
		-.375	.260		.244	-.250	.965
		-.125	.280		.262	.000	1.228
		.125	.620		.581	.250	1.809
		.375	1.050		.984	.500	2.793
		.625	1.400		1.312	.750	4.105
		.875	2.670		2.502	1.000	6.607
		1.125	4.990		4.676	1.250	11.283
		1.375	7.280		6.822	1.500	18.105
		1.625	12.220		11.452	1.750	29.557
		1.875	8.850		8.294	2.000	37.850
		2.125	19.180		17.974	2.250	55.824
		2.375	21.790		20.420	2.500	76.244
		2.625	14.940		14.001	2.750	90.245
		2.875	8.120		7.609	3.000	97.854
		3.125	1.930		1.809	3.250	99.663
		3.375	.310		.291	3.500	99.953
		3.625	.050		.047	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.710

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.036 STANDARD DEVIATION = .666 SKEWNESS = -.614 KURTOSIS = 2.631

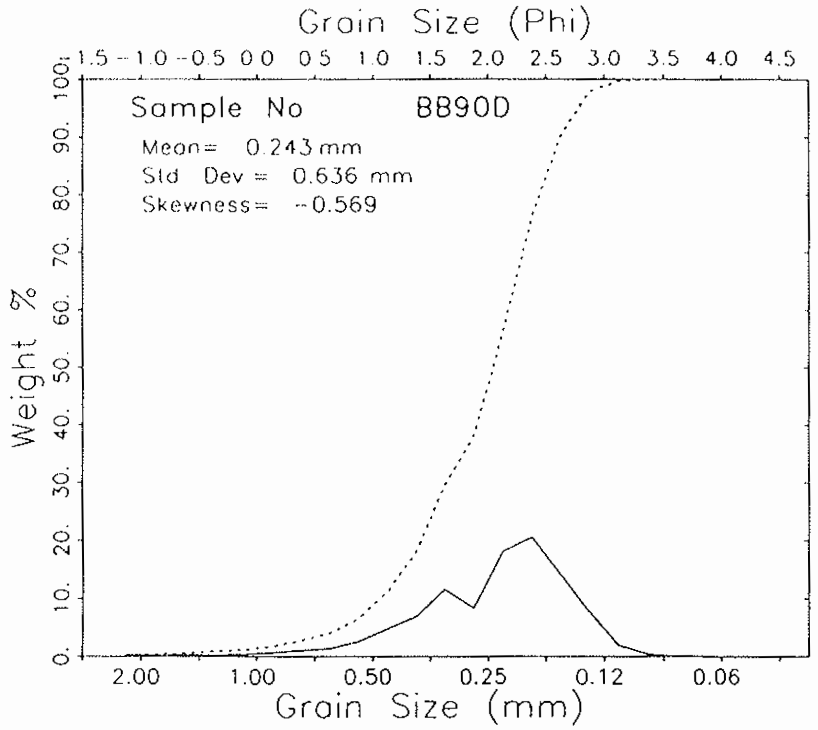
DISPERSION = .386 STANDARD DEVIATION = .509 DEVIATION FROM NORMAL DISTR. = -11.52%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.217	.839	1.423	1.651	2.169	2.485	2.638	2.906	3.150

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.031	2.077	FINE SAND
STANDARD DEVIATION	.608	.617	MODERATELY WELL SORTED
SKEWNESS(1)	-.228	-.257	COARSE-SKEWED
SKEWNESS(2)	-.487		
KURTOSIS	.700	1.015	MESOKURTIC

~ LANGUAGE=PCL3GUI



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB90D	060699						
Bogue Banks Beach Samples BB90D LTT							
		-1.125	.220		.206	-1.000	.206
		-.875	.150		.141	-.750	.347
		-.625	.230		.216	-.500	.563
		-.375	.260		.244	-.250	.807
		-.125	.280		.263	.000	1.070
		.125	.620		.582	.250	1.652
		.375	1.050		.986	.500	2.638
		.625	1.400		1.314	.750	3.952
		.875	2.670		2.506	1.000	6.458
		1.125	4.990		4.684	1.250	11.141
		1.375	7.280		6.833	1.500	17.974
		1.625	12.220		11.470	1.750	29.444
		1.875	8.850		8.307	2.000	37.751
		2.125	19.180		18.003	2.250	55.754
		2.375	21.790		20.452	2.500	76.206
		2.625	14.940		14.023	2.750	90.229
		2.875	8.120		7.622	3.000	97.851
		3.125	1.930		1.812	3.250	99.662
		3.375	.310		.291	3.500	99.953
		3.625	.050		.047	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.540

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

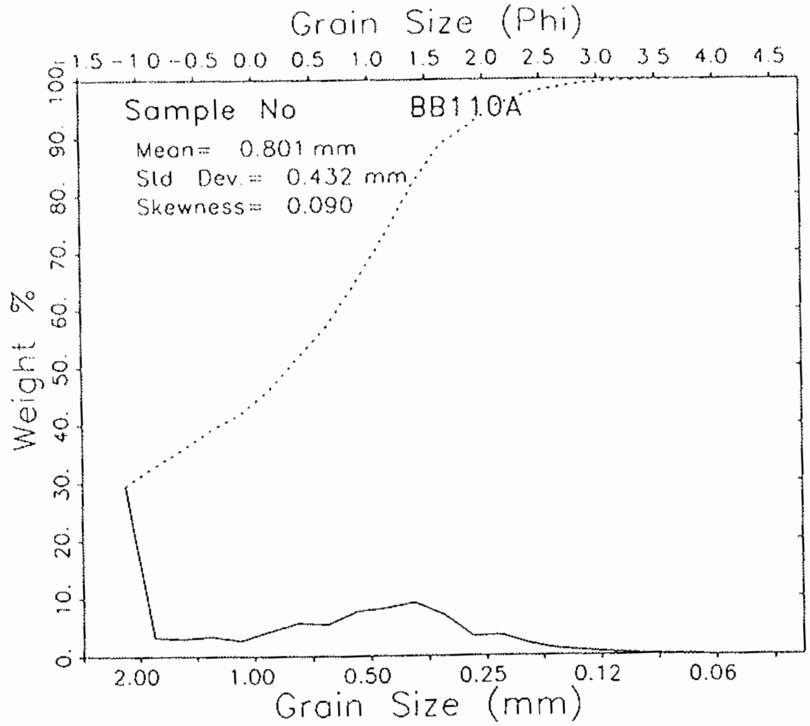
MOMENT MEASURES:

MEAN = 2.041 STANDARD DEVIATION = .654 SKEWNESS = -.569 KURTOSIS = 2.215
DISPERSION = .384 STANDARD DEVIATION = .586 DEVIATION FROM NORMAL DISTR. = -10.47%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.067	.855	1.428	1.653	2.170	2.485	2.639	2.906	3.159

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.033	2.079	FINE SAND
STANDARD DEVIATION	.606	.614	MODERATELY WELL SORTED
SKEWNESS(1)	-.226	-.254	COARSE-SKEWED
SKEWNESS(2)	-.478		
KURTOSIS	.694	1.011	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB110A	060699						
Bogue Banks Beach Samples BB110A Dune							
		-1.125	29.540		29.419	-1.000	29.419
		-.875	3.230		3.217	-.750	32.636
		-.625	3.020		3.008	-.500	35.644
		-.375	3.410		3.396	-.250	39.040
		-.125	2.630		2.619	.000	41.659
		.125	4.230		4.213	.250	45.872
		.375	5.640		5.617	.500	51.489
		.625	5.410		5.388	.750	56.877
		.875	7.620		7.589	1.000	64.466
		1.125	8.150		8.117	1.250	72.582
		1.375	9.070		9.033	1.500	81.615
		1.625	7.030		7.001	1.750	88.617
		1.875	3.360		3.346	2.000	91.963
		2.125	3.500		3.486	2.250	95.449
		2.375	1.980		1.972	2.500	97.421
		2.625	1.040		1.036	2.750	98.456
		2.875	.730		.727	3.000	99.183
		3.125	.360		.359	3.250	99.542
		3.375	.220		.219	3.500	99.761
		3.625	.130		.129	3.750	99.890
		3.875	.110		.110	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.410

PERCENT FINER THAN 4.00 PHI = .19 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

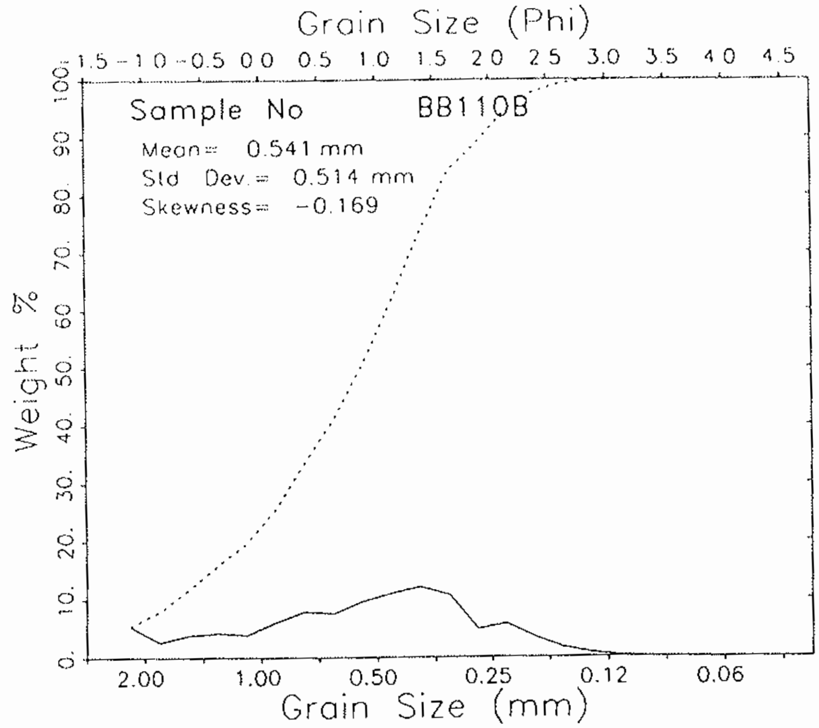
MEAN = .321 STANDARD DEVIATION = 1.212 SKEWNESS = .090 KURTOSIS = -1.145

DISPERSION = .476 STANDARD DEVIATION = .724 DEVIATION FROM NORMAL DISTR. = -40.23%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.208	-1.114	-1.038	.434	1.317	1.585	2.218	2.937

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.236	.302	COARSE SAND
STANDARD DEVIATION	1.350	1.194	POORLY SORTED
SKEWNESS(1)	-.147	-.053	NEAR SYMMETRICAL
SKEWNESS(2)	.053		
KURTOSIS	.269	.596	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB110B	060699						
Bogue Banks Beach Samples BB110B Berm							
		-1.125	5.260	5.284	-1.000	5.284	
		-.875	2.550	2.562	-.750	7.845	
		-.625	3.720	3.737	-.500	11.582	
		-.375	4.130	4.149	-.250	15.731	
		-.125	3.800	3.817	.000	19.548	
		.125	5.930	5.957	.250	25.505	
		.375	7.740	7.775	.500	33.280	
		.625	7.470	7.504	.750	40.784	
		.875	9.520	9.563	1.000	50.347	
		1.125	10.890	10.939	1.250	61.286	
		1.375	11.990	12.044	1.500	73.330	
		1.625	10.570	10.618	1.750	83.948	
		1.875	4.720	4.741	2.000	88.689	
		2.125	5.610	5.635	2.250	94.324	
		2.375	3.320	3.335	2.500	97.659	
		2.625	1.540	1.547	2.750	99.206	
		2.875	.610	.613	3.000	99.819	
		3.125	.140	.141	3.250	99.960	
		3.375	.040	.040	3.500	100.000	
		3.625	.000	.000	3.750	100.000	
		3.875	.000	.000	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 99.550

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

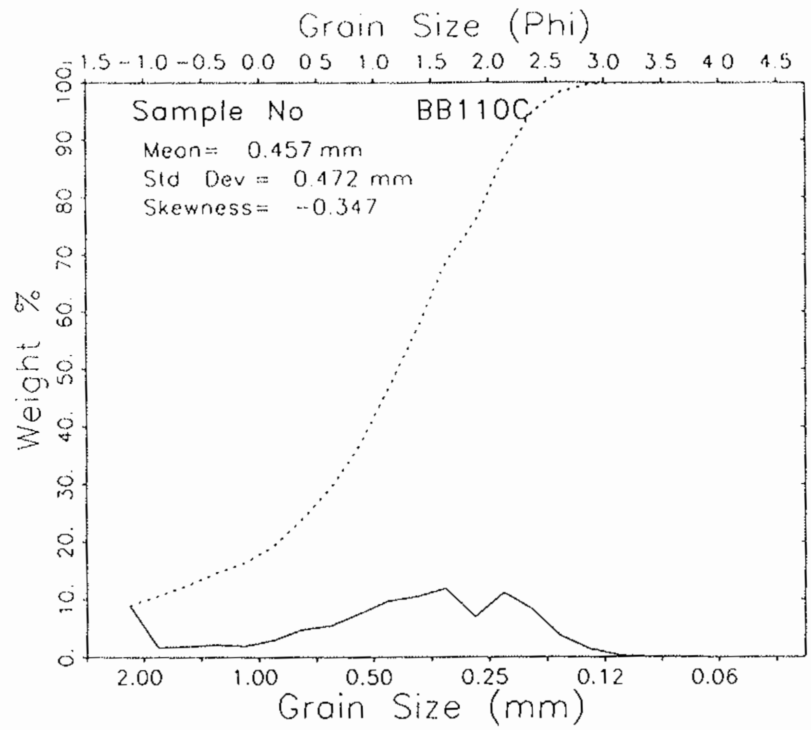
MOMENT MEASURES:

MEAN = .855 STANDARD DEVIATION = .961 SKEWNESS = -.169 KURTOSIS = -.532
DISPERSION = .561 STANDARD DEVIATION = .880 DEVIATION FROM NORMAL DISTR. = -8.39%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.203	-1.013	-.232	.229	.991	1.539	1.753	2.301	2.717

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.760	.837	COARSE SAND
STANDARD DEVIATION	.993	.998	MODERATELY SORTED
SKEWNESS(1)	-.232	-.221	COARSE-SKEWED
SKEWNESS(2)	-.350		
KURTOSIS	.669	1.036	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB110C	060699					
Bogue Banks Beach Sample BB110C MBF						
		-1.125	10.350	8.926	-1.000	8.926
		-.875	1.850	1.596	-.750	10.522
		-.625	2.100	1.811	-.500	12.333
		-.375	2.450	2.113	-.250	14.446
		-.125	2.160	1.863	.000	16.309
		.125	3.370	2.906	.250	19.215
		.375	5.480	4.726	.500	23.941
		.625	6.210	5.356	.750	29.297
		.875	8.670	7.477	1.000	36.774
		1.125	11.140	9.608	1.250	46.382
		1.375	12.070	10.410	1.500	56.792
		1.625	13.710	11.824	1.750	68.616
		1.875	7.990	6.891	2.000	75.507
		2.125	12.780	11.022	2.250	86.529
		2.375	9.480	8.176	2.500	94.705
		2.625	4.150	3.579	2.750	98.284
		2.875	1.550	1.337	3.000	99.621
		3.125	.330	.285	3.250	99.905
		3.375	.090	.078	3.500	99.983
		3.625	.020	.017	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.950

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

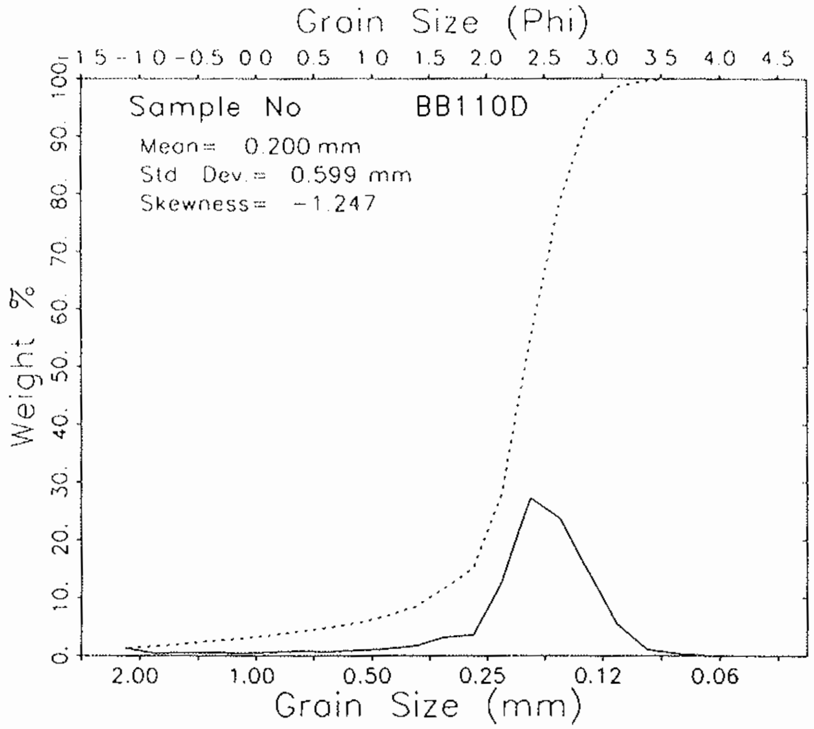
MEAN = 1.130 STANDARD DEVIATION = 1.083 SKEWNESS = -.347 KURTOSIS = -.345

DISPERSION = .550 STANDARD DEVIATION = .859 DEVIATION FROM NORMAL DISTR. = -20.64%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.222	-1.110	-.041	.549	1.337	1.982	2.193	2.521	2.884

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.076	1.163	MEDIUM SAND
STANDARD DEVIATION	1.117	1.109	POORLY SORTED
SKEWNESS(1)	-.234	-.291	COARSE-SKEWED
SKEWNESS(2)	-.565		
KURTOSIS	.625	1.039	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB110D	060699					
Bogue Banks Beach Samples B110D LTT						
		-1.125	1.220	1.212	-1.000	1.212
		-.875	.350	.348	-.750	1.560
		-.625	.440	.437	-.500	1.997
		-.375	.480	.477	-.250	2.474
		-.125	.430	.427	.000	2.902
		.125	.540	.537	.250	3.438
		.375	.730	.725	.500	4.164
		.625	.600	.596	.750	4.760
		.875	.880	.874	1.000	5.635
		1.125	1.170	1.163	1.250	6.797
		1.375	1.640	1.630	1.500	8.427
		1.625	3.150	3.130	1.750	11.557
		1.875	3.480	3.458	2.000	15.015
		2.125	12.630	12.551	2.250	27.566
		2.375	27.360	27.189	2.500	54.755
		2.625	23.900	23.750	2.750	78.505
		2.875	14.680	14.588	3.000	93.094
		3.125	5.460	5.426	3.250	98.519
		3.375	1.060	1.053	3.500	99.573
		3.625	.350	.348	3.750	99.921
		3.875	.080	.079	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.630

PERCENT FINER THAN 4.00 PHI = .02 PERCENT COARSER THAN -1.00 PHI = .00

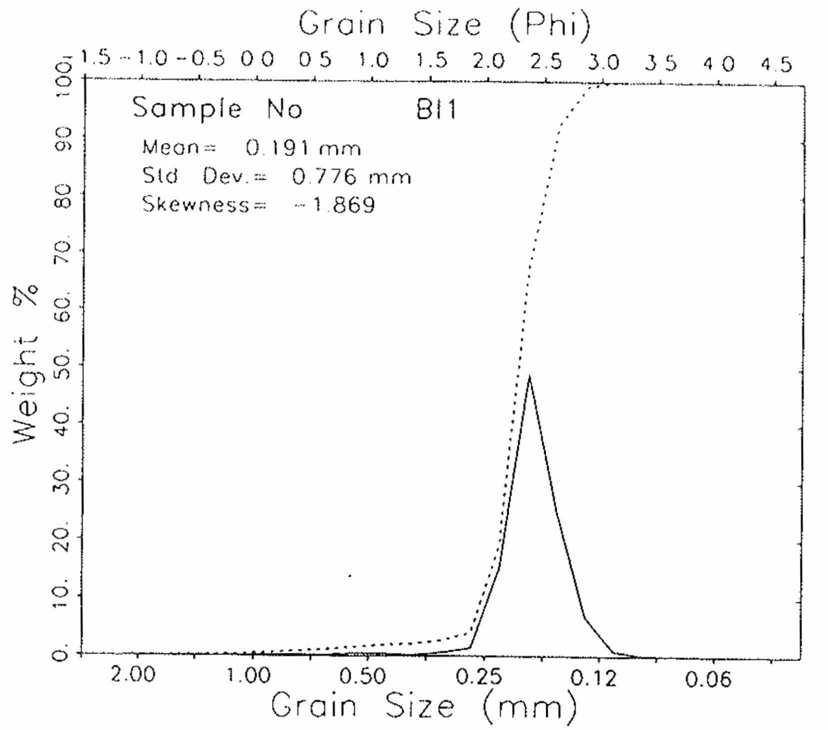
MOMENT MEASURES:

MEAN = 2.320 STANDARD DEVIATION = .739 SKEWNESS = -1.247 KURTOSIS = 7.816
DISPERSION = .307 STANDARD DEVIATION = .491 DEVIATION FROM NORMAL DISTR. = -33.62%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.044	.819	2.020	2.199	2.456	2.713	2.844	3.088	3.364

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.432	2.440	FINE SAND
STANDARD DEVIATION	.412	.550	MODERATELY WELL SORTED
SKEWNESS(1)	-.059	-.251	COARSE-SKEWED
SKEWNESS(2)	-1.220		
KURTOSIS	1.752	1.809	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BI1	060699					
Bogue Banks Bogue Inlet Bi1 Grab						
		-1.125	.060	.060	-1.000	.060
		-.875	.060	.060	-.750	.120
		-.625	.090	.090	-.500	.210
		-.375	.090	.090	-.250	.300
		-.125	.120	.120	.000	.421
		.125	.200	.200	.250	.621
		.375	.250	.250	.500	.871
		.625	.260	.260	.750	1.132
		.875	.360	.361	1.000	1.492
		1.125	.420	.421	1.250	1.913
		1.375	.160	.160	1.500	2.073
		1.625	.580	.581	1.750	2.654
		1.875	1.290	1.292	2.000	3.946
		2.125	15.250	15.273	2.250	19.219
		2.375	48.750	48.823	2.500	68.042
		2.625	24.420	24.457	2.750	92.499
		2.875	6.610	6.620	3.000	99.119
		3.125	.790	.791	3.250	99.910
		3.375	.090	.090	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.850

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

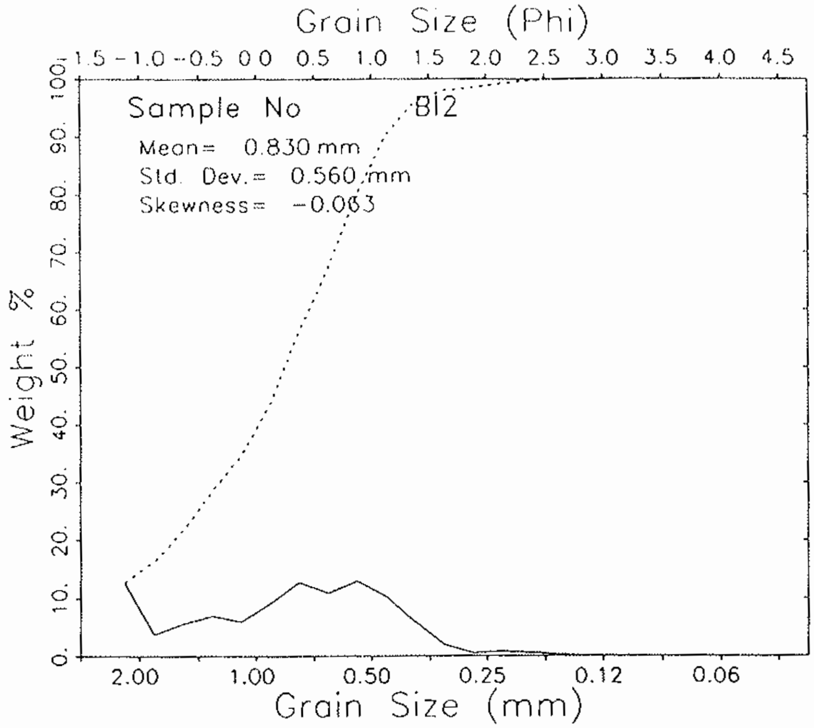
MEAN = 2.388 STANDARD DEVIATION = .366 SKEWNESS = -1.869 KURTOSIS = 24.790

DISPERSION = .014 STANDARD DEVIATION = .250 DEVIATION FROM NORMAL DISTR. = -31.67%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.624	2.017	2.197	2.280	2.408	2.571	2.663	2.844	2.996

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.430	2.423	
			FINE SAND
STANDARD DEVIATION	.233	.242	
			VERY WELL SORTED
SKEWNESS(1)	.097	.077	
			NEAR SYMMETRICAL
SKEWNESS(2)	.100		
KURTOSIS	.776	1.163	
			LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BI2	060699						
Bogue Banks Bogue Inlet BI2 Grab							
		-1.125	12.610		12.649	-1.000	12.649
		-.875	3.600		3.611	-.750	16.260
		-.625	5.530		5.547	-.500	21.808
		-.375	6.840		6.861	-.250	28.669
		-.125	5.900		5.918	.000	34.587
		.125	9.050		9.078	.250	43.665
		.375	12.630		12.669	.500	56.335
		.625	10.760		10.793	.750	67.128
		.875	12.810		12.850	1.000	79.978
		1.125	10.220		10.252	1.250	90.230
		1.375	5.790		5.808	1.500	96.038
		1.625	1.880		1.886	1.750	97.924
		1.875	.490		.492	2.000	98.415
		2.125	.720		.722	2.250	99.137
		2.375	.570		.572	2.500	99.709
		2.625	.220		.221	2.750	99.930
		2.875	.070		.070	3.000	100.000
		3.125	.000		.000	3.250	100.000
		3.375	.000		.000	3.500	100.000
		3.625	.000		.000	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.690

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

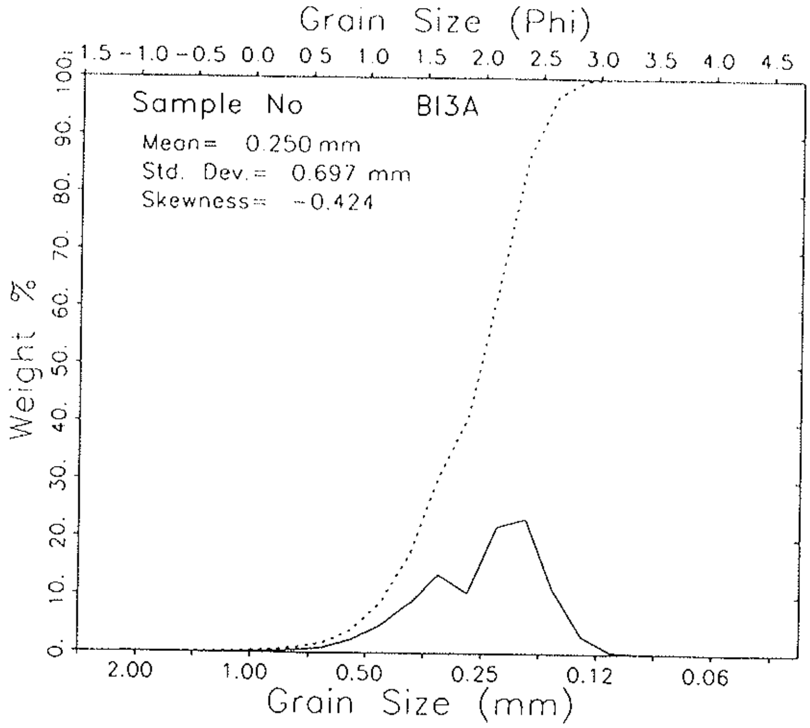
MOMENT MEASURES:

MEAN = .269 STANDARD DEVIATION = .837 SKEWNESS = -.063 KURTOSIS = -.665
DISPERSION = .466 STANDARD DEVIATION = .708 DEVIATION FROM NORMAL DISTR. = -15.36%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.230	-1.151	-.768	-.384	.375	.903	1.098	1.455	2.202

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.165	.235	COARSE SAND
STANDARD DEVIATION	.933	.861	MODERATELY SORTED
SKEWNESS(1)	-.225	-.198	COARSE-SKEWED
SKEWNESS(2)	-.239		
KURTOSIS	.397	.830	PLATYKURTIC



SAMPLE NO. DATE

BI3A 070699

Bogue Inlet - Station 3A

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.020	.020	-1.000	.020
-.875	.060	.059	-.750	.079
-.625	.040	.039	-.500	.118
-.375	.040	.039	-.250	.158
-.125	.100	.099	.000	.257
.125	.190	.188	.250	.444
.375	.410	.405	.500	.849
.625	.800	.790	.750	1.638
.875	2.260	2.231	1.000	3.869
1.125	4.740	4.678	1.250	8.547
1.375	8.560	8.448	1.500	16.996
1.625	13.730	13.551	1.750	30.547
1.875	10.520	10.383	2.000	40.930
2.125	22.140	21.852	2.250	62.781
2.375	23.530	23.223	2.500	86.005
2.625	10.870	10.728	2.750	96.733
2.875	2.920	2.882	3.000	99.615
3.125	.320	.316	3.250	99.931
3.375	.070	.069	3.500	100.000
3.625	.000	.000	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.320

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

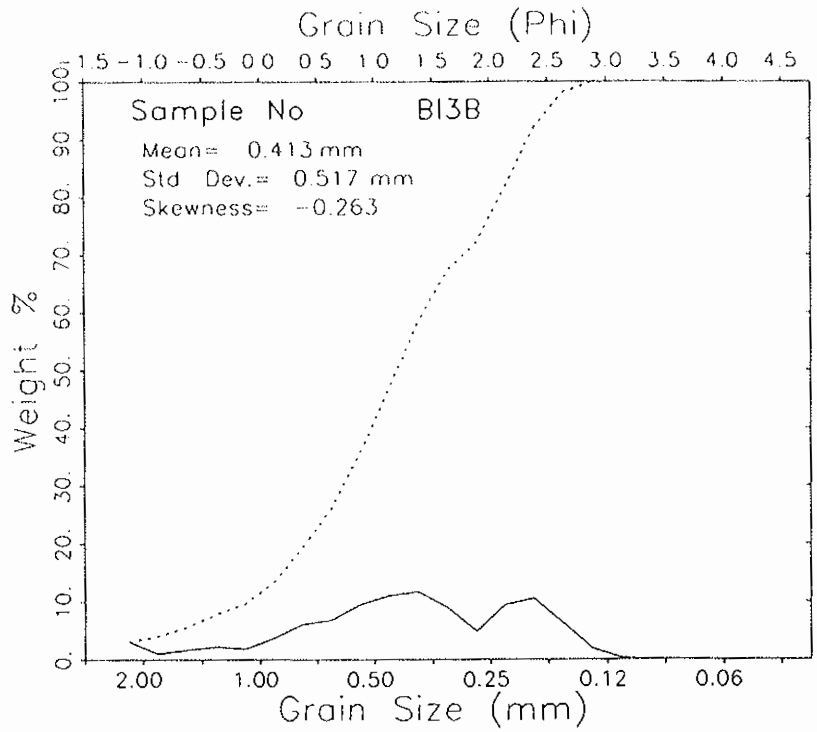
MEAN = 2.001 STANDARD DEVIATION = .521 SKEWNESS = -.424 KURTOSIS = 1.274

DISPERSION = .297 STANDARD DEVIATION = .480 DEVIATION FROM NORMAL DISTR. = -7.94%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.548	1.060	1.471	1.648	2.104	2.382	2.478	2.710	2.947

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.974	2.018	
STANDARD DEVIATION	.504	.502	FINE SAND
SKEWNESS(1)	-.257	-.261	MODERATELY WELL SORTED
SKEWNESS(2)	-.434		COARSE-SKEWED
KURTOSIS	.636	.921	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BI3B	060699						
Bogue Banks Bogue Inlet BI3B Middle							
		-1.125	3.710		3.059	-1.000	3.059
		-.875	1.170		.965	-.750	4.023
		-.625	1.950		1.608	-.500	5.631
		-.375	2.600		2.144	-.250	7.775
		-.125	2.220		1.830	.000	9.605
		.125	4.560		3.760	.250	13.365
		.375	7.380		6.085	.500	19.449
		.625	8.220		6.777	.750	26.226
		.875	11.450		9.440	1.000	35.667
		1.125	13.280		10.949	1.250	46.616
		1.375	14.090		11.617	1.500	58.232
		1.625	10.810		8.913	1.750	67.145
		1.875	5.790		4.774	2.000	71.919
		2.125	11.390		9.391	2.250	81.309
		2.375	12.740		10.504	2.500	91.813
		2.625	7.540		6.217	2.750	98.030
		2.875	2.160		1.781	3.000	99.810
		3.125	.230		.190	3.250	100.000
		3.375	.000		.000	3.500	100.000
		3.625	.000		.000	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 121.290

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

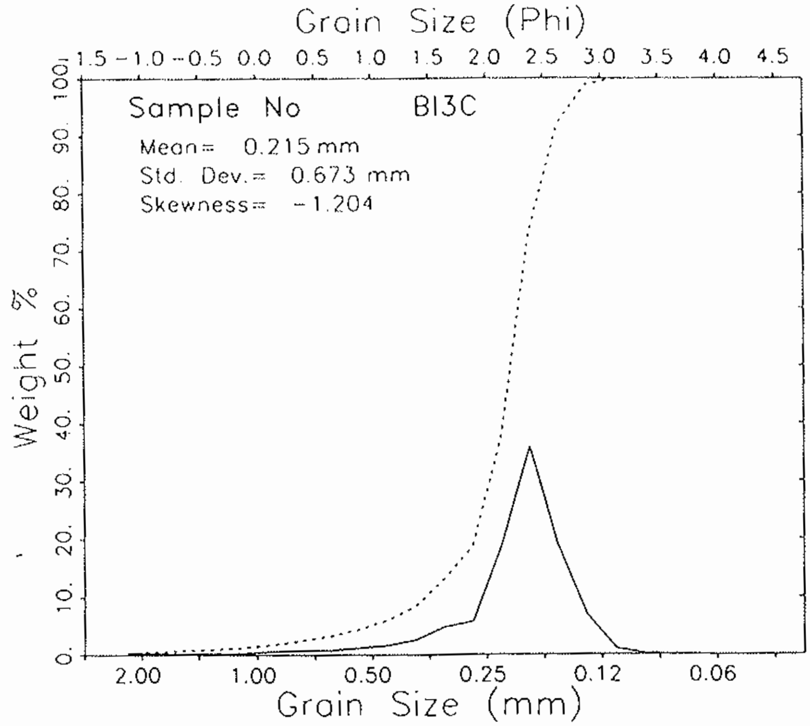
MOMENT MEASURES:

MEAN = 1.276 STANDARD DEVIATION = .953 SKEWNESS = -.263 KURTOSIS = -.164
DISPERSION = .545 STANDARD DEVIATION = .848 DEVIATION FROM NORMAL DISTR. = -10.99%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.168	-.598	.358	.705	1.323	2.082	2.314	2.628	2.886

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.336	1.332	MEDIUM SAND
STANDARD DEVIATION	.978	.978	MODERATELY SORTED
SKEWNESS(1)	.014	-.089	NEAR SYMMETRICAL
SKEWNESS(2)	-.315		
KURTOSIS	.650	.960	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B13C	060699						
Bogue Banks Bogue Inlet B13C Lowe							
		-1.125	.330		.321	-1.000	.321
		-.875	.200		.195	-.750	.516
		-.625	.210		.204	-.500	.720
		-.375	.220		.214	-.250	.934
		-.125	.260		.253	.000	1.187
		.125	.530		.516	.250	1.702
		.375	.730		.710	.500	2.412
		.625	.780		.759	.750	3.171
		.875	1.170		1.138	1.000	4.309
		1.125	1.630		1.585	1.250	5.894
		1.375	2.510		2.441	1.500	8.336
		1.625	4.840		4.708	1.750	13.043
		1.875	5.850		5.690	2.000	18.734
		2.125	19.340		18.811	2.250	37.545
		2.375	36.940		35.930	2.500	73.475
		2.625	19.160		18.636	2.750	92.112
		2.875	6.990		6.799	3.000	98.911
		3.125	.960		.934	3.250	99.844
		3.375	.130		.126	3.500	99.971
		3.625	.030		.029	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.810

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

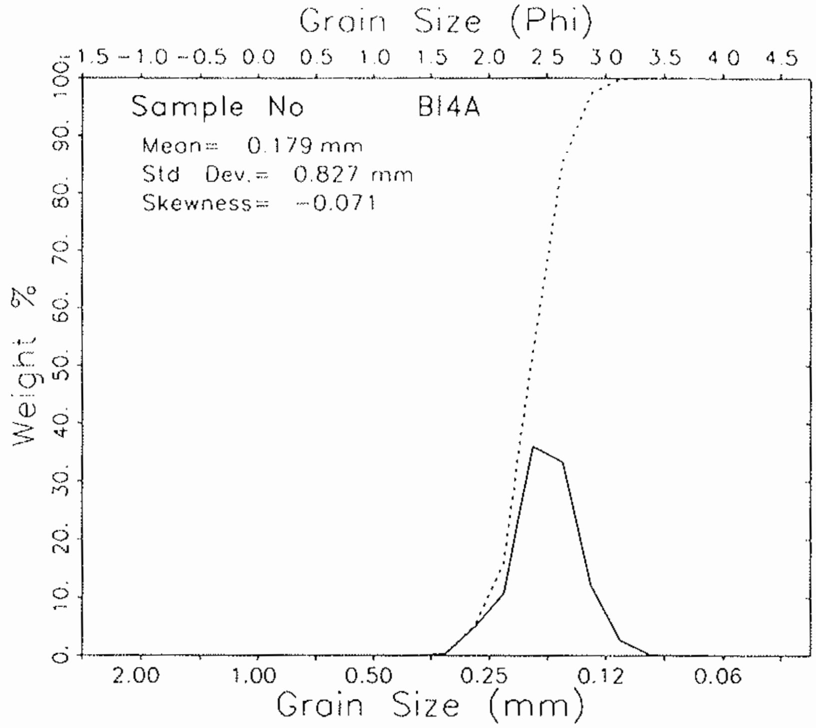
MOMENT MEASURES:

MEAN = 2.217 STANDARD DEVIATION = .571 SKEWNESS = -1.204 KURTOSIS = 8.483
DISPERSION = .231 STANDARD DEVIATION = .412 DEVIATION FROM NORMAL DISTR. = -27.91%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.185	1.109	1.880	2.083	2.337	2.520	2.641	2.856	3.024

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.261	2.286	FINE SAND
STANDARD DEVIATION	.381	.455	WELL SORTED
SKEWNESS(1)	-.200	-.303	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.930		
KURTOSIS	1.295	1.638	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BI4A	060699						
Bogue Banks Bogue Inlet BI4A							
		-1.125	.000		.000	-1.000	.000
		-.875	.000		.000	-.750	.000
		-.625	.000		.000	-.500	.000
		-.375	.000		.000	-.250	.000
		-.125	.000		.000	.000	.000
		.125	.000		.000	.250	.000
		.375	.000		.000	.500	.000
		.625	.000		.000	.750	.000
		.875	.000		.000	1.000	.000
		1.125	.000		.000	1.250	.000
		1.375	.000		.000	1.500	.000
		1.625	.340		.341	1.750	.341
		1.875	4.850		4.865	2.000	5.206
		2.125	10.810		10.844	2.250	16.050
		2.375	35.910		36.022	2.500	52.071
		2.625	33.210		33.313	2.750	85.385
		2.875	11.880		11.917	3.000	97.302
		3.125	2.550		2.558	3.250	99.860
		3.375	.140		.140	3.500	100.000
		3.625	.000		.000	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.690

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

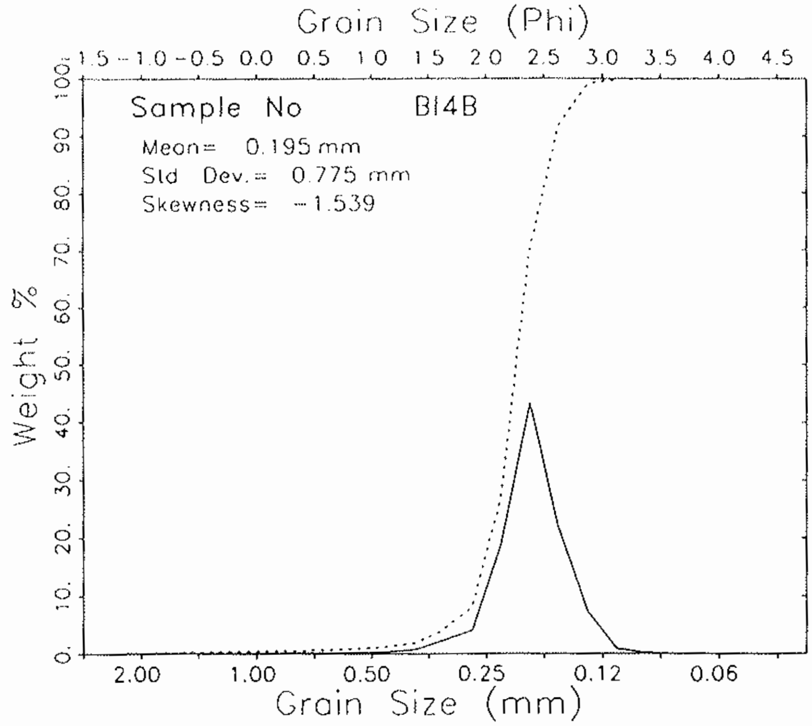
MOMENT MEASURES:

MEAN = 2.484 STANDARD DEVIATION = .274 SKEWNESS = -.071 KURTOSIS = .270
DISPERSION = .048 STANDARD DEVIATION = .271 DEVIATION FROM NORMAL DISTR. = -1.40%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.784	1.989	2.249	2.312	2.486	2.672	2.740	2.952	3.166

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.494	2.491	FINE SAND
STANDARD DEVIATION	.245	.268	VERY WELL SORTED
SKEWNESS(1)	.035	.002	NEAR SYMMETRICAL
SKEWNESS(2)	-.061		
KURTOSIS	.961	1.096	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B14B	060699					
Bogue Banks Bogue Inlet B14B Lower						
		-1.125	.140	.124	-1.000	.124
		-.875	.070	.062	-.750	.187
		-.625	.090	.080	-.500	.266
		-.375	.070	.062	-.250	.329
		-.125	.060	.053	.000	.382
		.125	.090	.080	.250	.462
		.375	.120	.107	.500	.568
		.625	.110	.098	.750	.666
		.875	.210	.187	1.000	.853
		1.125	.360	.320	1.250	1.172
		1.375	.710	.631	1.500	1.803
		1.625	2.490	2.212	1.750	4.015
		1.875	4.480	3.979	2.000	7.994
		2.125	21.300	18.920	2.250	26.914
		2.375	48.890	43.427	2.500	70.341
		2.625	24.300	21.585	2.750	91.926
		2.875	8.020	7.124	3.000	99.050
		3.125	.940	.835	3.250	99.885
		3.375	.130	.115	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 112.580

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

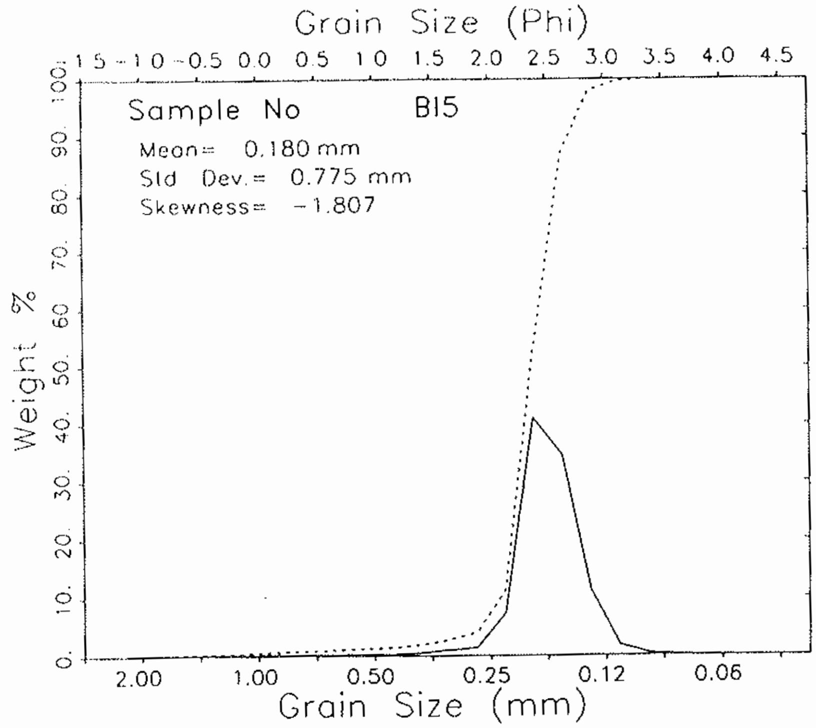
MOMENT MEASURES:

MEAN = 2.358 STANDARD DEVIATION = .367 SKEWNESS = -1.539 KURTOSIS = 22.052
DISPERSION = .078 STANDARD DEVIATION = .290 DEVIATION FROM NORMAL DISTR. = -21.17%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.115	1.812	2.106	2.225	2.383	2.554	2.658	2.858	2.998

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.382	2.382	FINE SAND
STANDARD DEVIATION	.276	.297	VERY WELL SORTED
SKEWNESS(1)	-.003	-.048	NEAR SYMMETRICAL
SKEWNESS(2)	-.174		
KURTOSIS	.893	1.302	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B15	060699					
Bogue Banks Bogue Inlet B15 Grab						
		-1.125	.060	.059	-1.000	.059
		-.875	.050	.049	-.750	.108
		-.625	.080	.079	-.500	.187
		-.375	.130	.128	-.250	.315
		-.125	.110	.108	.000	.423
		.125	.190	.187	.250	.611
		.375	.170	.167	.500	.778
		.625	.150	.148	.750	.926
		.875	.190	.187	1.000	1.113
		1.125	.220	.217	1.250	1.329
		1.375	.410	.404	1.500	1.733
		1.625	.880	.867	1.750	2.600
		1.875	1.330	1.310	2.000	3.909
		2.125	7.450	7.336	2.250	11.246
		2.375	41.680	41.044	2.500	52.290
		2.625	35.090	34.554	2.750	86.844
		2.875	11.250	11.078	3.000	97.922
		3.125	1.730	1.704	3.250	99.626
		3.375	.310	.305	3.500	99.931
		3.625	.070	.069	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.550

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

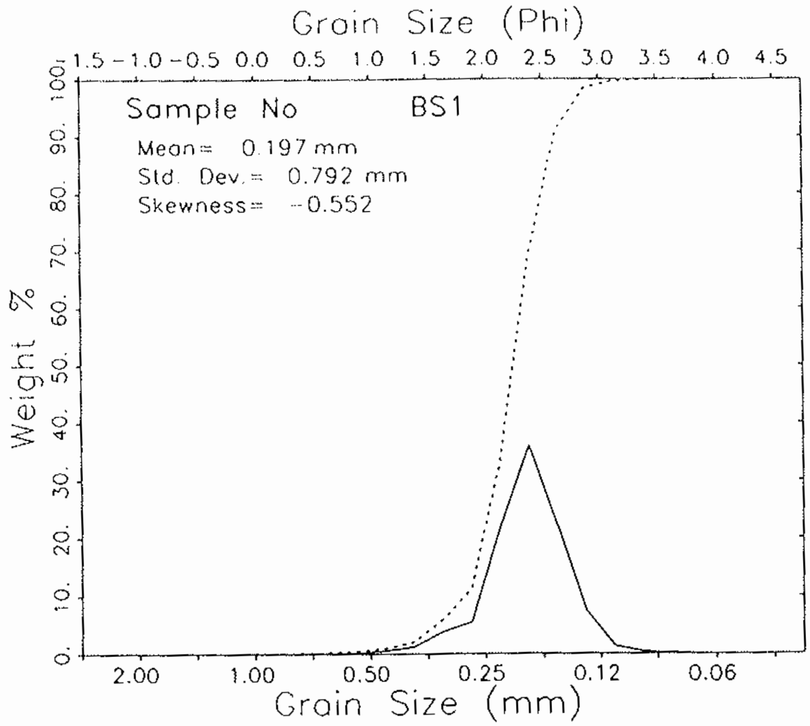
MOMENT MEASURES:

MEAN = 2.470 STANDARD DEVIATION = .367 SKEWNESS = -1.807 KURTOSIS = 25.170
DISPERSION = .035 STANDARD DEVIATION = .262 DEVIATION FROM NORMAL DISTR. = -28.60%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.849	2.037	2.279	2.334	2.486	2.664	2.729	2.934	3.158

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.504	2.498	FINE SAND
STANDARD DEVIATION	.225	.249	VERY WELL SORTED
SKEWNESS(1)	.081	.040	NEAR SYMMETRICAL
SKEWNESS(2)	-.002		
KURTOSIS	.991	1.112	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bs1	060699					
Bogue Banks Bogue Sound BS1 Surface						
		-1.125	.000	.000	-1.000	.000
		-.875	.000	.000	-.750	.000
		-.625	.040	.039	-.500	.039
		-.375	.020	.019	-.250	.058
		-.125	.030	.029	.000	.087
		.125	.040	.039	.250	.126
		.375	.060	.058	.500	.185
		.625	.080	.078	.750	.262
		.875	.180	.175	1.000	.437
		1.125	.450	.437	1.250	.875
		1.375	1.170	1.137	1.500	2.012
		1.625	3.860	3.753	1.750	5.765
		1.875	5.560	5.405	2.000	11.171
		2.125	22.380	21.758	2.250	32.928
		2.375	37.000	35.971	2.500	68.899
		2.625	22.790	22.156	2.750	91.056
		2.875	7.540	7.330	3.000	98.386
		3.125	1.220	1.186	3.250	99.572
		3.375	.310	.301	3.500	99.874
		3.625	.130	.126	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.860

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

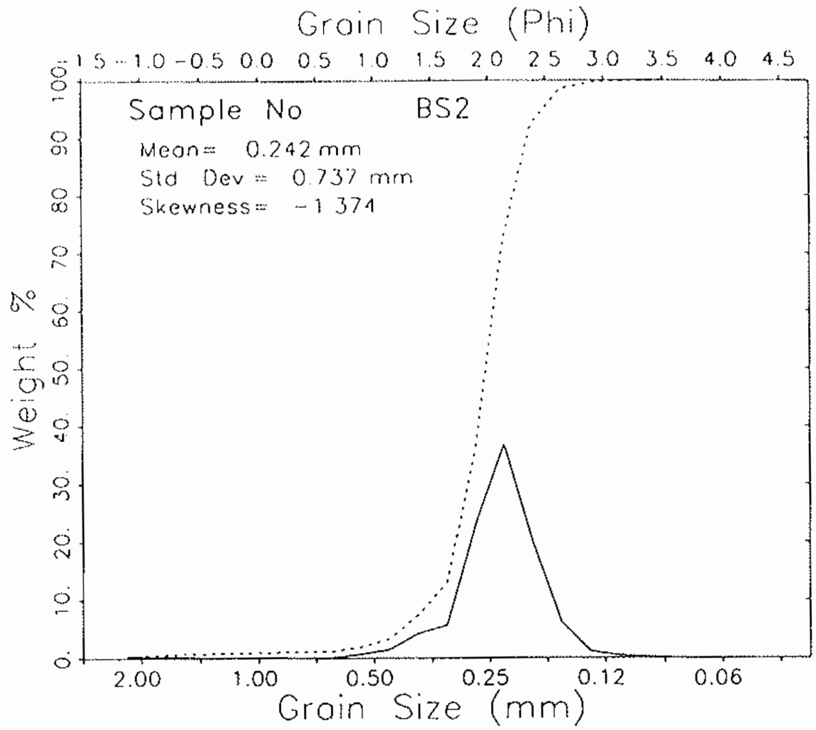
MOMENT MEASURES:

MEAN = 2.346 STANDARD DEVIATION = .356 SKEWNESS = -.552 KURTOSIS = 5.481
DISPERSION = .132 STANDARD DEVIATION = .328 DEVIATION FROM NORMAL DISTR. = -7.91%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.277	1.699	2.055	2.159	2.369	2.569	2.670	2.885	3.129

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.363	2.365	FINE SAND
STANDARD DEVIATION	.307	.333	VERY WELL SORTED
SKEWNESS(1)	-.019	-.074	NEAR SYMMETRICAL
SKEWNESS(2)	-.250		
KURTOSIS	.928	1.185	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BS2	060699					
Bogue Banks Bogue Sound BS2 (-2.5')						
		-1.125	.340	.343	-1.000	.343
		-.875	.180	.182	-.750	.525
		-.625	.210	.212	-.500	.736
		-.375	.030	.030	-.250	.767
		-.125	.110	.111	.000	.878
		.125	.120	.121	.250	.999
		.375	.060	.061	.500	1.059
		.625	.090	.091	.750	1.150
		.875	.660	.666	1.000	1.816
		1.125	1.370	1.382	1.250	3.198
		1.375	4.080	4.116	1.500	7.314
		1.625	5.480	5.528	1.750	12.842
		1.875	22.660	22.859	2.000	35.701
		2.125	36.530	36.851	2.250	72.551
		2.375	19.730	19.903	2.500	92.454
		2.625	5.960	6.012	2.750	98.467
		2.875	1.050	1.059	3.000	99.526
		3.125	.360	.363	3.250	99.889
		3.375	.110	.111	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.130

PERCENT FINER THAN 4.00 PHI = .00   PERCENT COARSER THAN -1.00 PHI = .00

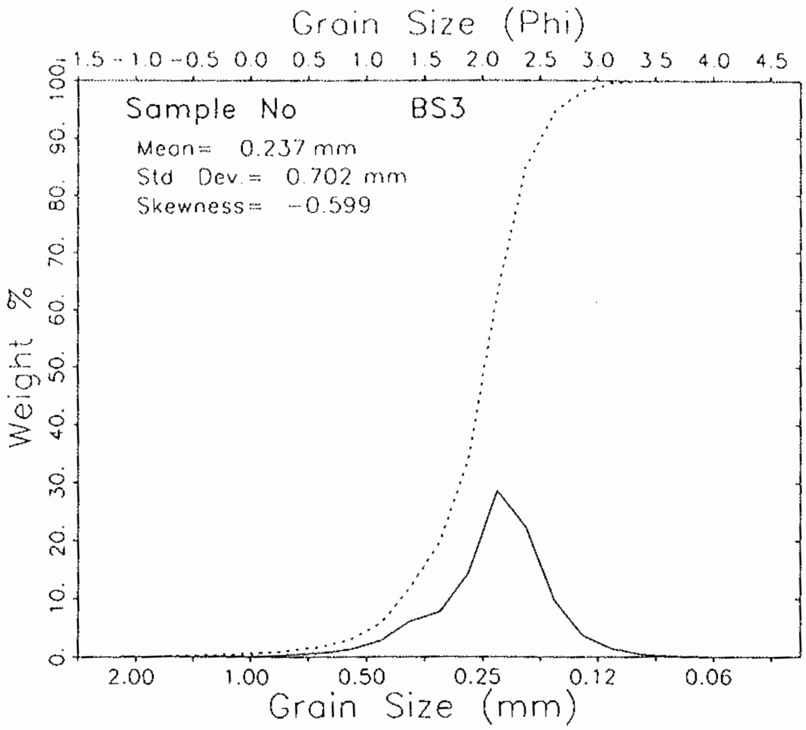
MOMENT MEASURES:

MEAN = 2.049   STANDARD DEVIATION = .440   SKEWNESS = -1.374   KURTOSIS = 15.852
DISPERSION = .149   STANDARD DEVIATION = .341   DEVIATION FROM NORMAL DISTR. = -22.53%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.255	1.359	1.785	1.883	2.097	2.281	2.394	2.606	2.876

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.089	2.092	FINE SAND
STANDARD DEVIATION	.305	.341	VERY WELL SORTED
SKEWNESS(1)	-.026	-.105	COARSE-SKEWED
SKEWNESS(2)	-.375		
KURTOSIS	1.046	1.284	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BS3	060699					
Bogue Banks Bogue Sound BS3 Surface						
		-1.125	.110	.100	-1.000	.100
		-.875	.030	.027	-.750	.127
		-.625	.110	.100	-.500	.227
		-.375	.180	.164	-.250	.391
		-.125	.110	.100	.000	.491
		.125	.260	.236	.250	.727
		.375	.450	.409	.500	1.136
		.625	.670	.609	.750	1.746
		.875	1.440	1.309	1.000	3.055
		1.125	3.070	2.791	1.250	5.846
		1.375	6.630	6.028	1.500	11.874
		1.625	8.440	7.673	1.750	19.547
		1.875	15.820	14.383	2.000	33.930
		2.125	31.550	28.684	2.250	62.615
		2.375	24.570	22.338	2.500	84.953
		2.625	10.550	9.592	2.750	94.545
		2.875	3.920	3.564	3.000	98.109
		3.125	1.510	1.373	3.250	99.482
		3.375	.460	.418	3.500	99.900
		3.625	.110	.100	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.990

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

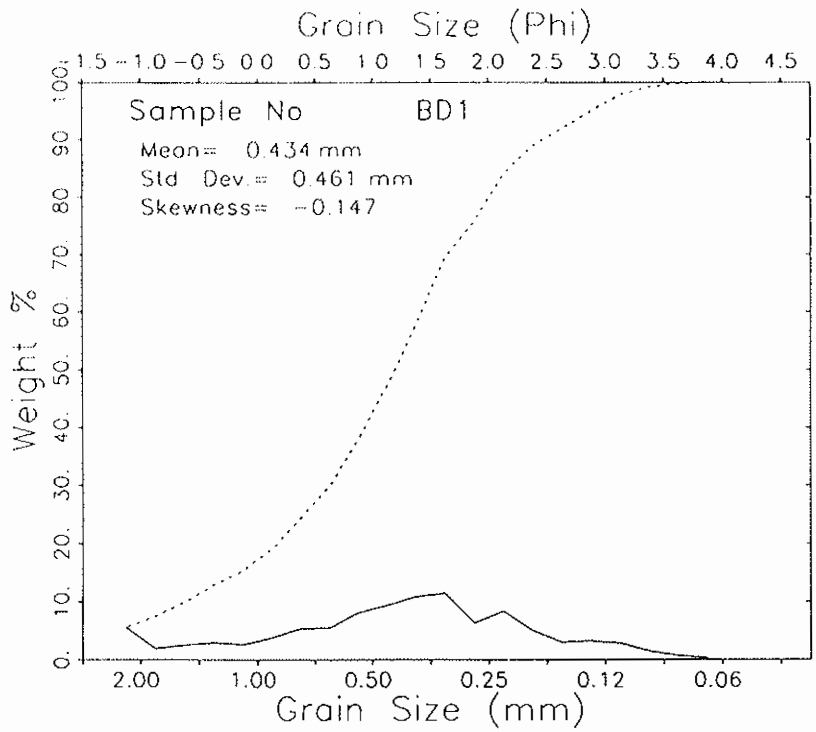
MOMENT MEASURES:

MEAN = 2.078 STANDARD DEVIATION = .510 SKEWNESS = -.599 KURTOSIS = 4.166
DISPERSION = .279 STANDARD DEVIATION = .460 DEVIATION FROM NORMAL DISTR. = -9.85%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.417	1.174	1.634	1.845	2.140	2.389	2.489	2.782	3.162

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.062	2.088	FINE SAND
STANDARD DEVIATION	.427	.457	WELL SORTED
SKEWNESS(1)	-.183	-.192	COARSE-SKEWED
SKEWNESS(2)	-.379		
KURTOSIS	.881	1.212	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BD1	060699					
Bogue Banks USACE Disposal at Plum						
		-1.125	5.520	5.547	-1.000	5.547
		-.875	1.860	1.869	-.750	7.416
		-.625	2.470	2.482	-.500	9.898
		-.375	2.870	2.884	-.250	12.781
		-.125	2.530	2.542	.000	15.324
		.125	3.740	3.758	.250	19.082
		.375	5.310	5.336	.500	24.417
		.625	5.360	5.386	.750	29.803
		.875	8.020	8.059	1.000	37.862
		1.125	9.270	9.315	1.250	47.176
		1.375	10.730	10.782	1.500	57.958
		1.625	11.370	11.425	1.750	69.383
		1.875	6.160	6.190	2.000	75.573
		2.125	8.300	8.340	2.250	83.913
		2.375	4.920	4.944	2.500	88.857
		2.625	2.940	2.954	2.750	91.811
		2.875	3.130	3.145	3.000	94.956
		3.125	2.810	2.824	3.250	97.779
		3.375	1.410	1.417	3.500	99.196
		3.625	.600	.603	3.750	99.799
		3.875	.200	.201	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.520

PERCENT FINER THAN 4.00 PHI = .34 PERCENT COARSER THAN -1.00 PHI = .00

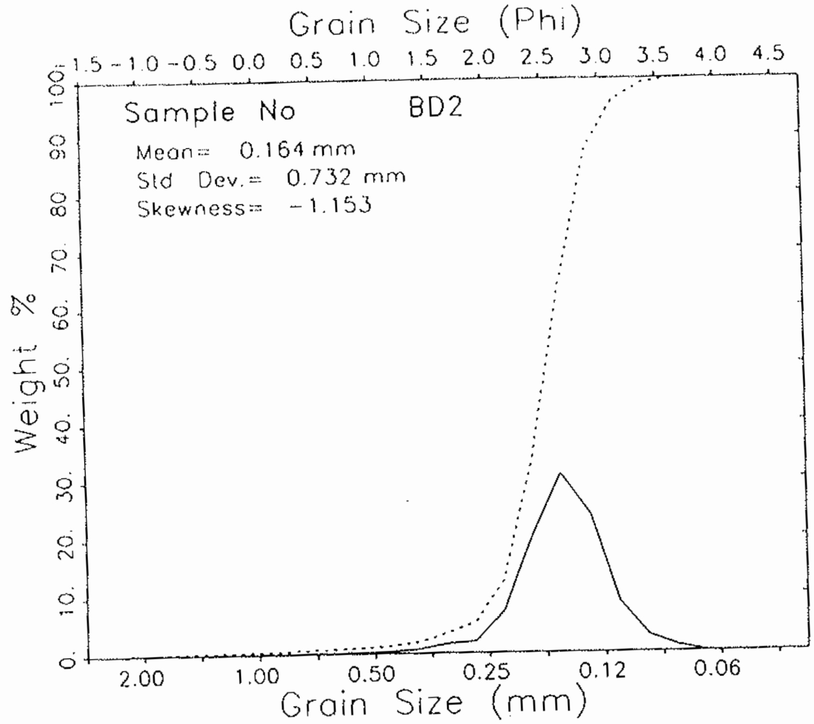
MOMENT MEASURES:

MEAN = 1.204 STANDARD DEVIATION = 1.117 SKEWNESS = -.147 KURTOSIS = -.336
DISPERSION = .621 STANDARD DEVIATION = 1.011 DEVIATION FROM NORMAL DISTR. = -9.45%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.205	-1.025	.045	.527	1.315	1.977	2.254	3.004	3.465

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.150	1.205	MEDIUM SAND
STANDARD DEVIATION	1.105	1.163	POORLY SORTED
SKEWNESS(1)	-.150	-.156	COARSE-SKEWED
SKEWNESS(2)	-.295		
KURTOSIS	.823	1.139	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BD2	060699						
Bogue Banks USACE disposal BD2 100M Plum							
		-1.125	.120		.111	-1.000	.111
		-.875	.080		.074	-.750	.186
		-.625	.080		.074	-.500	.260
		-.375	.080		.074	-.250	.334
		-.125	.080		.074	.000	.408
		.125	.110		.102	.250	.511
		.375	.130		.121	.500	.631
		.625	.140		.130	.750	.761
		.875	.200		.186	1.000	.947
		1.125	.320		.297	1.250	1.244
		1.375	.640		.594	1.500	1.838
		1.625	1.630		1.513	1.750	3.351
		1.875	2.090		1.940	2.000	5.291
		2.125	7.800		7.240	2.250	12.531
		2.375	21.650		20.097	2.500	32.628
		2.625	33.290		30.901	2.750	63.529
		2.875	25.850		23.995	3.000	87.524
		3.125	9.310		8.642	3.250	96.166
		3.375	3.050		2.831	3.500	98.997
		3.625	1.080		1.003	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.730

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

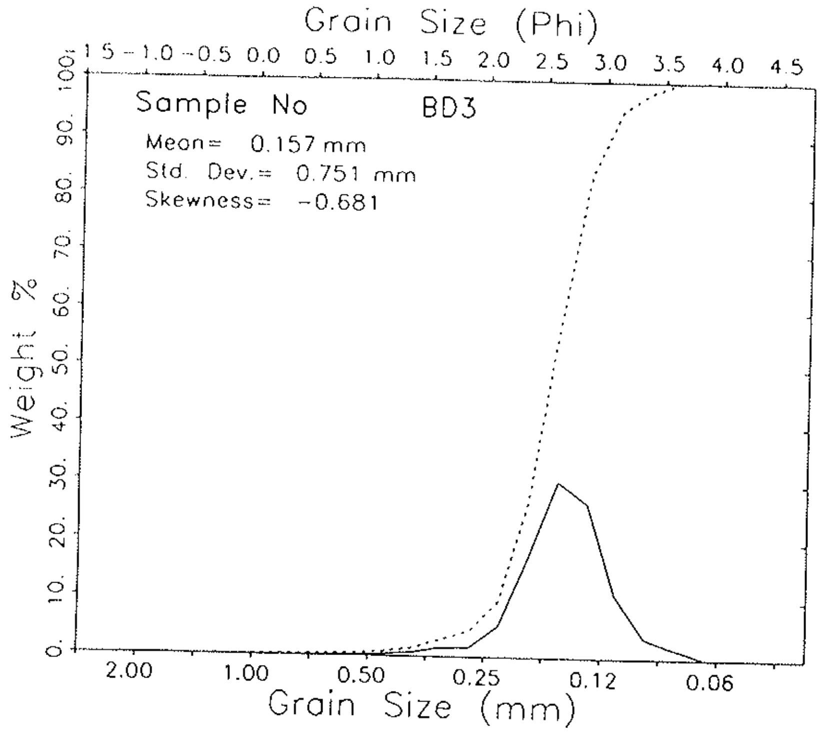
MOMENT MEASURES:

MEAN = 2.607 STANDARD DEVIATION = .451 SKEWNESS = -1.153 KURTOSIS = 13.763
DISPERSION = .192 STANDARD DEVIATION = .377 DEVIATION FROM NORMAL DISTR. = -16.45%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.045	1.962	2.293	2.405	2.641	2.870	2.963	3.216	3.501

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.628	2.632	FINE SAND
STANDARD DEVIATION	.335	.357	WELL SORTED
SKEWNESS(1)	-.037	-.059	NEAR SYMMETRICAL
SKEWNESS(2)	-.153		
KURTOSIS	.871	1.106	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BD3	060699					
Bogue Banks USACE Disposal BD3 500M Plum						
		-1.125	.020	.019	-1.000	.019
		-.875	.020	.019	-.750	.037
		-.625	.030	.028	-.500	.065
		-.375	.030	.028	-.250	.093
		-.125	.030	.028	.000	.121
		.125	.060	.056	.250	.177
		.375	.070	.065	.500	.243
		.625	.080	.075	.750	.317
		.875	.170	.159	1.000	.476
		1.125	.300	.280	1.250	.756
		1.375	.700	.654	1.500	1.410
		1.625	1.570	1.466	1.750	2.876
		1.875	1.620	1.513	2.000	4.389
		2.125	5.650	5.276	2.250	9.665
		2.375	18.490	17.266	2.500	26.931
		2.625	32.400	30.255	2.750	57.186
		2.875	28.580	26.688	3.000	83.873
		3.125	11.610	10.841	3.250	94.715
		3.375	3.690	3.446	3.500	98.160
		3.625	1.840	1.718	3.750	99.879
		3.875	.130	.121	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.090

PERCENT FINER THAN 4.00 PHI = .41 PERCENT COARSER THAN -1.00 PHI = .00

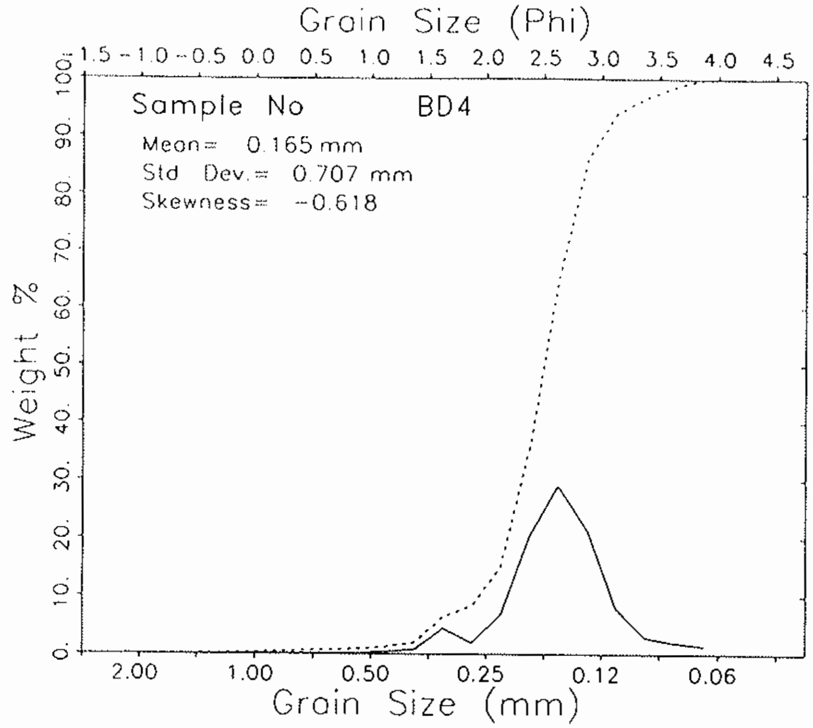
MOMENT MEASURES:

MEAN = 2.672 STANDARD DEVIATION = .413 SKEWNESS = -.681 KURTOSIS = 7.561
DISPERSION = .187 STANDARD DEVIATION = .372 DEVIATION FROM NORMAL DISTR. = -9.97%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.343	2.029	2.342	2.472	2.691	2.917	3.003	3.271	3.622

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.672	2.678	
STANDARD DEVIATION	.331	.353	FINE SAND
SKEWNESS(1)	-.055	-.061	WELL SORTED
SKEWNESS(2)	-.123		NEAR SYMMETRICAL
KURTOSIS	.878	1.144	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BD4	060699						
Bogue Banks USACE Disposal BD4 2' below							
		-1.125	.050		.049	-1.000	.049
		-.875	.040		.039	-.750	.087
		-.625	.070		.068	-.500	.155
		-.375	.060		.058	-.250	.213
		-.125	.100		.097	.000	.310
		.125	.130		.126	.250	.437
		.375	.170		.165	.500	.602
		.625	.150		.146	.750	.747
		.875	.130		.126	1.000	.873
		1.125	.370		.359	1.250	1.232
		1.375	.710		.689	1.500	1.921
		1.625	4.560		4.424	1.750	6.346
		1.875	1.950		1.892	2.000	8.238
		2.125	7.010		6.802	2.250	15.039
		2.375	21.130		20.502	2.500	35.541
		2.625	29.883		28.995	2.750	64.536
		2.875	22.020		21.366	3.000	85.902
		3.125	8.160		7.917	3.250	93.819
		3.375	2.950		2.862	3.500	96.682
		3.625	1.990		1.931	3.750	98.612
		3.875	1.430		1.388	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.063

PERCENT FINER THAN 4.00 PHI = 1.00 PERCENT COARSER THAN -1.00 PHI = .00

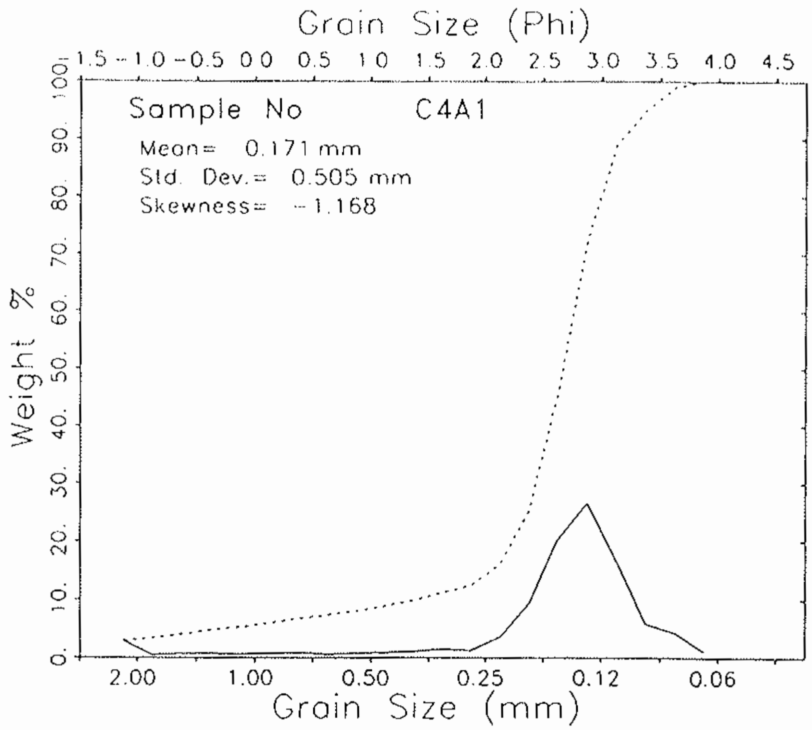
MOMENT MEASURES:

MEAN = 2.597 STANDARD DEVIATION = .500 SKEWNESS = -.618 KURTOSIS = 6.563
DISPERSION = .250 STANDARD DEVIATION = .430 DEVIATION FROM NORMAL DISTR. = -14.00%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.088	1.674	2.262	2.371	2.625	2.872	2.978	3.353	3.820

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.620	2.621	FINE SAND
STANDARD DEVIATION	.358	.433	WELL SORTED
SKEWNESS(1)	-.014	-.073	NEAR SYMMETRICAL
SKEWNESS(2)	-.310		
KURTOSIS	1.345	1.374	LEPTOKURTIC



SAMPLE NO. DATE

c4a1 060699

Bogue Banks C4A1 0-2.2

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	3.080	2.861	-1.000	2.861
-.875	.470	.437	-.750	3.298
-.625	.730	.678	-.500	3.976
-.375	.780	.725	-.250	4.700
-.125	.560	.520	.000	5.221
.125	.760	.706	.250	5.927
.375	.820	.762	.500	6.688
.625	.630	.585	.750	7.274
.875	.810	.752	1.000	8.026
1.125	.870	.808	1.250	8.834
1.375	1.100	1.022	1.500	9.856
1.625	1.480	1.375	1.750	11.231
1.875	1.270	1.180	2.000	12.411
2.125	3.770	3.502	2.250	15.913
2.375	10.150	9.429	2.500	25.341
2.625	21.970	20.409	2.750	45.750
2.875	28.660	26.623	3.000	72.373
3.125	17.890	16.619	3.250	88.992
3.375	6.260	5.815	3.500	94.807
3.625	4.500	4.180	3.750	98.987
3.875	1.090	1.013	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.650

PERCENT FINER THAN 4.00 PHI = .55 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

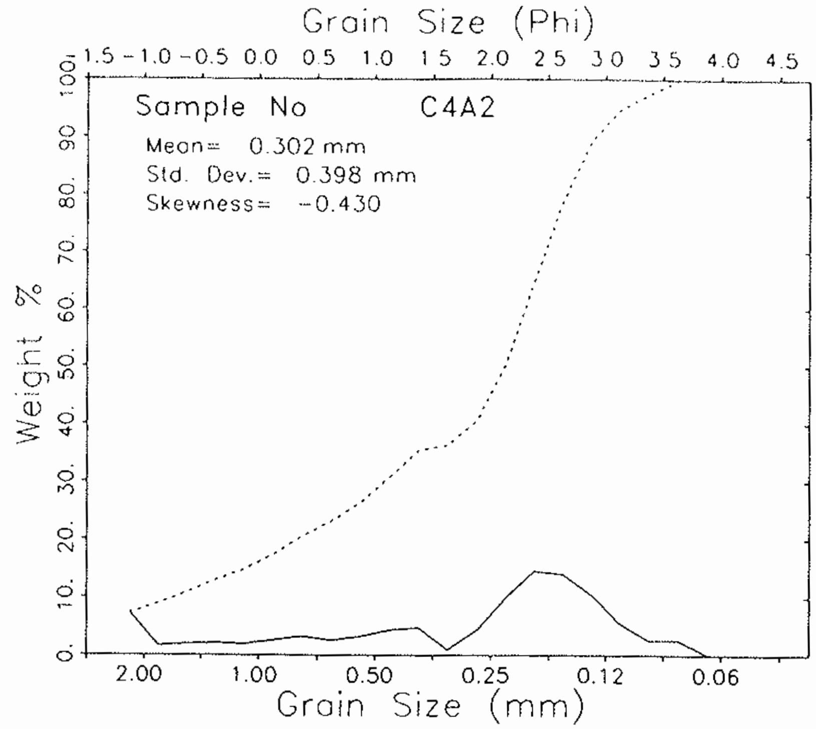
MEAN = 2.544 STANDARD DEVIATION = .986 SKEWNESS = -1.168 KURTOSIS = 5.469

DISPERSION = .361 STANDARD DEVIATION = .556 DEVIATION FROM NORMAL DISTR. = -43.63%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.163	-.106	2.252	2.491	2.790	3.040	3.175	3.512	3.753

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	2.714	2.739	FINE SAND
STANDARD DEVIATION	.461	.779	MODERATELY SORTED
SKEWNESS(1)	-.165	-.383	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-2.357		
KURTOSIS	2.921	2.703	VERY LEPTOKURTIC
.779			MODERATELY SORTED
SKEWNESS(1)	-.165		



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C4A2 060699					
Bogue Banks C4A2 0-2.7					
	-1.125	7.340	7.280	-1.000	7.280
	-.875	1.630	1.617	-.750	8.897
	-.625	1.900	1.885	-.500	10.782
	-.375	2.110	2.093	-.250	12.874
	-.125	1.870	1.855	.000	14.729
	.125	2.610	2.589	.250	17.318
	.375	3.280	3.253	.500	20.571
	.625	2.590	2.569	.750	23.140
	.875	3.230	3.204	1.000	26.344
	1.125	4.310	4.275	1.250	30.619
	1.375	4.740	4.701	1.500	35.320
	1.625	.910	.903	1.750	36.223
	1.875	4.320	4.285	2.000	40.508
	2.125	9.930	9.849	2.250	50.357
	2.375	14.580	14.461	2.500	64.818
	2.625	14.080	13.965	2.750	78.784
	2.875	10.590	10.504	3.000	89.288
	3.125	5.530	5.485	3.250	94.773
	3.375	2.590	2.569	3.500	97.342
	3.625	2.580	2.559	3.750	99.901
	3.875	.100	.099	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.820

PERCENT FINER THAN 4.00 PHI = 5.11 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.725 STANDARD DEVIATION = 1.329 SKEWNESS = -.430 KURTOSIS = -.389

DISPERSION = .582 STANDARD DEVIATION = .925 DEVIATION FROM NORMAL DISTR. = -30.41%

PERCENTILES:

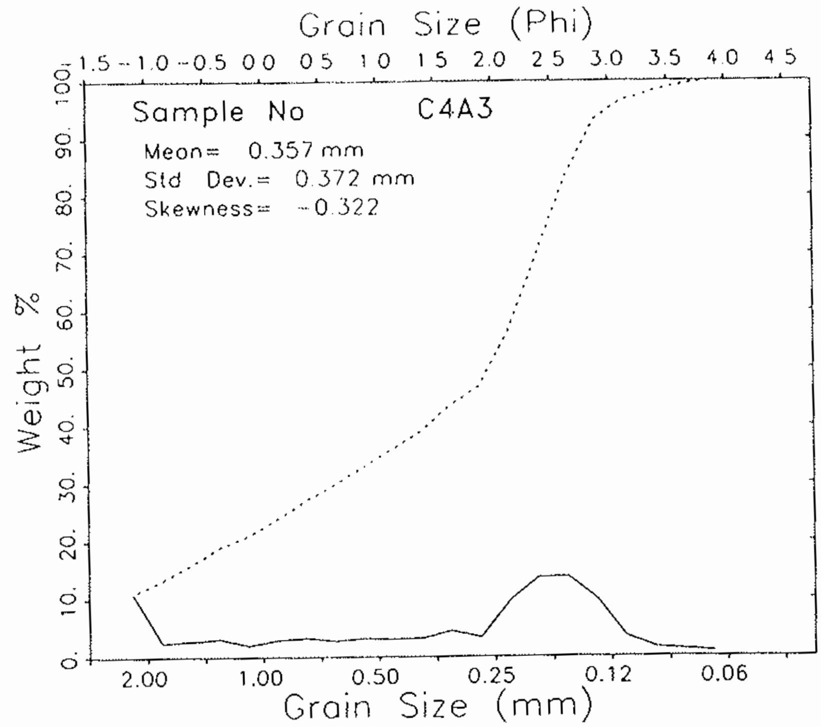
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.216	-1.078	.123	.895	2.241	2.682	2.874	3.272	3.662

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.498	1.746	MEDIUM SAND
STANDARD DEVIATION	1.376	1.347	POORLY SORTED
SKEWNESS(1)	-.540	-.533	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.832		
KURTOSIS	.581	.998	MESOKURTIC

1.347

POORLY SORTED

SKEWNESS(1) -.540



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C4A3	060699					
Bogue Banks C4A3 Comp						
		-1.125	11.800	10.823	-1.000	10.823
		-.875	2.580	2.366	-.750	13.189
		-.625	2.980	2.733	-.500	15.922
		-.375	3.310	3.036	-.250	18.958
		-.125	2.120	1.944	.000	20.903
		.125	3.140	2.880	.250	23.782
		.375	3.520	3.228	.500	27.011
		.625	3.000	2.752	.750	29.762
		.875	3.430	3.146	1.000	32.908
		1.125	3.280	3.008	1.250	35.917
		1.375	3.390	3.109	1.500	39.026
		1.625	4.800	4.402	1.750	43.428
		1.875	3.610	3.311	2.000	46.739
		2.125	10.300	9.447	2.250	56.186
		2.375	14.790	13.565	2.500	69.751
		2.625	14.840	13.611	2.750	83.362
		2.875	10.660	9.777	3.000	93.140
		3.125	3.720	3.412	3.250	96.551
		3.375	1.630	1.495	3.500	98.046
		3.625	1.270	1.165	3.750	99.211
		3.875	.860	.789	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.030

PERCENT FINER THAN 4.00 PHI = 3.04 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

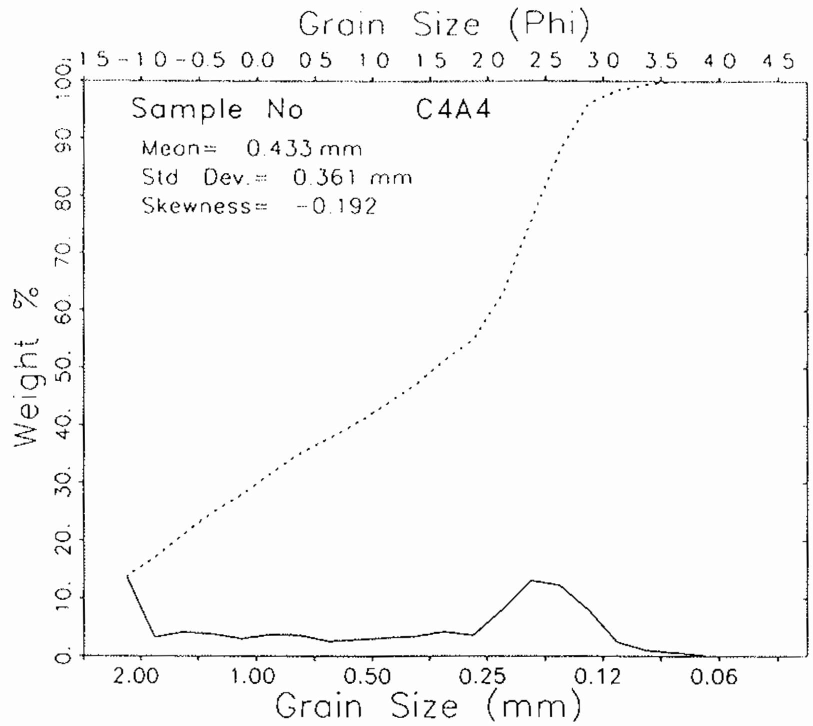
MEAN = 1.488 STANDARD DEVIATION = 1.427 SKEWNESS = -.322 KURTOSIS = -.922

DISPERSION = .595 STANDARD DEVIATION = .951 DEVIATION FROM NORMAL DISTR. = -33.33%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.135	-.494	.344	2.086	2.596	2.766	3.136	3.705

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.136	1.453	MEDIUM SAND
STANDARD DEVIATION	1.630	1.462	POORLY SORTED
SKEWNESS(1)	-.583	-.546	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.666		
KURTOSIS	.310	.777	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C4A4	060699					
Bogue Banks C4A4 0-2.5						
		-1.125	14.340	13.758	-1.000	13.758
		-.875	3.380	3.243	-.750	17.001
		-.625	4.270	4.097	-.500	21.098
		-.375	4.000	3.838	-.250	24.935
		-.125	3.120	2.993	.000	27.929
		.125	3.880	3.723	.250	31.651
		.375	3.680	3.531	.500	35.182
		.625	2.670	2.562	.750	37.743
		.875	2.940	2.821	1.000	40.564
		1.125	3.260	3.128	1.250	43.692
		1.375	3.530	3.387	1.500	47.079
		1.625	4.400	4.221	1.750	51.300
		1.875	3.670	3.521	2.000	54.821
		2.125	8.310	7.973	2.250	62.794
		2.375	13.580	13.029	2.500	75.823
		2.625	12.720	12.204	2.750	88.026
		2.875	8.360	8.021	3.000	96.047
		3.125	2.450	2.351	3.250	98.398
		3.375	.980	.940	3.500	99.338
		3.625	.590	.566	3.750	99.904
		3.875	.100	.096	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.230

PERCENT FINER THAN 4.00 PHI = 1.07 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

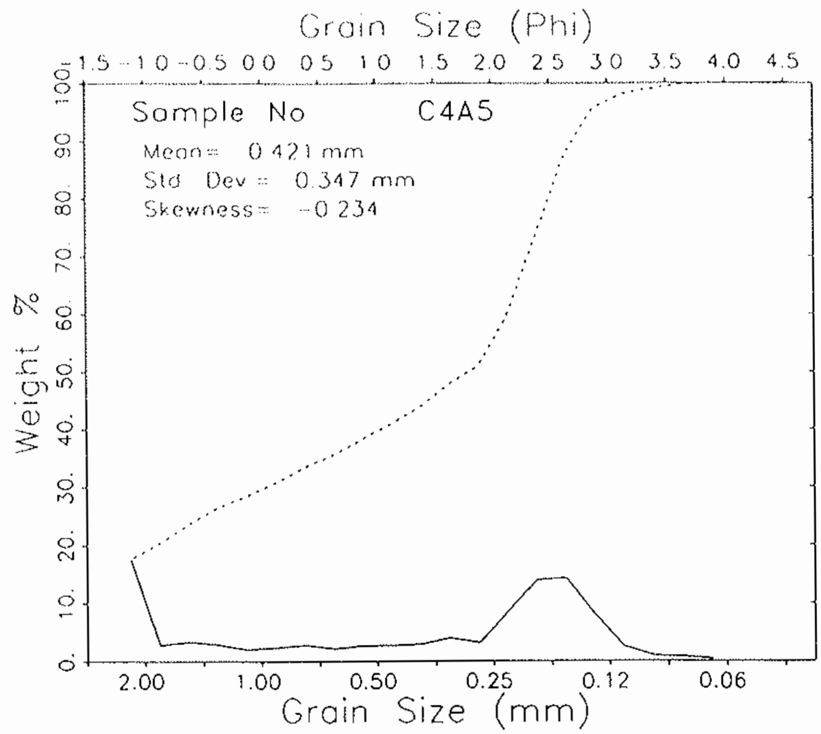
MEAN = 1.207 STANDARD DEVIATION = 1.471 SKEWNESS = -.192 KURTOSIS = -1.347

DISPERSION = .592 STANDARD DEVIATION = .945 DEVIATION FROM NORMAL DISTR. = -35.74%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.232	-1.159	-.827	-.245	1.673	2.484	2.668	2.967	3.410

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.920	1.171	MEDIUM SAND
STANDARD DEVIATION	1.747	1.499	POORLY SORTED
SKEWNESS(1)	-.431	-.402	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.440		
KURTOSIS	.181	.620	VERY PLATYKURTIC
1.499			POORLY SORTED
SKEWNESS(1)	-.431		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT (PHI)	CLASS LIMITS	CUM PERCENT
C4A5	060699						
Bogue Banks C4A5 0-2.8							
		-1.125	19.140	17.564	-1.000	17.564	
		-.875	2.970	2.726	-.750	20.290	
		-.625	3.600	3.304	-.500	23.594	
		-.375	3.090	2.836	-.250	26.429	
		-.125	2.170	1.991	.000	28.421	
		.125	2.490	2.285	.250	30.706	
		.375	3.010	2.762	.500	33.468	
		.625	2.310	2.120	.750	35.588	
		.875	2.900	2.661	1.000	38.249	
		1.125	2.930	2.689	1.250	40.938	
		1.375	3.130	2.872	1.500	43.810	
		1.625	4.350	3.992	1.750	47.802	
		1.875	3.460	3.175	2.000	50.977	
		2.125	9.420	8.645	2.250	59.622	
		2.375	15.140	13.894	2.500	73.516	
		2.625	15.390	14.123	2.750	87.639	
		2.875	8.720	8.002	3.000	95.641	
		3.125	2.660	2.441	3.250	98.082	
		3.375	.950	.872	3.500	98.954	
		3.625	.750	.688	3.750	99.642	
		3.875	.390	.358	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 108.970

PERCENT FINER THAN 4.00 PHI = .94 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.248 STANDARD DEVIATION = 1.527 SKEWNESS = -.234 KURTOSIS = -1.332

DISPERSION = .548 STANDARD DEVIATION = .854 DEVIATION FROM NORMAL DISTR. = -44.10%

PERCENTILES:

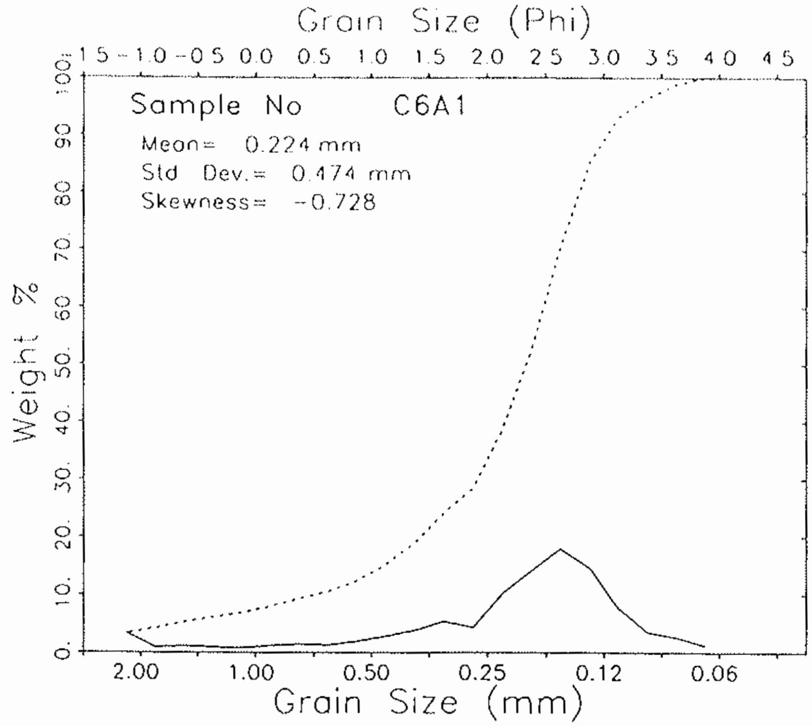
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.179	-1.022	-.376	1.923	2.526	2.686	2.980	3.517

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.832	1.195	MEDIUM SAND
STANDARD DEVIATION	1.854	1.557	POORLY SORTED
SKEWNESS(1)	-.509	-.540	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.552		
KURTOSIS	.122	.587	VERY PLATYKURTIC

1.557

POORLY SORTED

SKEWNESS(1) -.509



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C6A1	060699						
Bogue Banks C6A1 0-2.9							
		-1.125	3.210	3.280		-1.000	3.280
		-.875	.830	.848		-.750	4.128
		-.625	1.020	1.042		-.500	5.170
		-.375	.880	.899		-.250	6.069
		-.125	.700	.715		.000	6.784
		.125	1.090	1.114		.250	7.897
		.375	1.390	1.420		.500	9.318
		.625	1.180	1.206		.750	10.523
		.875	1.870	1.911		1.000	12.434
		1.125	2.650	2.707		1.250	15.141
		1.375	3.640	3.719		1.500	18.860
		1.625	5.160	5.272		1.750	24.132
		1.875	4.200	4.291		2.000	28.423
		2.125	9.900	10.114		2.250	38.537
		2.375	13.810	14.109		2.500	52.646
		2.625	17.530	17.910		2.750	70.556
		2.875	14.360	14.671		3.000	85.227
		3.125	7.490	7.652		3.250	92.879
		3.375	3.370	3.443		3.500	96.322
		3.625	2.460	2.513		3.750	98.835
		3.875	1.140	1.165		4.000	100.000

TOTAL WEIGHT (GRAMS) = 97.880

PERCENT FINER THAN 4.00 PHI = 2.20 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.157 STANDARD DEVIATION = 1.077 SKEWNESS = -.728 KURTOSIS = 1.916

DISPERSION = .519 STANDARD DEVIATION = .800 DEVIATION FROM NORMAL DISTR. = -25.72%

PERCENTILES:

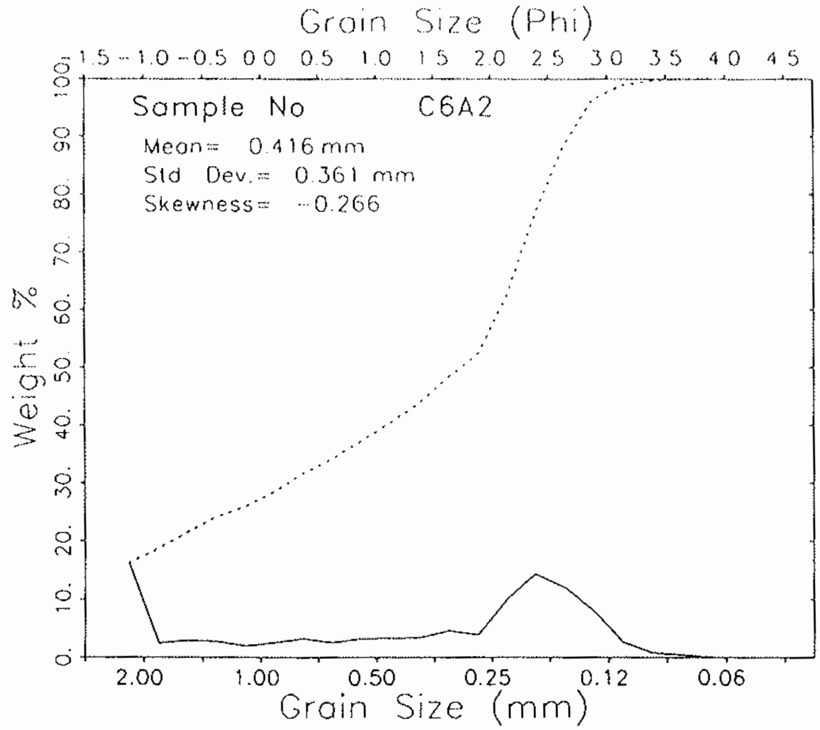
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.174	-.541	1.308	1.801	2.453	2.826	2.979	3.404	3.785

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.143	2.247	FINE SAND
STANDARD DEVIATION	.836	1.016	POORLY SORTED
SKEWNESS(1)	-.371	-.444	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.222		
KURTOSIS	1.360	1.577	VERY LEPTOKURTIC

1.016

POORLY SORTED

SKEWNESS(1) -.371



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C6A2	060699					
Bogue Bank C6A2 0-1.2						
		-1.125	17.870	16.275	-1.000	16.275
		-.875	2.620	2.386	-.750	18.661
		-.625	3.090	2.814	-.500	21.475
		-.375	2.870	2.614	-.250	24.089
		-.125	2.110	1.922	.000	26.011
		.125	2.740	2.495	.250	28.506
		.375	3.450	3.142	.500	31.648
		.625	2.710	2.468	.750	34.117
		.875	3.400	3.097	1.000	37.213
		1.125	3.500	3.188	1.250	40.401
		1.375	3.650	3.324	1.500	43.725
		1.625	4.920	4.481	1.750	48.206
		1.875	4.200	3.825	2.000	52.031
		2.125	10.900	9.927	2.250	61.958
		2.375	15.690	14.290	2.500	76.248
		2.625	13.280	12.095	2.750	88.342
		2.875	8.790	8.005	3.000	96.348
		3.125	2.800	2.550	3.250	98.898
		3.375	.770	.701	3.500	99.599
		3.625	.390	.355	3.750	99.954
		3.875	.050	.046	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.800

PERCENT FINER THAN 4.00 PHI = .51 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

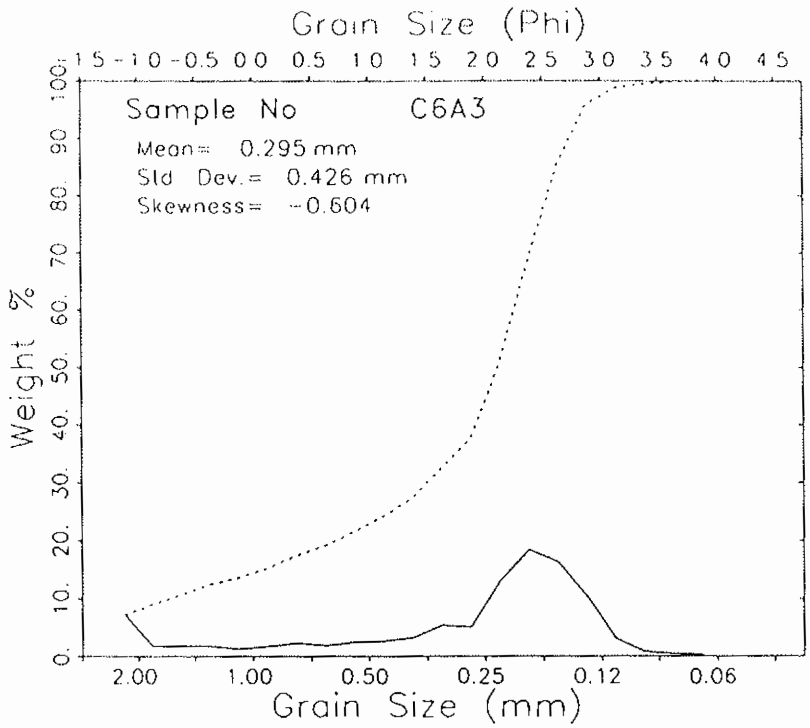
MEAN = 1.266 STANDARD DEVIATION = 1.471 SKEWNESS = -.266 KURTOSIS = -1.225

DISPERSION = .553 STANDARD DEVIATION = .865 DEVIATION FROM NORMAL DISTR. = -41.20%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.173	-1.004	-.132	1.867	2.478	2.660	2.958	3.286

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.828	1.174	MEDIUM SAND
STANDARD DEVIATION	1.832	1.542	POORLY SORTED
SKEWNESS(1)	-.567	-.520	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.532		
KURTOSIS	.127	.649	VERY PLATYKURTIC
1.542			POORLY SORTED
SKEWNESS(1)	-.567		



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C6A3 060699						
Bogue Banks C6A3 Part 1						
	-1.125	8.220		7.229	-1.000	7.229
	-.875	1.970		1.732	-.750	8.961
	-.625	1.930		1.697	-.500	10.659
	-.375	1.910		1.680	-.250	12.338
	-.125	1.350		1.187	.000	13.526
	.125	1.890		1.662	.250	15.188
	.375	2.510		2.207	.500	17.395
	.625	2.030		1.785	.750	19.180
	.875	2.680		2.357	1.000	21.537
	1.125	2.940		2.586	1.250	24.123
	1.375	3.600		3.166	1.500	27.289
	1.625	6.010		5.285	1.750	32.574
	1.875	5.700		5.013	2.000	37.587
	2.125	14.780		12.998	2.250	50.585
	2.375	20.930		18.406	2.500	68.991
	2.625	18.550		16.313	2.750	85.305
	2.875	11.820		10.395	3.000	95.700
	3.125	3.370		2.964	3.250	98.663
	3.375	.840		.739	3.500	99.402
	3.625	.460		.405	3.750	99.807
	3.875	.220		.193	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.710

PERCENT FINER THAN 4.00 PHI = .50 PERCENT COARSER THAN -1.00 PHI = .00

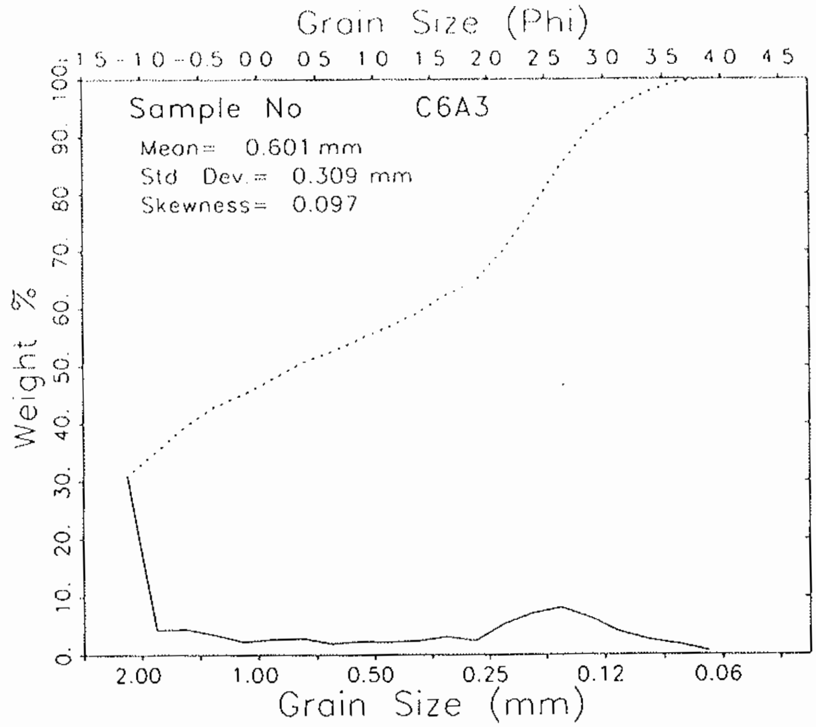
MOMENT MEASURES:

MEAN = 1.760 STANDARD DEVIATION = 1.232 SKEWNESS = -.604 KURTOSIS = .326
DISPERSION = .508 STANDARD DEVIATION = .779 DEVIATION FROM NORMAL DISTR. = -36.79%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.215	-1.077	.342	1.319	2.239	2.592	2.730	2.983	3.364

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.536	1.770	MEDIUM SAND
STANDARD DEVIATION	1.194	1.212	POORLY SORTED
SKEWNESS(1)	-.589	-.611	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.077		
KURTOSIS	.700	1.307	LEPTOKURTIC
1.212			POORLY SORTED
SKEWNESS(1)	-.589		



SAMPLE NO. DATE MIDPOINT (PHI) (GRAM) HEIGHT HEIGHT PERCENT CLASS LIMITS (PHI) CUM PERCENT

C6A3 060699
Bogue Banks C6A3 Part 2

MIDPOINT (PHI)	(GRAM)	HEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	31.640	30.829	-1.000	30.829
-.875	4.350	4.239	-.750	35.068
-.625	4.510	4.394	-.500	39.462
-.375	3.510	3.420	-.250	42.882
-.125	2.260	2.202	.000	45.084
.125	2.720	2.650	.250	47.735
.375	2.890	2.816	.500	50.551
.625	1.910	1.861	.750	52.412
.875	2.280	2.222	1.000	54.633
1.125	2.180	2.124	1.250	56.757
1.375	2.410	2.348	1.500	59.106
1.625	3.160	3.079	1.750	62.185
1.875	2.470	2.407	2.000	64.591
2.125	5.330	5.193	2.250	69.785
2.375	7.280	7.093	2.500	76.878
2.625	8.300	8.087	2.750	84.965
2.875	6.470	6.304	3.000	91.270
3.125	4.020	3.917	3.250	95.187
3.375	2.540	2.475	3.500	97.661
3.625	1.780	1.734	3.750	99.396
3.875	.620	.604	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.630

PERCENT FINER THAN 4.00 PHI = .74 PERCENT COARSER THAN -1.00 PHI = .00

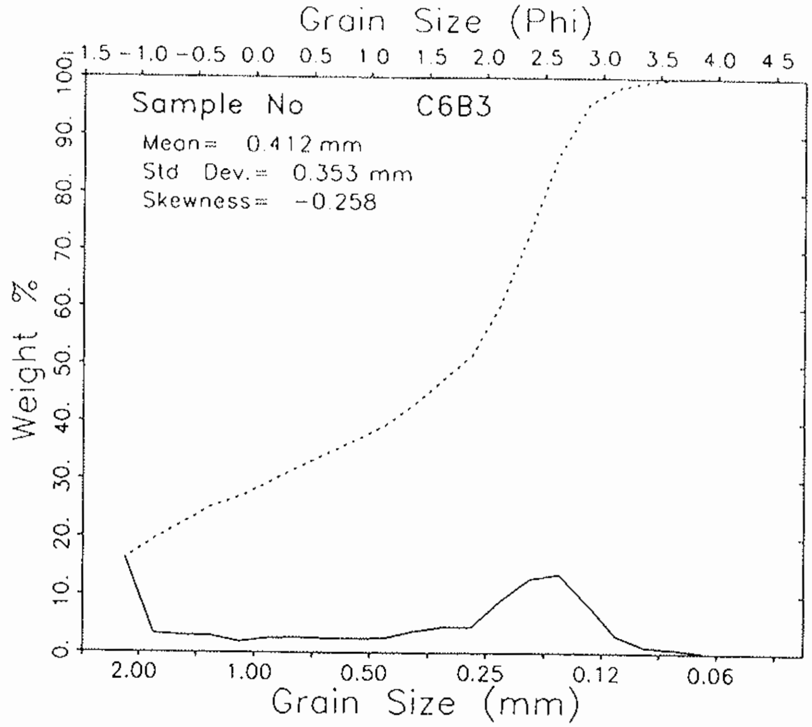
MOMENT MEASURES:

MEAN = .734 STANDARD DEVIATION = 1.694 SKEWNESS = .097 KURTOSIS = -1.590
DISPERSION = .525 STANDARD DEVIATION = .810 DEVIATION FROM NORMAL DISTR. = -52.18%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.209	-1.120	-1.047	.451	2.434	2.720	3.238	3.693

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.800	.684	COARSE SAND
STANDARD DEVIATION	1.920	1.634	POORLY SORTED
SKEWNESS(1)	.182	.217	FINE-SKEWED
SKEWNESS(2)	.293		
KURTOSIS	.158	.524	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	HEIGHT	HEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C6B3	060699						
Bogue Banks C6B3 Part 2 (0-1.3)							
		-1.125	17.050		16.257	-1.000	16.257
		-.875	3.350		3.194	-.750	19.451
		-.625	3.000		2.860	-.500	22.311
		-.375	2.960		2.822	-.250	25.133
		-.125	1.880		1.793	.000	26.926
		.125	2.610		2.489	.250	29.415
		.375	2.700		2.574	.500	31.989
		.625	2.540		2.422	.750	34.411
		.875	2.520		2.403	1.000	36.813
		1.125	2.620		2.498	1.250	39.312
		1.375	3.780		3.604	1.500	42.916
		1.625	4.580		4.367	1.750	47.283
		1.875	4.570		4.357	2.000	51.640
		2.125	9.430		8.991	2.250	60.631
		2.375	13.380		12.757	2.500	73.389
		2.625	14.240		13.577	2.750	86.966
		2.875	8.860		8.448	3.000	95.414
		3.125	2.990		2.851	3.250	98.265
		3.375	1.040		.992	3.500	99.256
		3.625	.670		.639	3.750	99.895
		3.875	.110		.105	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.880

PERCENT FINER THAN 4.00 PHI = 1.26 PERCENT COARSER THAN -1.00 PHI = .00

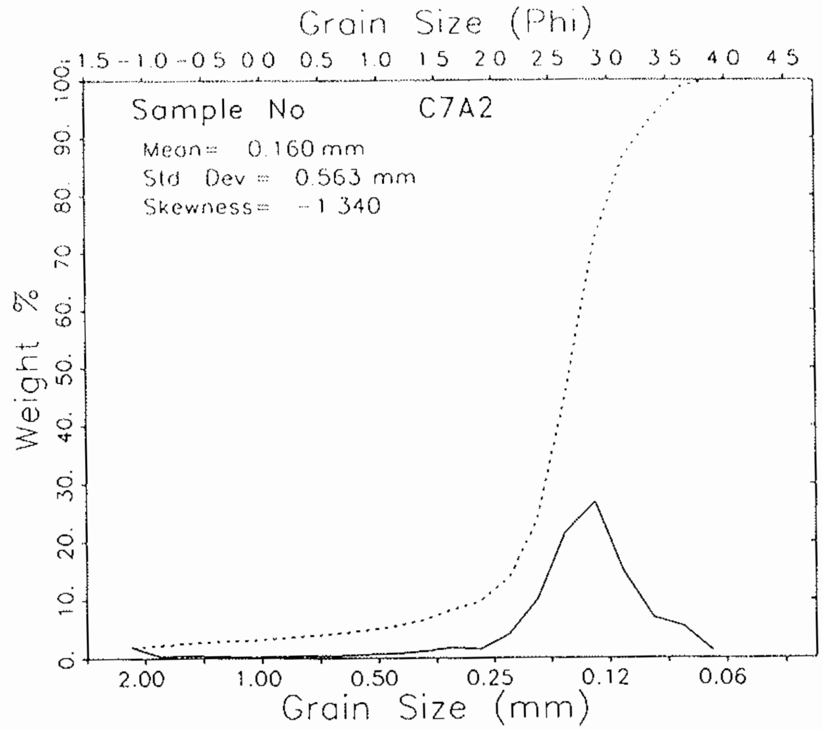
MOMENT MEASURES:

MEAN = 1.281 STANDARD DEVIATION = 1.502 SKEWNESS = -.258 KURTOSIS = -1.261
DISPERSION = .560 STANDARD DEVIATION = .879 DEVIATION FROM NORMAL DISTR. = -41.46%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.173	-1.004	-.262	1.906	2.530	2.695	2.988	3.435

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.846	1.199	MEDIUM SAND
STANDARD DEVIATION	1.850	1.555	POORLY SORTED
SKEWNESS(1)	-.573	-.527	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.540		
KURTOSIS	.125	.611	VERY PLATYKURTIC
1.555			POORLY SORTED
SKEWNESS(1)	-.573		



SAMPLE NO. DATE

C7A2 060699

Bogue Banks C7A2 0-2.7

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	1.840	1.865	-1.000	1.865
-.875	.260	.264	-.750	2.129
-.625	.380	.385	-.500	2.514
-.375	.270	.274	-.250	2.788
-.125	.220	.223	.000	3.011
.125	.330	.335	.250	3.345
.375	.390	.395	.500	3.740
.625	.380	.385	.750	4.126
.875	.530	.537	1.000	4.663
1.125	.710	.720	1.250	5.383
1.375	1.010	1.024	1.500	6.406
1.625	1.700	1.723	1.750	8.130
1.875	1.460	1.480	2.000	9.610
2.125	3.920	3.974	2.250	13.583
2.375	9.870	10.005	2.500	23.588
2.625	21.380	21.673	2.750	45.261
2.875	26.390	26.751	3.000	72.012
3.125	14.360	14.557	3.250	86.569
3.375	6.730	6.822	3.500	93.391
3.625	5.280	5.352	3.750	98.743
3.875	1.240	1.257	4.000	100.000

TOTAL WEIGHT (GRAMS) = 98.650

PERCENT FINER THAN 4.00 PHI = 1.30 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.648 STANDARD DEVIATION = .829 SKEWNESS = -1.314 KURTOSIS = 8.726

DISPERSION = .338 STANDARD DEVIATION = .527 DEVIATION FROM NORMAL DISTR. = -36.47%

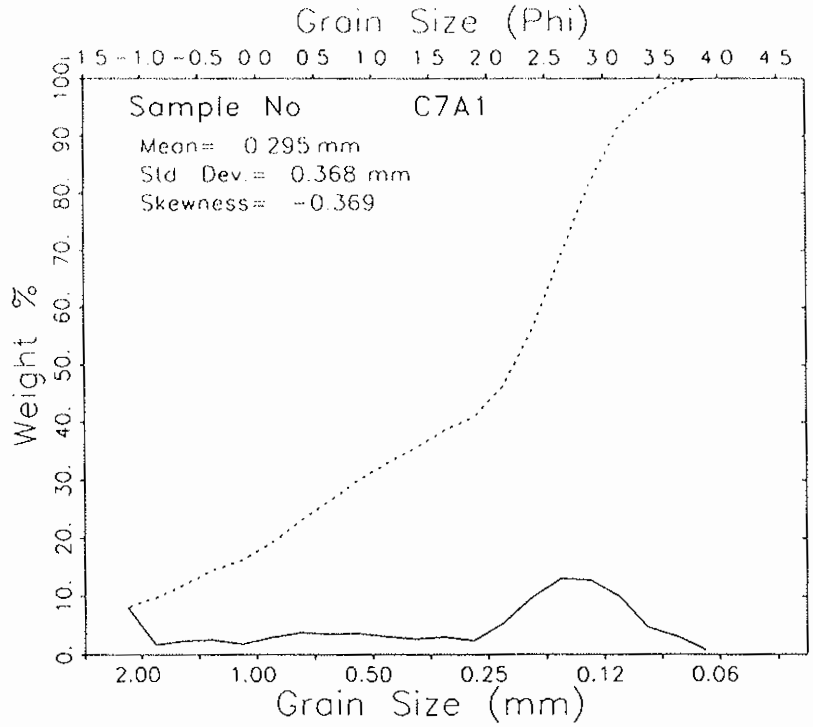
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.116	1.117	2.310	2.516	2.794	3.051	3.206	3.575	3.801

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	2.758	2.770	FINE SAND
STANDARD DEVIATION	.448	.596	MODERATELY WELL SORTED
SKEWNESS(1)	-.081	-.223	COARSE-SKEWED
SKEWNESS(2)	-1.001		
KURTOSIS	1.745	1.883	VERY LEPTOKURTIC

.596 MODERATELY WELL SORTED

SKEWNESS(1) -.081



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C7A1	060699						
Bogue Banks C7A1 0-1							
		-1.125	8.130		8.046	-1.000	8.046
		-.875	1.690		1.672	-.750	9.718
		-.625	2.310		2.286	-.500	12.004
		-.375	2.500		2.474	-.250	14.478
		-.125	1.780		1.762	.000	16.239
		.125	2.950		2.919	.250	19.159
		.375	3.750		3.711	.500	22.870
		.625	3.480		3.444	.750	26.314
		.875	3.590		3.553	1.000	29.866
		1.125	3.080		3.048	1.250	32.914
		1.375	2.660		2.632	1.500	35.547
		1.625	3.040		3.008	1.750	38.555
		1.875	2.300		2.276	2.000	40.831
		2.125	5.380		5.324	2.250	46.155
		2.375	9.820		9.718	2.500	55.873
		2.625	13.140		13.003	2.750	68.877
		2.875	12.820		12.687	3.000	81.564
		3.125	9.980		9.876	3.250	91.440
		3.375	4.660		4.612	3.500	96.051
		3.625	3.190		3.157	3.750	99.208
		3.875	.800		.792	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.050

PERCENT FINER THAN 4.00 PHI = 1.47 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.761 STANDARD DEVIATION = 1.442 SKEWNESS = -.369 KURTOSIS = -.737

DISPERSION = .615 STANDARD DEVIATION = .996 DEVIATION FROM NORMAL DISTR. = -30.80%

PERCENTILES:

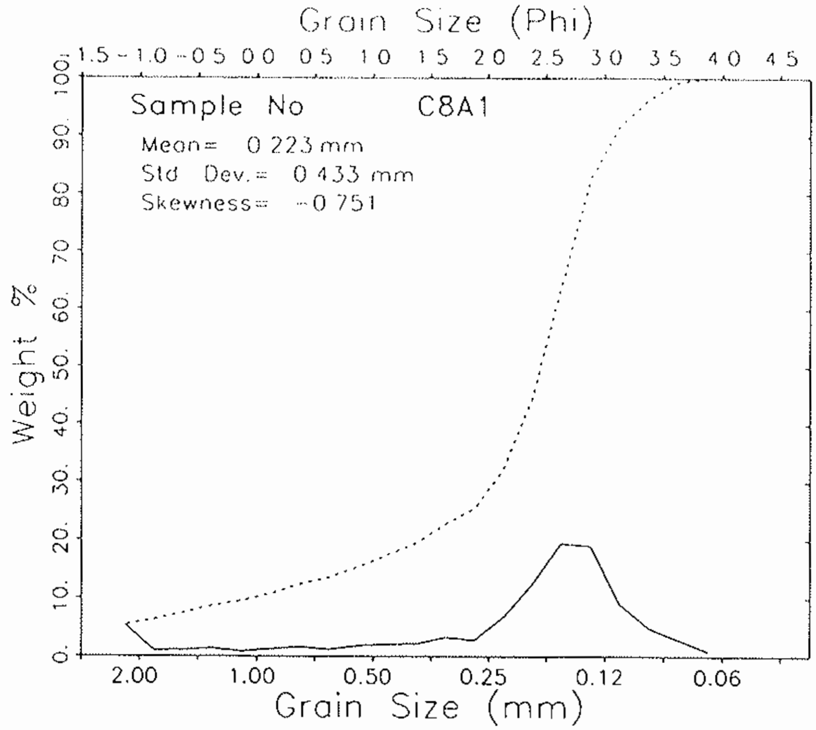
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.219	-1.095	-.034	.655	2.349	2.871	3.062	3.443	3.734

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.514	1.792	MEDIUM SAND
STANDARD DEVIATION	1.548	1.461	POORLY SORTED
SKEWNESS(1)	-.540	-.529	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.759		
KURTOSIS	.466	.839	PLATYKURTIC

1.461

POORLY SORTED

SKEWNESS(1) -.540



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C8A1	060699					
Bogue Banks C8A1 0-3.4						
		-1.125	5.410	5.346	-1.000	5.346
		-.875	.950	.939	-.750	6.285
		-.625	1.080	1.067	-.500	7.352
		-.375	1.340	1.324	-.250	8.676
		-.125	.830	.820	.000	9.496
		.125	1.260	1.245	.250	10.741
		.375	1.600	1.581	.500	12.322
		.625	1.180	1.166	.750	13.488
		.875	1.850	1.828	1.000	15.316
		1.125	2.050	2.026	1.250	17.342
		1.375	2.160	2.134	1.500	19.476
		1.625	3.220	3.182	1.750	22.658
		1.875	2.740	2.708	2.000	25.366
		2.125	6.770	6.690	2.250	32.055
		2.375	12.530	12.381	2.500	44.437
		2.625	19.510	19.279	2.750	63.715
		2.875	19.150	18.923	3.000	82.638
		3.125	9.050	8.943	3.250	91.581
		3.375	4.890	4.832	3.500	96.413
		3.625	2.850	2.816	3.750	99.229
		3.875	.780	.771	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.200

PERCENT FINER THAN 4.00 PHI = 2.75 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

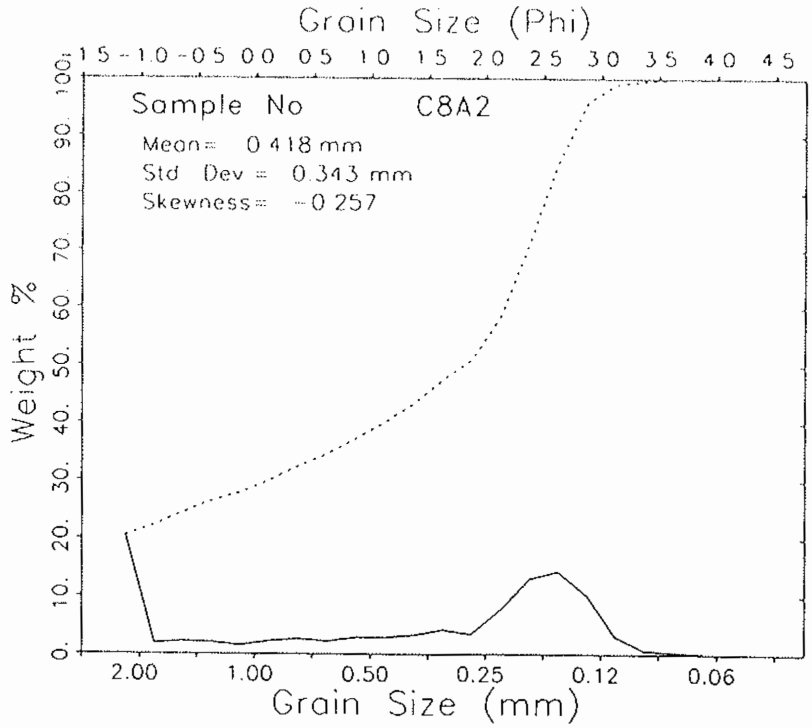
MEAN = 2.165 STANDARD DEVIATION = 1.209 SKEWNESS = -.751 KURTOSIS = 1.423

DISPERSION = .497 STANDARD DEVIATION = .761 DEVIATION FROM NORMAL DISTR. = -37.09%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.203	-1.016	1.084	1.966	2.572	2.899	3.038	3.427	3.730

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.061	2.232	FINE SAND
STANDARD DEVIATION	.977	1.162	POORLY SORTED
SKEWNESS(1)	-.523	-.569	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.399		
KURTOSIS	1.274	1.952	VERY LEPTOKURTIC
1.162			POORLY SORTED
SKEWNESS(1)	-.523		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C8A2	060699						
Bogue Bank C8A2 0-1.6							
		-1.125	22.380		20.390	-1.000	20.390
		-.875	2.000		1.822	-.750	22.212
		-.625	2.350		2.141	-.500	24.353
		-.375	2.150		1.959	-.250	26.312
		-.125	1.610		1.467	.000	27.779
		.125	2.340		2.132	.250	29.911
		.375	2.770		2.524	.500	32.434
		.625	2.310		2.105	.750	34.539
		.875	3.040		2.770	1.000	37.309
		1.125	3.110		2.833	1.250	40.142
		1.375	3.520		3.207	1.500	43.349
		1.625	4.580		4.173	1.750	47.522
		1.875	3.700		3.371	2.000	50.893
		2.125	8.340		7.598	2.250	58.491
		2.375	14.240		12.974	2.500	71.465
		2.625	15.580		14.195	2.750	85.660
		2.875	11.200		10.204	3.000	95.864
		3.125	3.390		3.089	3.250	98.952
		3.375	.700		.638	3.500	99.590
		3.625	.360		.328	3.750	99.918
		3.875	.090		.082	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.760

PERCENT FINER THAN 4.00 PHI = .39 PERCENT COARSER THAN -1.00 PHI = .00

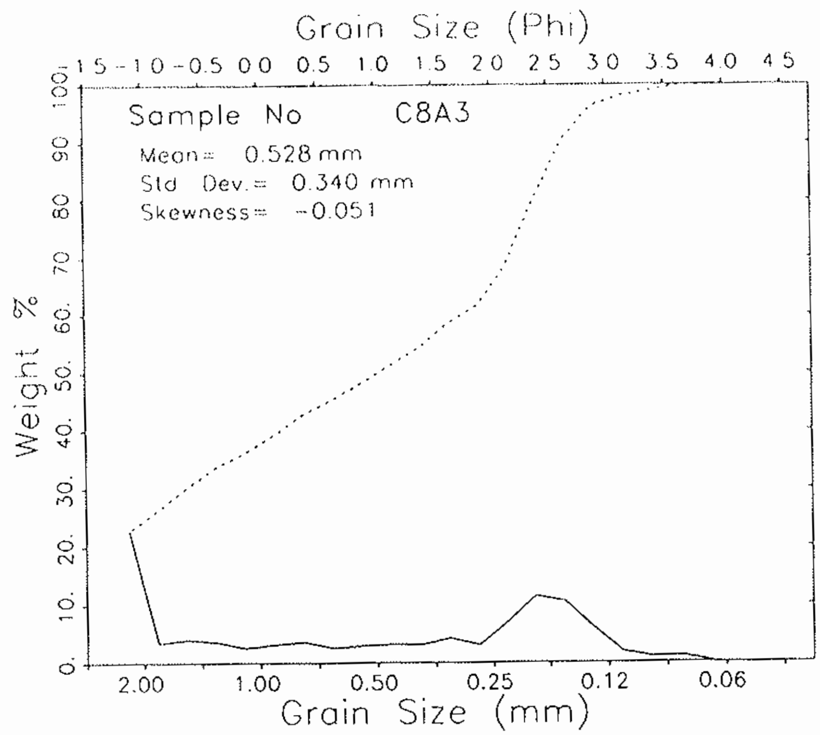
MOMENT MEASURES:

MEAN = 1.257 STANDARD DEVIATION = 1.545 SKEWNESS = -.257 KURTOSIS = -1.324
DISPERSION = .513 STANDARD DEVIATION = .788 DEVIATION FROM NORMAL DISTR. = -48.99%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.189	-1.054	-.417	1.934	2.562	2.721	2.979	3.269

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.833	1.200	MEDIUM SAND
STANDARD DEVIATION	1.887	1.575	POORLY SORTED
SKEWNESS(1)	-.583	-.541	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.550		
KURTOSIS	.104	.573	VERY PLATYKURTIC
1.575			POORLY SORTED
SKEWNESS(1)	-.583		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C8A3	060699						
Bogue Bank C8A3 0-1.5							
		-1.125	25.170		22.749	-1.000	22.749
		-.875	3.770		3.407	-.750	26.157
		-.625	4.410		3.986	-.500	30.143
		-.375	3.890		3.516	-.250	33.659
		-.125	2.780		2.513	.000	36.171
		.125	3.470		3.136	.250	39.308
		.375	3.900		3.525	.500	42.833
		.625	2.750		2.486	.750	45.318
		.875	3.210		2.901	1.000	48.219
		1.125	3.440		3.109	1.250	51.329
		1.375	3.390		3.064	1.500	54.393
		1.625	4.540		4.103	1.750	58.496
		1.875	3.320		3.001	2.000	61.497
		2.125	7.720		6.978	2.250	68.474
		2.375	12.590		11.379	2.500	79.854
		2.625	11.560		10.448	2.750	90.302
		2.875	6.500		5.875	3.000	96.177
		3.125	1.960		1.772	3.250	97.948
		3.375	.990		.895	3.500	98.843
		3.625	1.120		1.012	3.750	99.855
		3.875	.160		.145	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.640

PERCENT FINER THAN 4.00 PHI = 2.07 PERCENT COARSER THAN -1.00 PHI = .00

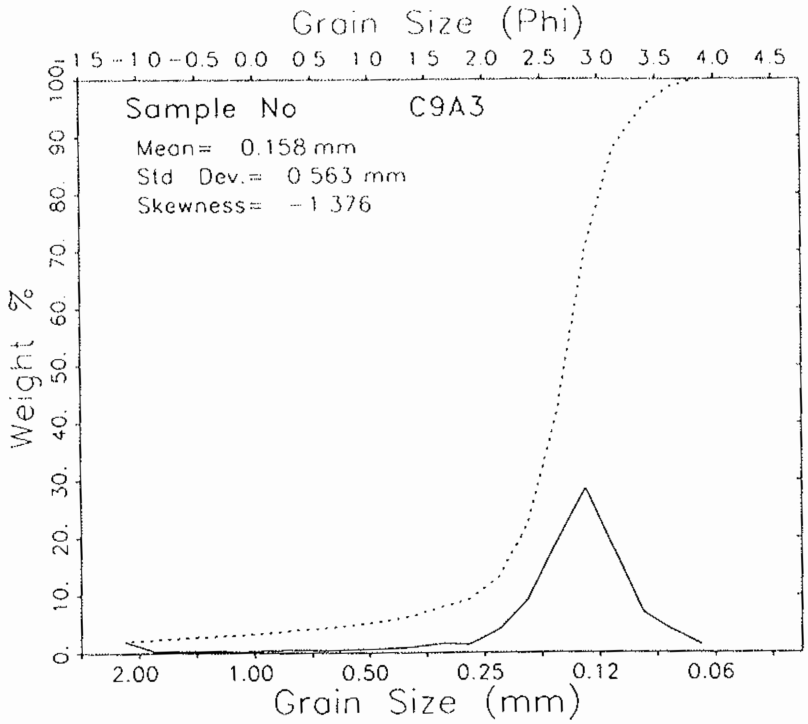
MOMENT MEASURES:

MEAN = .921 STANDARD DEVIATION = 1.558 SKEWNESS = -.051 KURTOSIS = -1.552
DISPERSION = .557 STANDARD DEVIATION = .872 DEVIATION FROM NORMAL DISTR. = -44.06%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.195	-1.074	-.835	1.143	2.393	2.599	2.950	3.539

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.763	.889	COARSE SAND
STANDARD DEVIATION	1.837	1.546	POORLY SORTED
SKEWNESS(1)	-.207	-.168	COARSE-SKEWED
SKEWNESS(2)	-.145		
KURTOSIS	.128	.526	VERY PLATYKURTIC
1.546			POORLY SORTED
SKEWNESS(1)	-.207		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
c9a-3	070699					
Bogue Banks - Core C9A-3						
		-1.125	2.190	1.996	-1.000	1.996
		-.875	.290	.264	-.750	2.261
		-.625	.310	.283	-.500	2.543
		-.375	.310	.283	-.250	2.826
		-.125	.240	.219	.000	3.044
		.125	.420	.383	.250	3.427
		.375	.530	.483	.500	3.910
		.625	.410	.374	.750	4.284
		.875	.550	.501	1.000	4.785
		1.125	.690	.629	1.250	5.414
		1.375	.950	.866	1.500	6.280
		1.625	1.630	1.486	1.750	7.766
		1.875	1.560	1.422	2.000	9.188
		2.125	4.320	3.938	2.250	13.126
		2.375	10.090	9.197	2.500	22.322
		2.625	21.050	19.187	2.750	41.509
		2.875	31.290	28.521	3.000	70.030
		3.125	19.560	17.829	3.250	87.859
		3.375	7.690	7.009	3.500	94.868
		3.625	4.200	3.828	3.750	98.697
		3.875	1.430	1.303	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.710

PERCENT FINER THAN 4.00 PHI = 1.12 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

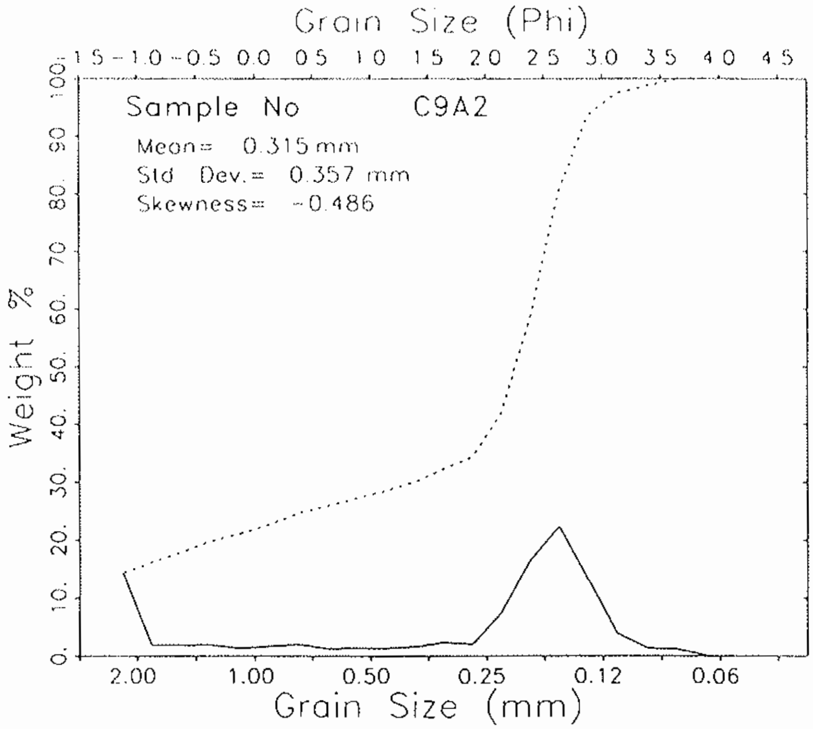
MEAN = 2.660 STANDARD DEVIATION = .830 SKEWNESS = -1.376 KURTOSIS = 9.189

DISPERSION = .322 STANDARD DEVIATION = .508 DEVIATION FROM NORMAL DISTR. = -38.83%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.125	1.085	2.328	2.535	2.824	3.070	3.196	3.509	3.808

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.762	2.783	FINE SAND
STANDARD DEVIATION	.434	.584	MODERATELY WELL SORTED
SKEWNESS(1)	-.144	-.290	COARSE-SKEWED
SKEWNESS(2)	-1.216		
KURTOSIS	1.793	1.857	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C9A2	060699						
Bogue Bank C9A2 0-2.2							
		-1.125	14.120		14.266	-1.000	14.266
		-.875	1.780		1.798	-.750	16.064
		-.625	1.790		1.808	-.500	17.872
		-.375	1.870		1.889	-.250	19.762
		-.125	1.290		1.303	.000	21.065
		.125	1.580		1.596	.250	22.661
		.375	1.910		1.930	.500	24.591
		.625	1.210		1.222	.750	25.813
		.875	1.310		1.323	1.000	27.137
		1.125	1.270		1.283	1.250	28.420
		1.375	1.500		1.515	1.500	29.935
		1.625	2.310		2.334	1.750	32.269
		1.875	2.030		2.051	2.000	34.320
		2.125	7.360		7.436	2.250	41.756
		2.375	16.240		16.407	2.500	58.163
		2.625	22.070		22.297	2.750	80.461
		2.875	13.030		13.164	3.000	93.625
		3.125	3.750		3.789	3.250	97.414
		3.375	1.260		1.273	3.500	98.687
		3.625	1.160		1.172	3.750	99.859
		3.875	.140		.141	4.000	100.000

TOTAL WEIGHT (GRAMS) = 98.980

PERCENT FINER THAN 4.00 PHI = 1.38 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.665 STANDARD DEVIATION = 1.485 SKEWNESS = -.486 KURTOSIS = -.633

DISPERSION = .452 STANDARD DEVIATION = .685 DEVIATION FROM NORMAL DISTR. = -53.89%

PERCENTILES:

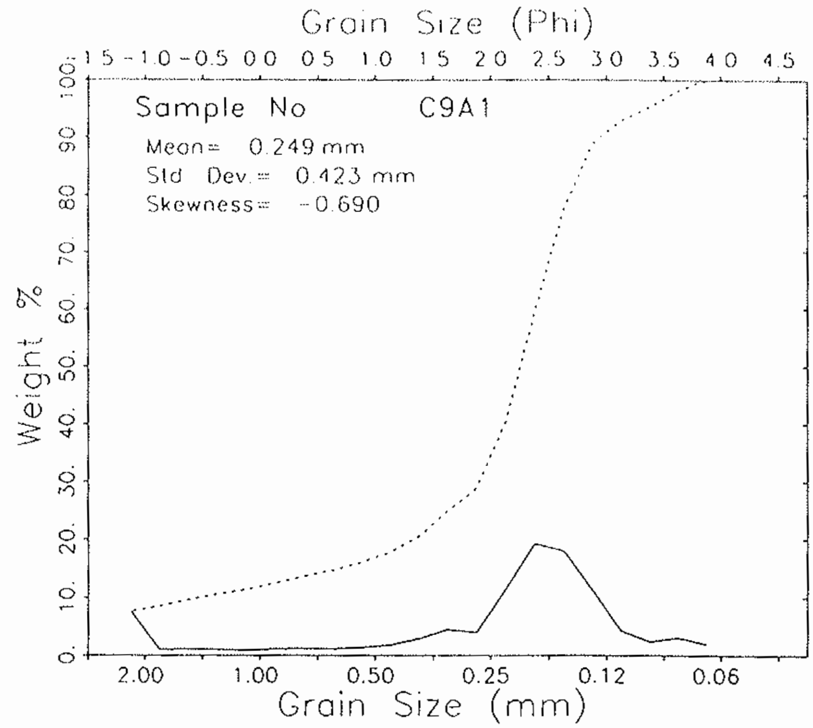
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.232	-1.162	-.759	.584	2.376	2.689	2.817	3.091	3.567

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.029	1.478	MEDIUM SAND
STANDARD DEVIATION	1.788	1.538	POORLY SORTED
SKEWNESS(1)	-.753	-.708	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.789		
KURTOSIS	.189	.828	PLATYKURTIC

1.538

POORLY SORTED

SKEWNESS(1) -.753



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C9A1	060699						
Bogue Bank C9A1 0-1.4							
		-1.125	7.890	7.534		-1.000	7.534
		-.875	1.010	.964		-.750	8.499
		-.625	1.130	1.079		-.500	9.578
		-.375	1.040	.993		-.250	10.571
		-.125	.820	.783		.000	11.354
		.125	1.110	1.060		.250	12.414
		.375	1.210	1.155		.500	13.570
		.625	1.120	1.070		.750	14.639
		.875	1.380	1.318		1.000	15.957
		1.125	1.840	1.757		1.250	17.714
		1.375	2.900	2.769		1.500	20.483
		1.625	4.580	4.374		1.750	24.857
		1.875	4.110	3.925		2.000	28.782
		2.125	11.970	11.430		2.250	40.212
		2.375	20.130	19.223		2.500	59.435
		2.625	18.800	17.953		2.750	77.387
		2.875	11.820	11.287		3.000	88.675
		3.125	4.350	4.154		3.250	92.828
		3.375	2.440	2.330		3.500	95.159
		3.625	3.090	2.951		3.750	98.109
		3.875	1.980	1.891		4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.720

PERCENT FINER THAN 4.00 PHI = 3.75 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.006 STANDARD DEVIATION = 1.242 SKEWNESS = -.690 KURTOSIS = 1.142
DISPERSION = .497 STANDARD DEVIATION = .759 DEVIATION FROM NORMAL DISTR. = -38.87%

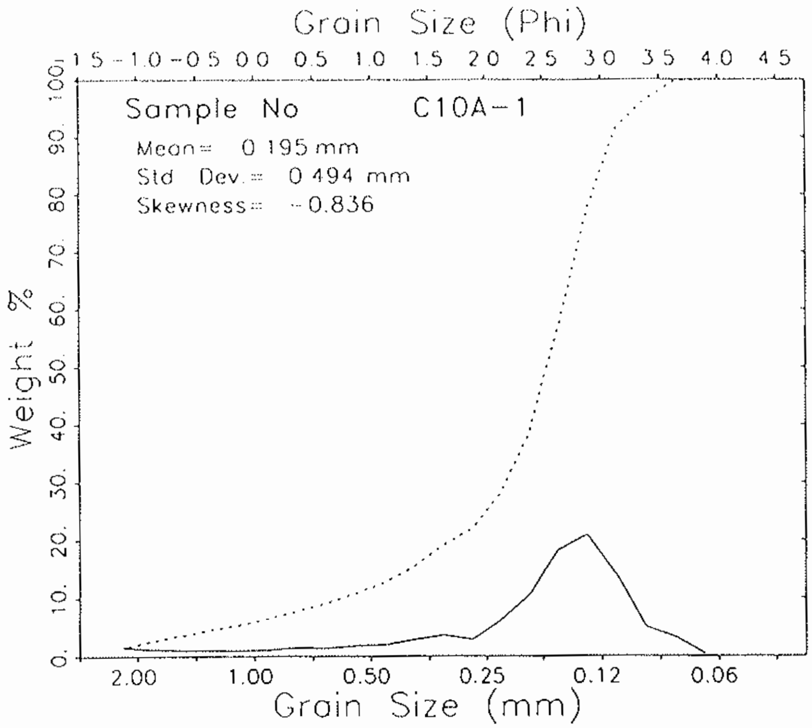
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.217	-1.084	1.006	1.759	2.377	2.717	2.896	3.483	3.868

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.951	2.093	FINE SAND
STANDARD DEVIATION	.945	1.165	POORLY SORTED
SKEWNESS(1)	-.451	-.483	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.246		
KURTOSIS	1.416	1.955	VERY LEPTOKURTIC

1.165 POORLY SORTED

SKEWNESS(1) -.451



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10A-1 070699					
Bogue Banks - Core C10A-1					
	-1.125	1.480	1.470	-1.000	1.470
	-.875	1.110	1.103	-.750	2.573
	-.625	.950	.944	-.500	3.517
	-.375	.950	.944	-.250	4.461
	-.125	.870	.864	.000	5.325
	.125	1.100	1.093	.250	6.418
	.375	1.370	1.361	.500	7.779
	.625	1.340	1.331	.750	9.110
	.875	1.690	1.679	1.000	10.789
	1.125	1.920	1.907	1.250	12.696
	1.375	2.850	2.831	1.500	15.528
	1.625	3.610	3.586	1.750	19.114
	1.875	2.810	2.792	2.000	21.905
	2.125	6.130	6.090	2.250	27.995
	2.375	10.430	10.362	2.500	38.357
	2.625	18.230	18.110	2.750	56.467
	2.875	20.970	20.833	3.000	77.300
	3.125	14.170	14.077	3.250	91.377
	3.375	5.020	4.987	3.500	96.364
	3.625	3.240	3.219	3.750	99.583
	3.875	.420	.417	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.660

PERCENT FINER THAN 4.00 PHI = 1.57 PERCENT COARSER THAN -1.00 PHI = .00

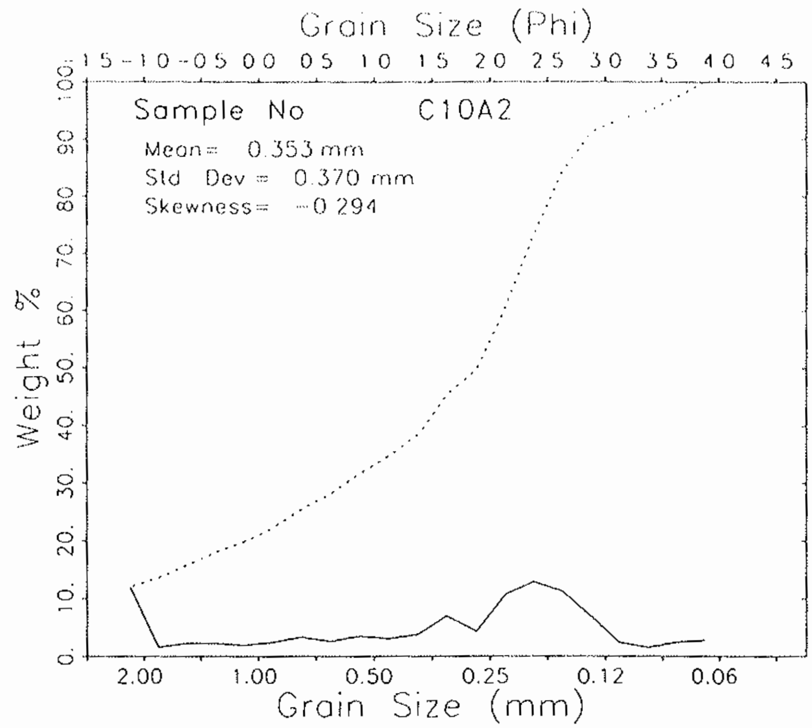
MOMENT MEASURES:

MEAN = 2.355 STANDARD DEVIATION = 1.018 SKEWNESS = -.836 KURTOSIS = 2.531
DISPERSION = .471 STANDARD DEVIATION = .716 DEVIATION FROM NORMAL DISTR. = -29.66%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.080	-.094	1.533	2.127	2.661	2.972	3.119	3.432	3.705

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	2.326	2.438	FINE SAND
STANDARD DEVIATION	.793	.931	MODERATELY SORTED
SKEWNESS(1)	-.422	-.492	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.251		
KURTOSIS	1.223	1.709	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10A2	060699					
Bogue Banks C10A2 1-2.5						
		-1.125	11.510	11.956	-1.000	11.956
		-.875	1.510	1.569	-.750	13.524
		-.625	2.110	2.192	-.500	15.716
		-.375	2.150	2.233	-.250	17.950
		-.125	1.780	1.849	.000	19.798
		.125	2.300	2.389	.250	22.188
		.375	3.190	3.314	.500	25.501
		.625	2.460	2.555	.750	28.057
		.875	3.380	3.511	1.000	31.567
		1.125	2.940	3.054	1.250	34.621
		1.375	3.560	3.698	1.500	38.319
		1.625	6.730	6.991	1.750	45.310
		1.875	4.150	4.311	2.000	49.621
		2.125	10.280	10.678	2.250	60.299
		2.375	12.300	12.777	2.500	73.076
		2.625	10.820	11.239	2.750	84.315
		2.875	6.610	6.866	3.000	91.181
		3.125	2.210	2.296	3.250	93.477
		3.375	1.390	1.444	3.500	94.921
		3.625	2.280	2.368	3.750	97.289
		3.875	2.610	2.711	4.000	100.000

TOTAL WEIGHT (GRAMS) = 96.270

PERCENT FINER THAN 4.00 PHI = 6.04 PERCENT COARSER THAN -1.00 PHI = .00

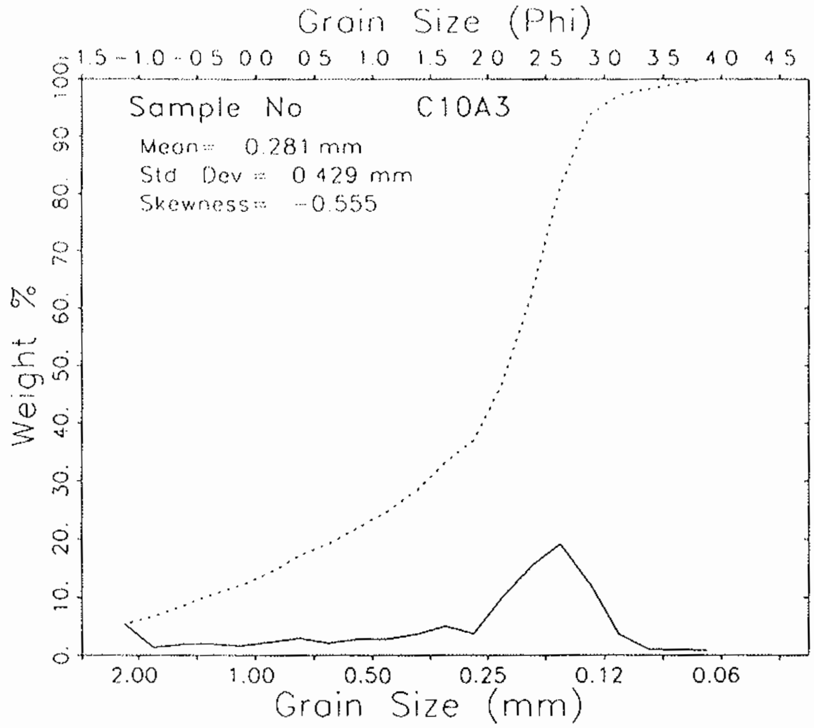
MOMENT MEASURES:

MEAN = 1.503 STANDARD DEVIATION = 1.433 SKEWNESS = -.294 KURTOSIS = -.769
DISPERSION = .610 STANDARD DEVIATION = .985 DEVIATION FROM NORMAL DISTR. = -31.24%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.229	-1.145	-.468	.462	2.009	2.543	2.743	3.508	3.908

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.137	1.428	MEDIUM SAND
STANDARD DEVIATION	1.606	1.508	POORLY SORTED
SKEWNESS(1)	-.543	-.449	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.515		
KURTOSIS	.449	.917	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10A3	060699					
Bogue Banks C10A3 1-2.5						
		-1.125	5.670	5.356	-1.000	5.356
		-.875	1.400	1.322	-.750	6.678
		-.625	1.950	1.842	-.500	8.520
		-.375	2.030	1.917	-.250	10.437
		-.125	1.640	1.549	.000	11.986
		.125	2.370	2.239	.250	14.225
		.375	3.090	2.919	.500	17.144
		.625	2.200	2.078	.750	19.222
		.875	2.870	2.711	1.000	21.933
		1.125	2.890	2.730	1.250	24.662
		1.375	3.770	3.561	1.500	28.223
		1.625	5.220	4.931	1.750	33.154
		1.875	3.970	3.750	2.000	36.904
		2.125	10.680	10.088	2.250	46.992
		2.375	16.230	15.330	2.500	62.322
		2.625	20.160	19.042	2.750	81.364
		2.875	13.120	12.393	3.000	93.756
		3.125	3.720	3.514	3.250	97.270
		3.375	1.060	1.001	3.500	98.271
		3.625	.970	.916	3.750	99.188
		3.875	.860	.812	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.870

PERCENT FINER THAN 4.00 PHI = 1.76 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

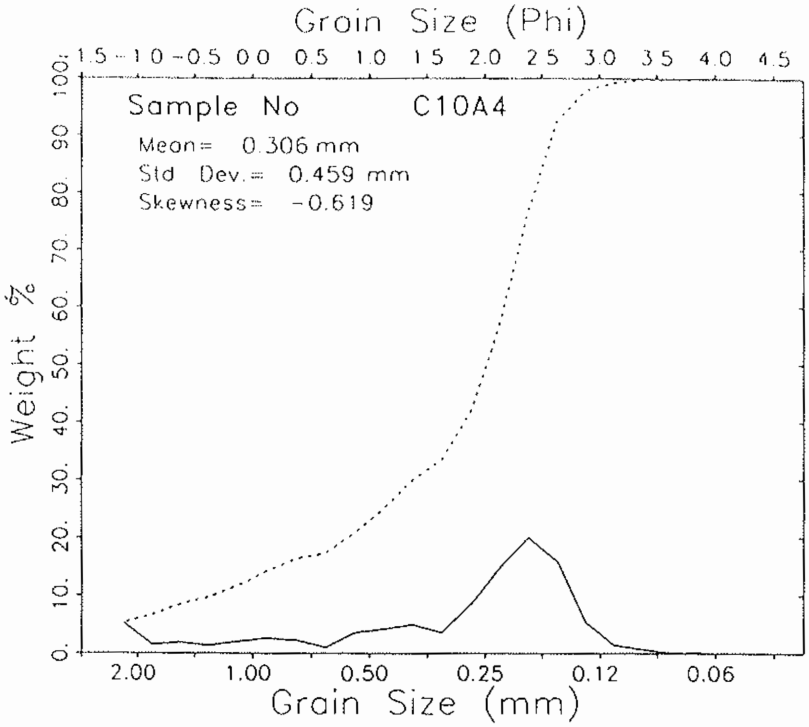
MEAN = 1.831 STANDARD DEVIATION = 1.220 SKEWNESS = -.555 KURTOSIS = .236

DISPERSION = .537 STANDARD DEVIATION = .833 DEVIATION FROM NORMAL DISTR. = -31.75%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.203	-1.017	.402	1.274	2.299	2.666	2.803	3.088	3.699

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.603	1.835	MEDIUM SAND
STANDARD DEVIATION	1.201	1.222	POORLY SORTED
SKEWNESS(1)	-.580	-.598	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.052		
KURTOSIS	.710	1.208	LEPTOKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT / WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10A4 060699					
Bogue Bank C10A4 0-2.5					
	-1.125	5.430	5.218	-1.000	5.218
	-.875	1.490	1.432	-.750	6.649
	-.625	1.850	1.778	-.500	8.427
	-.375	1.330	1.278	-.250	9.705
	-.125	2.030	1.951	.000	11.656
	.125	2.620	2.518	.250	14.173
	.375	2.270	2.181	.500	16.354
	.625	.970	.932	.750	17.286
	.875	3.730	3.584	1.000	20.871
	1.125	4.310	4.141	1.250	25.012
	1.375	5.110	4.910	1.500	29.922
	1.625	3.700	3.555	1.750	33.477
	1.875	8.780	8.437	2.000	41.914
	2.125	15.340	14.740	2.250	56.654
	2.375	20.780	19.967	2.500	76.621
	2.625	16.540	15.893	2.750	92.515
	2.875	5.500	5.285	3.000	97.800
	3.125	1.480	1.422	3.250	99.222
	3.375	.620	.596	3.500	99.817
	3.625	.080	.077	3.750	99.894
	3.875	.110	.106	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.070

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

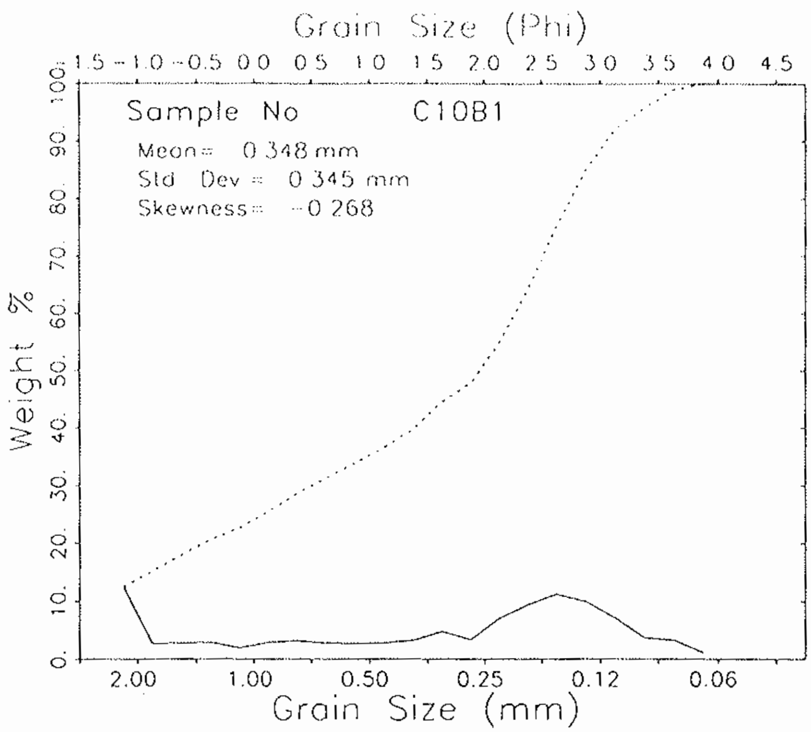
MOMENT MEASURES:

MEAN = 1.717 STANDARD DEVIATION = 1.125 SKEWNESS = -.619 KURTOSIS = .565
DISPERSION = .493 STANDARD DEVIATION = .752 DEVIATION FROM NORMAL DISTR. = -33.11%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.202	-1.010	.459	1.249	2.137	2.480	2.616	2.868	3.211

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.538	1.738	MEDIUM SAND
STANDARD DEVIATION	1.078	1.127	POORLY SORTED
SKEWNESS(1)	-.556	-.590	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.121		
KURTOSIS	.798	1.292	LEPTOKURTIC
1.127			POORLY SORTED
SKEWNESS(1)	-.556		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10B1	060699					
Bogue Bank C10B2 0-3.6						
		-1.125	13.070	12.473	-1.000	12.473
		-.875	2.780	2.653	-.750	15.125
		-.625	2.870	2.739	-.500	17.864
		-.375	2.940	2.806	-.250	20.670
		-.125	1.990	1.899	.000	22.569
		.125	2.940	2.806	.250	25.375
		.375	3.250	3.101	.500	28.476
		.625	2.820	2.691	.750	31.167
		.875	2.790	2.662	1.000	33.830
		1.125	2.830	2.701	1.250	36.530
		1.375	3.340	3.187	1.500	39.718
		1.625	4.940	4.714	1.750	44.432
		1.875	3.430	3.273	2.000	47.705
		2.125	7.270	6.938	2.250	54.643
		2.375	9.760	9.314	2.500	63.956
		2.625	11.690	11.156	2.750	75.112
		2.875	10.360	9.886	3.000	84.999
		3.125	7.400	7.062	3.250	92.060
		3.375	3.810	3.636	3.500	95.696
		3.625	3.400	3.245	3.750	98.941
		3.875	1.110	1.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.790

PERCENT FINER THAN 4.00 PHI = 1.60 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

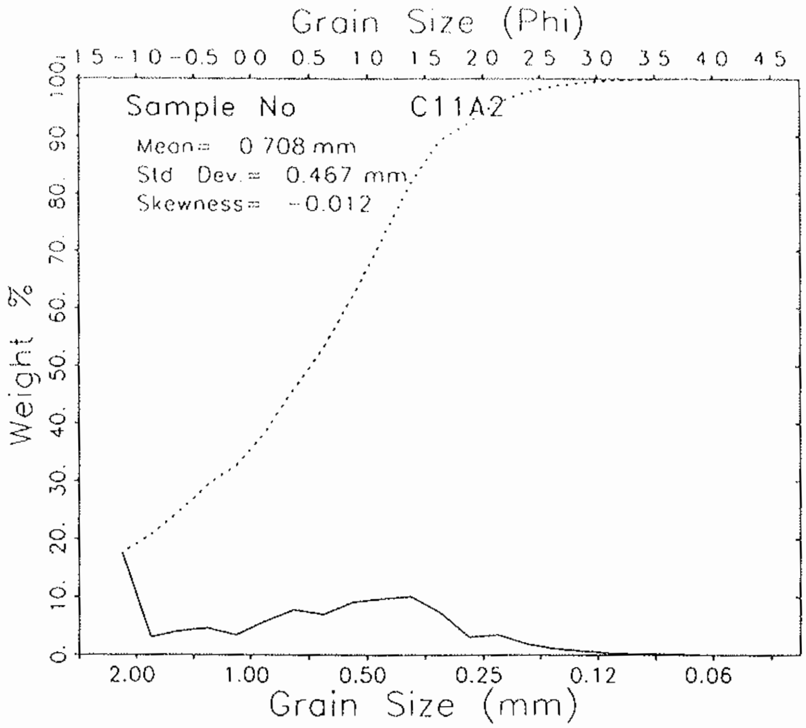
MEAN = 1.522 STANDARD DEVIATION = 1.537 SKEWNESS = -.268 KURTOSIS = -1.085

DISPERSION = .632 STANDARD DEVIATION = 1.037 DEVIATION FROM NORMAL DISTR. = -32.50%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.230	-1.150	-.670	.217	2.083	2.747	2.975	3.452	3.764

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.152	1.462	MEDIUM SAND
STANDARD DEVIATION	1.822	1.608	POORLY SORTED
SKEWNESS(1)	-.511	-.458	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.511		
KURTOSIS	.263	.745	PLATYKURTIC
1.608			POORLY SORTED
SKEWNESS(1)	-.511		



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C11A2	060699					
Bogue Bank C11A2 0-1.1 , 1.4-1.6'						
		-1.125	17.840	17.630	-1.000	17.630
		-.875	3.040	3.004	-.750	20.634
		-.625	4.090	4.042	-.500	24.676
		-.375	4.630	4.576	-.250	29.252
		-.125	3.460	3.419	.000	32.671
		.125	5.780	5.712	.250	38.383
		.375	7.810	7.718	.500	46.101
		.625	7.090	7.007	.750	53.108
		.875	9.180	9.072	1.000	62.180
		1.125	9.760	9.645	1.250	71.825
		1.375	10.190	10.070	1.500	81.895
		1.625	7.430	7.343	1.750	89.238
		1.875	3.110	3.073	2.000	92.312
		2.125	3.470	3.429	2.250	95.741
		2.375	1.910	1.888	2.500	97.628
		2.625	1.090	1.077	2.750	98.705
		2.875	.610	.603	3.000	99.308
		3.125	.340	.336	3.250	99.644
		3.375	.200	.198	3.500	99.842
		3.625	.120	.119	3.750	99.960
		3.875	.040	.040	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.190

PERCENT FINER THAN 4.00 PHI = .10 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .498 STANDARD DEVIATION = 1.098 SKEWNESS = -.012 KURTOSIS = -.882
DISPERSION = .541 STANDARD DEVIATION = .840 DEVIATION FROM NORMAL DISTR. = -23.50%

PERCENTILES:

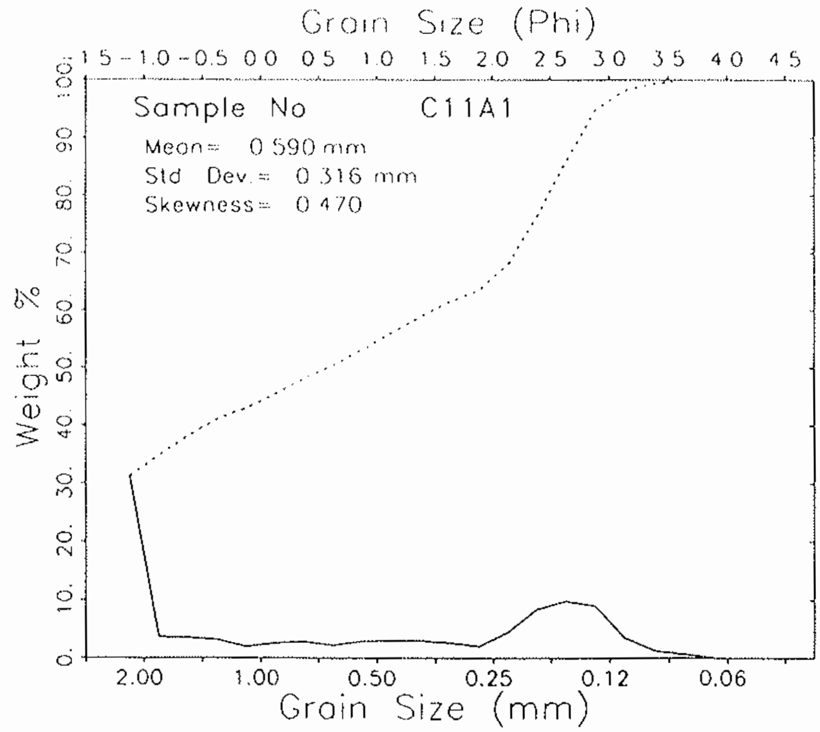
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.179	-1.023	-.482	.639	1.329	1.572	2.196	2.872

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	.274	.396	COARSE SAND
STANDARD DEVIATION	1.297	1.160	POORLY SORTED
SKEWNESS(1)	-.281	-.179	COARSE-SKEWED
SKEWNESS(2)	-.101		
KURTOSIS	.301	.764	PLATYKURTIC

.297 1.160

POORLY SORTED

SKEWNESS(1) -.281



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C11A1 060699						
Bogue Bank C11A1 0-3.0						
	-1.125	34.160		31.111	-1.000	31.111
	-.875	3.880		3.534	-.750	34.645
	-.625	3.680		3.352	-.500	37.996
	-.375	3.320		3.024	-.250	41.020
	-.125	2.110		1.922	.000	42.942
	.125	2.680		2.441	.250	45.383
	.375	3.020		2.750	.500	48.133
	.625	2.360		2.149	.750	50.282
	.875	3.070		2.796	1.000	53.078
	1.125	3.170		2.887	1.250	55.965
	1.375	3.130		2.851	1.500	58.816
	1.625	2.810		2.559	1.750	61.375
	1.875	2.150		1.958	2.000	63.333
	2.125	4.830		4.399	2.250	67.732
	2.375	9.100		8.288	2.500	76.020
	2.625	10.640		9.690	2.750	85.710
	2.875	9.800		8.925	3.000	94.636
	3.125	3.740		3.406	3.250	98.042
	3.375	1.350		1.230	3.500	99.271
	3.625	.730		.665	3.750	99.936
	3.875	.070		.064	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.800

PERCENT FINER THAN 4.00 PHI = .73 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .761 STANDARD DEVIATION = 1.662 SKEWNESS = .047 KURTOSIS = -1.656

DISPERSION = .491 STANDARD DEVIATION = .749 DEVIATION FROM NORMAL DISTR. = -54.91%

PERCENTILES:

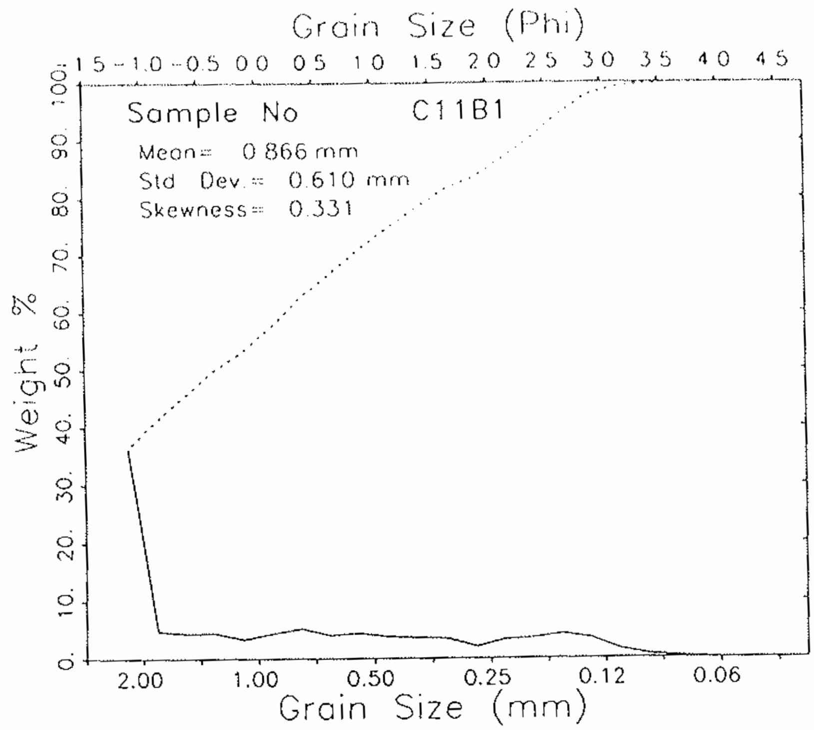
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.210	-1.121	-1.049	.717	2.469	2.706	3.027	3.445

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.792	.767	COARSE SAND
STANDARD DEVIATION	1.914	1.599	POORLY SORTED
SKEWNESS(1)	.039	.065	NEAR SYMMETRICAL
SKEWNESS(2)	.100		
KURTOSIS	.107	.493	VERY PLATYKURTIC

1.599

POORLY SORTED

SKEWNESS(1) .039



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C11B-1	070699						
Bogue Bank - C11B-1							
		-1.125	36.650		36.316	-1.000	36.316
		-.875	4.780		4.736	-.750	41.052
		-.625	4.360		4.320	-.500	45.373
		-.375	4.400		4.360	-.250	49.732
		-.125	3.340		3.310	.000	53.042
		.125	4.360		4.320	.250	57.362
		.375	5.150		5.103	.500	62.465
		.625	3.980		3.944	.750	66.409
		.875	4.320		4.281	1.000	70.690
		1.125	3.750		3.716	1.250	74.405
		1.375	3.620		3.587	1.500	77.992
		1.625	3.390		3.359	1.750	81.352
		1.875	2.010		1.992	2.000	83.343
		2.125	3.270		3.240	2.250	86.583
		2.375	3.530		3.498	2.500	90.081
		2.625	4.200		4.162	2.750	94.243
		2.875	3.450		3.419	3.000	97.662
		3.125	1.460		1.447	3.250	99.108
		3.375	.570		.565	3.500	99.673
		3.625	.250		.248	3.750	99.921
		3.875	.080		.079	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.920

PERCENT FINER THAN 4.00 PHI = .12 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

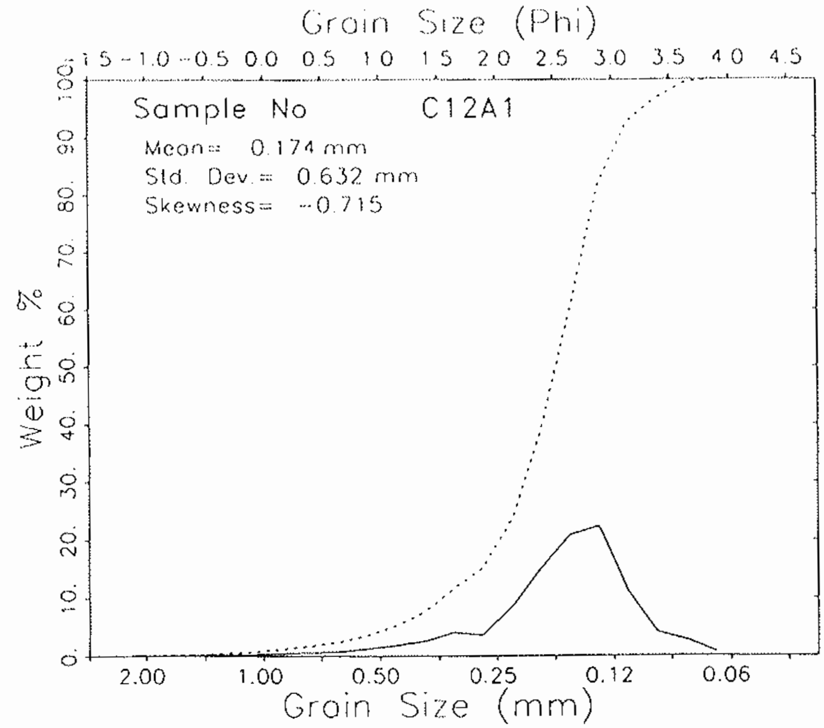
MEAN = .208 STANDARD DEVIATION = 1.403 SKEWNESS = .331 KURTOSIS = -.914

DISPERSION = .470 STANDARD DEVIATION = .714 DEVIATION FROM NORMAL DISTR. = -49.12%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.243	-1.216	-1.140	-1.078	-.230	1.291	2.051	2.805	3.231

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.455	.227	COARSE SAND
STANDARD DEVIATION	1.595	1.407	POORLY SORTED
SKEWNESS(1)	.430	.470	STRONGLY FINE-SKEWED
SKEWNESS(2)	.642		
KURTOSIS	.260	.696	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C12A1	060699						
Bogue Bank C12A1 Parts 1&2							
		-1.125	.120		.113	-1.000	.113
		-.875	.050		.047	-.750	.160
		-.625	.120		.113	-.500	.273
		-.375	.210		.198	-.250	.471
		-.125	.190		.179	.000	.650
		.125	.440		.414	.250	1.064
		.375	.620		.584	.500	1.648
		.625	.690		.650	.750	2.297
		.875	1.180		1.111	1.000	3.408
		1.125	1.790		1.685	1.250	5.093
		1.375	2.610		2.457	1.500	7.550
		1.625	4.180		3.935	1.750	11.486
		1.875	3.800		3.577	2.000	15.063
		2.125	8.970		8.445	2.250	23.508
		2.375	16.010		15.072	2.500	38.580
		2.625	22.060		20.768	2.750	59.349
		2.875	23.570		22.190	3.000	81.538
		3.125	11.680		10.996	3.250	92.534
		3.375	4.330		4.076	3.500	96.611
		3.625	2.930		2.758	3.750	99.369
		3.875	.670		.631	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.220

PERCENT FINER THAN 4.00 PHI = .27 PERCENT COARSER THAN -1.00 PHI = .00

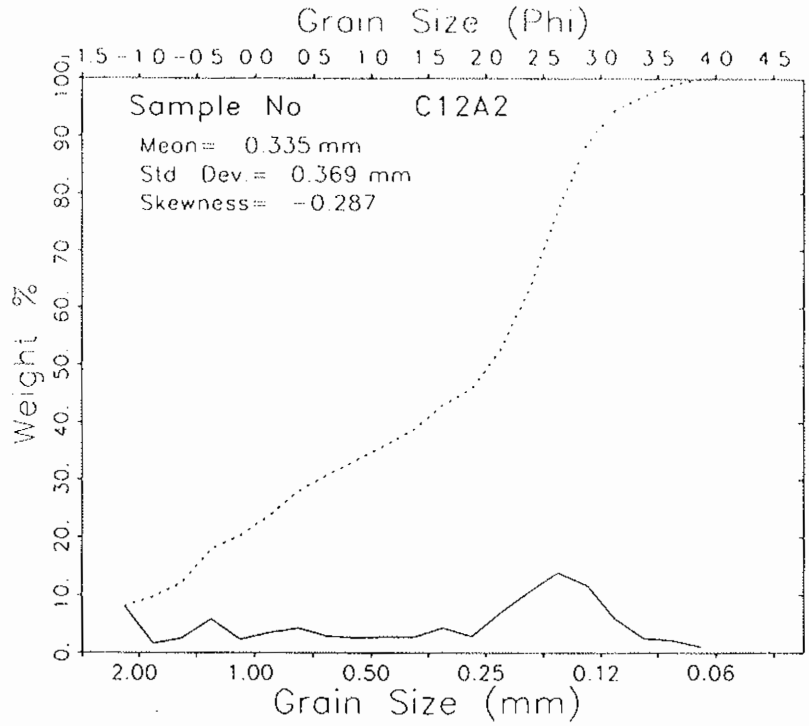
MOMENT MEASURES:

MEAN = 2.523 STANDARD DEVIATION = .662 SKEWNESS = -.715 KURTOSIS = 3.625
DISPERSION = .372 STANDARD DEVIATION = .570 DEVIATION FROM NORMAL DISTR. = -13.88%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.211	1.236	2.028	2.275	2.637	2.926	3.056	3.401	3.717

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.542	2.574	FINE SAND
STANDARD DEVIATION	.514	.585	MODERATELY WELL SORTED
SKEWNESS(1)	-.186	-.240	COARSE-SKEWED
SKEWNESS(2)	-.620		
KURTOSIS	1.106	1.362	LEPTOKURTIC
.585			MODERATELY WELL SORTED
SKEWNESS(1)	-.186		



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C12A@	060699					
Bogue Banks C12A2 COMP						
		-1.125	8.980	8.087	-1.000	8.087
		-.875	1.720	1.549	-.750	9.636
		-.625	2.730	2.459	-.500	12.095
		-.375	6.490	5.845	-.250	17.939
		-.125	2.580	2.323	.000	20.263
		.125	3.850	3.467	.250	23.730
		.375	4.680	4.215	.500	27.945
		.625	3.130	2.819	.750	30.764
		.875	2.840	2.558	1.000	33.321
		1.125	2.980	2.684	1.250	36.005
		1.375	3.010	2.711	1.500	38.716
		1.625	4.810	4.332	1.750	43.048
		1.875	3.140	2.828	2.000	45.875
		2.125	7.640	6.880	2.250	52.756
		2.375	11.640	10.483	2.500	63.238
		2.625	15.300	13.779	2.750	77.017
		2.875	12.900	11.617	3.000	88.635
		3.125	6.430	5.791	3.250	94.425
		3.375	2.750	2.477	3.500	96.902
		3.625	2.330	2.098	3.750	99.000
		3.875	1.110	1.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.040

PERCENT FINER THAN 4.00 PHI = 2.60 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

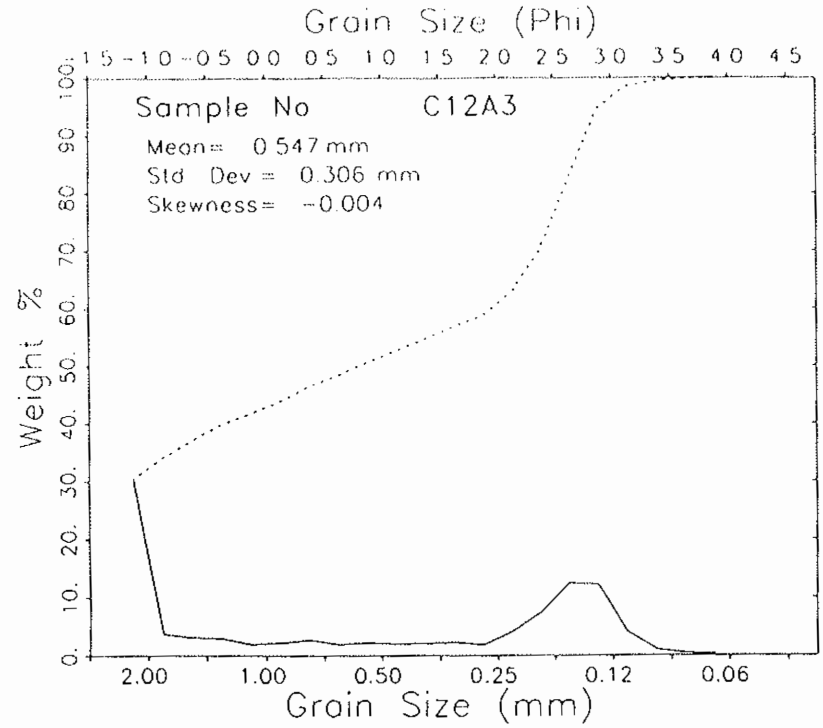
MEAN = 1.577 STANDARD DEVIATION = 1.438 SKEWNESS = -.287 KURTOSIS = -1.002

DISPERSION = .621 STANDARD DEVIATION = 1.011 DEVIATION FROM NORMAL DISTR. = -29.71%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.219	-1.095	-.333	.325	2.150	2.713	2.900	3.308	3.750

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.204	1.572	MEDIUM SAND
STANDARD DEVIATION	1.617	1.475	POORLY SORTED
SKEWNESS(1)	-.536	-.505	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.646		
KURTOSIS	.362	.756	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C12A3	060699						
Bogue Bank C12A3 0-2.4							
		-1.125	31.800		30.355	-1.000	30.355
		-.875	3.780		3.608	-.750	33.963
		-.625	3.170		3.026	-.500	36.989
		-.375	2.990		2.854	-.250	39.843
		-.125	2.000		1.909	.000	41.753
		.125	2.230		2.129	.250	43.881
		.375	2.720		2.596	.500	46.478
		.625	2.000		1.909	.750	48.387
		.875	2.250		2.148	1.000	50.535
		1.125	2.090		1.995	1.250	52.530
		1.375	2.120		2.024	1.500	54.553
		1.625	2.320		2.215	1.750	56.768
		1.875	1.930		1.842	2.000	58.610
		2.125	4.210		4.019	2.250	62.629
		2.375	7.670		7.321	2.500	69.950
		2.625	12.970		12.381	2.750	82.331
		2.875	12.730		12.152	3.000	94.483
		3.125	4.140		3.952	3.250	98.435
		3.375	1.010		.964	3.500	99.399
		3.625	.410		.391	3.750	99.790
		3.875	.220		.210	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.760

PERCENT FINER THAN 4.00 PHI = .37 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .871 STANDARD DEVIATION = 1.707 SKEWNESS = -.004 KURTOSIS = -1.725
DISPERSION = .465 STANDARD DEVIATION = .706 DEVIATION FROM NORMAL DISTR. = -58.66%

PERCENTILES:

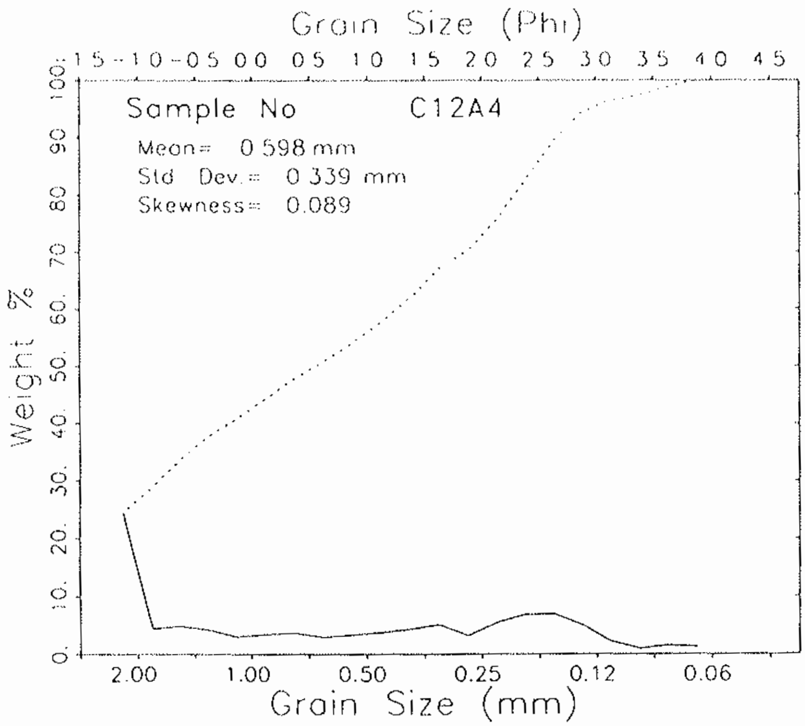
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.209	-1.118	-1.044	.938	2.602	2.784	3.033	3.397

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.833	.868	COARSE SAND
STANDARD DEVIATION	1.951	1.618	POORLY SORTED
SKEWNESS(1)	-.054	-.033	NEAR SYMMETRICAL
SKEWNESS(2)	-.013		
KURTOSIS	.087	.477	VERY PLATYKURTIC

1.618

POORLY SORTED

SKEWNESS(1) -.054



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C12A4	060699					
Bogue Bank C12A4 0-3.7						
		-1.125	45.210	24.450	-1.000	24.450
		-.875	8.170	4.418	-.750	28.868
		-.625	8.880	4.802	-.500	33.670
		-.375	7.680	4.153	-.250	37.824
		-.125	5.510	2.980	.000	40.804
		.125	6.300	3.407	.250	44.211
		.375	6.740	3.645	.500	47.856
		.625	5.270	2.850	.750	50.706
		.875	6.070	3.283	1.000	53.988
		1.125	6.890	3.726	1.250	57.715
		1.375	7.890	4.267	1.500	61.982
		1.625	9.400	5.084	1.750	67.065
		1.875	5.760	3.115	2.000	70.180
		2.125	10.030	5.424	2.250	75.604
		2.375	12.580	6.803	2.500	82.408
		2.625	12.710	6.874	2.750	89.281
		2.875	9.140	4.943	3.000	94.224
		3.125	3.910	2.115	3.250	96.339
		3.375	1.700	.919	3.500	97.258
		3.625	2.790	1.509	3.750	98.767
		3.875	2.280	1.233	4.000	100.000

TOTAL WEIGHT (GRAMS) = 184.910

PERCENT FINER THAN 4.00 PHI = 3.67 PERCENT COARSER THAN -1.00 PHI = .00

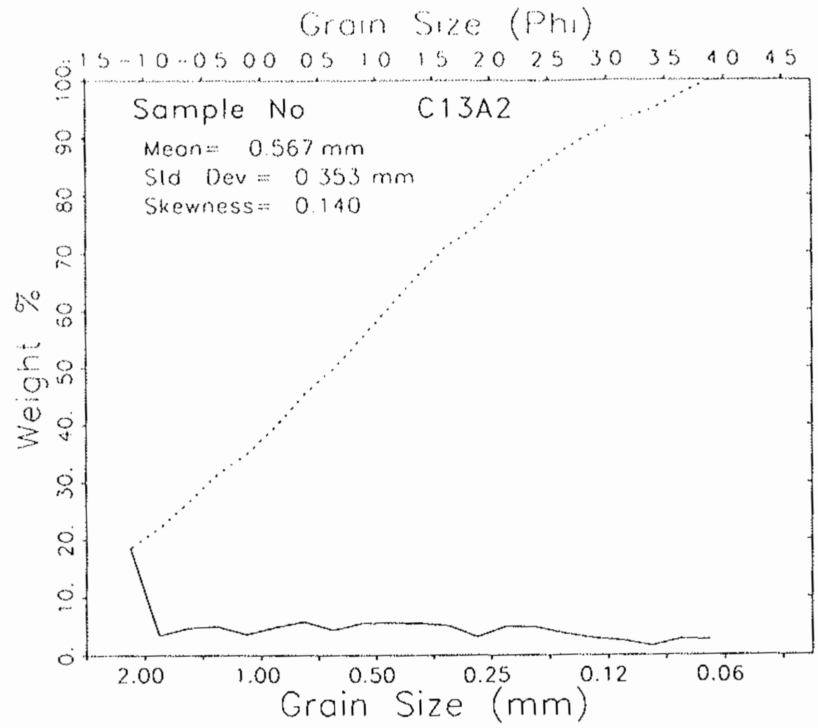
MOMENT MEASURES:

MEAN = .742 STANDARD DEVIATION = 1.561 SKEWNESS = .089 KURTOSIS = -1.393
DISPERSION = .591 STANDARD DEVIATION = .943 DEVIATION FROM NORMAL DISTR. = -39.58%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.199	-1.086	-.969	.680	2.222	2.558	3.092	3.797

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	.736	.720	COARSE SAND
STANDARD DEVIATION	1.822	1.561	POORLY SORTED
SKEWNESS(1)	.026	.073	NEAR SYMMETRICAL
SKEWNESS(2)	.142		
KURTOSIS	.177	.551	VERY PLATYKURTIC
1.561			POORLY SORTED
SKEWNESS(1)	.026		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT / WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C13A2	060699					
Bogue Bank C13A2 0-1.9						
		-1.125	17.710	18.469	-1.000	18.469
		-.875	3.260	3.400	-.750	21.869
		-.625	4.420	4.609	-.500	26.478
		-.375	4.660	4.860	-.250	31.338
		-.125	3.410	3.556	.000	34.894
		.125	4.640	4.839	.250	39.733
		.375	5.450	5.684	.500	45.417
		.625	4.100	4.276	.750	49.692
		.875	5.260	5.485	1.000	55.178
		1.125	5.320	5.548	1.250	60.726
		1.375	5.210	5.433	1.500	66.159
		1.625	4.840	5.047	1.750	71.207
		1.875	3.030	3.160	2.000	74.366
		2.125	4.660	4.860	2.250	79.226
		2.375	4.640	4.839	2.500	84.065
		2.625	3.560	3.713	2.750	87.778
		2.875	2.770	2.889	3.000	90.666
		3.125	2.330	2.430	3.250	93.096
		3.375	1.500	1.564	3.500	94.661
		3.625	2.600	2.711	3.750	97.372
		3.875	2.520	2.628	4.000	100.000

TOTAL WEIGHT (GRAMS) = 95.890

PERCENT FINER THAN 4.00 PHI = 8.24 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .819 STANDARD DEVIATION = 1.501 SKEWNESS = .140 KURTOSIS = -1.031
DISPERSION = .650 STANDARD DEVIATION = 1.081 DEVIATION FROM NORMAL DISTR. = -27.95%

PERCENTILES:

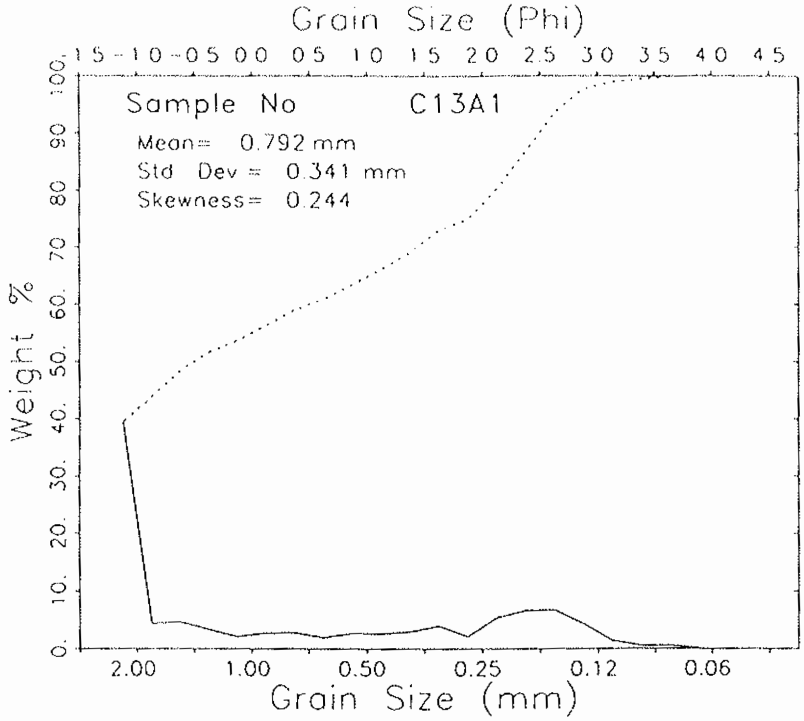
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.182	-1.033	-.580	.764	2.033	2.497	3.531	3.905

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.732	.742	COARSE SAND
STANDARD DEVIATION	1.765	1.597	POORLY SORTED
SKEWNESS(1)	-.018	.078	NEAR SYMMETRICAL
SKEWNESS(2)	.233		
KURTOSIS	.335	.739	PLATYKURTIC

1.597

POORLY SORTED

SKEWNESS(1) -.018



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C13A1	060699						
Bogue Bank C13A1 0-2.7							
		-1.125	41.450	39.397		-1.000	39.397
		-.875	4.550	4.325		-.750	43.722
		-.625	4.770	4.534		-.500	48.256
		-.375	3.490	3.317		-.250	51.573
		-.125	2.140	2.034		.000	53.607
		.125	2.810	2.671		.250	56.278
		.375	2.880	2.737		.500	59.015
		.625	1.990	1.891		.750	60.907
		.875	2.730	2.595		1.000	63.502
		1.125	2.720	2.585		1.250	66.087
		1.375	3.060	2.908		1.500	68.995
		1.625	4.050	3.849		1.750	72.845
		1.875	2.140	2.034		2.000	74.879
		2.125	5.550	5.275		2.250	80.154
		2.375	6.940	6.596		2.500	86.750
		2.625	6.990	6.644		2.750	93.394
		2.875	4.420	4.201		3.000	97.595
		3.125	1.380	1.312		3.250	98.907
		3.375	.510	.485		3.500	99.392
		3.625	.510	.485		3.750	99.876
		3.875	.130	.124		4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.210

PERCENT FINER THAN 4.00 PHI = 1.16 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .337 STANDARD DEVIATION = 1.554 SKEWNESS = .244 KURTOSIS = -1.385
DISPERSION = .426 STANDARD DEVIATION = .645 DEVIATION FROM NORMAL DISTR. = -58.48%

PERCENTILES:

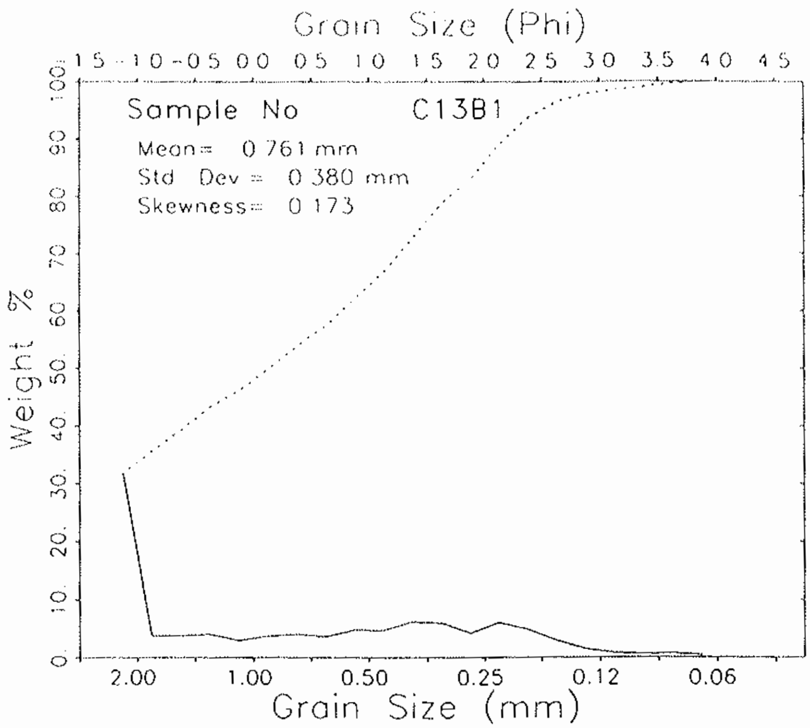
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.244	-1.218	-1.148	-1.091	-.369	2.006	2.396	2.846	3.298

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.624	.293	COARSE SAND
STANDARD DEVIATION	1.772	1.502	POORLY SORTED
SKEWNESS(1)	.560	.571	STRONGLY FINE-SKEWED
SKEWNESS(2)	.667		
KURTOSIS	.147	.538	VERY PLATYKURTIC

1.502

POORLY SORTED

SKEWNESS(1) .560



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C13B1	060699					
Bouge Bank C13B1 0-2.2						
		-1.125	32.400	31.730	-1.000	31.730
		-.875	3.840	3.761	-.750	35.491
		-.625	3.780	3.702	-.500	39.193
		-.375	4.030	3.947	-.250	43.140
		-.125	2.950	2.889	.000	46.029
		.125	3.740	3.663	.250	49.692
		.375	4.070	3.986	.500	53.677
		.625	3.670	3.594	.750	57.272
		.875	4.790	4.691	1.000	61.963
		1.125	4.700	4.603	1.250	66.565
		1.375	6.290	6.160	1.500	72.725
		1.625	6.050	5.925	1.750	78.650
		1.875	4.200	4.113	2.000	82.764
		2.125	6.060	5.935	2.250	88.698
		2.375	4.900	4.799	2.500	93.497
		2.625	2.930	2.869	2.750	96.367
		2.875	1.440	1.410	3.000	97.777
		3.125	.700	.686	3.250	98.462
		3.375	.530	.519	3.500	98.981
		3.625	.640	.627	3.750	99.608
		3.875	.400	.392	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.110

PERCENT FINER THAN 4.00 PHI = .81 PERCENT COARSER THAN -1.00 PHI = .00

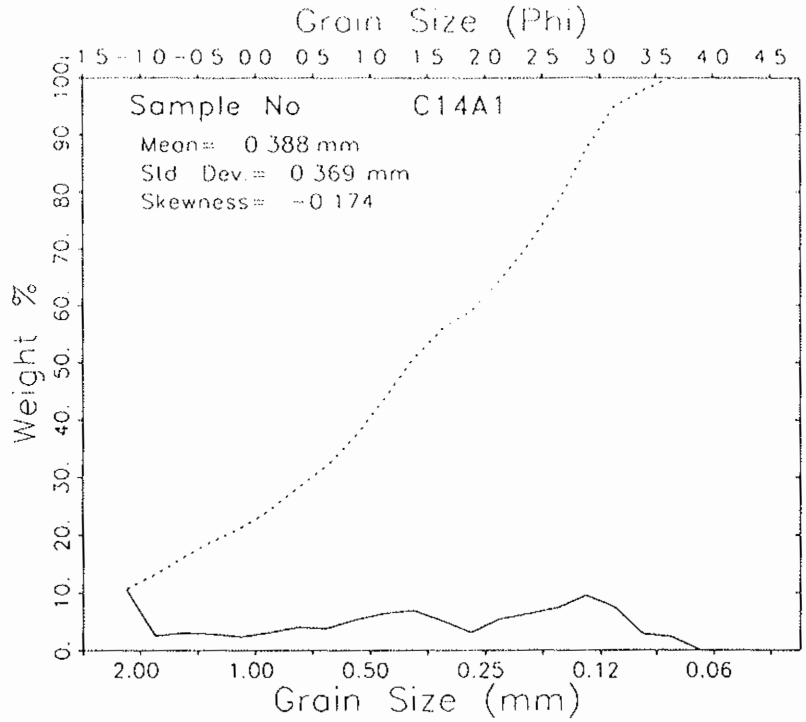
MOMENT MEASURES:

MEAN = .394 STANDARD DEVIATION = 1.396 SKEWNESS = .173 KURTOSIS = -1.203
DISPERSION = .507 STANDARD DEVIATION = .778 DEVIATION FROM NORMAL DISTR. = -44.23%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.211	-1.124	-1.053	.269	1.596	2.052	2.631	3.507

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.464	.399	COARSE SAND
STANDARD DEVIATION	1.508	1.376	POORLY SORTED
SKEWNESS(1)	.123	.176	FINE-SKEWED
SKEWNESS(2)	.278		
KURTOSIS	.210	.594	VERY PLATYKURTIC
1.376			POORLY SORTED
SKEWNESS(1)	.123		



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14A1	060699					
Bogue Banks C14A1 0-2.4						
		-1.125	11.190	10.606	-1.000	10.606
		-.875	2.650	2.512	-.750	13.117
		-.625	3.110	2.948	-.500	16.065
		-.375	2.990	2.834	-.250	18.899
		-.125	2.430	2.303	.000	21.202
		.125	3.210	3.042	.250	24.244
		.375	4.190	3.971	.500	28.215
		.625	4.000	3.791	.750	32.006
		.875	5.620	5.327	1.000	37.333
		1.125	6.770	6.416	1.250	43.749
		1.375	7.260	6.881	1.500	50.630
		1.625	5.440	5.156	1.750	55.786
		1.875	3.240	3.071	2.000	58.857
		2.125	5.690	5.393	2.250	64.250
		2.375	6.660	6.312	2.500	70.562
		2.625	7.720	7.317	2.750	77.879
		2.875	9.970	9.449	3.000	87.328
		3.125	7.910	7.497	3.250	94.825
		3.375	2.950	2.796	3.500	97.621
		3.625	2.420	2.294	3.750	99.915
		3.875	.090	.085	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.510

PERCENT FINER THAN 4.00 PHI = .58 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.367 STANDARD DEVIATION = 1.438 SKEWNESS = -.174 KURTOSIS = -1.069
DISPERSION = .653 STANDARD DEVIATION = 1.089 DEVIATION FROM NORMAL DISTR. = -24.28%

PERCENTILES:

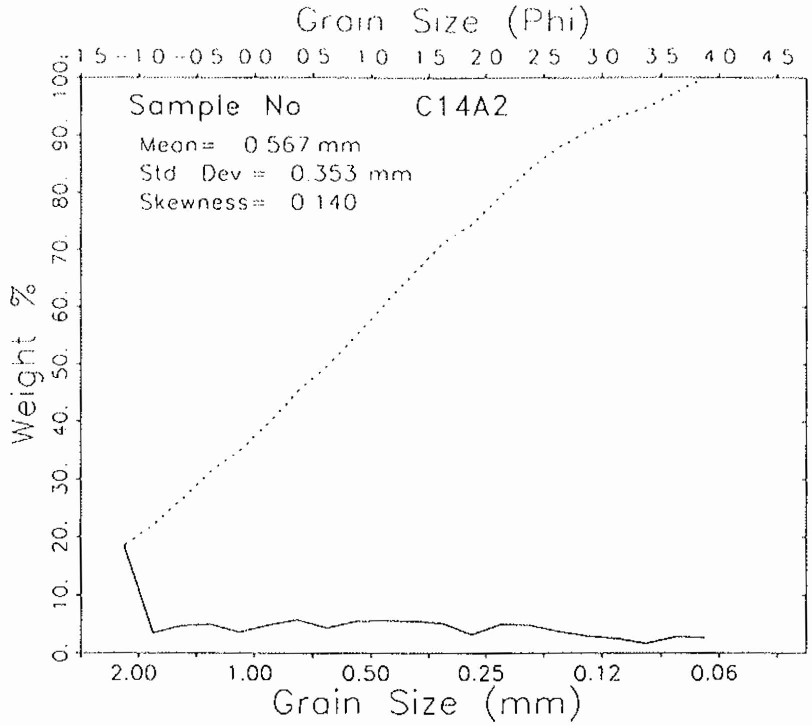
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.226	-1.132	-.505	.298	1.477	2.652	2.912	3.266	3.650

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.203	1.295	MEDIUM SAND
STANDARD DEVIATION	1.709	1.521	POORLY SORTED
SKEWNESS(1)	-.160	-.173	COARSE-SKEWED
SKEWNESS(2)	-.240		
KURTOSIS	.287	.766	PLATYKURTIC

1.709 1.521

POORLY SORTED

SKEWNESS(1) -.160



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14A2	060699					
Bogue Bank C14A2 0-1.9						
		-1.125	17.710	18.469	-1.000	18.469
		-.875	3.260	3.400	-.750	21.869
		-.625	4.420	4.609	-.500	26.478
		-.375	4.660	4.860	-.250	31.338
		-.125	3.410	3.556	.000	34.894
		.125	4.640	4.839	.250	39.733
		.375	5.450	5.684	.500	45.417
		.625	4.100	4.276	.750	49.692
		.875	5.260	5.485	1.000	55.178
		1.125	5.320	5.548	1.250	60.726
		1.375	5.210	5.433	1.500	66.159
		1.625	4.840	5.047	1.750	71.207
		1.875	3.030	3.160	2.000	74.366
		2.125	4.660	4.860	2.250	79.226
		2.375	4.640	4.839	2.500	84.065
		2.625	3.560	3.713	2.750	87.778
		2.875	2.770	2.889	3.000	90.666
		3.125	2.330	2.430	3.250	93.096
		3.375	1.500	1.564	3.500	94.661
		3.625	2.600	2.711	3.750	97.372
		3.875	2.520	2.628	4.000	100.000

TOTAL WEIGHT (GRAMS) = 95.890

PERCENT FINER THAN 4.00 PHI = 8.24 PERCENT COARSER THAN -1.00 PHI = .00

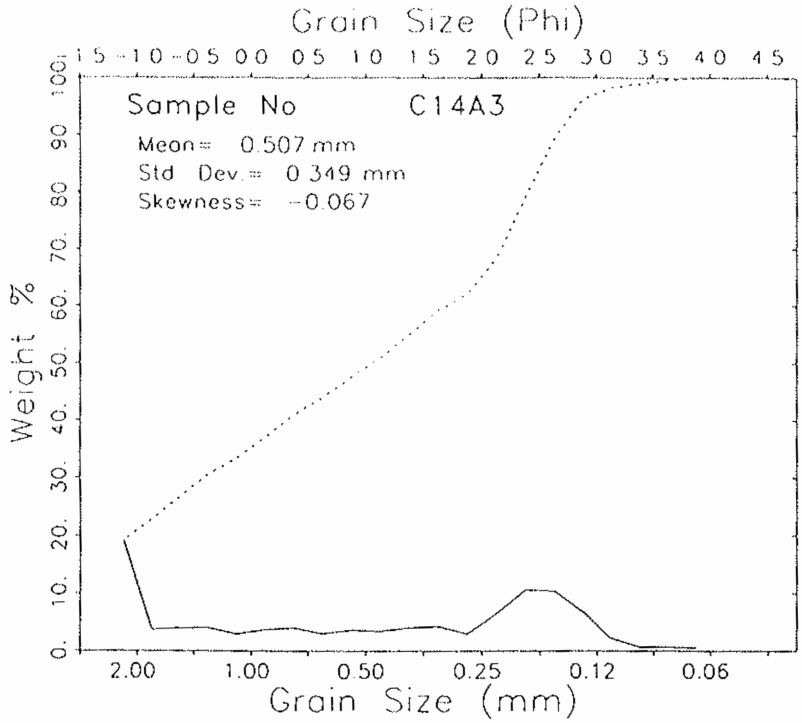
MOMENT MEASURES:

MEAN = .819 STANDARD DEVIATION = 1.501 SKEWNESS = .140 KURTOSIS = -1.031
DISPERSION = .650 STANDARD DEVIATION = 1.081 DEVIATION FROM NORMAL DISTR. = -27.95%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.182	-1.033	-.500	.764	2.033	2.497	3.531	3.905

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.732	.742	COARSE SAND
STANDARD DEVIATION	1.765	1.597	POORLY SORTED
SKEWNESS(1)	-.018	.078	NEAR SYMMETRICAL
SKEWNESS(2)	.233		
KURTOSIS	.335	.739	PLATYKURTIC
1.597			POORLY SORTED
SKEWNESS(1)	-.018		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
C14A3	060699					
Bogue Bank C14A3 Part 3, 0-2.5						
		-1.125	20.460	19.111	-1.000	19.111
		-.875	3.910	3.652	-.750	22.763
		-.625	4.130	3.858	-.500	26.621
		-.375	4.220	3.942	-.250	30.562
		-.125	3.060	2.858	.000	33.421
		.125	3.880	3.624	.250	37.045
		.375	4.230	3.951	.500	40.996
		.625	3.140	2.933	.750	43.929
		.875	3.840	3.587	1.000	47.515
		1.125	3.630	3.391	1.250	50.906
		1.375	4.250	3.970	1.500	54.876
		1.625	4.530	4.231	1.750	59.107
		1.875	3.070	2.868	2.000	61.975
		2.125	6.960	6.501	2.250	68.476
		2.375	11.330	10.583	2.500	79.058
		2.625	11.020	10.293	2.750	89.352
		2.875	7.200	6.725	3.000	96.077
		3.125	2.290	2.139	3.250	98.216
		3.375	.710	.663	3.500	98.879
		3.625	.700	.654	3.750	99.533
		3.875	.500	.467	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.060

PERCENT FINER THAN 4.00 PHI = .94 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .979 STANDARD DEVIATION = 1.518 SKEWNESS = -.067 KURTOSIS = -1.471
DISPERSION = .590 STANDARD DEVIATION = .942 DEVIATION FROM NORMAL DISTR. = -37.95%

PERCENTILES:

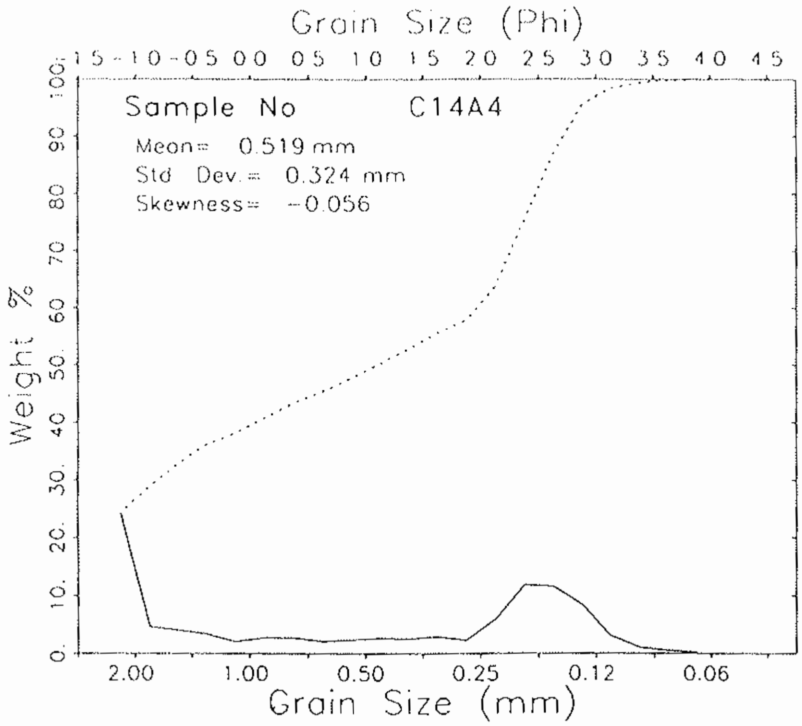
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.237	-1.185	-1.041	-.605	1.183	2.404	2.620	2.960	3.546

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.790	.921	COARSE SAND
STANDARD DEVIATION	1.830	1.543	POORLY SORTED
SKEWNESS(1)	-.215	-.179	COARSE-SKEWED
SKEWNESS(2)	-.161		
KURTOSIS	.132	.564	VERY PLATYKURTIC

1.543

POORLY SORTED

SKEWNESS(1) -.215



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
C14A4	060699					
Bogue Bank C14A4 0-1.4						
		-1.125	26.410	24.187	-1.000	24.187
		-.875	4.990	4.570	-.750	28.757
		-.625	4.320	3.956	-.500	32.714
		-.375	3.650	3.343	-.250	36.056
		-.125	2.180	1.997	.000	38.053
		.125	2.910	2.665	.250	40.718
		.375	2.880	2.638	.500	43.356
		.625	2.220	2.033	.750	45.389
		.875	2.540	2.326	1.000	47.715
		1.125	2.770	2.537	1.250	50.252
		1.375	2.720	2.491	1.500	52.743
		1.625	3.080	2.821	1.750	55.564
		1.875	2.460	2.253	2.000	57.817
		2.125	6.290	5.761	2.250	63.577
		2.375	12.880	11.796	2.500	75.373
		2.625	12.650	11.585	2.750	86.959
		2.875	9.150	8.380	3.000	95.338
		3.125	3.270	2.995	3.250	98.333
		3.375	1.070	.980	3.500	99.313
		3.625	.550	.504	3.750	99.817
		3.875	.200	.183	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.190

PERCENT FINER THAN 4.00 PHI = .26 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .945 STANDARD DEVIATION = 1.627 SKEWNESS = -.056 KURTOSIS = -1.650

DISPERSION = .526 STANDARD DEVIATION = .812 DEVIATION FROM NORMAL DISTR. = -50.08%

PERCENTILES:

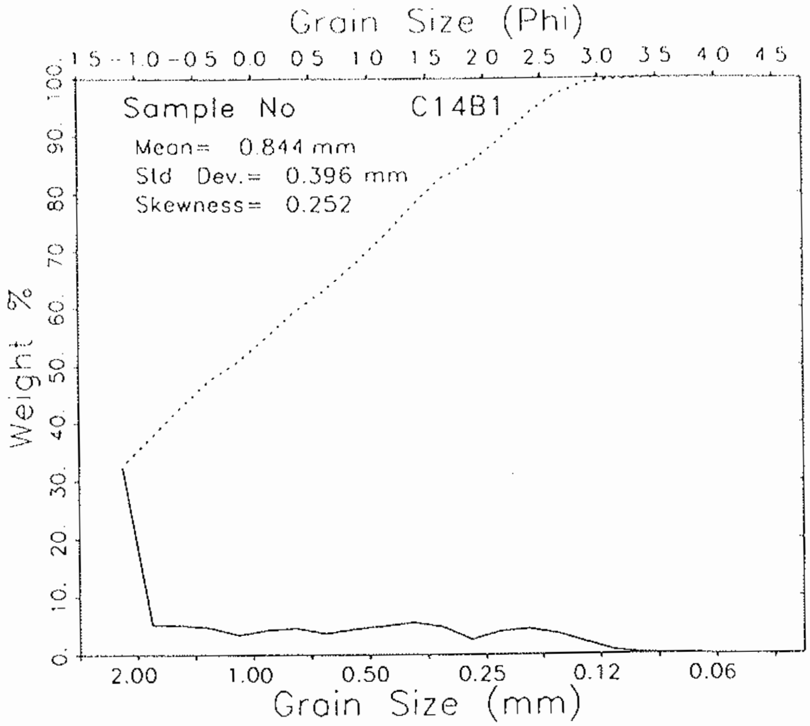
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.198	-1.085	-.956	1.225	2.492	2.686	2.990	3.420

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.801	.942	COARSE SAND
STANDARD DEVIATION	1.885	1.577	POORLY SORTED
SKEWNESS(1)	-.225	-.191	COARSE-SKEWED
SKEWNESS(2)	-.175		
KURTOSIS	.111	.498	VERY PLATYKURTIC

1.577

POORLY SORTED

SKEWNESS(1) -.225



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14B1	060699						
Bogue Bank C14B1 0-1.9							
		-1.125	34.820		32.512	-1.000	32.512
		-.875	5.510		5.145	-.750	37.656
		-.625	5.370		5.014	-.500	42.670
		-.375	5.010		4.678	-.250	47.348
		-.125	3.620		3.380	.000	50.728
		.125	4.550		4.248	.250	54.977
		.375	4.880		4.556	.500	59.533
		.625	3.870		3.613	.750	63.147
		.875	4.720		4.407	1.000	67.554
		1.125	5.210		4.865	1.250	72.418
		1.375	5.830		5.444	1.500	77.862
		1.625	5.060		4.725	1.750	82.586
		1.875	2.760		2.577	2.000	85.163
		2.125	4.250		3.968	2.250	89.132
		2.375	4.740		4.426	2.500	93.557
		2.625	3.780		3.529	2.750	97.087
		2.875	2.190		2.045	3.000	99.132
		3.125	.570		.532	3.250	99.664
		3.375	.160		.149	3.500	99.813
		3.625	.110		.103	3.750	99.916
		3.875	.090		.084	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.100

PERCENT FINER THAN 4.00 PHI = .14 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .244 STANDARD DEVIATION = 1.338 SKEWNESS = .252 KURTOSIS = -1.109

DISPERSION = .491 STANDARD DEVIATION = .749 DEVIATION FROM NORMAL DISTR. = -43.99%

PERCENTILES:

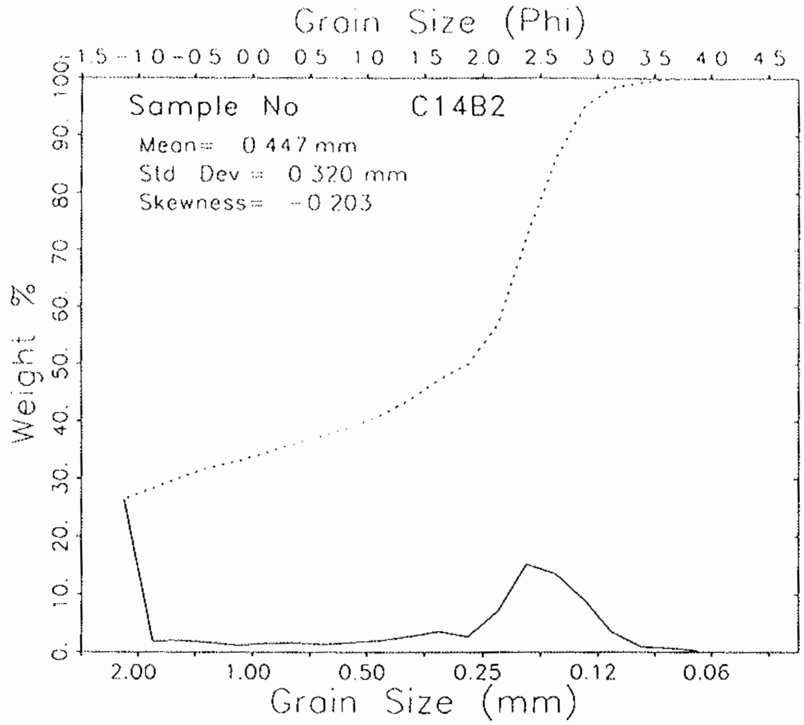
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.212	-1.127	-1.058	-.054	1.369	1.887	2.602	2.984

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.380	.235	COARSE SAND
STANDARD DEVIATION	1.507	1.331	POORLY SORTED
SKEWNESS(1)	.208	.340	STRONGLY FINE-SKEWED
SKEWNESS(2)	.497		
KURTOSIS	.265	.644	VERY PLATYKURTIC

1.331

POORLY SORTED

SKEWNESS(1) .288



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14B2	060699					
Bogue Bank C14B2 Part 1, 0-1.8						
		-1.125	28.430	26.370	-1.000	26.370
		-.875	2.020	1.874	-.750	28.244
		-.625	2.130	1.976	-.500	30.220
		-.375	1.800	1.670	-.250	31.889
		-.125	1.220	1.132	.000	33.021
		.125	1.610	1.493	.250	34.514
		.375	1.710	1.586	.500	36.101
		.625	1.390	1.289	.750	37.390
		.875	1.790	1.660	1.000	39.050
		1.125	2.140	1.985	1.250	41.035
		1.375	2.890	2.681	1.500	43.716
		1.625	3.840	3.562	1.750	47.278
		1.875	2.860	2.653	2.000	49.930
		2.125	7.520	6.975	2.250	56.906
		2.375	16.430	15.240	2.500	72.145
		2.625	14.660	13.598	2.750	85.743
		2.875	9.860	9.146	3.000	94.889
		3.125	3.690	3.423	3.250	98.312
		3.375	.970	.900	3.500	99.212
		3.625	.650	.603	3.750	99.814
		3.875	.200	.186	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.810

PERCENT FINER THAN 4.00 PHI = .18 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

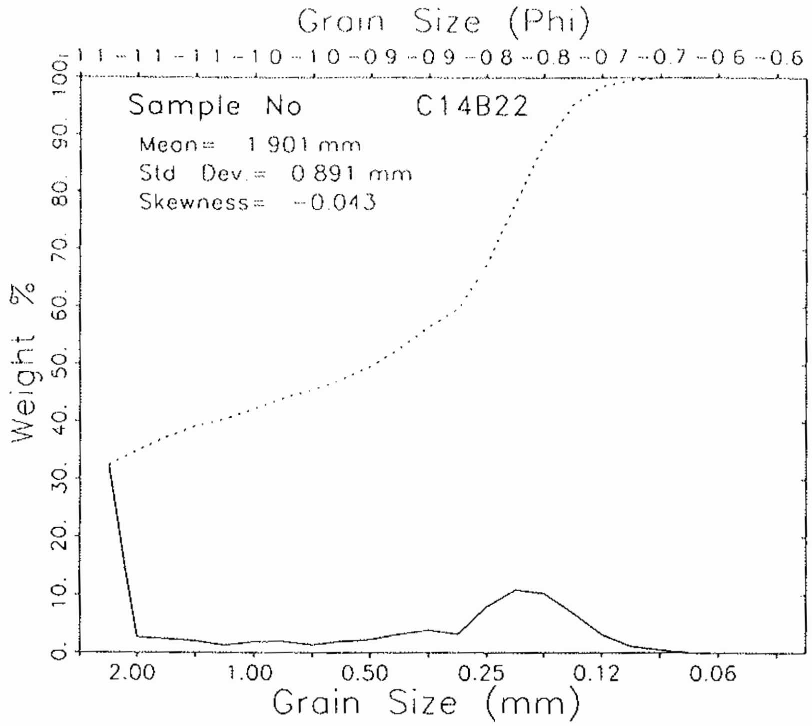
MEAN = 1.161 STANDARD DEVIATION = 1.645 SKEWNESS = -.203 KURTOSIS = -1.535

DISPERSION = .452 STANDARD DEVIATION = .686 DEVIATION FROM NORMAL DISTR. = -58.31%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.203	-1.098	-1.013	2.002	2.552	2.718	3.008	3.441

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.810	1.207	MEDIUM SAND
STANDARD DEVIATION	1.908	1.592	POORLY SORTED
SKEWNESS(1)	-.625	-.574	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.576		
KURTOSIS	.103	.484	VERY PLATYKURTIC
1.592			POORLY SORTED
SKEWNESS(1)	-.625		



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14B22	060699					
Bogue Banks C14B2 Part 2, 0-1.8						
		-1.125	34.510	32.334	-1.112	32.334
		-1.100	2.770	2.595	-1.087	34.929
		-1.075	2.440	2.286	-1.063	37.215
		-1.050	2.070	1.939	-1.038	39.155
		-1.025	1.300	1.218	-1.013	40.373
		-1.000	1.960	1.836	-.988	42.209
		-.975	2.020	1.893	-.963	44.102
		-.950	1.420	1.330	-.938	45.432
		-.925	1.990	1.865	-.913	47.297
		-.900	2.400	2.249	-.888	49.546
		-.875	3.340	3.129	-.863	52.675
		-.850	4.040	3.785	-.838	56.460
		-.825	3.390	3.176	-.813	59.636
		-.800	8.380	7.852	-.788	67.488
		-.775	11.570	10.840	-.763	78.328
		-.750	10.870	10.185	-.738	88.513
		-.725	7.280	6.821	-.713	95.334
		-.700	3.290	3.083	-.688	98.417
		-.675	1.150	1.077	-.663	99.494
		-.650	.500	.468	-.638	99.963
		-.625	.040	.037	-.613	100.000

TOTAL WEIGHT (GRAMS) = 106.730

PERCENT FINER THAN -.61 PHI = .41 PERCENT COARSER THAN -1.11 PHI = .00

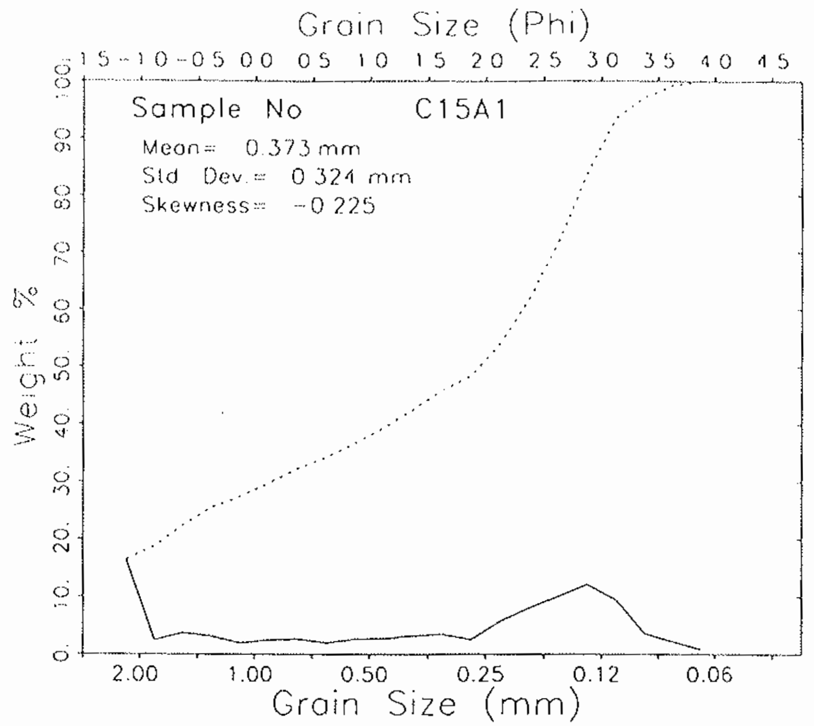
MOMENT MEASURES:

MEAN = -.927 STANDARD DEVIATION = .166 SKEWNESS = -.043 KURTOSIS = -1.699
DISPERSION = -.549 STANDARD DEVIATION = .068 DEVIATION FROM NORMAL DISTR. = -58.85%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.137	-1.134	-1.125	-1.118	-.884	-.770	-.749	-.714	-.674

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	-.937	-.919	VERY COARSE SAND
STANDARD DEVIATION	.188	.158	VERY WELL SORTED
SKEWNESS(1)	-.281	-.236	COARSE-SKEWED
SKEWNESS(2)	-.211		
KURTOSIS	.115	.495	VERY PLATYKURTIC
.158			VERY WELL SORTED
SKEWNESS(1)	-.281		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C15A1	060699						
Bogue Banks C15A1 0-2.0							
		-1.125	17.140		16.366	-1.000	16.366
		-.875	2.460		2.349	-.750	18.715
		-.625	3.850		3.676	-.500	22.391
		-.375	3.240		3.094	-.250	25.485
		-.125	1.950		1.862	.000	27.347
		.125	2.540		2.425	.250	29.772
		.375	2.640		2.521	.500	32.293
		.625	1.950		1.862	.750	34.154
		.875	2.690		2.569	1.000	36.723
		1.125	2.780		2.654	1.250	39.377
		1.375	3.270		3.122	1.500	42.500
		1.625	3.570		3.409	1.750	45.909
		1.875	2.600		2.483	2.000	48.391
		2.125	5.890		5.624	2.250	54.015
		2.375	8.370		7.992	2.500	62.007
		2.625	10.460		9.988	2.750	71.995
		2.875	12.610		12.040	3.000	84.035
		3.125	9.860		9.415	3.250	93.450
		3.375	3.750		3.581	3.500	97.030
		3.625	2.250		2.148	3.750	99.179
		3.875	.860		.821	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.730

PERCENT FINER THAN 4.00 PHI = 1.35 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

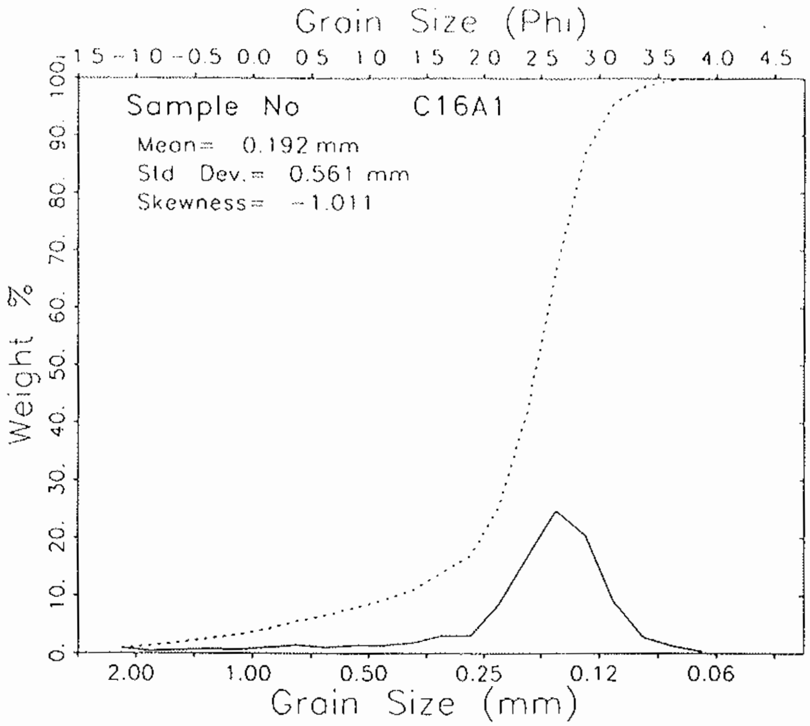
MEAN = 1.422 STANDARD DEVIATION = 1.626 SKEWNESS = -.225 KURTOSIS = -1.330

DISPERSION = .598 STANDARD DEVIATION = .958 DEVIATION FROM NORMAL DISTR. = -41.06%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.174	-1.006	-.289	2.072	2.812	2.999	3.358	3.729

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.997	1.355	MEDIUM SAND
STANDARD DEVIATION	2.002	1.688	POORLY SORTED
SKEWNESS(1)	-.537	-.484	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.489		
KURTOSIS	.132	.599	VERY PLATYKURTIC
1.688			POORLY SORTED
SKEWNESS(1)	-.537		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C16A1	060699						
Bogue Bank C16A1 0-1.9							
		-1.125	.940	.910	-1.000	.910	
		-.875	.410	.397	-.750	1.307	
		-.625	.530	.513	-.500	1.820	
		-.375	.730	.707	-.250	2.527	
		-.125	.650	.629	.000	3.157	
		.125	1.030	.997	.250	4.154	
		.375	1.410	1.365	.500	5.520	
		.625	1.040	1.007	.750	6.527	
		.875	1.320	1.278	1.000	7.805	
		1.125	1.380	1.336	1.250	9.141	
		1.375	1.820	1.762	1.500	10.903	
		1.625	3.100	3.002	1.750	13.905	
		1.875	3.040	2.944	2.000	16.849	
		2.125	8.640	8.366	2.250	25.215	
		2.375	17.170	16.626	2.500	41.842	
		2.625	25.470	24.664	2.750	66.505	
		2.875	21.120	20.451	3.000	86.957	
		3.125	9.070	8.783	3.250	95.739	
		3.375	2.830	2.740	3.500	98.480	
		3.625	1.260	1.220	3.750	99.700	
		3.875	.310	.300	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 103.270

PERCENT FINER THAN 4.00 PHI = .16 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.378 STANDARD DEVIATION = .833 SKEWNESS = -1.011 KURTOSIS = 4.668

DISPERSION = .360 STANDARD DEVIATION = .581 DEVIATION FROM NORMAL DISTR. = -30.27%

PERCENTILES:

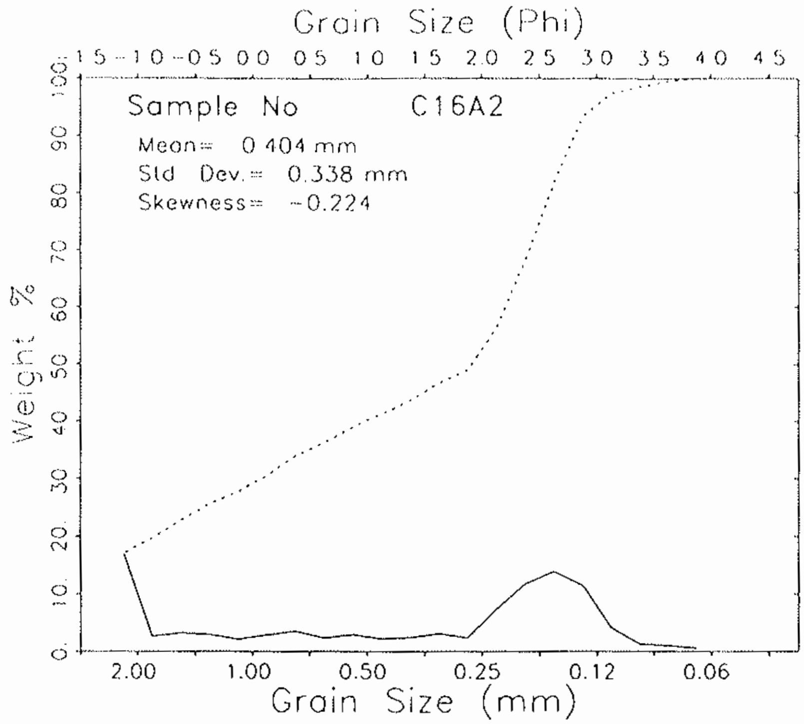
1.	5.	16.	25.	50.	75.	84.	95.	99.
-.943	.405	1.928	2.244	2.583	2.854	2.964	3.229	3.607

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.446	2.491	FINE SAND
STANDARD DEVIATION	.518	.687	MODERATELY WELL SORTED
SKEWNESS(1)	-.264	-.403	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.478		
KURTOSIS	1.726	1.897	VERY LEPTOKURTIC

.687

MODERATELY WELL SORTED

SKEWNESS(1) -.264



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C16A2	060699					
Bogue Banks C16A2 0-2.1						
		-1.125	17.190	17.047	-1.000	17.047
		-.875	2.580	2.559	-.750	19.605
		-.625	3.140	3.114	-.500	22.719
		-.375	2.920	2.896	-.250	25.615
		-.125	2.110	2.092	.000	27.707
		.125	2.800	2.777	.250	30.484
		.375	3.480	3.451	.500	33.935
		.625	2.300	2.281	.750	36.216
		.875	2.930	2.906	1.000	39.121
		1.125	2.150	2.132	1.250	41.253
		1.375	2.390	2.370	1.500	43.624
		1.625	3.040	3.015	1.750	46.638
		1.875	2.360	2.340	2.000	48.979
		2.125	7.370	7.309	2.250	56.287
		2.375	11.780	11.682	2.500	67.969
		2.625	13.890	13.774	2.750	81.743
		2.875	11.600	11.503	3.000	93.247
		3.125	4.060	4.026	3.250	97.273
		3.375	1.260	1.250	3.500	98.522
		3.625	.940	.932	3.750	99.455
		3.875	.550	.545	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.840

PERCENT FINER THAN 4.00 PHI = .78 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

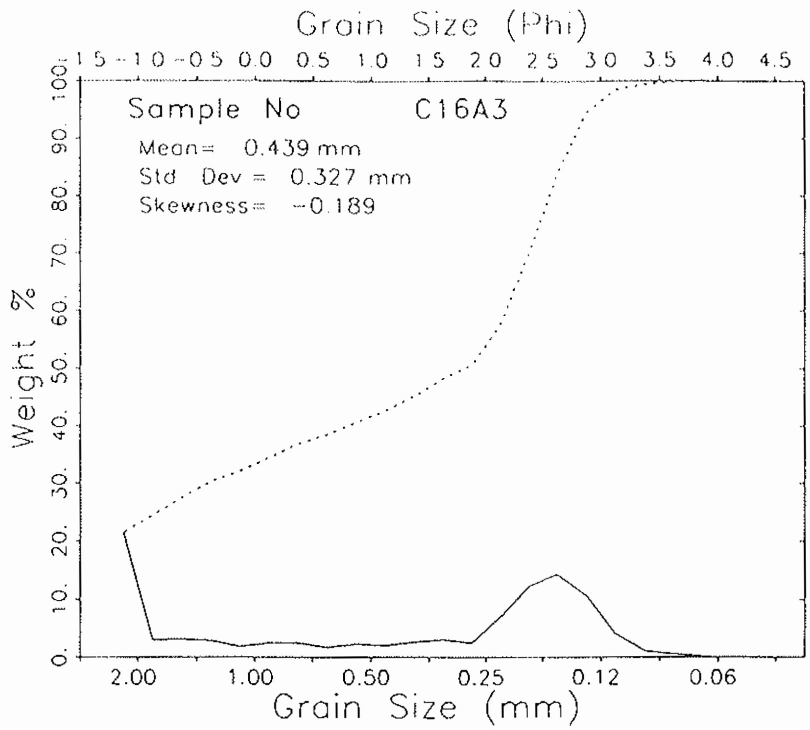
MEAN = 1.306 STANDARD DEVIATION = 1.563 SKEWNESS = -.224 KURTOSIS = -1.351

DISPERSION = .560 STANDARD DEVIATION = .879 DEVIATION FROM NORMAL DISTR. = -43.80%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.177	-1.015	-.303	2.035	2.628	2.799	3.109	3.628

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.892	1.273	MEDIUM SAND
STANDARD DEVIATION	1.907	1.603	POORLY SORTED
SKEWNESS(1)	-.599	-.549	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.560		
KURTOSIS	.124	.599	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C16A3	060699					
Bogue Banks C16A5 0-1.6						
		-1.125	22.440	21.484	-1.000	21.484
		-.875	3.060	2.930	-.750	24.414
		-.625	3.190	3.054	-.500	27.468
		-.375	2.960	2.834	-.250	30.302
		-.125	1.850	1.771	.000	32.073
		.125	2.450	2.346	.250	34.418
		.375	2.470	2.365	.500	36.783
		.625	1.710	1.637	.750	38.420
		.875	2.280	2.183	1.000	40.603
		1.125	2.070	1.982	1.250	42.585
		1.375	2.690	2.575	1.500	45.160
		1.625	3.100	2.968	1.750	48.128
		1.875	2.490	2.384	2.000	50.512
		2.125	7.230	6.922	2.250	57.434
		2.375	12.690	12.149	2.500	69.584
		2.625	14.850	14.217	2.750	83.801
		2.875	11.090	10.618	3.000	94.418
		3.125	4.150	3.973	3.250	98.392
		3.375	1.030	.986	3.500	99.378
		3.625	.500	.479	3.750	99.856
		3.875	.150	.144	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.450

PERCENT FINER THAN 4.00 PHI = .20 PERCENT COARSER THAN -1.00 PHI = .00

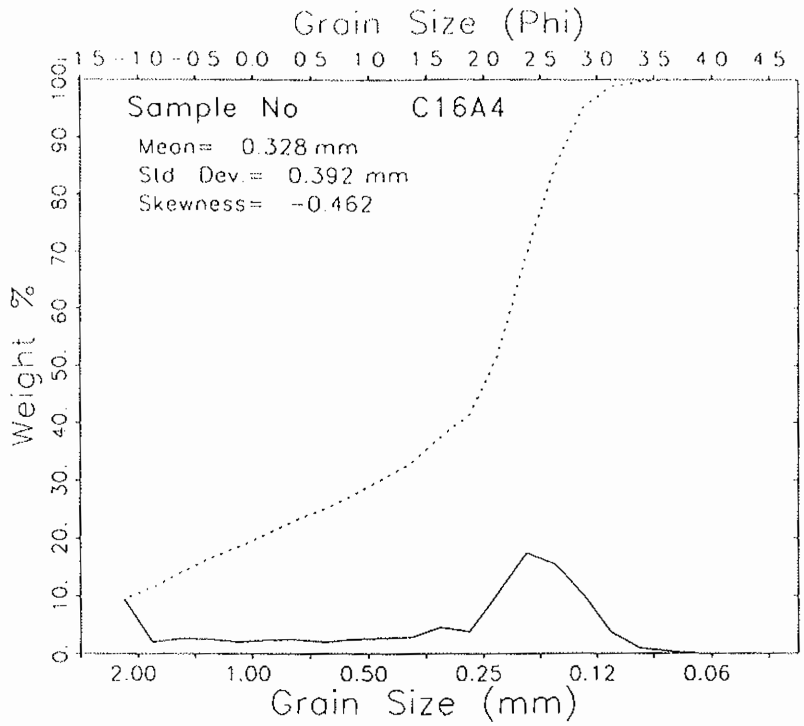
MOMENT MEASURES:

MEAN = 1.187 STANDARD DEVIATION = 1.614 SKEWNESS = -.189 KURTOSIS = -1.516
DISPERSION = .514 STANDARD DEVIATION = .791 DEVIATION FROM NORMAL DISTR. = -50.99%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.192	-1.064	-.702	1.946	2.595	2.755	3.037	3.404

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.845	1.212	MEDIUM SAND
STANDARD DEVIATION	1.909	1.595	POORLY SORTED
SKEWNESS(1)	-.577	-.530	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.536		
KURTOSIS	.107	.526	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C16A4	060699						
Bogue Bank C16A4 0-0.8							
		-1.125	9.710	9.446		-1.000	9.446
		-.875	1.990	1.936		-.750	11.382
		-.625	2.660	2.588		-.500	13.970
		-.375	2.550	2.481		-.250	16.451
		-.125	2.030	1.975		.000	18.426
		.125	2.350	2.286		.250	20.712
		.375	2.470	2.403		.500	23.115
		.625	2.010	1.955		.750	25.071
		.875	2.500	2.432		1.000	27.503
		1.125	2.700	2.627		1.250	30.129
		1.375	2.910	2.831		1.500	32.960
		1.625	4.690	4.563		1.750	37.523
		1.875	3.930	3.823		2.000	41.346
		2.125	10.790	10.497		2.250	51.844
		2.375	17.910	17.424		2.500	69.267
		2.625	15.940	15.507		2.750	84.775
		2.875	10.560	10.273		3.000	95.048
		3.125	3.780	3.677		3.250	98.726
		3.375	.900	.876		3.500	99.601
		3.625	.370	.360		3.750	99.961
		3.875	.040	.039		4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.790

PERCENT FINER THAN 4.00 PHI = .26 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.607 STANDARD DEVIATION = 1.351 SKEWNESS = -.462 KURTOSIS = -.524
DISPERSION = .535 STANDARD DEVIATION = .830 DEVIATION FROM NORMAL DISTR. = -38.57%

PERCENTILES:

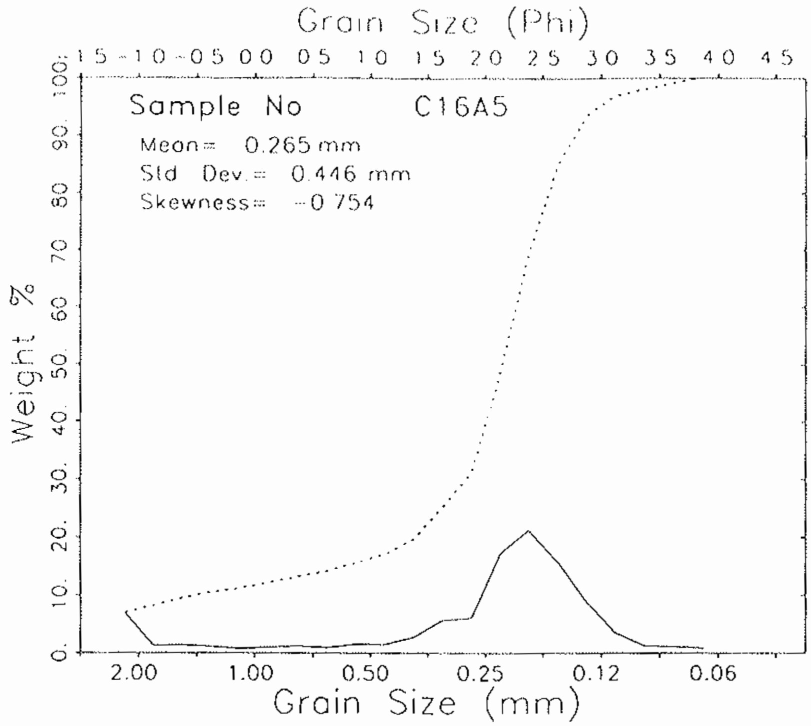
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.118	-.295	.741	2.206	2.592	2.738	2.999	3.328

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.221	1.549	MEDIUM SAND
STANDARD DEVIATION	1.516	1.382	POORLY SORTED
SKEWNESS(1)	-.650	-.632	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.835		
KURTOSIS	.357	.911	MESOKURTIC

1.382

POORLY SORTED

SKEWNESS(1) -.650



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C16A5	060699						
Bogue Banks C16A5 0-1.6							
		-1.125	22.440	21.484		-1.000	21.484
		-.875	3.060	2.930		-.750	24.414
		-.625	3.190	3.054		-.500	27.468
		-.375	2.960	2.834		-.250	30.302
		-.125	1.850	1.771		.000	32.073
		.125	2.450	2.346		.250	34.418
		.375	2.470	2.365		.500	36.783
		.625	1.710	1.637		.750	38.420
		.875	2.280	2.183		1.000	40.603
		1.125	2.070	1.982		1.250	42.585
		1.375	2.690	2.575		1.500	45.160
		1.625	3.100	2.968		1.750	48.128
		1.875	2.490	2.384		2.000	50.512
		2.125	7.230	6.922		2.250	57.434
		2.375	12.690	12.149		2.500	69.584
		2.625	14.850	14.217		2.750	83.801
		2.875	11.090	10.618		3.000	94.418
		3.125	4.150	3.973		3.250	98.392
		3.375	1.030	.986		3.500	99.378
		3.625	.500	.479		3.750	99.856
		3.875	.150	.144		4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.450

PERCENT FINER THAN 4.00 PHI = .20 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

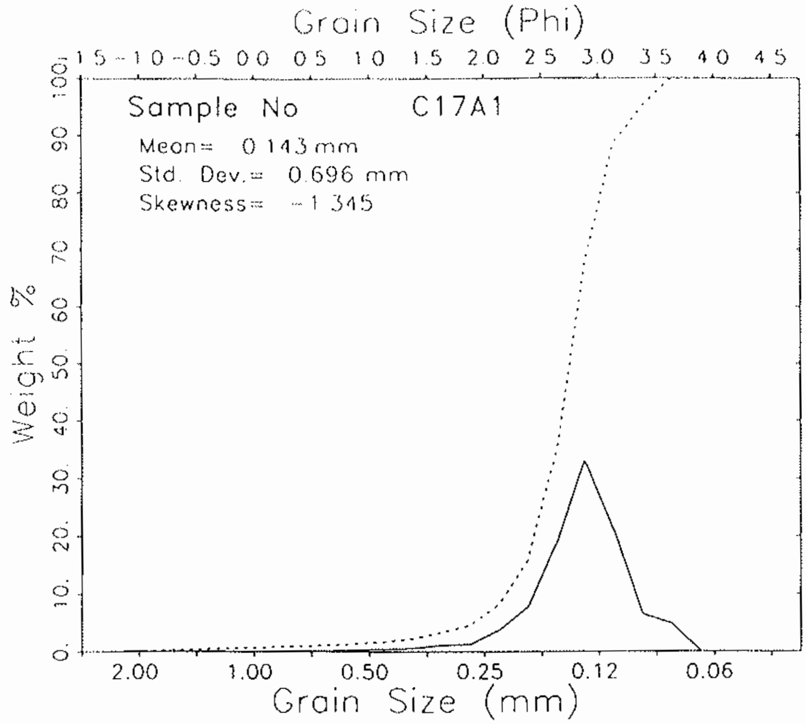
MEAN = 1.187 STANDARD DEVIATION = 1.614 SKEWNESS = -.189 KURTOSIS = -1.516

DISPERSION = .514 STANDARD DEVIATION = .791 DEVIATION FROM NORMAL DISTR. = -50.99%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.230	-1.192	-1.064	-.702	1.946	2.595	2.755	3.037	3.404

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.845	1.212	MEDIUM SAND
STANDARD DEVIATION	1.909	1.595	POORLY SORTED
SKEWNESS(1)	-.577	-.530	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.536		
KURTOSIS	.107	.526	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C17A1	060699						
Bogue Bank C17A1 COMP							
		-1.125	.190		.187	-1.000	.187
		-.875	.070		.069	-.750	.256
		-.625	.130		.128	-.500	.385
		-.375	.140		.138	-.250	.523
		-.125	.080		.079	.000	.601
		.125	.160		.158	.250	.759
		.375	.160		.158	.500	.917
		.625	.150		.148	.750	1.065
		.875	.270		.266	1.000	1.331
		1.125	.350		.345	1.250	1.676
		1.375	.570		.562	1.500	2.238
		1.625	1.080		1.065	1.750	3.303
		1.875	1.200		1.183	2.000	4.486
		2.125	3.700		3.648	2.250	8.134
		2.375	7.770		7.660	2.500	15.794
		2.625	18.940		18.673	2.750	34.467
		2.875	33.580		33.107	3.000	67.574
		3.125	21.380		21.079	3.250	88.652
		3.375	6.440		6.349	3.500	95.001
		3.625	4.910		4.841	3.750	99.842
		3.875	.160		.158	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.430

PERCENT FINER THAN 4.00 PHI = 1.50 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.807 STANDARD DEVIATION = .523 SKEWNESS = -1.345 KURTOSIS = 14.197
DISPERSION = .220 STANDARD DEVIATION = .401 DEVIATION FROM NORMAL DISTR. = -23.22%

PERCENTILES:

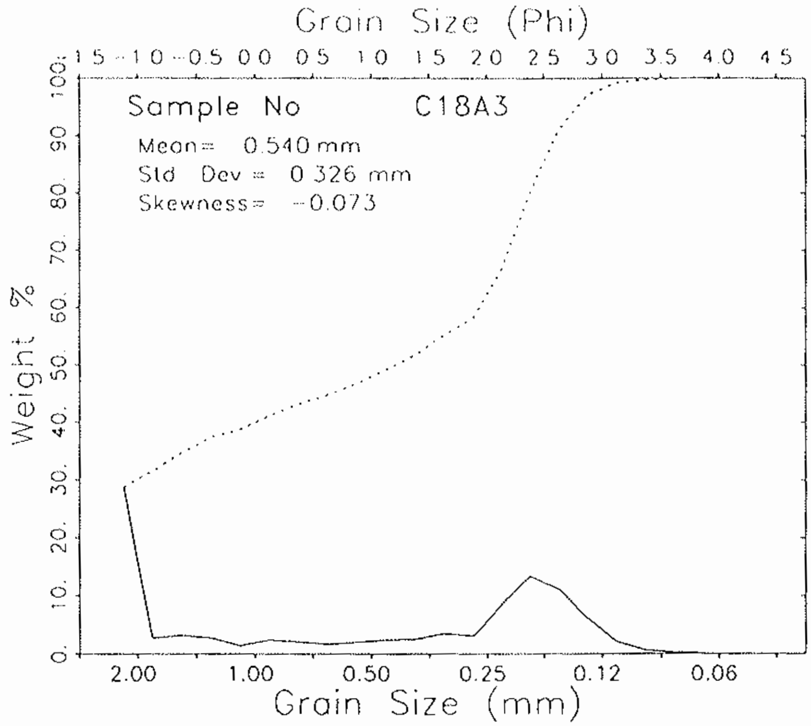
1.	5.	16.	25.	50.	75.	84.	95.	99.
.641	2.035	2.503	2.623	2.867	3.088	3.195	3.500	3.707

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.849	2.855	FINE SAND
STANDARD DEVIATION	.346	.395	WELL SORTED
SKEWNESS(1)	-.053	-.095	NEAR SYMMETRICAL
SKEWNESS(2)	-.288		
KURTOSIS	1.116	1.291	LEPTOKURTIC

346 .395

WELL SORTED

SKEWNESS(1) -.053



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C18A3	060699					
Bogue Bank C18A3 0-0.9						
		-1.125	31.000	28.728	-1.000	28.728
		-.875	2.940	2.724	-.750	31.452
		-.625	3.410	3.160	-.500	34.612
		-.375	2.950	2.734	-.250	37.346
		-.125	1.510	1.399	.000	38.745
		.125	2.530	2.345	.250	41.090
		.375	2.230	2.067	.500	43.156
		.625	1.740	1.612	.750	44.769
		.875	2.140	1.983	1.000	46.752
		1.125	2.550	2.363	1.250	49.115
		1.375	2.680	2.484	1.500	51.599
		1.625	3.760	3.484	1.750	55.083
		1.875	3.260	3.021	2.000	58.104
		2.125	9.120	8.451	2.250	66.555
		2.375	14.370	13.317	2.500	79.872
		2.625	12.000	11.120	2.750	90.992
		2.875	6.610	6.125	3.000	97.118
		3.125	2.190	2.029	3.250	99.147
		3.375	.560	.519	3.500	99.666
		3.625	.260	.241	3.750	99.907
		3.875	.100	.093	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.910

PERCENT FINER THAN 4.00 PHI = .13 PERCENT COARSER THAN -1.00 PHI = .00

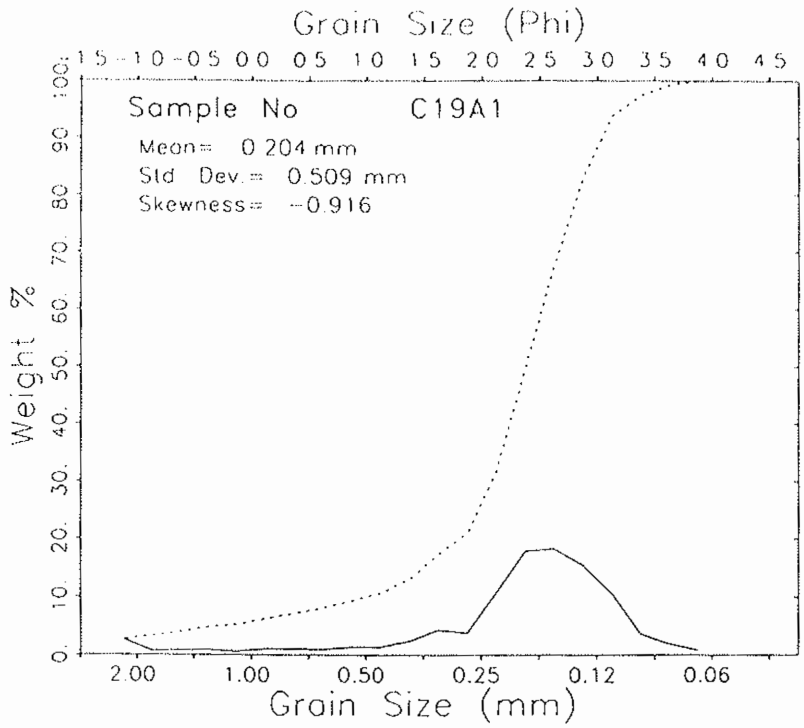
MOMENT MEASURES:

MEAN = .890 STANDARD DEVIATION = 1.617 SKEWNESS = -.073 KURTOSIS = -1.682
DISPERSION = .466 STANDARD DEVIATION = .708 DEVIATION FROM NORMAL DISTR. = -56.26%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.206	-1.111	-1.032	1.339	2.409	2.593	2.914	3.232

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.741	.940	COARSE SAND
STANDARD DEVIATION	1.852	1.550	POORLY SORTED
SKEWNESS(1)	-.323	-.279	COARSE-SKEWED
SKEWNESS(2)	-.262		
KURTOSIS	.112	.491	VERY PLATYKURTIC
1.550			POORLY SORTED
SKEWNESS(1)	-.323		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C19A1	060699						
Bogue Banks C19A1 0-2.0							
		-1.125	2.890		2.598	-1.000	2.598
		-.875	.670		.602	-.750	3.201
		-.625	.770		.692	-.500	3.893
		-.375	.850		.764	-.250	4.657
		-.125	.570		.512	.000	5.170
		.125	1.090		.980	.250	6.150
		.375	1.110		.998	.500	7.148
		.625	.960		.863	.750	8.011
		.875	1.450		1.304	1.000	9.315
		1.125	1.480		1.331	1.250	10.646
		1.375	2.590		2.329	1.500	12.974
		1.625	4.730		4.253	1.750	17.227
		1.875	4.120		3.704	2.000	20.931
		2.125	11.930		10.726	2.250	31.658
		2.375	19.800		17.803	2.500	49.461
		2.625	20.240		18.198	2.750	67.659
		2.875	17.220		15.483	3.000	83.142
		3.125	11.820		10.628	3.250	93.769
		3.375	3.970		3.570	3.500	97.339
		3.625	2.080		1.870	3.750	99.209
		3.875	.880		.791	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.220

PERCENT FINER THAN 4.00 PHI = 1.00 PERCENT COARSER THAN -1.00 PHI = .00

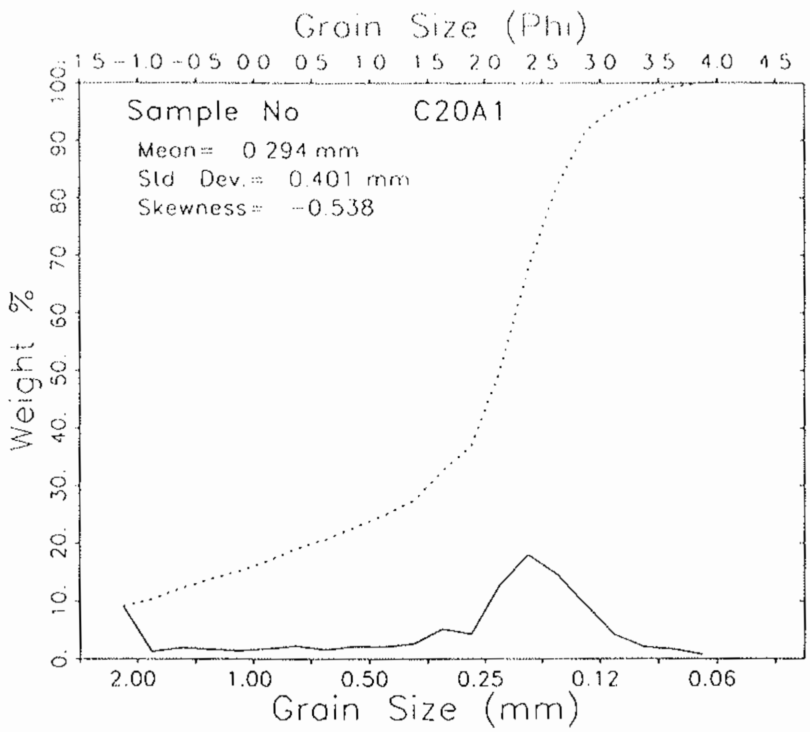
MOMENT MEASURES:

MEAN = 2.290 STANDARD DEVIATION = .974 SKEWNESS = -.916 KURTOSIS = 3.606
DISPERSION = .453 STANDARD DEVIATION = .687 DEVIATION FROM NORMAL DISTR. = -29.44%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.154	-.083	1.678	2.095	2.507	2.869	3.020	3.336	3.722

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.349	2.402	FINE SAND
STANDARD DEVIATION	.671	.854	MODERATELY SORTED
SKEWNESS(1)	-.236	-.376	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.312		
KURTOSIS	1.547	1.811	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C20A1	060699					
Bogue Banks C20A1 0-1.3						
		-1.125	10.040	9.083	-1.000	9.083
		-.875	1.310	1.185	-.750	10.268
		-.625	2.060	1.864	-.500	12.131
		-.375	1.810	1.637	-.250	13.769
		-.125	1.530	1.384	.000	15.153
		.125	1.930	1.746	.250	16.899
		.375	2.420	2.189	.500	19.088
		.625	1.710	1.547	.750	20.635
		.875	2.350	2.126	1.000	22.761
		1.125	2.290	2.072	1.250	24.833
		1.375	2.800	2.533	1.500	27.366
		1.625	5.660	5.120	1.750	32.486
		1.875	4.730	4.279	2.000	36.765
		2.125	14.060	12.719	2.250	49.484
		2.375	19.830	17.939	2.500	67.424
		2.625	16.160	14.619	2.750	82.043
		2.875	10.420	9.426	3.000	91.469
		3.125	4.580	4.143	3.250	95.612
		3.375	2.230	2.017	3.500	97.630
		3.625	1.820	1.646	3.750	99.276
		3.875	.800	.724	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.540

PERCENT FINER THAN 4.00 PHI = 2.71 PERCENT COARSER THAN -1.00 PHI = .00

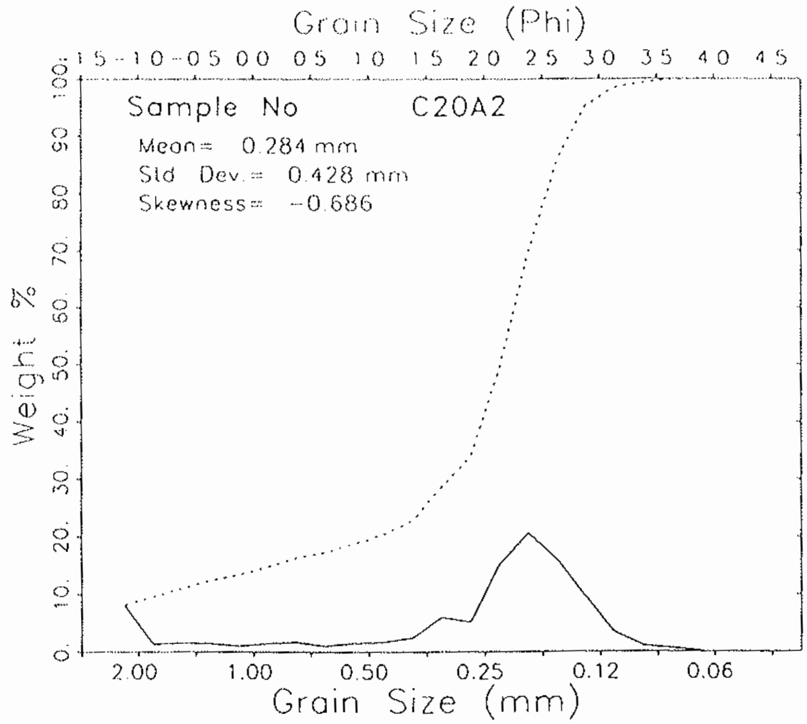
MOMENT MEASURES:

MEAN = 1.765 STANDARD DEVIATION = 1.318 SKEWNESS = -.538 KURTOSIS = .032
DISPERSION = .536 STANDARD DEVIATION = .831 DEVIATION FROM NORMAL DISTR. = -36.93%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.222	-1.112	.121	1.267	2.257	2.630	2.802	3.213	3.708

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.462	1.727	MEDIUM SAND
STANDARD DEVIATION	1.340	1.326	POORLY SORTED
SKEWNESS(1)	-.594	-.576	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.900		
KURTOSIS	.614	1.301	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C20A2	060699						
Bogue Bank C20A2 0-1.5							
		-1.125	8.570		8.143	-1.000	8.143
		-.875	1.410		1.340	-.750	9.482
		-.625	1.570		1.492	-.500	10.974
		-.375	1.420		1.349	-.250	12.323
		-.125	1.050		.998	.000	13.321
		.125	1.450		1.378	.250	14.698
		.375	1.690		1.606	.500	16.304
		.625	1.010		.960	.750	17.264
		.875	1.510		1.435	1.000	18.698
		1.125	1.750		1.663	1.250	20.361
		1.375	2.540		2.413	1.500	22.774
		1.625	6.280		5.967	1.750	28.741
		1.875	5.430		5.159	2.000	33.900
		2.125	15.950		15.154	2.250	49.055
		2.375	21.640		20.561	2.500	69.615
		2.625	16.840		16.000	2.750	85.615
		2.875	9.950		9.454	3.000	95.069
		3.125	3.450		3.278	3.250	98.347
		3.375	.980		.931	3.500	99.278
		3.625	.610		.580	3.750	99.857
		3.875	.150		.143	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.250

PERCENT FINER THAN 4.00, PHI = 1.21 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.815 STANDARD DEVIATION = 1.225 SKEWNESS = -.686 KURTOSIS = .750

DISPERSION = .467 STANDARD DEVIATION = .709 DEVIATION FROM NORMAL DISTR. = -42.13%

PERCENTILES:

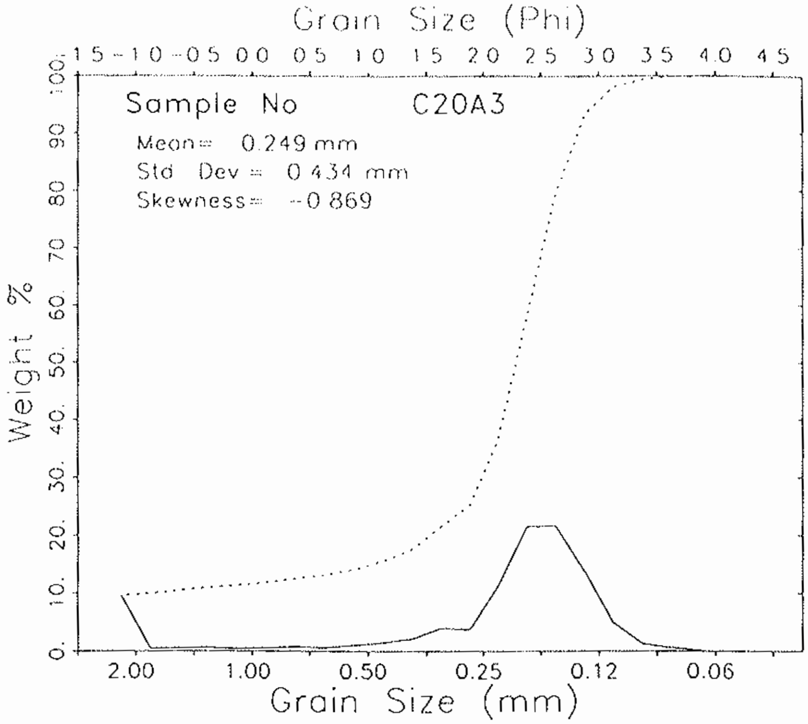
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.219	-1.096	.453	1.593	2.261	2.584	2.725	2.998	3.425

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.589	1.813	MEDIUM SAND
STANDARD DEVIATION	1.136	1.188	POORLY SORTED
SKEWNESS(1)	-.592	-.616	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.154		
KURTOSIS	.802	1.694	VERY LEPTOKURTIC

1.188

POORLY SORTED

SKEWNESS(1) -.592



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C20A3	060699					
Bogue Bank C20A3 0-0.5						
		-1.125	9.660	9.526	-1.000	9.526
		-.875	.400	.394	-.750	9.920
		-.625	.490	.483	-.500	10.403
		-.375	.550	.542	-.250	10.946
		-.125	.360	.355	.000	11.301
		.125	.510	.503	.250	11.804
		.375	.720	.710	.500	12.514
		.625	.570	.562	.750	13.076
		.875	1.000	.986	1.000	14.062
		1.125	1.430	1.410	1.250	15.472
		1.375	2.070	2.041	1.500	17.513
		1.625	3.980	3.925	1.750	21.438
		1.875	3.790	3.737	2.000	25.175
		2.125	11.360	11.202	2.250	36.377
		2.375	21.810	21.507	2.500	57.884
		2.625	21.880	21.576	2.750	79.460
		2.875	13.950	13.756	3.000	93.216
		3.125	4.910	4.842	3.250	98.057
		3.375	1.270	1.252	3.500	99.310
		3.625	.600	.592	3.750	99.901
		3.875	.100	.099	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.410

PERCENT FINER THAN 4.00 PHI = .12 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

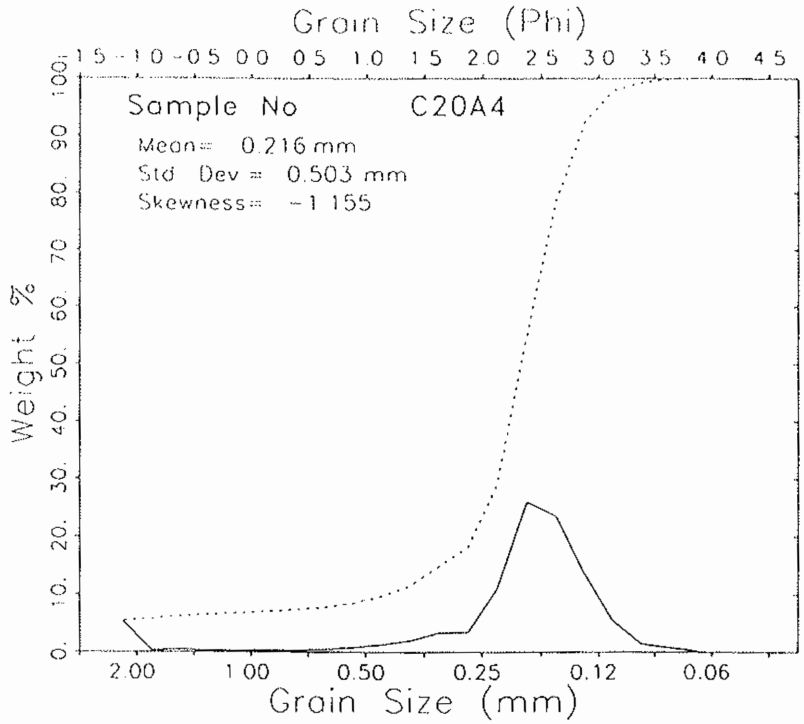
MEAN = 2.007 STANDARD DEVIATION = 1.205 SKEWNESS = -.869 KURTOSIS = 1.910

DISPERSION = .381 STANDARD DEVIATION = .582 DEVIATION FROM NORMAL DISTR. = -51.72%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.119	1.315	1.988	2.408	2.698	2.833	3.092	3.438

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.074	2.185	FINE SAND
STANDARD DEVIATION	.759	1.017	POORLY SORTED
SKEWNESS(1)	-.441	-.558	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.873		
KURTOSIS	1.774	2.431	VERY LEPTOKURTIC
1.017			POORLY SORTED
SKEWNESS(1)	-.441		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C20A4	060699						
Bogue Bank C20A4 COMP							
		-1.125	5.080		5.412	-1.000	5.412
		-.875	.320		.341	-.750	5.753
		-.625	.390		.415	-.500	6.168
		-.375	.300		.320	-.250	6.488
		-.125	.200		.213	.000	6.701
		.125	.280		.298	.250	6.999
		.375	.310		.330	.500	7.329
		.625	.340		.362	.750	7.691
		.875	.670		.714	1.000	8.405
		1.125	1.120		1.193	1.250	9.598
		1.375	1.750		1.864	1.500	11.463
		1.625	3.080		3.281	1.750	14.744
		1.875	3.160		3.366	2.000	18.110
		2.125	10.280		10.951	2.250	29.061
		2.375	24.490		26.089	2.500	55.151
		2.625	22.140		23.586	2.750	78.737
		2.875	12.760		13.593	3.000	92.330
		3.125	5.090		5.422	3.250	97.752
		3.375	1.280		1.364	3.500	99.116
		3.625	.690		.735	3.750	99.851
		3.875	.140		.149	4.000	100.000

TOTAL WEIGHT (GRAMS) = 93.870

PERCENT FINER THAN 4.00 PHI = .10 PERCENT COARSER THAN -1.00 PHI = .00

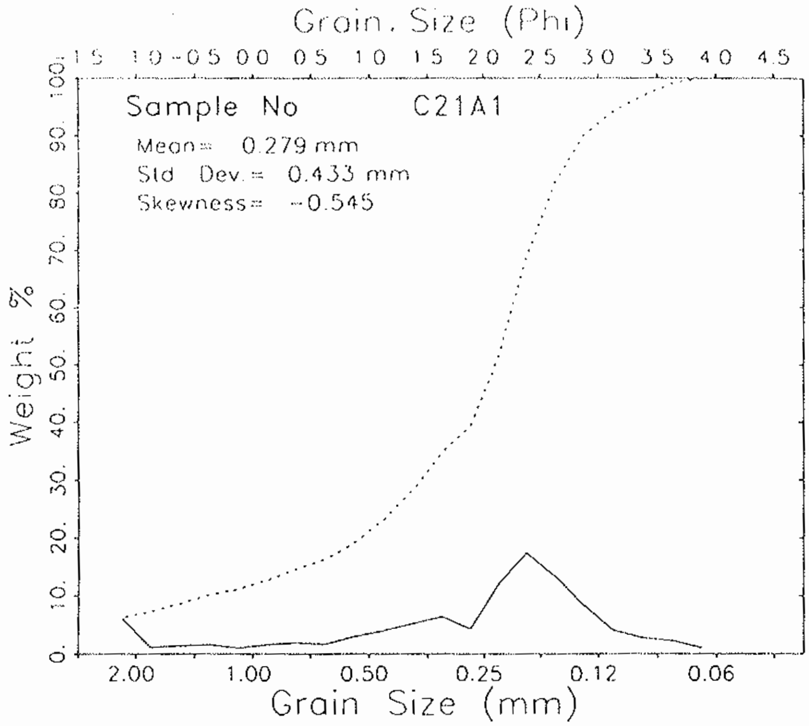
MOMENT MEASURES:

MEAN = 2.208 STANDARD DEVIATION = .990 SKEWNESS = -1.155 KURTOSIS = 5.085
DISPERSION = .329 STANDARD DEVIATION = .516 DEVIATION FROM NORMAL DISTR. = -47.87%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.204	-1.019	1.843	2.157	2.451	2.710	2.847	3.123	3.479

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.345	2.380	FINE SAND
STANDARD DEVIATION	.502	.878	MODERATELY SORTED
SKEWNESS(1)	-.210	-.443	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-2.787		
KURTOSIS	3.128	3.069	EXTREMELY LEPTOKURTIC
.878			MODERATELY SORTED
SKEWNESS(1)	-.210		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C21A1	060699					
Bogue Banks C21A1 0-1.9						
		-1.125	6.160	6.172	-1.000	6.172
		-.875	1.080	1.082	-.750	7.255
		-.625	1.350	1.353	-.500	8.607
		-.375	1.510	1.513	-.250	10.120
		-.125	.960	.962	.000	11.082
		.125	1.580	1.583	.250	12.665
		.375	1.910	1.914	.500	14.579
		.625	1.620	1.623	.750	16.202
		.875	2.940	2.946	1.000	19.148
		1.125	3.940	3.948	1.250	23.096
		1.375	5.210	5.220	1.500	28.317
		1.625	6.400	6.413	1.750	34.729
		1.875	4.320	4.329	2.000	39.058
		2.125	11.920	11.944	2.250	51.002
		2.375	17.400	17.435	2.500	68.437
		2.625	13.270	13.297	2.750	81.733
		2.875	8.300	8.317	3.000	90.050
		3.125	4.070	4.078	3.250	94.128
		3.375	2.720	2.725	3.500	96.854
		3.625	2.210	2.214	3.750	99.068
		3.875	.930	.932	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.800

PERCENT FINER THAN 4.00 PHI = 1.61 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.844 STANDARD DEVIATION = 1.209 SKEWNESS = -.545 KURTOSIS = .517
DISPERSION = .563 STANDARD DEVIATION = .885 DEVIATION FROM NORMAL DISTR. = -26.77%

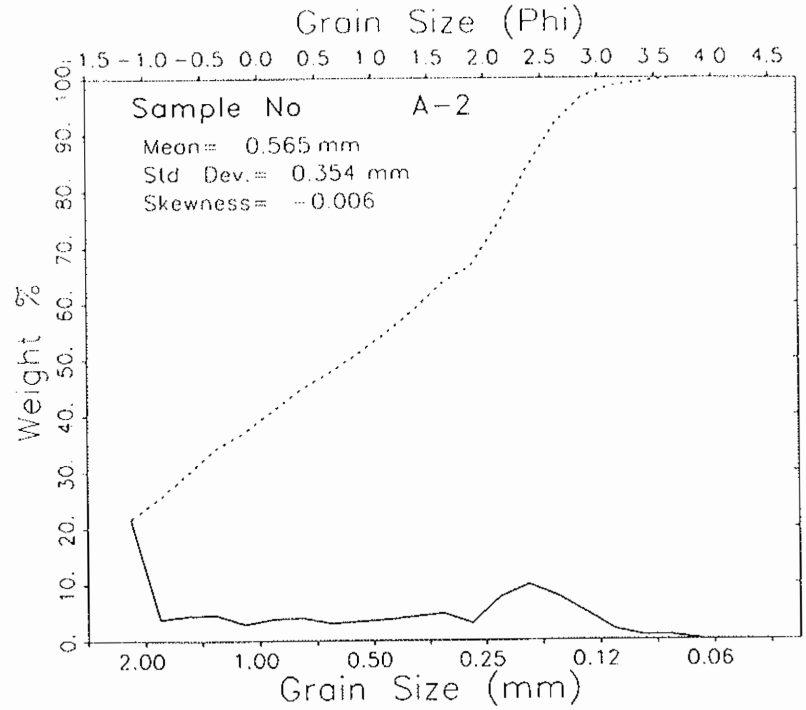
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.209	-1.047	.719	1.341	2.229	2.623	2.818	3.330	3.742

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.768	1.922	MEDIUM SAND
STANDARD DEVIATION	1.050	1.188	POORLY SORTED
SKEWNESS(1)	-.439	-.468	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.036		
KURTOSIS	1.085	1.399	LEPTOKURTIC

ANNEX E-2
Part 2

Phase II — November 1999
Sediment Sample Results
Core Logs



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-2 111199					
Bogue Banks Borrow A					
	-1.125	23.860	21.587	-1.000	21.587
	-.875	4.080	3.691	-.750	25.278
	-.625	4.830	4.370	-.500	29.648
	-.375	4.970	4.497	-.250	34.145
	-.125	3.180	2.877	.000	37.022
	.125	4.200	3.800	.250	40.821
	.375	4.368	3.945	.500	44.766
	.625	3.300	2.986	.750	47.752
	.875	3.640	3.293	1.000	51.045
	1.125	4.060	3.673	1.250	54.718
	1.375	4.650	4.207	1.500	58.925
	1.625	5.218	4.714	1.750	63.639
	1.875	3.260	2.949	2.000	66.588
	2.125	8.470	7.663	2.250	74.251
	2.375	10.850	9.816	2.500	84.068
	2.625	8.600	7.781	2.750	91.848
	2.875	5.420	4.904	3.000	96.752
	3.125	1.970	1.782	3.250	98.534
	3.375	.750	.679	3.500	99.213
	3.625	.790	.715	3.750	99.928
	3.875	.080	.072	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.530

PERCENT FINER THAN 4.00 PHI = 2.48 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

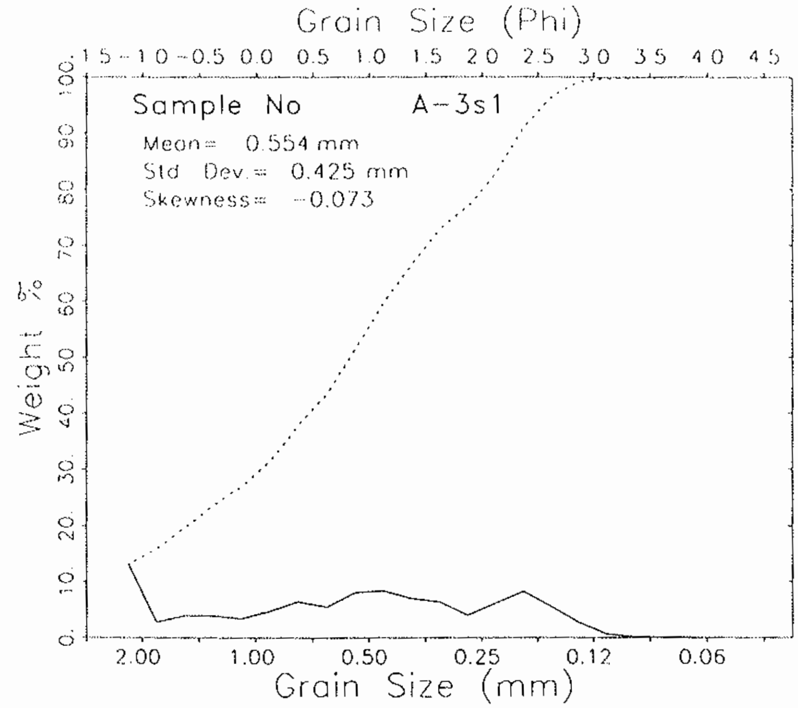
MEAN = .824 STANDARD DEVIATION = 1.497 SKEWNESS = -.006 KURTOSIS = -1.494

DISPERSION = .579 STANDARD DEVIATION = .918 DEVIATION FROM NORMAL DISTR. = -38.65%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.192	-1.065	-.769	.921	2.269	2.498	2.911	3.422

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.717	.785	COARSE SAND
STANDARD DEVIATION	1.781	1.512	POORLY SORTED
SKEWNESS(1)	-.114	-.072	NEAR SYMMETRICAL
SKEWNESS(2)	-.034		
KURTOSIS	.152	.553	VERY PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-3s1 111199					
Borrow A - A03s1					
	-1.125	14.800	13.067	-1.000	13.067
	-.875	3.080	2.719	-.750	15.787
	-.625	4.380	3.867	-.500	19.654
	-.375	4.390	3.876	-.250	23.530
	-.125	3.810	3.364	.000	26.894
	.125	5.310	4.688	.250	31.582
	.375	7.280	6.428	.500	38.010
	.625	6.160	5.439	.750	43.449
	.875	9.000	7.946	1.000	51.395
	1.125	9.370	8.273	1.250	59.668
	1.375	7.910	6.984	1.500	66.652
	1.625	7.100	6.269	1.750	72.921
	1.875	4.500	3.973	2.000	76.894
	2.125	6.920	6.110	2.250	83.004
	2.375	9.190	8.114	2.500	91.118
	2.625	6.190	5.465	2.750	96.583
	2.875	2.960	2.613	3.000	99.197
	3.125	.650	.574	3.250	99.770
	3.375	.140	.124	3.500	99.894
	3.625	.070	.062	3.750	99.956
	3.875	.050	.044	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.260

PERCENT FINER THAN 4.00 PHI = .06 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

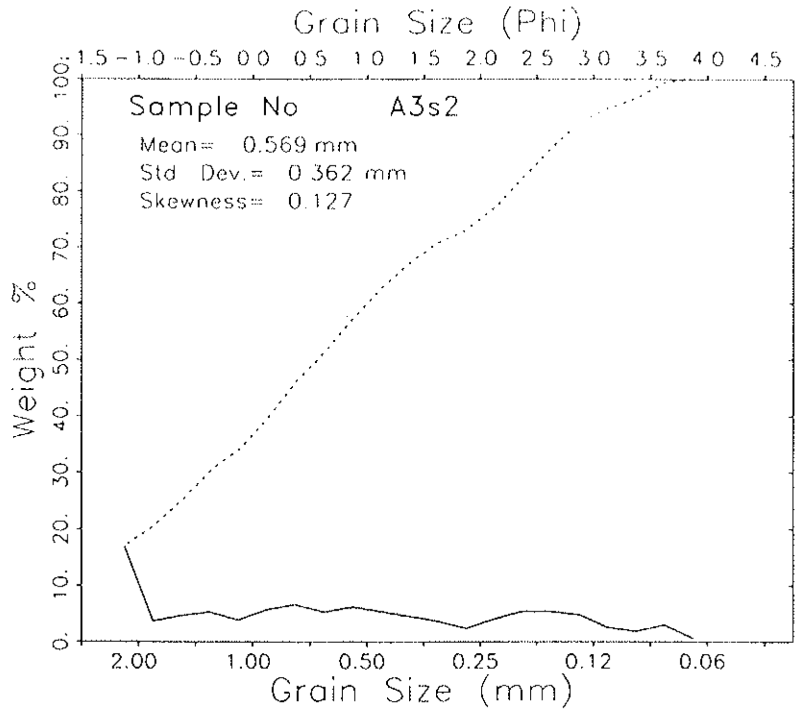
MEAN = .852 STANDARD DEVIATION = 1.235 SKEWNESS = -.073 KURTOSIS = -1.075

DISPERSION = .604 STANDARD DEVIATION = .973 DEVIATION FROM NORMAL DISTR. = -21.23%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.231	-1.154	-.736	-.141	.956	1.881	2.281	2.678	2.981

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.772	.834	COARSE SAND
STANDARD DEVIATION	1.508	1.335	POORLY SORTED
SKEWNESS(1)	-.122	-.112	COARSE-SKEWED
SKEWNESS(2)	-.129		
KURTOSIS	.270	.777	PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-3s2 111199						
Borrow A - A03s2 1.0-2.7 ft						
	-1.125	16.410	16.848		-1.000	16.848
	-.875	3.470	3.563		-.750	20.411
	-.625	4.440	4.559		-.500	24.969
	-.375	5.060	5.195		-.250	30.164
	-.125	3.690	3.789		.000	33.953
	.125	5.470	5.616		.250	39.569
	.375	6.350	6.520		.500	46.088
	.625	5.120	5.257		.750	51.345
	.875	5.940	6.099		1.000	57.444
	1.125	5.140	5.277		1.250	62.721
	1.375	4.330	4.446		1.500	67.166
	1.625	3.500	3.593		1.750	70.760
	1.875	2.220	2.279		2.000	73.039
	2.125	3.870	3.973		2.250	77.012
	2.375	5.140	5.277		2.500	82.290
	2.625	5.160	5.298		2.750	87.587
	2.875	4.560	4.682		3.000	92.269
	3.125	2.430	2.495		3.250	94.764
	3.375	1.750	1.797		3.500	96.561
	3.625	2.830	2.906		3.750	99.466
	3.875	.520	.534		4.000	100.000

TOTAL WEIGHT (GRAMS) = 97.400

PERCENT FINER THAN 4.00 PHI = 13.41 PERCENT COARSER THAN -1.00 PHI = .00

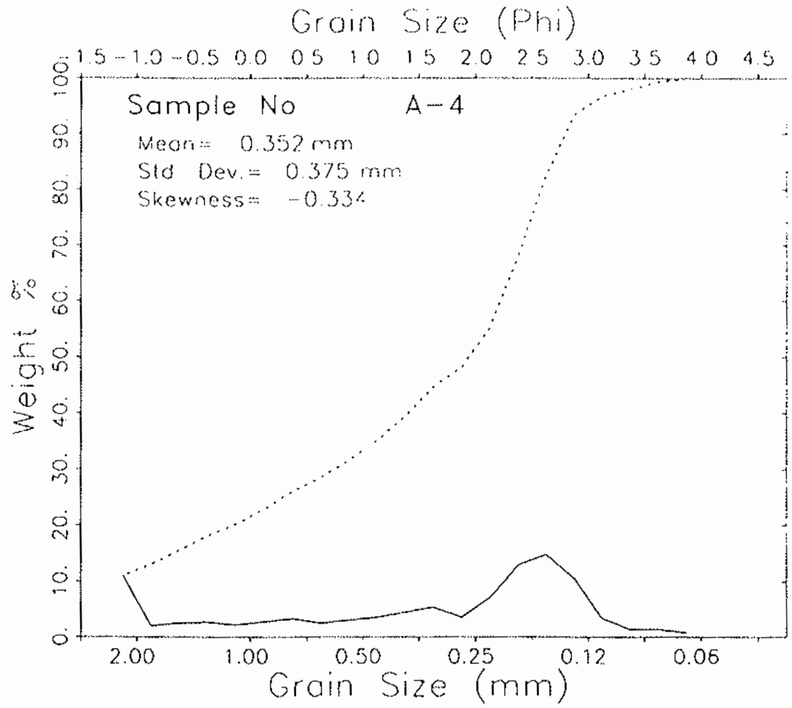
MOMENT MEASURES:

MEAN = .814 STANDARD DEVIATION = 1.465 SKEWNESS = .127 KURTOSIS = -1.116
DISPERSION = .648 STANDARD DEVIATION = 1.077 DEVIATION FROM NORMAL DISTR. = -26.50%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.176	-1.013	-.499	.686	2.123	2.581	3.283	3.710

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.784	.751	COARSE SAND
STANDARD DEVIATION	1.797	1.574	POORLY SORTED
SKEWNESS(1)	.055	.110	FINE-SKEWED
SKEWNESS(2)	.205		
KURTOSIS	.241	.697	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-4	111199					
Borrow A - A4						
		-1.125	12.710	11.023	-1.000	11.023
		-.875	2.270	1.969	-.750	12.992
		-.625	2.830	2.454	-.500	15.447
		-.375	3.050	2.645	-.250	18.092
		-.125	2.420	2.099	.000	20.191
		.125	3.120	2.706	.250	22.897
		.375	3.680	3.192	.500	26.088
		.625	2.880	2.498	.750	28.586
		.875	3.390	2.940	1.000	31.526
		1.125	4.030	3.495	1.250	35.022
		1.375	5.020	4.354	1.500	39.376
		1.625	6.130	5.317	1.750	44.692
		1.875	4.040	3.504	2.000	48.196
		2.125	8.180	7.095	2.250	55.291
		2.375	14.820	12.853	2.500	68.144
		2.625	16.940	14.692	2.750	82.836
		2.875	12.170	10.555	3.000	93.391
		3.125	3.820	3.313	3.250	96.704
		3.375	1.460	1.266	3.500	97.971
		3.625	1.550	1.344	3.750	99.315
		3.875	.790	.685	4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.300

PERCENT FINER THAN 4.00 PHI = 1.56 PERCENT COARSER THAN -1.00 PHI = .00

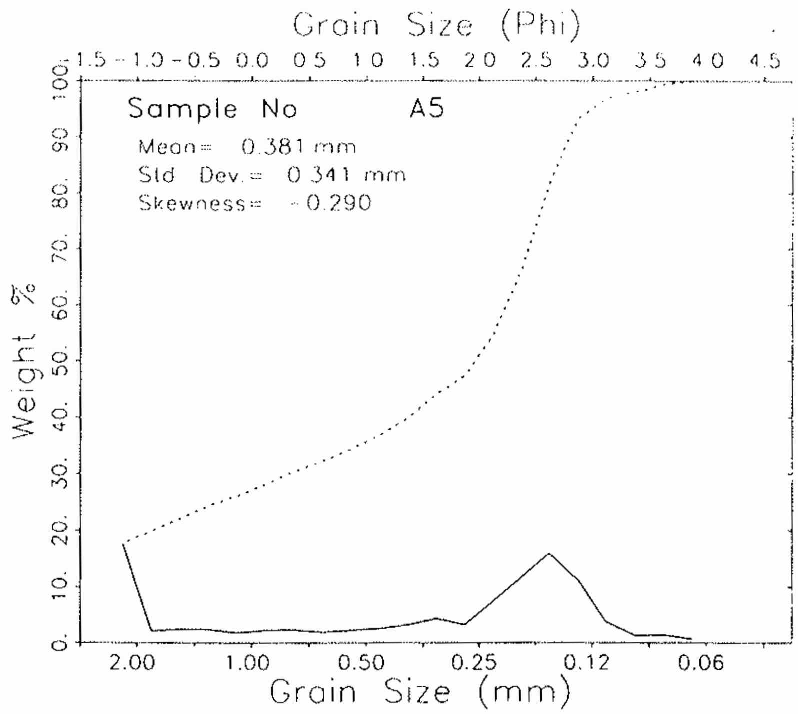
MOMENT MEASURES:

MEAN = 1.506 STANDARD DEVIATION = 1.416 SKEWNESS = -.334 KURTOSIS = -.858
DISPERSION = .592 STANDARD DEVIATION = .946 DEVIATION FROM NORMAL DISTR. = -33.20%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.137	-.448	.415	2.064	2.617	2.778	3.121	3.691

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.165	1.464	MEDIUM SAND
STANDARD DEVIATION	1.613	1.451	POORLY SORTED
SKEWNESS(1)	-.557	-.530	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.664		
KURTOSIS	.320	.793	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A5	111199						
Borrow A - A5							
		-1.125	20.440	17.653		-1.000	17.653
		-.875	2.420	2.090		-.750	19.743
		-.625	2.700	2.332		-.500	22.074
		-.375	2.630	2.271		-.250	24.346
		-.125	1.950	1.684		.000	26.030
		.125	2.470	2.133		.250	28.163
		.375	2.570	2.220		.500	30.383
		.625	2.110	1.822		.750	32.205
		.875	2.480	2.142		1.000	34.347
		1.125	2.850	2.461		1.250	36.808
		1.375	3.590	3.100		1.500	39.908
		1.625	4.910	4.240		1.750	44.149
		1.875	3.670	3.170		2.000	47.318
		2.125	8.500	7.341		2.250	54.659
		2.375	13.360	11.538		2.500	66.197
		2.625	18.280	15.787		2.750	81.985
		2.875	12.960	11.193		3.000	93.177
		3.125	4.240	3.662		3.250	96.839
		3.375	1.410	1.218		3.500	98.057
		3.625	1.480	1.278		3.750	99.335
		3.875	.770	.665		4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.790

PERCENT FINER THAN 4.00 PHI = .94 PERCENT COARSER THAN -1.00 PHI = .00

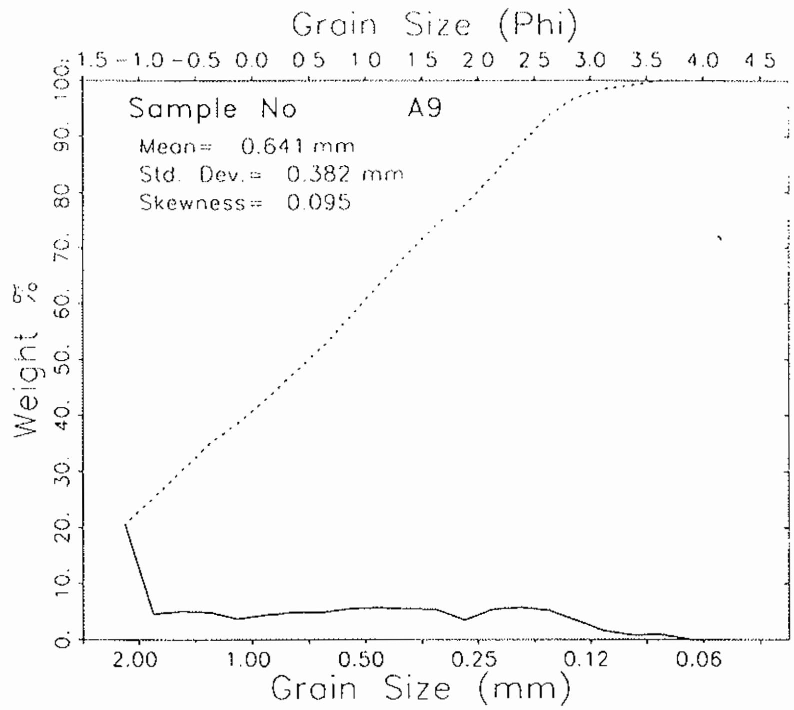
MOMENT MEASURES:

MEAN = 1.392 STANDARD DEVIATION = 1.554 SKEWNESS = -.290 KURTOSIS = -1.192
DISPERSION = .542 STANDARD DEVIATION = .843 DEVIATION FROM NORMAL DISTR. = -45.73%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.179	-1.023	-.153	2.091	2.639	2.795	3.124	3.684

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.886	1.288	MEDIUM SAND
STANDARD DEVIATION	1.909	1.607	POORLY SORTED
SKEWNESS(1)	-.631	-.576	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.586		
KURTOSIS	.127	.632	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A9	111199					
Borrow A - A9						
		-1.125	22.200	20.613	-1.000	20.613
		-.875	4.820	4.475	-.750	25.088
		-.625	5.330	4.949	-.500	30.037
		-.375	5.200	4.828	-.250	34.865
		-.125	3.960	3.677	.000	38.542
		.125	4.640	4.308	.250	42.851
		.375	5.150	4.782	.500	47.632
		.625	5.140	4.773	.750	52.405
		.875	5.860	5.441	1.000	57.846
		1.125	6.050	5.617	1.250	63.463
		1.375	5.840	5.422	1.500	68.886
		1.625	5.700	5.292	1.750	74.178
		1.875	3.650	3.389	2.000	77.567
		2.125	5.710	5.302	2.250	82.869
		2.375	6.030	5.599	2.500	88.468
		2.625	5.570	5.172	2.750	93.640
		2.875	3.590	3.333	3.000	96.973
		3.125	1.590	1.476	3.250	98.449
		3.375	.810	.752	3.500	99.202
		3.625	.840	.780	3.750	99.981
		3.875	.020	.019	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.700

PERCENT FINER THAN 4.00 PHI = 2.22 PERCENT COARSER THAN -1.00 PHI = .00

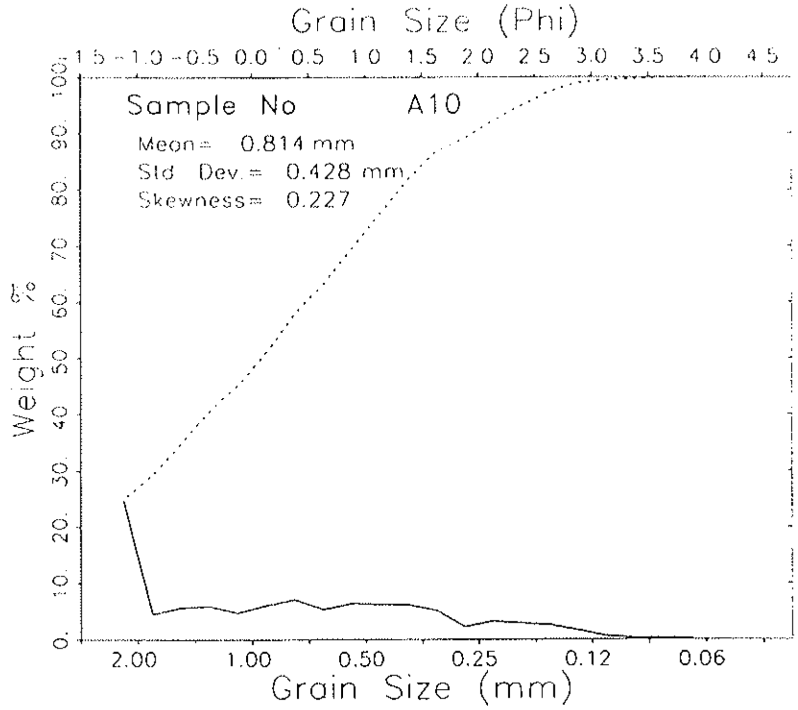
MOMENT MEASURES:

MEAN = .641 STANDARD DEVIATION = 1.390 SKEWNESS = .095 KURTOSIS = -1.234
DISPERSION = .604 STANDARD DEVIATION = .973 DEVIATION FROM NORMAL DISTR. = -30.03%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.189	-1.056	-.755	.624	1.811	2.300	2.852	3.433

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.622	.623	COARSE SAND
STANDARD DEVIATION	1.678	1.451	POORLY SORTED
SKEWNESS(1)	-.001	.051	NEAR SYMMETRICAL
SKEWNESS(2)	.124		
KURTOSIS	.204	.646	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT (PHI)	CLASS LIMITS	CUM PERCENT
A10	111199						
Borrow A - A10							
		-1.125	26.660	24.807	-1.000	24.807	
		-.875	4.710	4.383	-.750	29.190	
		-.625	5.940	5.527	-.500	34.717	
		-.375	6.230	5.797	-.250	40.514	
		-.125	4.950	4.606	.000	45.120	
		.125	6.380	5.937	.250	51.056	
		.375	7.450	6.932	.500	57.988	
		.625	5.580	5.192	.750	63.180	
		.875	6.740	6.272	1.000	69.452	
		1.125	6.620	6.160	1.250	75.612	
		1.375	6.540	6.085	1.500	81.697	
		1.625	5.460	5.080	1.750	86.778	
		1.875	2.320	2.159	2.000	88.936	
		2.125	3.340	3.108	2.250	92.044	
		2.375	2.980	2.773	2.500	94.817	
		2.625	2.660	2.475	2.750	97.292	
		2.875	1.700	1.582	3.000	98.874	
		3.125	.590	.549	3.250	99.423	
		3.375	.240	.223	3.500	99.646	
		3.625	.250	.233	3.750	99.879	
		3.875	.130	.121	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 107.470

PERCENT FINER THAN 4.00 PHI = .43 PERCENT COARSER THAN -1.00 PHI = .00

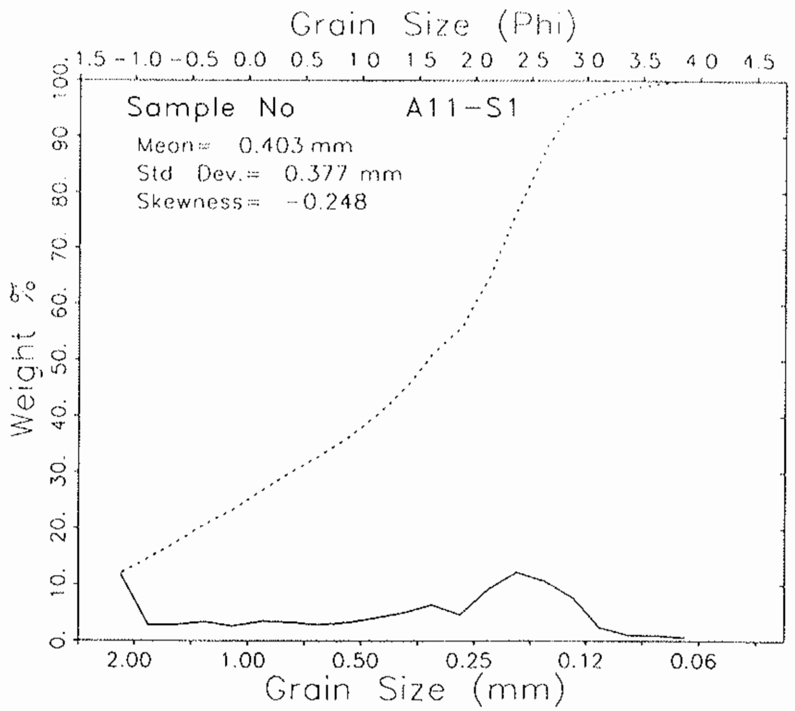
MOMENT MEASURES:

MEAN = .297 STANDARD DEVIATION = 1.224 SKEWNESS = .227 KURTOSIS = -.822
DISPERSION = .542 STANDARD DEVIATION = .843 DEVIATION FROM NORMAL DISTR. = -31.08%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.200	-1.089	-.989	.206	1.225	1.613	2.518	3.057

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.262	.243	COARSE SAND
STANDARD DEVIATION	1.351	1.239	POORLY SORTED
SKEWNESS(1)	.042	.143	FINE-SKEWED
SKEWNESS(2)	.336		
KURTOSIS	.376	.688	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A11	111199					
Borrow A - A11						
		-1.125	13.960	11.927	-1.000	11.927
		-.875	3.220	2.751	-.750	14.677
		-.625	3.310	2.828	-.500	17.505
		-.375	3.820	3.264	-.250	20.769
		-.125	2.970	2.537	.000	23.306
		.125	4.010	3.426	.250	26.732
		.375	3.780	3.229	.500	29.962
		.625	3.290	2.811	.750	32.772
		.875	3.710	3.170	1.000	35.942
		1.125	4.660	3.981	1.250	39.923
		1.375	5.690	4.861	1.500	44.784
		1.625	7.380	6.305	1.750	51.089
		1.875	5.290	4.519	2.000	55.609
		2.125	10.660	9.107	2.250	64.716
		2.375	14.250	12.174	2.500	76.890
		2.625	12.480	10.662	2.750	87.552
		2.875	9.080	7.757	3.000	95.310
		3.125	2.660	2.273	3.250	97.582
		3.375	1.130	.965	3.500	98.548
		3.625	1.020	.871	3.750	99.419
		3.875	.680	.581	4.000	100.000

TOTAL WEIGHT (GRAMS) = 117.050

PERCENT FINER THAN 4.00 PHI = .90 PERCENT COARSER THAN -1.00 PHI = .00

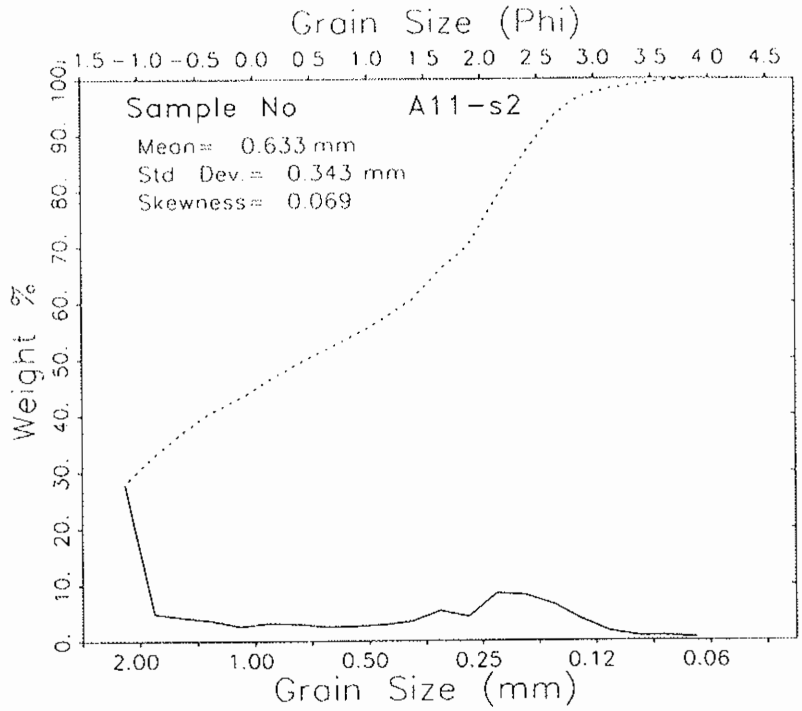
MOMENT MEASURES:

MEAN = 1.312 STANDARD DEVIATION = 1.407 SKEWNESS = -.248 KURTOSIS = -1.061
DISPERSION = .613 STANDARD DEVIATION = .992 DEVIATION FROM NORMAL DISTR. = -29.49%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.229	-1.145	-.633	.124	1.707	2.461	2.667	2.990	3.630

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.017	1.247	MEDIUM SAND
STANDARD DEVIATION	1.650	1.451	POORLY SORTED
SKEWNESS(1)	-.418	-.399	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.475		
KURTOSIS	.253	.725	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A11-s2	111199						
Borrow A - A11-s2							
		-1.125	30.610		27.926	-1.000	27.926
		-.875	5.300		4.835	-.750	32.762
		-.625	4.570		4.169	-.500	36.931
		-.375	3.930		3.585	-.250	40.516
		-.125	2.770		2.527	.000	43.044
		.125	3.470		3.166	.250	46.209
		.375	3.230		2.947	.500	49.156
		.625	2.720		2.482	.750	51.638
		.875	2.810		2.564	1.000	54.201
		1.125	3.040		2.773	1.250	56.975
		1.375	3.710		3.385	1.500	60.359
		1.625	5.830		5.319	1.750	65.678
		1.875	4.670		4.261	2.000	69.939
		2.125	9.170		8.366	2.250	78.305
		2.375	8.860		8.083	2.500	86.388
		2.625	7.110		6.487	2.750	92.875
		2.875	4.100		3.741	3.000	96.615
		3.125	1.660		1.514	3.250	98.130
		3.375	.750		.684	3.500	98.814
		3.625	.800		.730	3.750	99.544
		3.875	.500		.456	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.610

PERCENT FINER THAN 4.00 PHI = 1.14 PERCENT COARSER THAN -1.00 PHI = .00

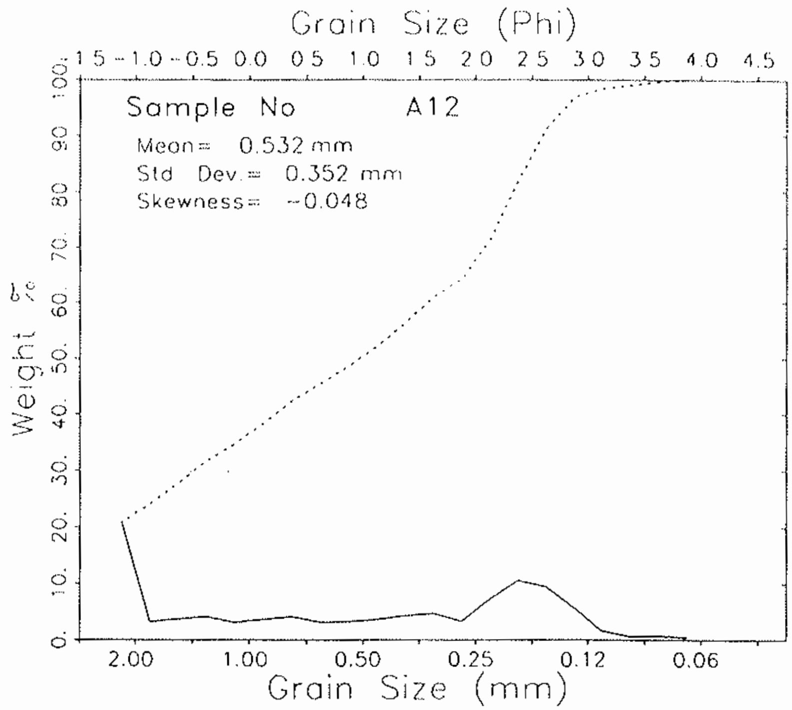
MOMENT MEASURES:

MEAN = .660 STANDARD DEVIATION = 1.543 SKEWNESS = .069 KURTOSIS = -1.525
DISPERSION = .536 STANDARD DEVIATION = .831 DEVIATION FROM NORMAL DISTR. = -46.13%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.205	-1.107	-1.026	.585	2.151	2.426	2.892	3.564

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.660	.635	COARSE SAND
STANDARD DEVIATION	1.766	1.504	POORLY SORTED
SKEWNESS(1)	.042	.084	NEAR SYMMETRICAL
SKEWNESS(2)	.146		
KURTOSIS	.160	.528	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A12	111199					
Borrow A -A12						
		-1.125	23.080	20.887	-1.000	20.887
		-.875	3.470	3.140	-.750	24.027
		-.625	4.040	3.656	-.500	27.683
		-.375	4.450	4.027	-.250	31.710
		-.125	3.390	3.068	.000	34.778
		.125	3.970	3.593	.250	38.371
		.375	4.470	4.045	.500	42.416
		.625	3.340	3.023	.750	45.439
		.875	3.480	3.149	1.000	48.588
		1.125	3.890	3.520	1.250	52.109
		1.375	4.650	4.208	1.500	56.317
		1.625	5.130	4.643	1.750	60.959
		1.875	3.560	3.222	2.000	64.181
		2.125	7.920	7.167	2.250	71.348
		2.375	11.610	10.507	2.500	81.855
		2.625	10.360	9.376	2.750	91.231
		2.875	6.200	5.611	3.000	96.842
		3.125	1.740	1.575	3.250	98.416
		3.375	.630	.570	3.500	98.986
		3.625	.660	.597	3.750	99.584
		3.875	.460	.416	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.500

PERCENT FINER THAN 4.00 PHI = .73   PERCENT COARSER THAN -1.00 PHI = .00

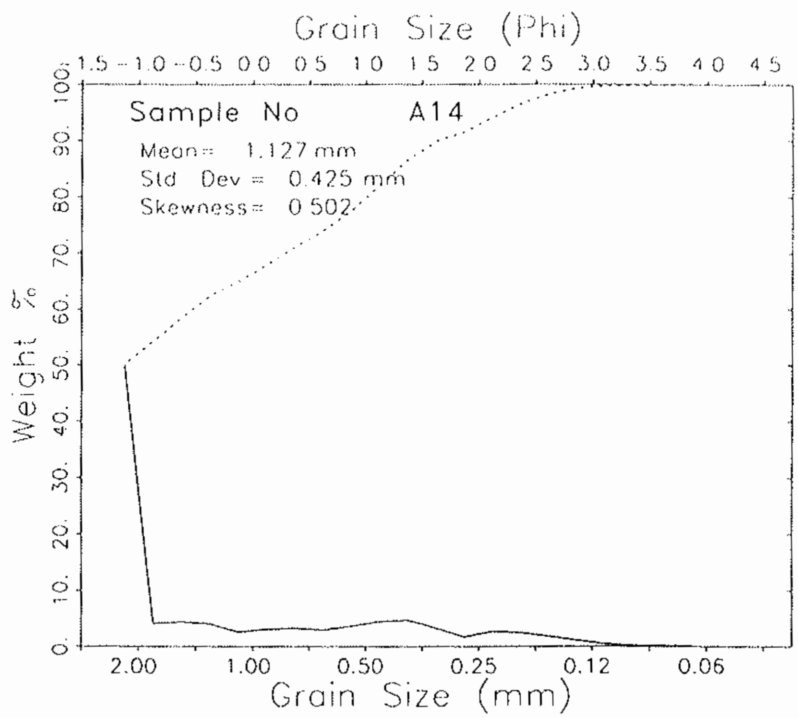
MOMENT MEASURES:

MEAN = .911 STANDARD DEVIATION = 1.506 SKEWNESS = -.048 KURTOSIS = -1.477
DISPERSION = .579 STANDARD DEVIATION = .917 DEVIATION FROM NORMAL DISTR. = -39.10%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.190	-1.058	-.683	1.100	2.337	2.557	2.918	3.506

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.749	.866	COARSE SAND
STANDARD DEVIATION	1.808	1.526	POORLY SORTED
SKEWNESS(1)	-.194	-.155	COARSE-SKEWED
SKEWNESS(2)	-.131		
KURTOSIS	.136	.557	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A14	111199					
Borrow A - A14						
		-1.125	59.210	50.085	-1.000	50.085
		-.875	4.790	4.052	-.750	54.136
		-.625	5.100	4.314	-.500	58.450
		-.375	4.720	3.993	-.250	62.443
		-.125	2.990	2.529	.000	64.972
		.125	3.540	2.994	.250	67.967
		.375	3.830	3.240	.500	71.206
		.625	3.370	2.851	.750	74.057
		.875	4.240	3.587	1.000	77.643
		1.125	5.180	4.382	1.250	82.025
		1.375	5.460	4.619	1.500	86.644
		1.625	3.840	3.248	1.750	89.892
		1.875	1.980	1.675	2.000	91.567
		2.125	3.140	2.656	2.250	94.223
		2.375	2.780	2.352	2.500	96.574
		2.625	2.050	1.734	2.750	98.308
		2.875	1.220	1.032	3.000	99.340
		3.125	.420	.355	3.250	99.695
		3.375	.160	.135	3.500	99.831
		3.625	.130	.110	3.750	99.941
		3.875	.070	.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 118.220

PERCENT FINER THAN 4.00 PHI = .08 PERCENT COARSER THAN -1.00 PHI = .00

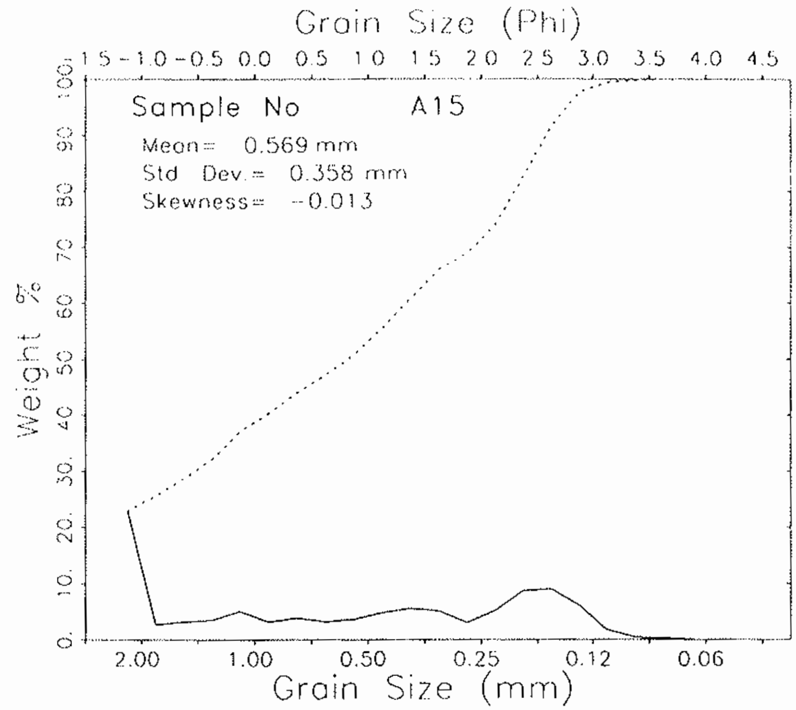
MOMENT MEASURES:

MEAN = -.172 STANDARD DEVIATION = 1.233 SKEWNESS = .502 KURTOSIS = -.312
DISPERSION = .298 STANDARD DEVIATION = .480 DEVIATION FROM NORMAL DISTR. = -61.03%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.245	-1.225	-1.170	-1.125	-1.000	.816	1.357	2.333	2.918

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.093	-.271	VERY COARSE SAND
STANDARD DEVIATION	1.264	1.171	POORLY SORTED
SKEWNESS(1)	.866	.870	STRONGLY FINE-SKEWED
SKEWNESS(2)	1.230		
KURTOSIS	.408	.751	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A15	111199						
Borrow A - A15							
		-1.125	25.490	22.882	-1.000	22.882	
		-.875	2.940	2.639	-.750	25.521	
		-.625	3.460	3.106	-.500	28.627	
		-.375	3.820	3.429	-.250	32.056	
		-.125	5.580	5.009	.000	37.065	
		.125	3.510	3.151	.250	40.215	
		.375	4.230	3.797	.500	44.013	
		.625	3.510	3.151	.750	47.163	
		.875	3.980	3.573	1.000	50.736	
		1.125	5.240	4.704	1.250	55.440	
		1.375	6.060	5.440	1.500	60.880	
		1.625	5.660	5.081	1.750	65.960	
		1.875	3.320	2.980	2.000	68.941	
		2.125	5.730	5.144	2.250	74.084	
		2.375	9.610	8.627	2.500	82.711	
		2.625	9.910	8.896	2.750	91.607	
		2.875	6.760	6.068	3.000	97.675	
		3.125	1.870	1.679	3.250	99.354	
		3.375	.440	.395	3.500	99.749	
		3.625	.220	.197	3.750	99.946	
		3.875	.060	.054	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 111.400

PERCENT FINER THAN 4.00 PHI = .04 PERCENT COARSER THAN -1.00 PHI = .00

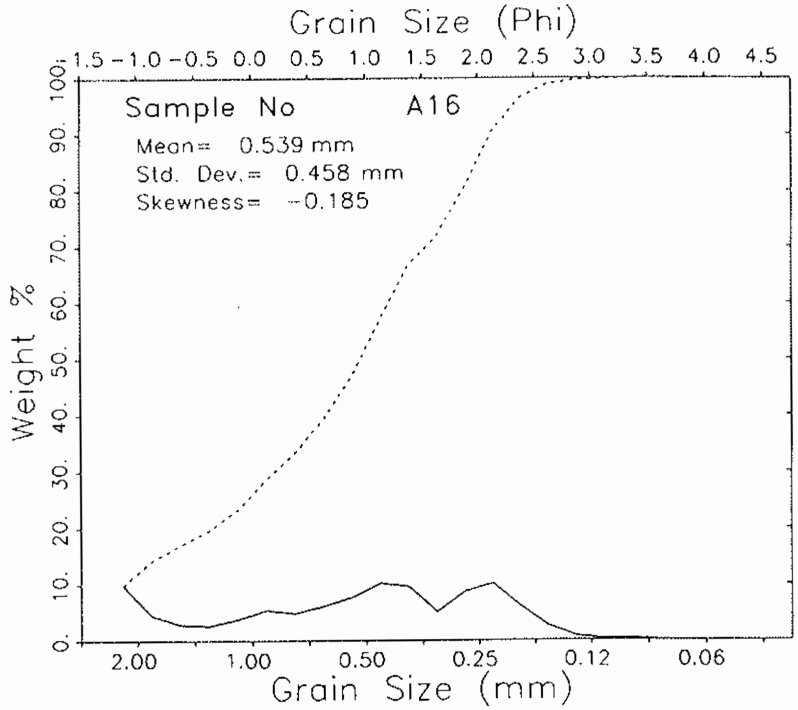
MOMENT MEASURES:

MEAN = .813 STANDARD DEVIATION = 1.480 SKEWNESS = -.013 KURTOSIS = -1.477
DISPERSION = .563 STANDARD DEVIATION = .884 DEVIATION FROM NORMAL DISTR. = -40.23%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.195	-1.075	-.799	.948	2.277	2.536	2.890	3.197

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.731	.803	COARSE SAND
STANDARD DEVIATION	1.806	1.522	POORLY SORTED
SKEWNESS(1)	-.121	-.085	NEAR SYMMETRICAL
SKEWNESS(2)	-.056		
KURTOSIS	.131	.544	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A16	111199					
Borrow A - A16						
		-1.125	12.180	9.736	-1.000	9.736
		-.875	5.530	4.420	-.750	14.157
		-.625	3.520	2.814	-.500	16.970
		-.375	3.190	2.550	-.250	19.520
		-.125	4.610	3.685	.000	23.205
		.125	6.700	5.356	.250	28.561
		.375	5.960	4.764	.500	33.325
		.625	7.530	6.019	.750	39.345
		.875	9.600	7.674	1.000	47.018
		1.125	12.680	10.136	1.250	57.154
		1.375	11.990	9.584	1.500	66.739
		1.625	6.310	5.044	1.750	71.783
		1.875	10.770	8.609	2.000	80.392
		2.125	12.620	10.088	2.250	90.480
		2.375	7.450	5.955	2.500	96.435
		2.625	3.110	2.486	2.750	98.921
		2.875	.780	.624	3.000	99.544
		3.125	.310	.248	3.250	99.792
		3.375	.260	.208	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 125.100

PERCENT FINER THAN 4.00 PHI = .31 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

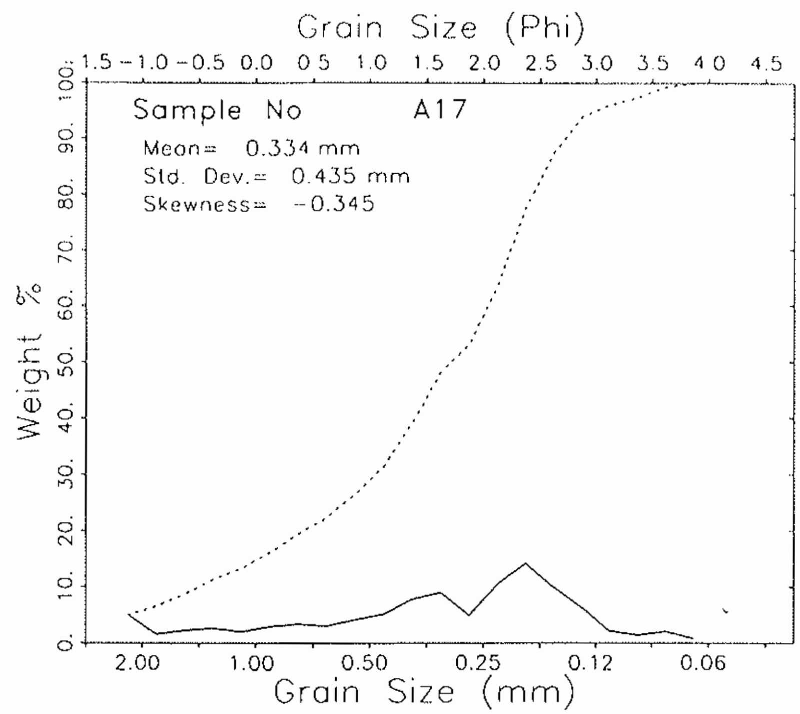
MEAN = .892 STANDARD DEVIATION = 1.128 SKEWNESS = -.185 KURTOSIS = -.902

DISPERSION = .578 STANDARD DEVIATION = .916 DEVIATION FROM NORMAL DISTR. = -18.83%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.122	-.586	.084	1.074	1.843	2.089	2.440	2.782

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.752	.859	COARSE SAND
STANDARD DEVIATION	1.338	1.209	POORLY SORTED
SKEWNESS(1)	-.241	-.237	COARSE-SKEWED
SKEWNESS(2)	-.310		
KURTOSIS	.331	.829	PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A17 111199					
Borrow A - A17					
	-1.125	5.380	4.965	-1.000	4.965
	-.875	1.650	1.523	-.750	6.488
	-.625	2.400	2.215	-.500	8.702
	-.375	2.820	2.602	-.250	11.305
	-.125	2.150	1.984	.000	13.289
	.125	3.100	2.861	.250	16.150
	.375	3.590	3.313	.500	19.463
	.625	3.200	2.953	.750	22.416
	.875	4.410	4.070	1.000	26.486
	1.125	5.450	5.030	1.250	31.515
	1.375	8.400	7.752	1.500	39.267
	1.625	9.650	8.905	1.750	48.173
	1.875	5.330	4.919	2.000	53.092
	2.125	11.270	10.401	2.250	63.492
	2.375	15.310	14.129	2.500	77.621
	2.625	10.720	9.893	2.750	87.514
	2.875	6.830	6.303	3.000	93.817
	3.125	2.330	2.150	3.250	95.967
	3.375	1.470	1.357	3.500	97.324
	3.625	2.100	1.938	3.750	99.262
	3.875	.800	.738	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.360

PERCENT FINER THAN 4.00 PHI = .97 PERCENT COARSER THAN -1.00 PHI = .00

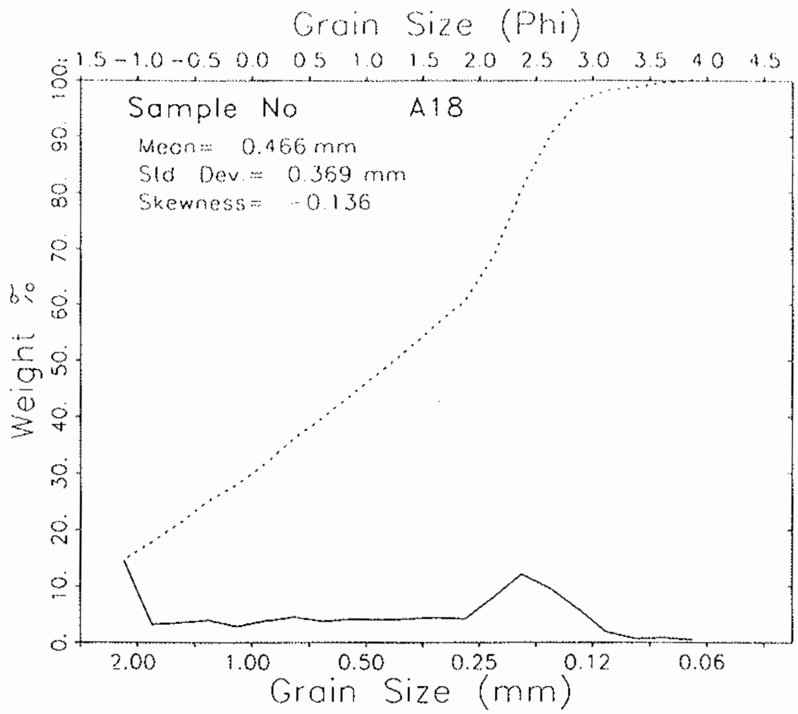
MOMENT MEASURES:

MEAN = 1.584 STANDARD DEVIATION = 1.201 SKEWNESS = -.345 KURTOSIS = -.259
DISPERSION = .614 STANDARD DEVIATION = .994 DEVIATION FROM NORMAL DISTR. = -17.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.200	-.994	.237	.909	1.843	2.454	2.661	3.138	3.716

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.449	1.580	MEDIUM SAND
STANDARD DEVIATION	1.212	1.232	POORLY SORTED
SKEWNESS(1)	-.325	-.349	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.636		
KURTOSIS	.704	1.096	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A18	111199					
Borrow A - A18						
		-1.125	15.410	14.646	-1.000	14.646
		-.875	3.300	3.136	-.750	17.782
		-.625	3.640	3.459	-.500	21.241
		-.375	4.120	3.916	-.250	25.157
		-.125	2.970	2.823	.000	27.979
		.125	4.020	3.821	.250	31.800
		.375	4.680	4.448	.500	36.248
		.625	3.880	3.688	.750	39.935
		.875	4.290	4.077	1.000	44.013
		1.125	4.180	3.973	1.250	47.985
		1.375	4.320	4.106	1.500	52.091
		1.625	4.630	4.400	1.750	56.491
		1.875	4.390	4.172	2.000	60.663
		2.125	8.400	7.983	2.250	68.647
		2.375	12.710	12.079	2.500	80.726
		2.625	10.170	9.665	2.750	90.392
		2.875	6.270	5.959	3.000	96.351
		3.125	1.930	1.834	3.250	98.185
		3.375	.650	.618	3.500	98.803
		3.625	.860	.817	3.750	99.620
		3.875	.400	.380	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.220

PERCENT FINER THAN 4.00 PHI = .68 PERCENT COARSER THAN -1.00 PHI = .00

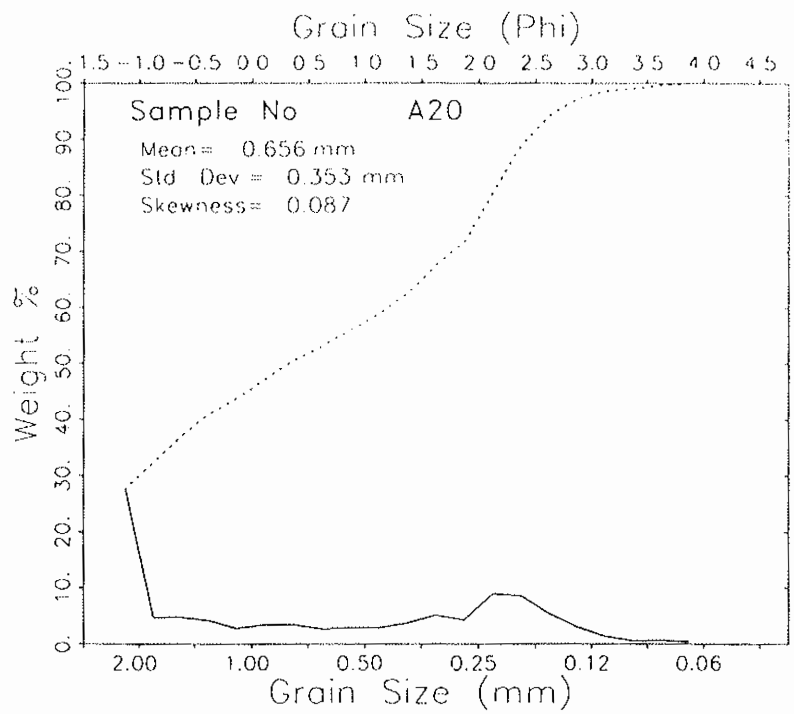
MOMENT MEASURES:

MEAN = 1.103 STANDARD DEVIATION = 1.439 SKEWNESS = -.136 KURTOSIS = -1.307
DISPERSION = .612 STANDARD DEVIATION = .990 DEVIATION FROM NORMAL DISTR. = -31.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.233	-1.165	-.892	-.260	1.373	2.381	2.585	2.943	3.560

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.846	1.022	MEDIUM SAND
STANDARD DEVIATION	1.738	1.492	POORLY SORTED
SKEWNESS(1)	-.303	-.269	COARSE-SKEWED
SKEWNESS(2)	-.278		
KURTOSIS	.182	.637	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A20	111199					
Borrow A - A20						
		-1.125	29.190	27.527	-1.000	27.527
		-.875	4.930	4.649	-.750	32.177
		-.625	4.970	4.687	-.500	36.863
		-.375	4.370	4.121	-.250	40.985
		-.125	2.910	2.744	.000	43.729
		.125	3.620	3.414	.250	47.143
		.375	3.630	3.423	.500	50.566
		.625	2.770	2.612	.750	53.178
		.875	2.990	2.820	1.000	55.998
		1.125	2.940	2.773	1.250	58.770
		1.375	3.890	3.668	1.500	62.439
		1.625	5.370	5.064	1.750	67.503
		1.875	4.480	4.225	2.000	71.728
		2.125	9.350	8.817	2.250	80.545
		2.375	8.950	8.440	2.500	88.985
		2.625	5.660	5.338	2.750	94.323
		2.875	3.130	2.952	3.000	97.275
		3.125	1.370	1.292	3.250	98.567
		3.375	.510	.481	3.500	99.048
		3.625	.580	.547	3.750	99.594
		3.875	.430	.406	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.040

PERCENT FINER THAN' 4.00 PHI = .93 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

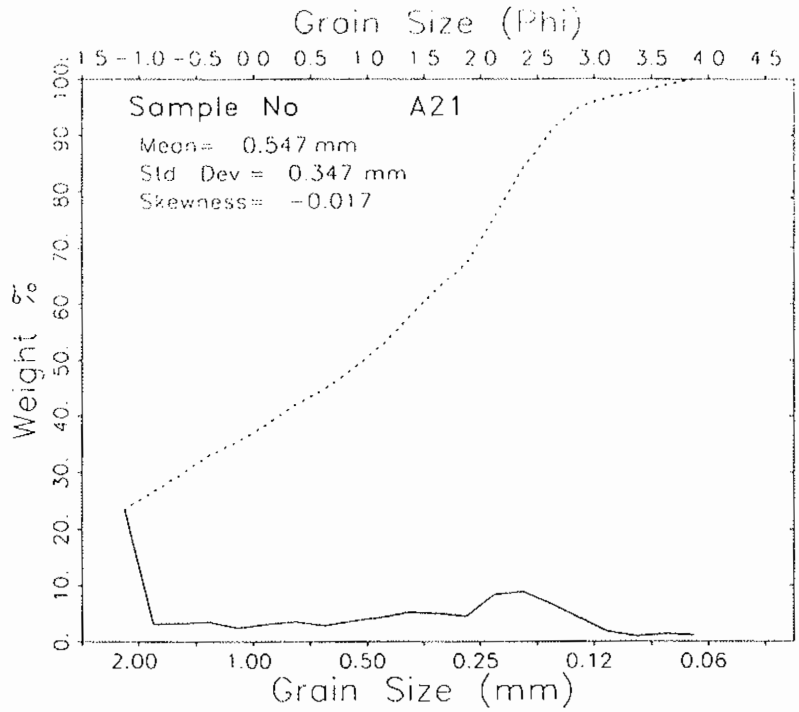
MEAN = .608 STANDARD DEVIATION = 1.504 SKEWNESS = .087 KURTOSIS = -1.494

DISPERSION = .535 STANDARD DEVIATION = .830 DEVIATION FROM NORMAL DISTR. = -44.81%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.205	-1.105	-1.023	.459	2.093	2.352	2.807	3.475

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.624	.569	COARSE SAND
STANDARD DEVIATION	1.729	1.472	POORLY SORTED
SKEWNESS(1)	.096	.133	FINE-SKEWED
SKEWNESS(2)	.198		
KURTOSIS	.161	.528	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A21	111199					
Borrow A - A21						
		-1.125	27.340	23.518	-1.000	23.518
		-.875	3.520	3.028	-.750	26.546
		-.625	3.750	3.226	-.500	29.772
		-.375	3.920	3.372	-.250	33.144
		-.125	2.820	2.426	.000	35.570
		.125	3.530	3.037	.250	38.606
		.375	4.040	3.475	.500	42.082
		.625	3.240	2.787	.750	44.869
		.875	4.180	3.596	1.000	48.465
		1.125	4.860	4.181	1.250	52.645
		1.375	5.950	5.118	1.500	57.763
		1.625	5.800	4.989	1.750	62.753
		1.875	5.070	4.361	2.000	67.114
		2.125	9.700	8.344	2.250	75.458
		2.375	10.190	8.766	2.500	84.224
		2.625	7.710	6.632	2.750	90.856
		2.875	4.850	4.172	3.000	95.028
		3.125	1.990	1.712	3.250	96.740
		3.375	1.060	.912	3.500	97.652
		3.625	1.480	1.273	3.750	98.925
		3.875	1.250	1.075	4.000	100.000

TOTAL WEIGHT (GRAMS) = 116.250

PERCENT FINER THAN 4.00 PHI = 2.01 PERCENT COARSER THAN -1.00 PHI = .00

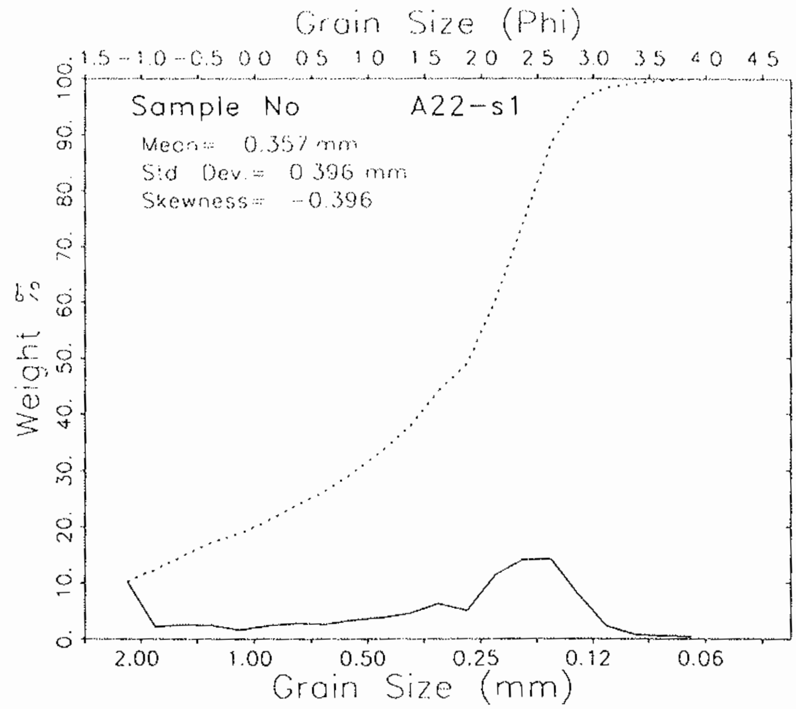
MOMENT MEASURES:

MEAN = .871 STANDARD DEVIATION = 1.527 SKEWNESS = -.017 KURTOSIS = -1.396
DISPERSION = .581 STANDARD DEVIATION = .923 DEVIATION FROM NORMAL DISTR. = -39.58%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.197	-1.080	-.878	1.092	2.236	2.494	2.998	3.767

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.707	.835	COARSE SAND
STANDARD DEVIATION	1.787	1.529	POORLY SORTED
SKEWNESS(1)	-.215	-.153	COARSE-SKEWED
SKEWNESS(2)	-.107		
KURTOSIS	.174	.552	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A22-s1	111199					
Borrow A - A22-s1						
		-1.125	10.600	10.184	-1.000	10.184
		-.875	2.260	2.171	-.750	12.356
		-.625	2.530	2.431	-.500	14.787
		-.375	2.490	2.392	-.250	17.179
		-.125	1.640	1.576	.000	18.755
		.125	2.410	2.316	.250	21.070
		.375	2.800	2.690	.500	23.761
		.625	2.670	2.565	.750	26.326
		.875	3.440	3.305	1.000	29.631
		1.125	3.830	3.680	1.250	33.311
		1.375	4.690	4.506	1.500	37.817
		1.625	6.510	6.255	1.750	44.072
		1.875	5.140	4.939	2.000	49.010
		2.125	11.730	11.270	2.250	60.281
		2.375	14.660	14.085	2.500	74.366
		2.625	14.690	14.114	2.750	88.480
		2.875	8.020	7.706	3.000	96.186
		3.125	2.350	2.258	3.250	98.444
		3.375	.770	.740	3.500	99.183
		3.625	.490	.471	3.750	99.654
		3.875	.360	.346	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.080

PERCENT FINER THAN 4.00 PHI = .54 PERCENT COARSER THAN -1.00 PHI = .00

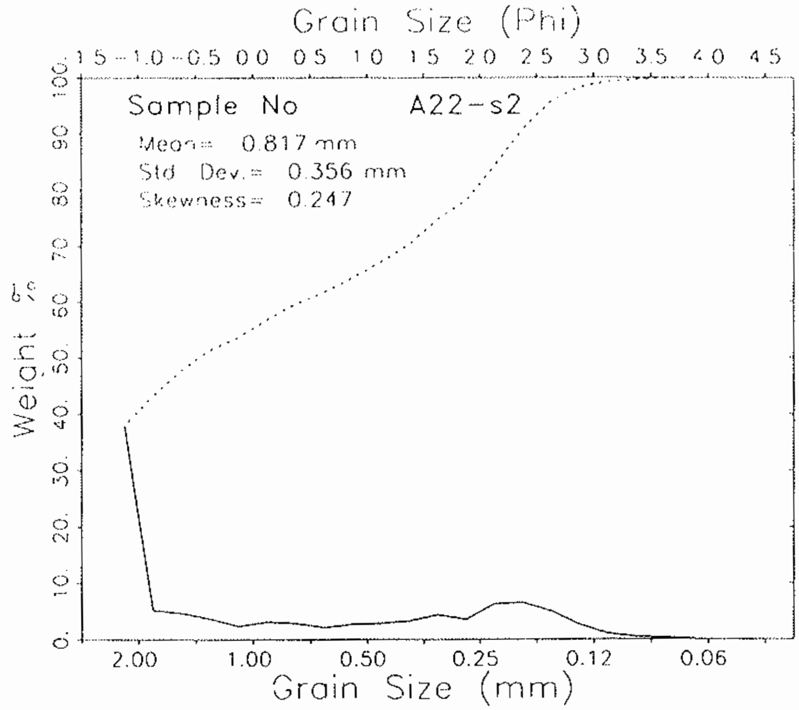
MOMENT MEASURES:

MEAN = 1.488 STANDARD DEVIATION = 1.337 SKEWNESS = -.396 KURTOSIS = -.638
DISPERSION = .570 STANDARD DEVIATION = .898 DEVIATION FROM NORMAL DISTR. = -32.80%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.225	-1.127	-.373	.621	2.022	2.511	2.671	2.962	3.438

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.149	1.440	MEDIUM SAND
STANDARD DEVIATION	1.522	1.380	POORLY SORTED
SKEWNESS(1)	-.574	-.557	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.726		
KURTOSIS	.343	.886	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A22-s2	111199						
Borrow A - A22-s2							
		-1.125	40.900	38.025		-1.000	38.025
		-.875	5.490	5.104		-.750	43.129
		-.625	4.960	4.611		-.500	47.741
		-.375	3.930	3.654		-.250	51.395
		-.125	2.470	2.296		.000	53.691
		.125	3.320	3.087		.250	56.778
		.375	3.000	2.789		.500	59.567
		.625	2.220	2.064		.750	61.631
		.875	2.840	2.640		1.000	64.271
		1.125	3.020	2.808		1.250	67.079
		1.375	3.420	3.180		1.500	70.258
		1.625	4.610	4.286		1.750	74.544
		1.875	3.710	3.449		2.000	77.994
		2.125	6.670	6.201		2.250	84.195
		2.375	6.950	6.462		2.500	90.656
		2.625	5.350	4.974		2.750	95.630
		2.875	2.790	2.594		3.000	98.224
		3.125	1.080	1.004		3.250	99.228
		3.375	.400	.372		3.500	99.600
		3.625	.330	.307		3.750	99.907
		3.875	.100	.093		4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.560

PERCENT FINER THAN 4.00 PHI = .53 PERCENT COARSER THAN -1.00 PHI = .00

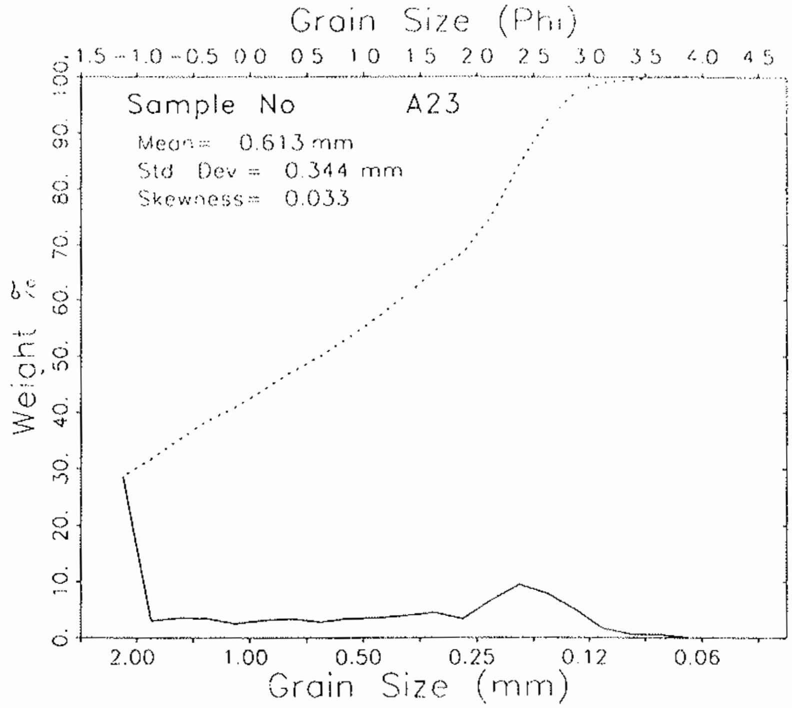
MOMENT MEASURES:

MEAN = .291 STANDARD DEVIATION = 1.409 SKEWNESS = .247 KURTOSIS = -1.344
DISPERSION = .439 STANDARD DEVIATION = .665 DEVIATION FROM NORMAL DISTR. = -55.32%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.243	-1.217	-1.145	-1.086	-.345	1.783	2.242	2.718	3.193

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.549	.251	COARSE SAND
STANDARD DEVIATION	1.693	1.443	POORLY SORTED
SKEWNESS(1)	.528	.542	STRONGLY FINE-SKEWED
SKEWNESS(2)	.647		
KURTOSIS	.162	.562	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A23	111199					
Borrow A -A23						
		-1.125	33.920	28.617	-1.000	28.617
		-.875	3.520	2.970	-.750	31.587
		-.625	4.110	3.467	-.500	35.054
		-.375	4.000	3.375	-.250	38.429
		-.125	2.940	2.480	.000	40.909
		.125	3.610	3.046	.250	43.955
		.375	3.910	3.299	.500	47.254
		.625	3.210	2.708	.750	49.962
		.875	4.020	3.392	1.000	53.354
		1.125	4.160	3.510	1.250	56.863
		1.375	4.590	3.872	1.500	60.736
		1.625	5.290	4.463	1.750	65.199
		1.875	3.900	3.290	2.000	68.489
		2.125	7.820	6.597	2.250	75.086
		2.375	11.110	9.373	2.500	84.460
		2.625	9.300	7.846	2.750	92.306
		2.875	5.940	5.011	3.000	97.317
		3.125	1.890	1.595	3.250	98.912
		3.375	.670	.565	3.500	99.477
		3.625	.590	.498	3.750	99.975
		3.875	.030	.025	4.000	100.000

TOTAL WEIGHT (GRAMS) = 118.530

PERCENT FINER THAN 4.00 PHI = 1.12 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

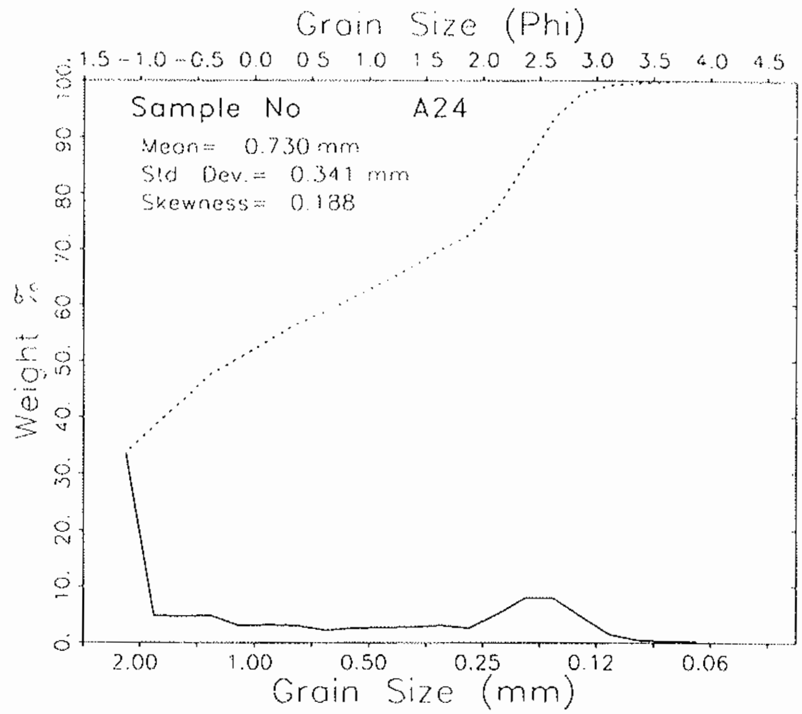
MEAN = .705 STANDARD DEVIATION = 1.539 SKEWNESS = .033 KURTOSIS = -1.564

DISPERSION = .521 STANDARD DEVIATION = .803 DEVIATION FROM NORMAL DISTR. = -47.84%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.206	-1.110	-1.032	.753	2.247	2.488	2.884	3.289

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.689	.710	COARSE SAND
STANDARD DEVIATION	1.799	1.519	POORLY SORTED
SKEWNESS(1)	-.036	.003	NEAR SYMMETRICAL
SKEWNESS(2)	.048		
KURTOSIS	.137	.511	VERY PLATYKURTIC



SAMPLE NO. DATE
A24 111199
Borrow A -A24

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	38.220	33.553	-1.000	33.553
-.875	5.340	4.688	-.750	38.241
-.625	5.290	4.644	-.500	42.885
-.375	5.390	4.732	-.250	47.617
-.125	3.340	2.932	.000	50.549
.125	3.540	3.108	.250	53.656
.375	3.430	3.011	.500	56.668
.625	2.450	2.151	.750	58.818
.875	2.940	2.581	1.000	61.399
1.125	3.010	2.642	1.250	64.042
1.375	3.100	2.721	1.500	66.763
1.625	3.480	3.055	1.750	69.818
1.875	2.950	2.590	2.000	72.408
2.125	5.690	4.995	2.250	77.403
2.375	8.960	7.866	2.500	85.269
2.625	9.020	7.919	2.750	93.188
2.875	5.230	4.591	3.000	97.779
3.125	1.560	1.370	3.250	99.148
3.375	.450	.395	3.500	99.544
3.625	.350	.307	3.750	99.851
3.875	.170	.149	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.910

PERCENT FINER THAN 4.00 PHI = .54 PERCENT COARSER THAN -1.00 PHI = .00

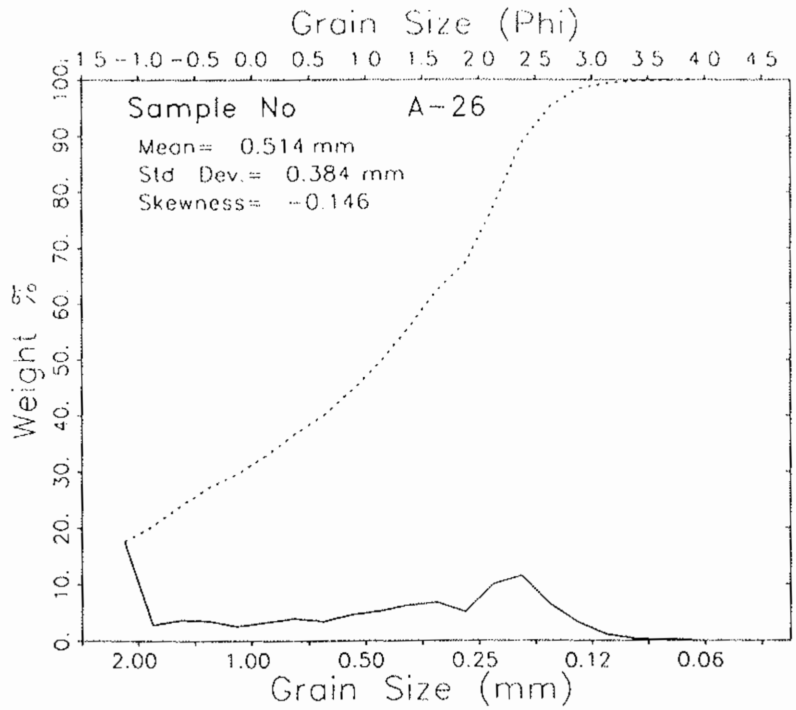
MOMENT MEASURES:

MEAN = .454 STANDARD DEVIATION = 1.551 SKEWNESS = .188 KURTOSIS = -1.478
DISPERSION = .478 STANDARD DEVIATION = .727 DEVIATION FROM NORMAL DISTR. = -53.15%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.243	-1.213	-1.131	-1.064	-.047	2.130	2.460	2.849	3.223

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.664	.427	COARSE SAND
STANDARD DEVIATION	1.795	1.513	POORLY SORTED
SKEWNESS(1)	.396	.411	STRONGLY FINE-SKEWED
SKEWNESS(2)	.482		
KURTOSIS	.131	.521	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-26	111199					
Borrow A - A26						
		-1.125	21.200	17.583	-1.000	17.583
		-.875	3.240	2.687	-.750	20.270
		-.625	4.250	3.525	-.500	23.795
		-.375	4.060	3.367	-.250	27.163
		-.125	2.950	2.447	.000	29.609
		.125	3.810	3.160	.250	32.769
		.375	4.590	3.807	.500	36.576
		.625	4.030	3.342	.750	39.919
		.875	5.410	4.487	1.000	44.406
		1.125	6.150	5.101	1.250	49.507
		1.375	7.430	6.162	1.500	55.669
		1.625	8.030	6.660	1.750	62.329
		1.875	6.040	5.010	2.000	67.338
		2.125	12.030	9.978	2.250	77.316
		2.375	13.820	11.462	2.500	88.778
		2.625	7.750	6.428	2.750	95.206
		2.875	3.770	3.127	3.000	98.333
		3.125	1.240	1.028	3.250	99.361
		3.375	.380	.315	3.500	99.677
		3.625	.260	.216	3.750	99.892
		3.875	.130	.108	4.000	100.000

TOTAL WEIGHT (GRAMS) = 120.570

PERCENT FINER THAN 4.00 PHI = .17 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

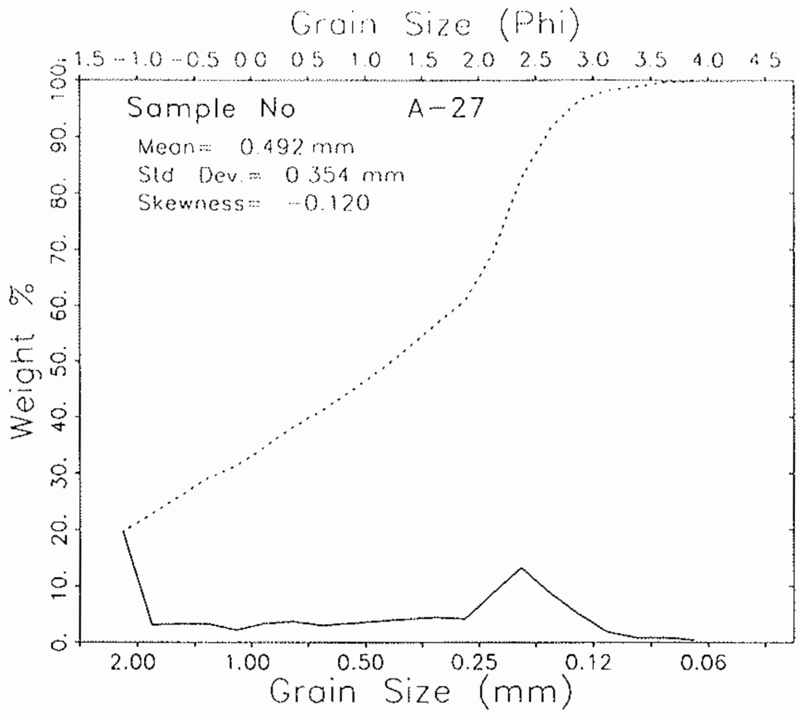
MEAN = .961 STANDARD DEVIATION = 1.380 SKEWNESS = -.146 KURTOSIS = -1.305

DISPERSION = .577 STANDARD DEVIATION = .914 DEVIATION FROM NORMAL DISTR. = -33.78%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.179	-1.023	-.411	1.270	2.192	2.396	2.742	3.162

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.687	.881	COARSE SAND
STANDARD DEVIATION	1.709	1.449	POORLY SORTED
SKEWNESS(1)	-.341	-.295	COARSE-SKEWED
SKEWNESS(2)	-.286		
KURTOSIS	.147	.617	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT (PHI)	CLASS LIMITS	CUM PERCENT
A-27	111199						
Borrow A - A27							
		-1.125	22.630	19.629	-1.000	19.629	
		-.875	3.530	3.062	-.750	22.691	
		-.625	3.750	3.253	-.500	25.943	
		-.375	3.710	3.218	-.250	29.161	
		-.125	2.500	2.168	.000	31.330	
		.125	3.810	3.305	.250	34.634	
		.375	4.150	3.600	.500	38.234	
		.625	3.470	3.010	.750	41.244	
		.875	3.800	3.296	1.000	44.540	
		1.125	4.250	3.686	1.250	48.226	
		1.375	4.650	4.033	1.500	52.260	
		1.625	5.040	4.372	1.750	56.631	
		1.875	4.670	4.051	2.000	60.682	
		2.125	10.020	8.691	2.250	69.373	
		2.375	15.260	13.236	2.500	82.609	
		2.625	10.010	8.682	2.750	91.292	
		2.875	5.740	4.979	3.000	96.270	
		3.125	2.110	1.830	3.250	98.100	
		3.375	.880	.763	3.500	98.864	
		3.625	.890	.772	3.750	99.636	
		3.875	.420	.364	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 115.290

PERCENT FINER THAN 4.00 PHI = .87 PERCENT COARSER THAN -1.00 PHI = .00

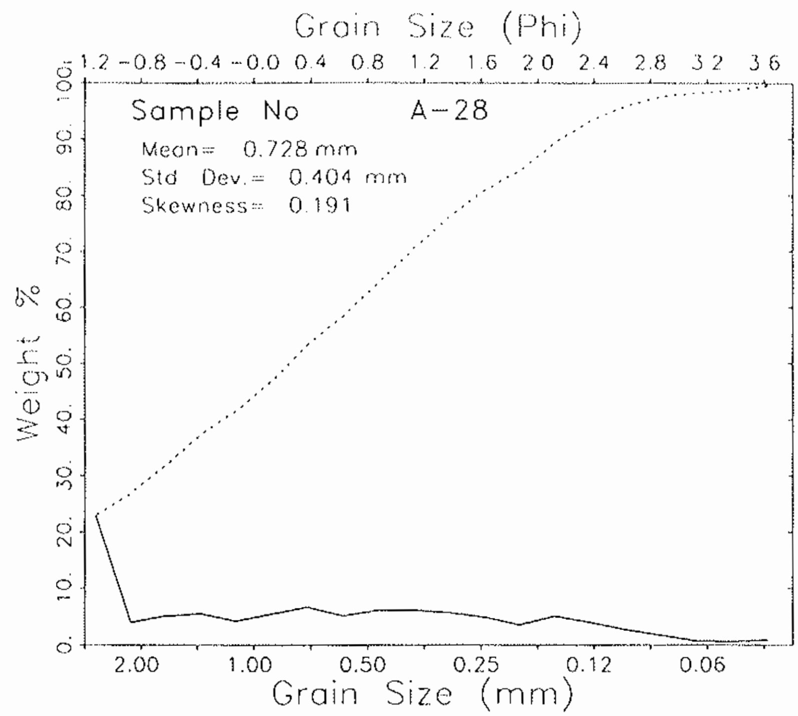
MOMENT MEASURES:

MEAN = 1.022 STANDARD DEVIATION = 1.497 SKEWNESS = -.120 KURTOSIS = -1.417
DISPERSION = .575 STANDARD DEVIATION = .909 DEVIATION FROM NORMAL DISTR. = -39.28%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.237	-1.186	-1.046	-.573	1.360	2.356	2.540	2.936	3.544

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.747	.951	COARSE SAND
STANDARD DEVIATION	1.793	1.521	POORLY SORTED
SKEWNESS(1)	-.342	-.289	COARSE-SKEWED
SKEWNESS(2)	-.270		
KURTOSIS	.150	.577	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT / WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-28	111199					
Borrow A - A28						
		-1.125	25.120	22.868	-1.000	22.868
		-.875	4.280	3.896	-.750	26.764
		-.625	5.520	5.025	-.500	31.789
		-.375	6.020	5.480	-.250	37.269
		-.125	4.570	4.160	.000	41.429
		.125	5.880	5.353	.250	46.782
		.375	7.160	6.518	.500	53.300
		.625	5.550	5.052	.750	58.352
		.875	6.660	6.063	1.000	64.415
		1.125	6.670	6.072	1.250	70.487
		1.375	6.200	5.644	1.500	76.131
		1.625	5.250	4.779	1.750	80.910
		1.875	3.840	3.496	2.000	84.406
		2.125	5.430	4.943	2.250	89.349
		2.375	4.250	3.869	2.500	93.218
		2.625	2.920	2.658	2.750	95.876
		2.875	1.790	1.629	3.000	97.506
		3.125	.720	.655	3.250	98.161
		3.375	.610	.555	3.500	98.716
		3.625	.850	.774	3.750	99.490
		3.875	.560	.510	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.850

PERCENT FINER THAN 4.00 PHI = 1.04 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

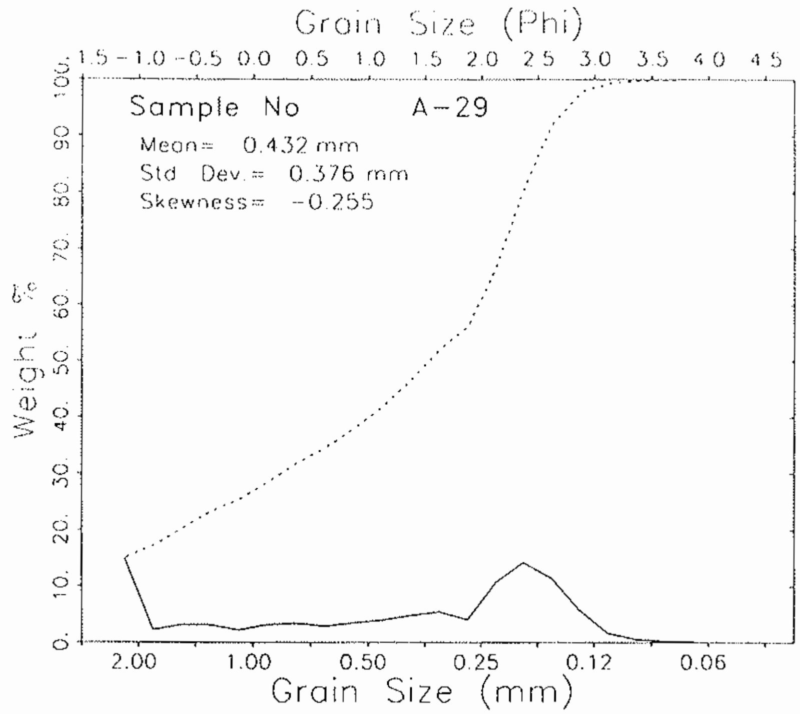
MEAN = .457 STANDARD DEVIATION = 1.308 SKEWNESS = .191 KURTOSIS = -.885

DISPERSION = .579 STANDARD DEVIATION = .918 DEVIATION FROM NORMAL DISTR. = -29.80%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.195	-1.075	-.863	.373	1.450	1.971	2.668	3.592

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.448	.423	COARSE SAND
STANDARD DEVIATION	1.523	1.347	POORLY SORTED
SKEWNESS(1)	.049	.118	FINE-SKEWED
SKEWNESS(2)	.238		
KURTOSIS	.268	.684	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-29	111199					
Borrow A - A29						
		-1.125	15.270	14.956	-1.000	14.956
		-.875	2.190	2.145	-.750	17.101
		-.625	3.100	3.036	-.500	20.137
		-.375	3.090	3.026	-.250	23.164
		-.125	2.210	2.165	.000	25.328
		.125	3.150	3.085	.250	28.413
		.375	3.370	3.301	.500	31.714
		.625	2.860	2.801	.750	34.515
		.875	3.450	3.379	1.000	37.894
		1.125	3.970	3.888	1.250	41.783
		1.375	4.860	4.760	1.500	46.543
		1.625	5.540	5.426	1.750	51.969
		1.875	4.040	3.957	2.000	55.926
		2.125	10.780	10.558	2.250	66.484
		2.375	14.440	14.143	2.500	80.627
		2.625	11.650	11.410	2.750	92.037
		2.875	5.770	5.651	3.000	97.689
		3.125	1.590	1.557	3.250	99.246
		3.375	.470	.460	3.500	99.706
		3.625	.250	.245	3.750	99.951
		3.875	.050	.049	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.100

PERCENT FINER THAN 4.00 PHI = .27 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

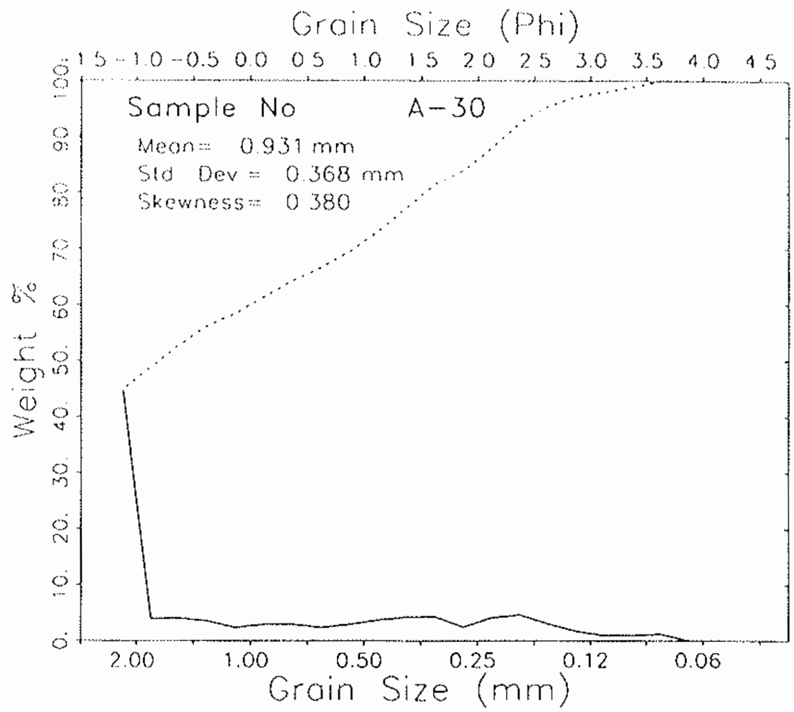
MEAN = 1.212 STANDARD DEVIATION = 1.410 SKEWNESS = -.255 KURTOSIS = -1.183

DISPERSION = .564 STANDARD DEVIATION = .887 DEVIATION FROM NORMAL DISTR. = -37.10%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.233	-1.166	-.878	-.038	1.659	2.401	2.574	2.881	3.211

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.848	1.118	MEDIUM SAND
STANDARD DEVIATION	1.726	1.476	POORLY SORTED
SKEWNESS(1)	-.470	-.433	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.465		
KURTOSIS	.172	.680	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-30	111199					
Borrow A - A30						
		-1.125	50.380	44.822	-1.000	44.822
		-.875	4.400	3.915	-.750	48.737
		-.625	4.430	3.941	-.500	52.678
		-.375	3.920	3.488	-.250	56.165
		-.125	2.630	2.340	.000	58.505
		.125	3.270	2.909	.250	61.415
		.375	3.260	2.900	.500	64.315
		.625	2.620	2.331	.750	66.646
		.875	3.230	2.874	1.000	69.520
		1.125	4.120	3.665	1.250	73.185
		1.375	4.680	4.164	1.500	77.349
		1.625	4.730	4.208	1.750	81.557
		1.875	2.700	2.402	2.000	83.959
		2.125	4.550	4.048	2.250	88.007
		2.375	5.080	4.520	2.500	92.527
		2.625	3.340	2.972	2.750	95.498
		2.875	1.820	1.619	3.000	97.117
		3.125	.960	.854	3.250	97.972
		3.375	.960	.854	3.500	98.826
		3.625	1.310	1.165	3.750	99.991
		3.875	.010	.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 112.400

PERCENT FINER THAN 4.00 PHI = 1.69 PERCENT COARSER THAN -1.00 PHI = .00

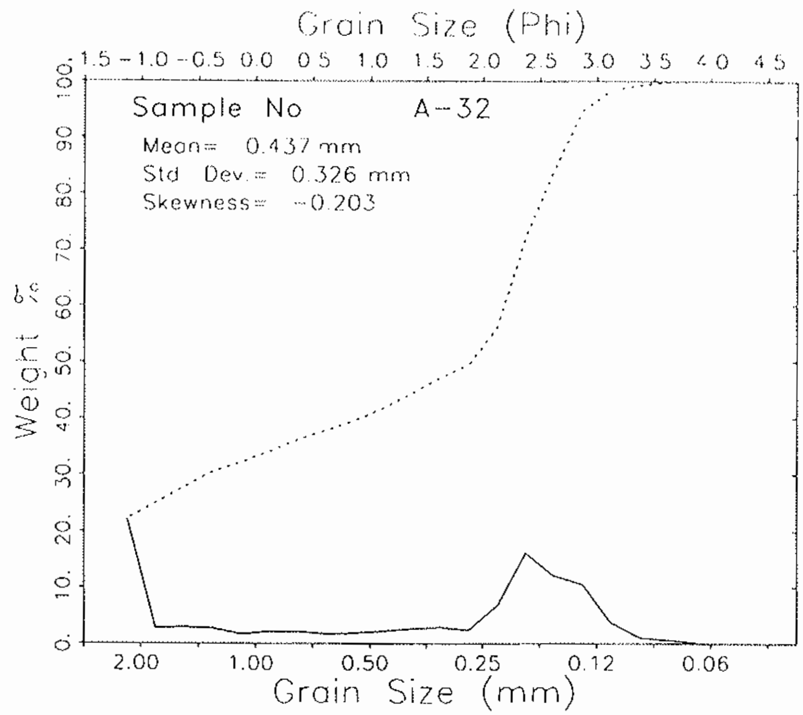
MOMENT MEASURES:

MEAN = .103 STANDARD DEVIATION = 1.441 SKEWNESS = .380 KURTOSIS = -.856
DISPERSION = .382 STANDARD DEVIATION = .583 DEVIATION FROM NORMAL DISTR. = -59.53%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.244	-1.222	-1.161	-1.111	-.670	1.359	2.003	2.708	3.537

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.421	.057	COARSE SAND
STANDARD DEVIATION	1.582	1.386	POORLY SORTED
SKEWNESS(1)	.690	.704	STRONGLY FINE-SKEWED
SKEWNESS(2)	.893		
KURTOSIS	.242	.652	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-32	111199						
Borrow A - A32							
		-1.125	23.410		22.206	-1.000	22.206
		-.875	2.840		2.694	-.750	24.900
		-.625	3.000		2.846	-.500	27.746
		-.375	2.820		2.675	-.250	30.421
		-.125	1.730		1.641	.000	32.062
		.125	2.140		2.030	.250	34.092
		.375	2.190		2.077	.500	36.170
		.625	1.730		1.641	.750	37.811
		.875	1.900		1.802	1.000	39.613
		1.125	2.270		2.153	1.250	41.766
		1.375	2.700		2.561	1.500	44.327
		1.625	2.990		2.836	1.750	47.164
		1.875	2.440		2.315	2.000	49.478
		2.125	7.030		6.669	2.250	56.147
		2.375	16.940		16.069	2.500	72.216
		2.625	12.610		11.962	2.750	84.178
		2.875	11.080		10.510	3.000	94.688
		3.125	3.840		3.643	3.250	98.330
		3.375	1.020		.968	3.500	99.298
		3.625	.600		.569	3.750	99.867
		3.875	.140		.133	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.420

PERCENT FINER THAN 4.00 PHI = .07 PERCENT COARSER THAN -1.00 PHI = .00

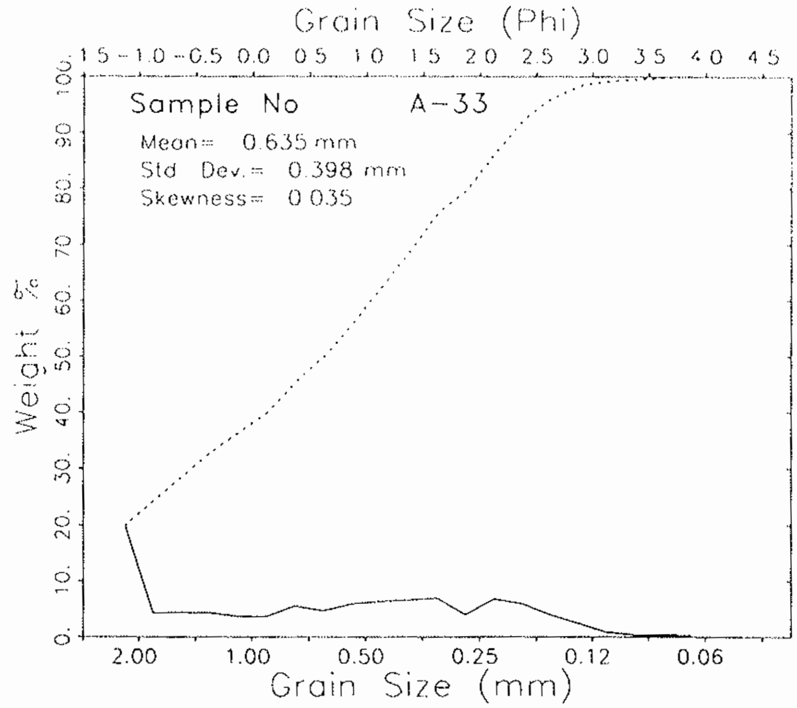
MOMENT MEASURES:

MEAN = 1.194 STANDARD DEVIATION = 1.615 SKEWNESS = -.203 KURTOSIS = -1.504
DISPERSION = .497 STANDARD DEVIATION = .760 DEVIATION FROM NORMAL DISTR. = -52.97%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.194	-1.070	-.741	2.020	2.558	2.746	3.021	3.423

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.838	1.232	MEDIUM SAND
STANDARD DEVIATION	1.908	1.593	POORLY SORTED
SKEWNESS(1)	-.619	-.572	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.579		
KURTOSIS	.105	.524	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-33	111199						
Borrow A - A33							
		-1.125	21.470		19.863	-1.000	19.863
		-.875	4.540		4.200	-.750	24.063
		-.625	4.630		4.283	-.500	28.347
		-.375	4.680		4.330	-.250	32.676
		-.125	3.900		3.608	.000	36.285
		.125	3.800		3.516	.250	39.800
		.375	5.890		5.449	.500	45.249
		.625	5.020		4.644	.750	49.894
		.875	6.330		5.856	1.000	55.750
		1.125	6.780		6.273	1.250	62.022
		1.375	7.130		6.596	1.500	68.619
		1.625	7.480		6.920	1.750	75.539
		1.875	4.200		3.886	2.000	79.425
		2.125	7.270		6.726	2.250	86.150
		2.375	6.350		5.875	2.500	92.025
		2.625	4.180		3.867	2.750	95.892
		2.875	2.540		2.350	3.000	98.242
		3.125	.910		.842	3.250	99.084
		3.375	.370		.342	3.500	99.426
		3.625	.360		.333	3.750	99.759
		3.875	.260		.241	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.090

PERCENT FINER THAN 4.00 PHI = .50 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

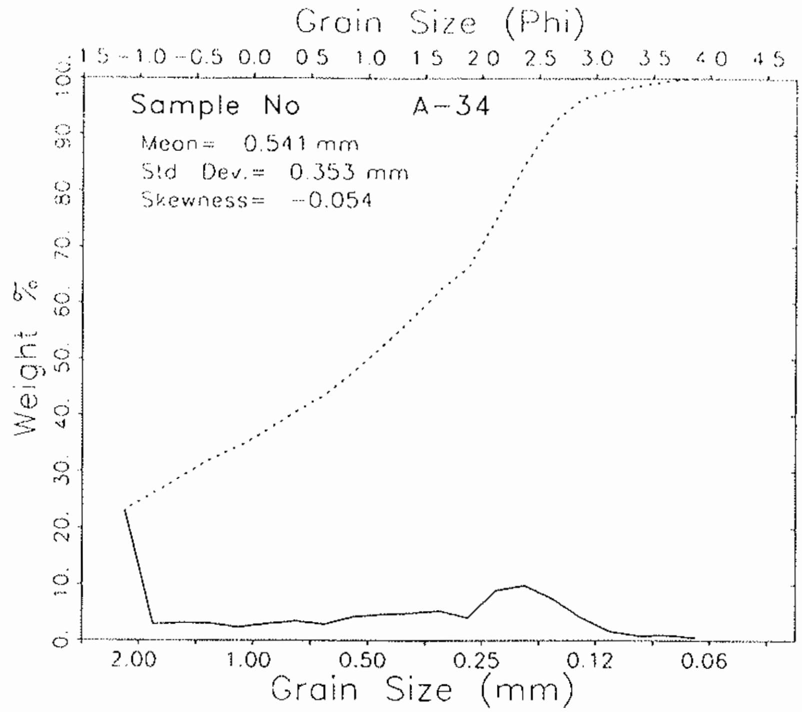
MEAN = .655 STANDARD DEVIATION = 1.330 SKEWNESS = .035 KURTOSIS = -1.221

DISPERSION = .592 STANDARD DEVIATION = .945 DEVIATION FROM NORMAL DISTR. = -28.93%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.237	-1.187	-1.049	-.695	.755	1.731	2.170	2.692	3.225

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.561	.625	COARSE SAND
STANDARD DEVIATION	1.609	1.392	POORLY SORTED
SKEWNESS(1)	-.120	-.061	NEAR SYMMETRICAL
SKEWNESS(2)	-.001		
KURTOSIS	.205	.655	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-34	111199					
Borrow A - A34						
		-1.125	24.170	23.176	-1.000	23.176
		-.875	2.950	2.829	-.750	26.004
		-.625	3.170	3.040	-.500	29.044
		-.375	3.120	2.992	-.250	32.036
		-.125	2.420	2.320	.000	34.356
		.125	3.030	2.905	.250	37.261
		.375	3.560	3.414	.500	40.675
		.625	2.950	2.829	.750	43.504
		.875	4.310	4.133	1.000	47.636
		1.125	4.750	4.555	1.250	52.191
		1.375	5.020	4.814	1.500	57.005
		1.625	5.420	5.197	1.750	62.202
		1.875	4.180	4.008	2.000	66.210
		2.125	9.270	8.889	2.250	75.098
		2.375	10.100	9.685	2.500	84.783
		2.625	7.670	7.354	2.750	92.137
		2.875	4.270	4.094	3.000	96.232
		3.125	1.590	1.525	3.250	97.756
		3.375	.880	.844	3.500	98.600
		3.625	.930	.892	3.750	99.492
		3.875	.530	.508	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.290

PERCENT FINER THAN 4.00 PHI = 1.13 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

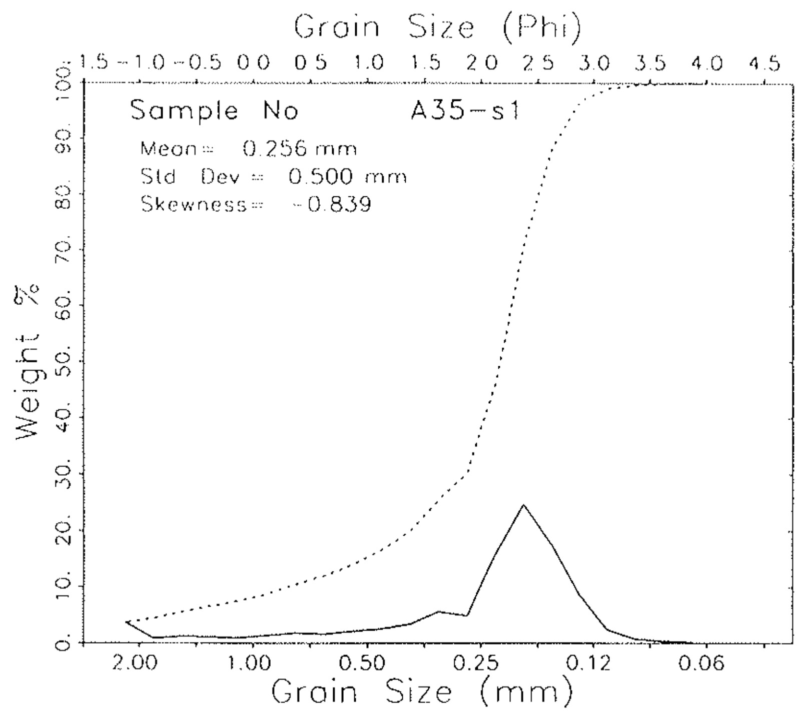
MEAN = .887 STANDARD DEVIATION = 1.501 SKEWNESS = -.054 KURTOSIS = -1.421

DISPERSION = .568 STANDARD DEVIATION = .896 DEVIATION FROM NORMAL DISTR. = -40.30%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.196	-1.077	-.839	1.130	2.247	2.480	2.925	3.612

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.701	.044	COARSE SAND
STANDARD DEVIATION	1.779	1.514	POORLY SORTED
SKEWNESS(1)	-.241	-.185	COARSE-SKEWED
SKEWNESS(2)	-.149		
KURTOSIS	.158	.547	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-35-s	111199					
Borrow A - A-35s1						
		-1.125	4.140	3.606	-1.000	3.606
		-.875	.890	.775	-.750	4.381
		-.625	1.280	1.115	-.500	5.496
		-.375	1.200	1.045	-.250	6.541
		-.125	.990	.862	.000	7.404
		.125	1.500	1.307	.250	8.710
		.375	1.970	1.716	.500	10.426
		.625	1.750	1.524	.750	11.950
		.875	2.340	2.038	1.000	13.988
		1.125	2.880	2.508	1.250	16.497
		1.375	3.820	3.327	1.500	19.824
		1.625	6.340	5.522	1.750	25.346
		1.875	5.520	4.808	2.000	30.154
		2.125	18.280	15.922	2.250	46.076
		2.375	28.330	24.676	2.500	70.752
		2.625	20.050	17.464	2.750	88.215
		2.875	9.680	8.431	3.000	96.647
		3.125	2.670	2.326	3.250	98.972
		3.375	.740	.645	3.500	99.617
		3.625	.330	.287	3.750	99.904
		3.875	.110	.096	4.000	100.000

TOTAL WEIGHT (GRAMS) = 114.810

PERCENT FINER THAN 4.00 PHI = .12 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

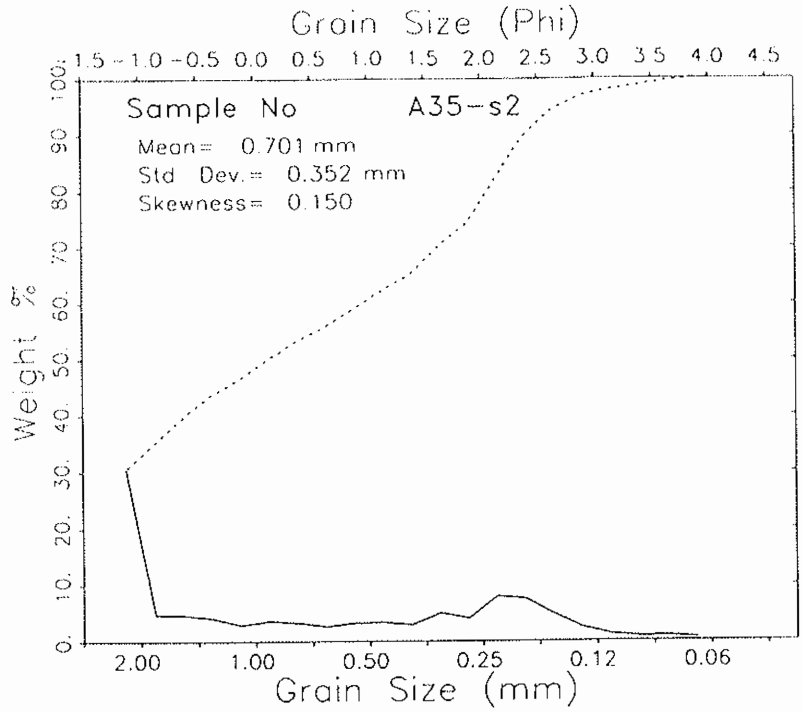
MEAN = 1.964 STANDARD DEVIATION = .999 SKEWNESS = -.839 KURTOSIS = 2.331

DISPERSION = .428 STANDARD DEVIATION = .648 DEVIATION FROM NORMAL DISTR. = -35.12%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.181	-.611	1.200	1.734	2.290	2.561	2.690	2.951	3.261

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.945	2.060	FINE SAND
STANDARD DEVIATION	.745	.912	MODERATELY SORTED
SKEWNESS(1)	-.463	-.546	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.504		
KURTOSIS	1.392	1.767	VERY LEPTOKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-35s- 111199					
Borrow A - A-35s2					
	-1.125	33.380	30.440	-1.000	30.440
	-.875	5.060	4.614	-.750	35.054
	-.625	5.080	4.632	-.500	39.686
	-.375	4.450	4.058	-.250	43.744
	-.125	3.120	2.845	.000	46.589
	.125	3.870	3.529	.250	50.119
	.375	3.550	3.237	.500	53.356
	.625	2.770	2.526	.750	55.882
	.875	3.540	3.228	1.000	59.110
	1.125	3.620	3.301	1.250	62.411
	1.375	3.140	2.863	1.500	65.274
	1.625	5.460	4.979	1.750	70.253
	1.875	4.400	4.012	2.000	74.266
	2.125	8.620	7.861	2.250	82.127
	2.375	8.230	7.505	2.500	89.632
	2.625	5.190	4.733	2.750	94.364
	2.875	2.660	2.426	3.000	96.790
	3.125	1.260	1.149	3.250	97.939
	3.375	.800	.730	3.500	98.669
	3.625	.910	.830	3.750	99.498
	3.875	.550	.502	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.660

PERCENT FINER THAN 4.00 PHI = 1.02 PERCENT COARSER THAN -1.00 PHI = .00

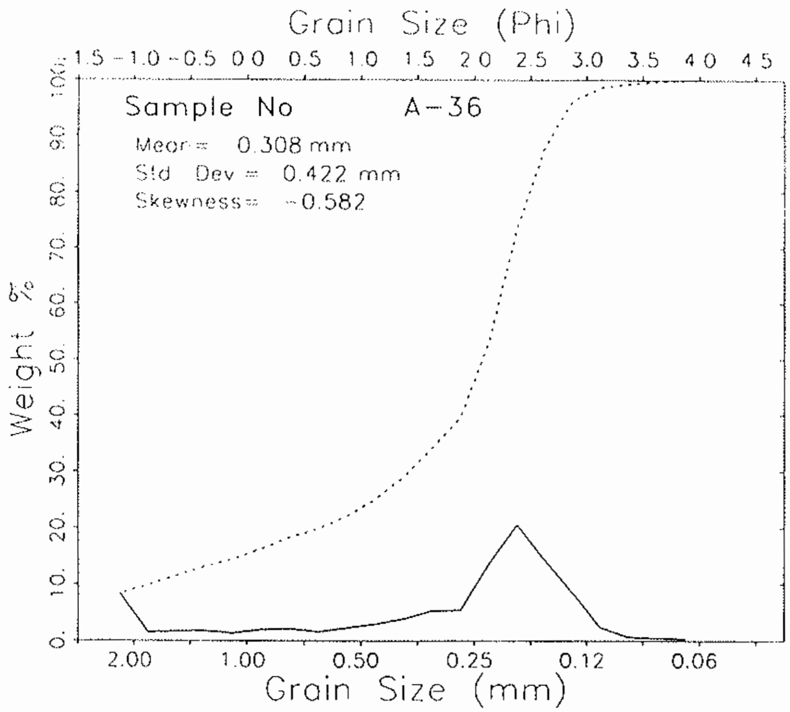
MOMENT MEASURES:

MEAN = .512 STANDARD DEVIATION = 1.508 SKEWNESS = .150 KURTOSIS = -1.400
DISPERSION = .521 STANDARD DEVIATION = .803 DEVIATION FROM NORMAL DISTR. = -46.78%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.209	-1.119	-1.045	.242	2.023	2.312	2.816	3.600

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.597	.478	COARSE SAND
STANDARD DEVIATION	1.715	1.468	POORLY SORTED
SKEWNESS(1)	.207	.243	FINE-SKEWED
SKEWNESS(2)	.327		
KURTOSIS	.173	.538	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-36	111199					
Borrow A - A36						
		-1.125	9.080	8.304	-1.000	8.304
		-.875	1.570	1.436	-.750	9.739
		-.625	1.820	1.664	-.500	11.404
		-.375	1.850	1.692	-.250	13.096
		-.125	1.380	1.262	.000	14.358
		.125	2.100	1.920	.250	16.278
		.375	2.250	2.058	.500	18.336
		.625	1.700	1.555	.750	19.890
		.875	2.410	2.204	1.000	22.094
		1.125	3.200	2.926	1.250	25.021
		1.375	4.200	3.841	1.500	28.861
		1.625	5.750	5.258	1.750	34.120
		1.875	5.880	5.377	2.000	39.497
		2.125	14.880	13.608	2.250	53.105
		2.375	22.450	20.530	2.500	73.635
		2.625	15.660	14.321	2.750	87.956
		2.875	9.140	8.358	3.000	96.315
		3.125	2.500	2.286	3.250	98.601
		3.375	.690	.631	3.500	99.232
		3.625	.520	.476	3.750	99.707
		3.875	.320	.293	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.350

PERCENT FINER THAN 4.00 PHI = .86 PERCENT COARSER THAN -1.00 PHI = .00

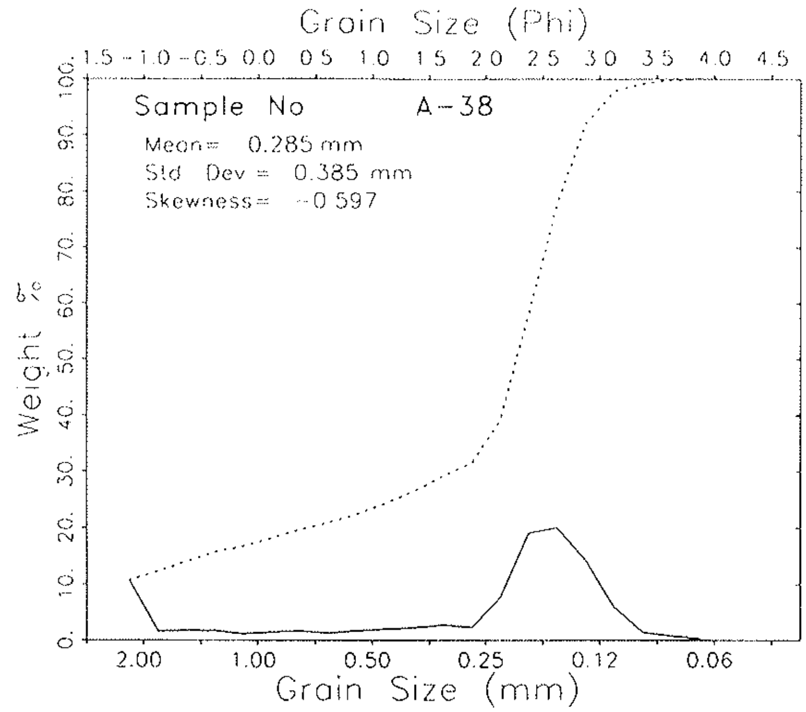
MOMENT MEASURES:

MEAN = 1.701 STANDARD DEVIATION = 1.244 SKEWNESS = -.582 KURTOSIS = .207
DISPERSION = .505 STANDARD DEVIATION = .773 DEVIATION FROM NORMAL DISTR. = -37.82%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.220	-1.099	.214	1.248	2.193	2.524	2.681	2.961	3.408

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.447	1.696	MEDIUM SAND
STANDARD DEVIATION	1.234	1.232	POORLY SORTED
SKEWNESS(1)	-.604	-.613	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.023		
KURTOSIS	.646	1.304	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-38	111199					
Borrow A - A38						
		-1.125	11.430	10.700	-1.000	10.700
		-.875	1.670	1.563	-.750	12.264
		-.625	1.830	1.713	-.500	13.977
		-.375	1.750	1.638	-.250	15.615
		-.125	1.110	1.039	.000	16.654
		.125	1.490	1.395	.250	18.049
		.375	1.690	1.582	.500	19.631
		.625	1.290	1.208	.750	20.839
		.875	1.710	1.601	1.000	22.440
		1.125	2.010	1.882	1.250	24.321
		1.375	2.290	2.144	1.500	26.465
		1.625	2.850	2.668	1.750	29.133
		1.875	2.410	2.256	2.000	31.389
		2.125	8.030	7.517	2.250	38.907
		2.375	20.310	19.013	2.500	57.920
		2.625	21.210	19.856	2.750	77.776
		2.875	15.220	14.248	3.000	92.024
		3.125	6.190	5.795	3.250	97.819
		3.375	1.380	1.292	3.500	99.111
		3.625	.730	.683	3.750	99.794
		3.875	.220	.206	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.820

PERCENT FINER THAN 4.00 PHI = .33 PERCENT COARSER THAN -1.00 PHI = .00

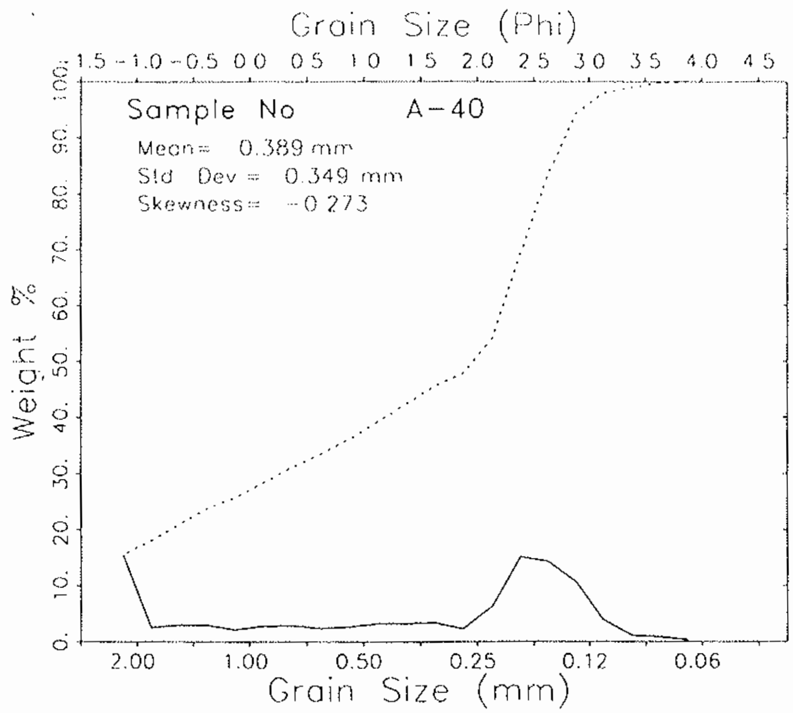
MOMENT MEASURES:

MEAN = 1.813 STANDARD DEVIATION = 1.377 SKEWNESS = -.597 KURTOSIS = .003
DISPERSION = .462 STANDARD DEVIATION = .701 DEVIATION FROM NORMAL DISTR. = -49.10%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.133	-.157	1.329	2.396	2.715	2.859	3.128	3.479

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.351	1.699	MEDIUM SAND
STANDARD DEVIATION	1.508	1.400	POORLY SORTED
SKEWNESS(1)	-.693	-.675	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.927		
KURTOSIS	.413	1.260	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-40	111199					
Borrow A - A40						
		-1.125	17.290	15.512	-1.000	15.512
		-.875	2.770	2.485	-.750	17.997
		-.625	3.200	2.871	-.500	20.868
		-.375	3.230	2.898	-.250	23.766
		-.125	2.250	2.019	.000	25.785
		.125	2.990	2.683	.250	28.468
		.375	3.100	2.781	.500	31.249
		.625	2.550	2.288	.750	33.537
		.875	2.860	2.566	1.000	36.103
		1.125	3.480	3.122	1.250	39.225
		1.375	3.530	3.167	1.500	42.392
		1.625	3.640	3.266	1.750	45.658
		1.875	2.520	2.261	2.000	47.919
		2.125	6.850	6.146	2.250	54.064
		2.375	16.750	15.028	2.500	69.092
		2.625	15.940	14.301	2.750	83.393
		2.875	11.960	10.730	3.000	94.123
		3.125	4.220	3.786	3.250	97.910
		3.375	1.140	1.023	3.500	98.932
		3.625	.890	.798	3.750	99.731
		3.875	.300	.269	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.460

PERCENT FINER THAN 4.00 PHI = .22   PERCENT COARSER THAN -1.00 PHI = .00

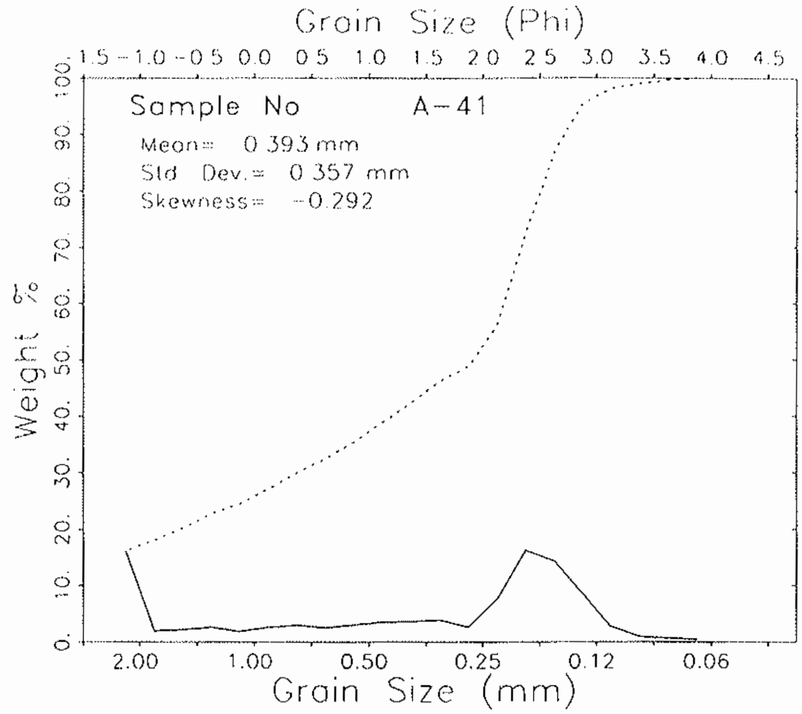
MOMENT MEASURES:

MEAN = 1.361   STANDARD DEVIATION = 1.519   SKEWNESS = -.273   KURTOSIS = -1.231
DISPERSION = .551   STANDARD DEVIATION = .861   DEVIATION FROM NORMAL DISTR. = -43.31%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.234	-1.169	-.951	-.097	2.085	2.603	2.764	3.058	3.521

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.907	1.299	MEDIUM SAND
STANDARD DEVIATION	1.858	1.569	POORLY SORTED
SKEWNESS(1)	-.634	-.587	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.614		
KURTOSIS	.138	.642	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-41	111199					
Borrow A - A41						
		-1.125	19.260	16.147	-1.000	16.147
		-.875	2.240	1.878	-.750	18.025
		-.625	2.530	2.121	-.500	20.146
		-.375	3.000	2.515	-.250	22.661
		-.125	2.200	1.844	.000	24.505
		.125	3.040	2.549	.250	27.054
		.375	3.470	2.909	.500	29.963
		.625	2.940	2.465	.750	32.428
		.875	3.590	3.010	1.000	35.438
		1.125	4.130	3.462	1.250	38.900
		1.375	4.200	3.521	1.500	42.421
		1.625	4.560	3.823	1.750	46.244
		1.875	3.070	2.574	2.000	48.818
		2.125	8.870	7.436	2.250	56.254
		2.375	19.330	16.206	2.500	72.460
		2.625	17.120	14.353	2.750	86.813
		2.875	10.250	8.593	3.000	95.406
		3.125	3.200	2.683	3.250	98.089
		3.375	1.070	.897	3.500	98.986
		3.625	.770	.646	3.750	99.631
		3.875	.440	.369	4.000	100.000

TOTAL WEIGHT (GRAMS) = 119.280

PERCENT FINER THAN 4.00 PHI = .89   PERCENT COARSER THAN -1.00 PHI = .00

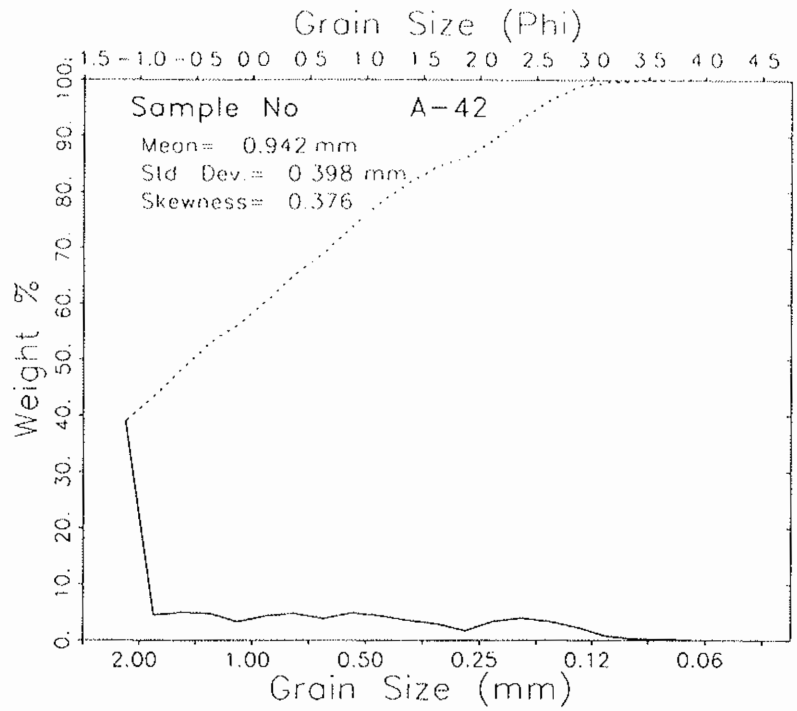
MOMENT MEASURES:

MEAN = 1.349   STANDARD DEVIATION = 1.484   SKEWNESS = -.292   KURTOSIS = -1.141
DISPERSION = .542   STANDARD DEVIATION = .842   DEVIATION FROM NORMAL DISTR. = -43.25%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.173	-1.002	.049	2.040	2.544	2.701	2.988	3.506

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.849	1.246	MEDIUM SAND
STANDARD DEVIATION	1.852	1.556	POORLY SORTED
SKEWNESS(1)	-.643	-.593	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.611		
KURTOSIS	.124	.683	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-42	111199					
Borrow A - A42						
		-1.125	43.190	38.973	-1.000	38.973
		-.875	4.820	4.349	-.750	43.323
		-.625	5.400	4.873	-.500	48.195
		-.375	5.270	4.755	-.250	52.951
		-.125	3.590	3.239	.000	56.190
		.125	4.770	4.304	.250	60.494
		.375	5.260	4.746	.500	65.241
		.625	4.180	3.772	.750	69.013
		.875	5.290	4.774	1.000	73.786
		1.125	4.810	4.340	1.250	78.127
		1.375	3.850	3.474	1.500	81.601
		1.625	3.200	2.888	1.750	84.488
		1.875	1.800	1.624	2.000	86.113
		2.125	3.620	3.267	2.250	89.379
		2.375	4.330	3.907	2.500	93.286
		2.625	3.640	3.285	2.750	96.571
		2.875	2.480	2.238	3.000	98.809
		3.125	.790	.713	3.250	99.522
		3.375	.280	.253	3.500	99.774
		3.625	.170	.153	3.750	99.928
		3.875	.080	.072	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.820

PERCENT FINER THAN 4.00 PHI = .17 PERCENT COARSER THAN -1.00 PHI = .00

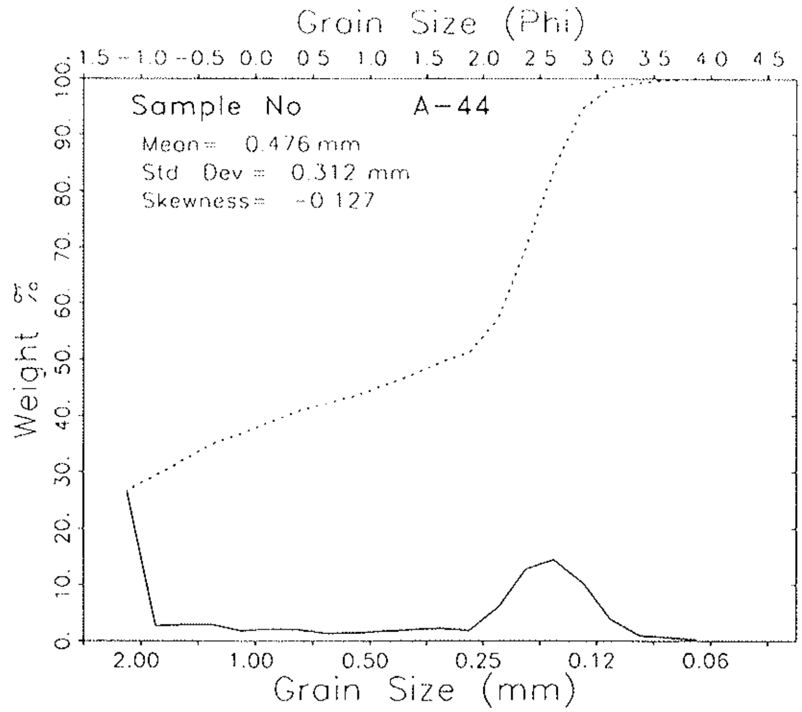
MOMENT MEASURES:

MEAN = .086 STANDARD DEVIATION = 1.329 SKEWNESS = .376 KURTOSIS = -.745
DISPERSION = .431 STANDARD DEVIATION = .653 DEVIATION FROM NORMAL DISTR. = -50.87%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.244	-1.218	-1.147	-1.090	-.405	1.070	1.708	2.630	3.067

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.280	.052	COARSE SAND
STANDARD DEVIATION	1.428	1.297	POORLY SORTED
SKEWNESS(1)	.480	.529	STRONGLY FINE-SKEWED
SKEWNESS(2)	.779		
KURTOSIS	.348	.730	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-44	111199					
Borrow A - A44						
		-1.125	31.120	26.619	-1.000	26.619
		-.875	3.100	2.652	-.750	29.270
		-.625	3.350	2.865	-.500	32.136
		-.375	3.360	2.874	-.250	35.010
		-.125	2.110	1.805	.000	36.815
		.125	2.380	2.036	.250	38.850
		.375	2.340	2.002	.500	40.852
		.625	1.570	1.343	.750	42.195
		.875	1.630	1.394	1.000	43.589
		1.125	2.040	1.745	1.250	45.334
		1.375	2.290	1.959	1.500	47.293
		1.625	2.590	2.215	1.750	49.508
		1.875	2.070	1.771	2.000	51.279
		2.125	6.810	5.825	2.250	57.104
		2.375	14.860	12.711	2.500	69.814
		2.625	16.840	14.404	2.750	84.219
		2.875	12.150	10.393	3.000	94.611
		3.125	4.390	3.755	3.250	98.366
		3.375	.990	.847	3.500	99.213
		3.625	.680	.582	3.750	99.795
		3.875	.240	.205	4.000	100.000

TOTAL WEIGHT (GRAMS) = 116.910

PERCENT FINER THAN 4.00 PHI = .23 PERCENT COARSER THAN -1.00 PHI = .00

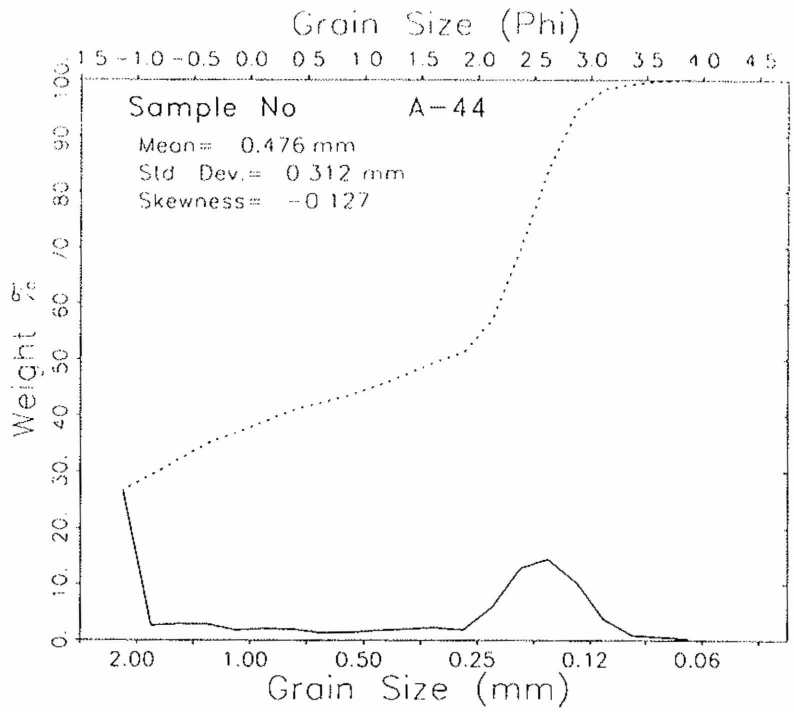
MOMENT MEASURES:

MEAN = 1.070 STANDARD DEVIATION = 1.682 SKEWNESS = -.127 KURTOSIS = -1.667
DISPERSION = .463 STANDARD DEVIATION = .702 DEVIATION FROM NORMAL DISTR. = -58.24%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.203	-1.100	-1.015	1.819	2.590	2.746	3.026	3.437

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.823	1.155	MEDIUM SAND
STANDARD DEVIATION	1.923	1.602	POORLY SORTED
SKEWNESS(1)	-.518	-.474	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.472		
KURTOSIS	.100	.481	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-44	111199					
Borrow A - A44						
		-1.125	31.120	26.619	-1.000	26.619
		-.875	3.100	2.652	-.750	29.270
		-.625	3.350	2.865	-.500	32.136
		-.375	3.360	2.874	-.250	35.010
		-.125	2.110	1.805	.000	36.815
		.125	2.380	2.036	.250	38.850
		.375	2.340	2.002	.500	40.852
		.625	1.570	1.343	.750	42.195
		.875	1.630	1.394	1.000	43.589
		1.125	2.040	1.745	1.250	45.334
		1.375	2.290	1.959	1.500	47.293
		1.625	2.590	2.215	1.750	49.508
		1.875	2.070	1.771	2.000	51.279
		2.125	6.810	5.825	2.250	57.104
		2.375	14.860	12.711	2.500	69.814
		2.625	16.840	14.404	2.750	84.219
		2.875	12.150	10.393	3.000	94.611
		3.125	4.390	3.755	3.250	98.366
		3.375	.990	.847	3.500	99.213
		3.625	.680	.582	3.750	99.795
		3.875	.240	.205	4.000	100.000

TOTAL WEIGHT (GRAMS) = 116.910

PERCENT FINER THAN 4.00 PHI = .23 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

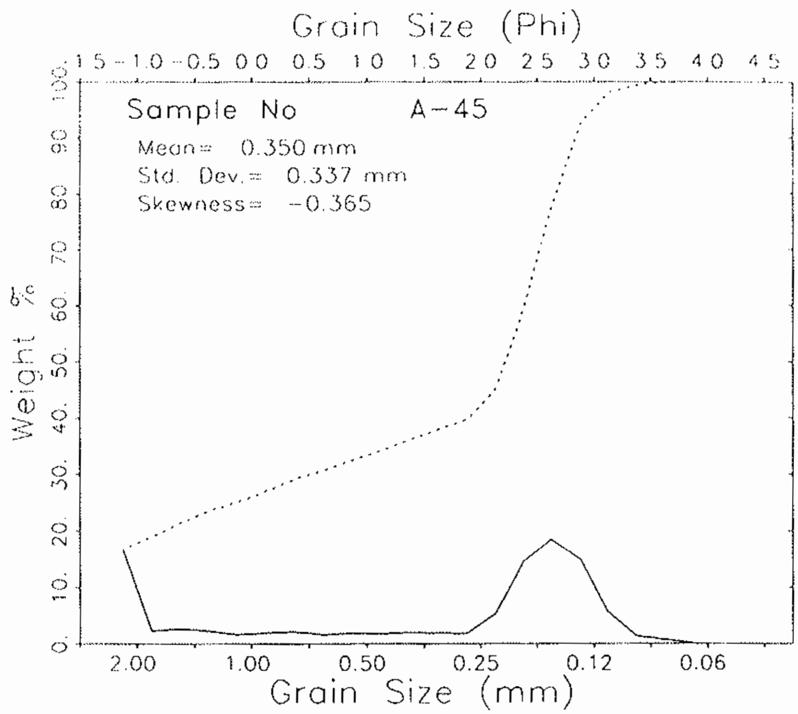
MEAN = 1.070 STANDARD DEVIATION = 1.682 SKEWNESS = -.127 KURTOSIS = -1.667

DISPERSION = .463 STANDARD DEVIATION = .702 DEVIATION FROM NORMAL DISTR. = -58.24%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.203	-1.100	-1.015	1.819	2.590	2.746	3.026	3.437

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.823	1.155	MEDIUM SAND
STANDARD DEVIATION	1.923	1.602	POORLY SORTED
SKEWNESS(1)	-.518	-.474	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.472		
KURTOSIS	.100	.481	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-45 Borrow A -A45	111199					
		-1.125	19.750	16.671	-1.000	16.671
		-.875	2.610	2.203	-.750	18.874
		-.625	2.990	2.524	-.500	21.398
		-.375	2.590	2.186	-.250	23.584
		-.125	1.810	1.528	.000	25.112
		.125	2.270	1.916	.250	27.028
		.375	2.460	2.076	.500	29.104
		.625	1.820	1.536	.750	30.641
		.875	2.180	1.840	1.000	32.481
		1.125	2.060	1.739	1.250	34.220
		1.375	2.260	1.908	1.500	36.127
		1.625	2.140	1.806	1.750	37.934
		1.875	1.990	1.680	2.000	39.613
		2.125	6.110	5.157	2.250	44.771
		2.375	17.020	14.367	2.500	59.137
		2.625	21.690	18.308	2.750	77.446
		2.875	17.760	14.991	3.000	92.437
		3.125	6.620	5.588	3.250	98.025
		3.375	1.510	1.275	3.500	99.299
		3.625	.740	.625	3.750	99.924
		3.875	.090	.076	4.000	100.000

TOTAL WEIGHT (GRAMS) = 118.470

PERCENT FINER THAN 4.00 PHI = .44 PERCENT COARSER THAN -1.00 PHI = .00

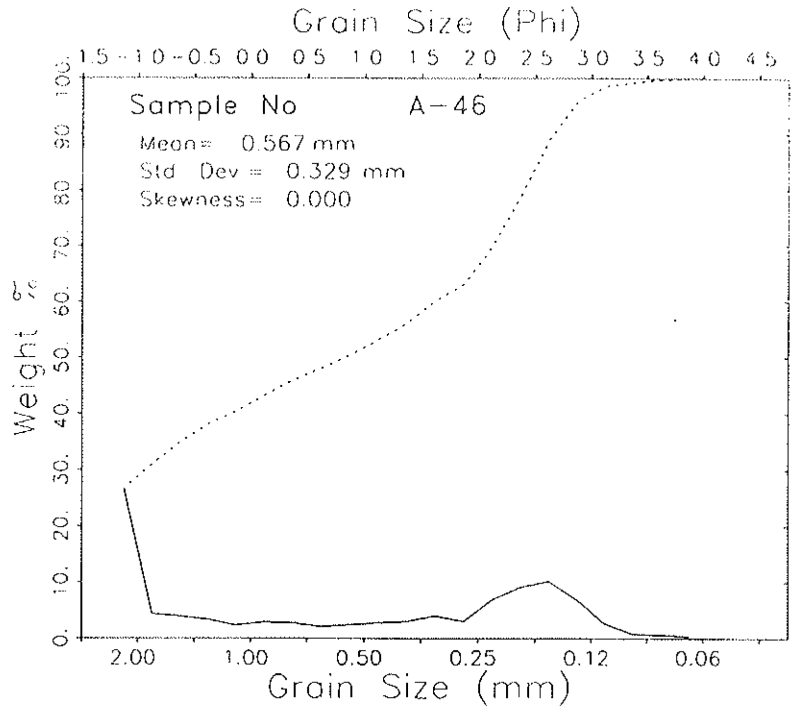
MOMENT MEASURES:

MEAN = 1.515 STANDARD DEVIATION = 1.569 SKEWNESS = -.365 KURTOSIS = -1.116
DISPERSION = .477 STANDARD DEVIATION = .726 DEVIATION FROM NORMAL DISTR. = -53.72%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.175	-1.010	-.018	2.341	2.717	2.859	3.115	3.441

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.925	1.397	MEDIUM SAND
STANDARD DEVIATION	1.935	1.617	POORLY SORTED
SKEWNESS(1)	-.732	-.686	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.709		
KURTOSIS	.109	.643	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-46	111199					
Borrow A - A46						
		-1.125	28.400	26.604	-1.000	26.604
		-.875	4.560	4.272	-.750	30.876
		-.625	4.160	3.897	-.500	34.773
		-.375	3.550	3.326	-.250	38.098
		-.125	2.440	2.286	.000	40.384
		.125	3.060	2.867	.250	43.251
		.375	2.920	2.735	.500	45.986
		.625	2.200	2.061	.750	48.047
		.875	2.530	2.370	1.000	50.417
		1.125	2.910	2.726	1.250	53.143
		1.375	3.170	2.970	1.500	56.112
		1.625	4.280	4.009	1.750	60.122
		1.875	3.210	3.007	2.000	63.129
		2.125	7.390	6.923	2.250	70.052
		2.375	9.640	9.030	2.500	79.082
		2.625	10.710	10.033	2.750	89.115
		2.875	7.270	6.810	3.000	95.925
		3.125	2.740	2.567	3.250	98.492
		3.375	.750	.703	3.500	99.194
		3.625	.550	.515	3.750	99.710
		3.875	.310	.290	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.750

PERCENT FINER THAN 4.00 PHI = .58 PERCENT COARSER THAN -1.00 PHI = .00

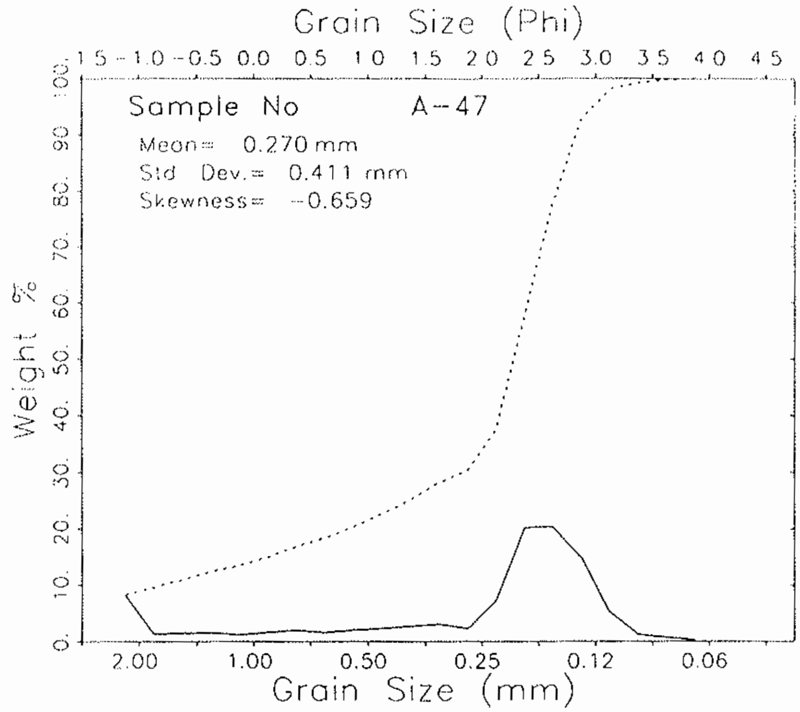
MOMENT MEASURES:

MEAN = .819 STANDARD DEVIATION = 1.603 SKEWNESS = .000 KURTOSIS = -1.625
DISPERSION = .530 STANDARD DEVIATION = .821 DEVIATION FROM NORMAL DISTR. = -48.82%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.203	-1.100	-1.015	.956	2.387	2.623	2.966	3.431

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.761	.826	COARSE SAND
STANDARD DEVIATION	1.861	1.562	POORLY SORTED
SKEWNESS(1)	-.105	-.070	NEAR SYMMETRICAL
SKEWNESS(2)	-.040		
KURTOSIS	.120	.502	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-47	111199					
Borrow A -A47						
		-1.125	8.490	8.197	-1.000	8.197
		-.875	1.340	1.294	-.750	9.491
		-.625	1.450	1.400	-.500	10.891
		-.375	1.510	1.458	-.250	12.349
		-.125	1.140	1.101	.000	13.450
		.125	1.570	1.516	.250	14.966
		.375	1.920	1.854	.500	16.820
		.625	1.650	1.593	.750	18.413
		.875	2.010	1.941	1.000	20.353
		1.125	2.330	2.250	1.250	22.603
		1.375	2.700	2.607	1.500	25.210
		1.625	3.080	2.974	1.750	28.184
		1.875	2.260	2.182	2.000	30.366
		2.125	7.450	7.193	2.250	37.559
		2.375	20.830	20.112	2.500	57.671
		2.625	21.040	20.315	2.750	77.986
		2.875	15.450	14.917	3.000	92.903
		3.125	5.340	5.156	3.250	98.059
		3.375	1.150	1.110	3.500	99.170
		3.625	.660	.637	3.750	99.807
		3.875	.200	.193	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.570

PERCENT FINER THAN 4.00 PHI = .16 PERCENT COARSER THAN -1.00 PHI = .00

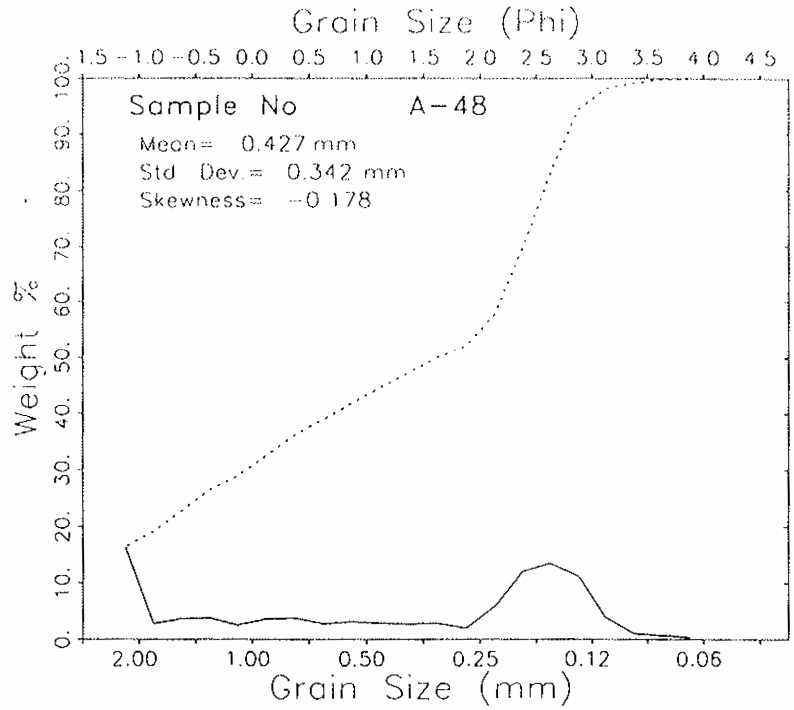
MOMENT MEASURES:

MEAN = 1.889 STANDARD DEVIATION = 1.283 SKEWNESS = -.659 KURTOSIS = .484
DISPERSION = .461 STANDARD DEVIATION = .699 DEVIATION FROM NORMAL DISTR. = -45.50%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.220	-1.098	.389	1.480	2.405	2.713	2.851	3.102	3.462

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.620	1.882	MEDIUM SAND
STANDARD DEVIATION	1.231	1.252	POORLY SORTED
SKEWNESS(1)	-.637	-.653	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.140		
KURTOSIS	.706	1.395	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-48	111199					
Borrow A - A48						
		-1.125	16.550	16.357	-1.000	16.357
		-.875	2.760	2.728	-.750	19.085
		-.625	3.600	3.558	-.500	22.643
		-.375	3.800	3.756	-.250	26.398
		-.125	2.530	2.500	.000	28.899
		.125	3.570	3.528	.250	32.427
		.375	3.780	3.736	.500	36.163
		.625	2.780	2.748	.750	38.911
		.875	3.070	3.034	1.000	41.945
		1.125	2.800	2.767	1.250	44.712
		1.375	2.650	2.619	1.500	47.331
		1.625	2.850	2.817	1.750	50.148
		1.875	1.900	1.878	2.000	52.026
		2.125	5.770	5.703	2.250	57.729
		2.375	12.110	11.969	2.500	69.698
		2.625	13.580	13.422	2.750	83.119
		2.875	11.350	11.218	3.000	94.337
		3.125	3.860	3.815	3.250	98.152
		3.375	.970	.959	3.500	99.110
		3.625	.620	.613	3.750	99.723
		3.875	.280	.277	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.180

PERCENT FINER THAN 4.00 PHI = .51 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

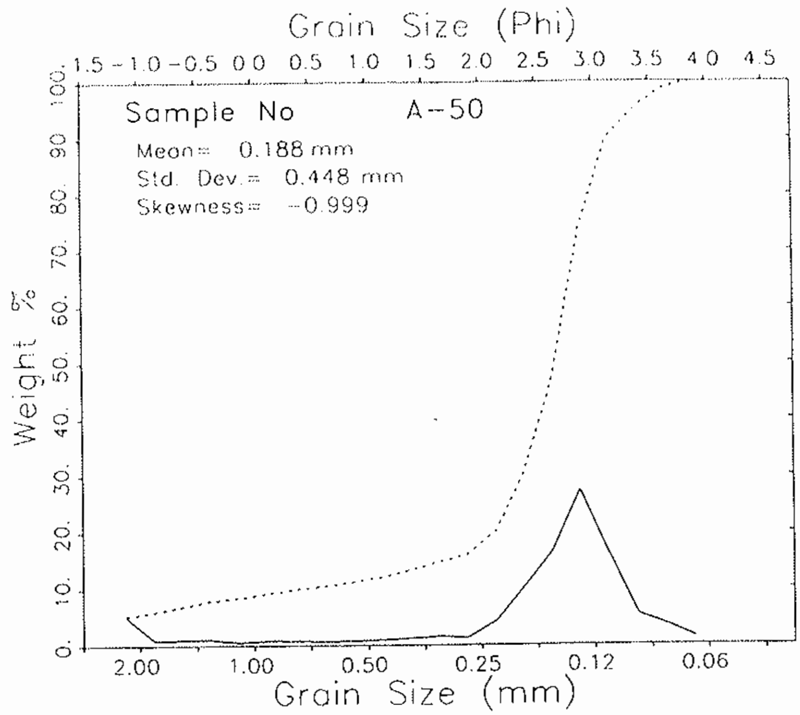
MEAN = 1.228 STANDARD DEVIATION = 1.547 SKEWNESS = -.178 KURTOSIS = -1.430

DISPERSION = .568 STANDARD DEVIATION = .894 DEVIATION FROM NORMAL DISTR. = -42.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.174	-1.005	-.343	1.737	2.599	2.770	3.043	3.471

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.882	1.167	MEDIUM SAND
STANDARD DEVIATION	1.888	1.583	POORLY SORTED
SKEWNESS(1)	-.453	-.417	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.425		
KURTOSIS	.117	.587	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-50	111199						
Borrow A - A50							
		-1.125	5.190		5.088	-1.000	5.088
		-.875	.780		.765	-.750	5.853
		-.625	1.010		.990	-.500	6.843
		-.375	1.010		.990	-.250	7.833
		-.125	.490		.480	.000	8.314
		.125	.840		.824	.250	9.137
		.375	.730		.716	.500	9.853
		.625	.620		.608	.750	10.461
		.875	.700		.686	1.000	11.147
		1.125	.900		.882	1.250	12.029
		1.375	1.190		1.167	1.500	13.196
		1.625	1.530		1.500	1.750	14.696
		1.875	1.240		1.216	2.000	15.912
		2.125	4.220		4.137	2.250	20.049
		2.375	10.370		10.167	2.500	30.216
		2.625	16.650		16.324	2.750	46.539
		2.875	27.840		27.294	3.000	73.833
		3.125	16.420		16.098	3.250	89.931
		3.375	5.380		5.275	3.500	95.206
		3.625	3.530		3.461	3.750	98.667
		3.875	1.360		1.333	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.000

PERCENT FINER THAN 4.00 PHI = 1.86 PERCENT COARSER THAN -1.00 PHI = .00

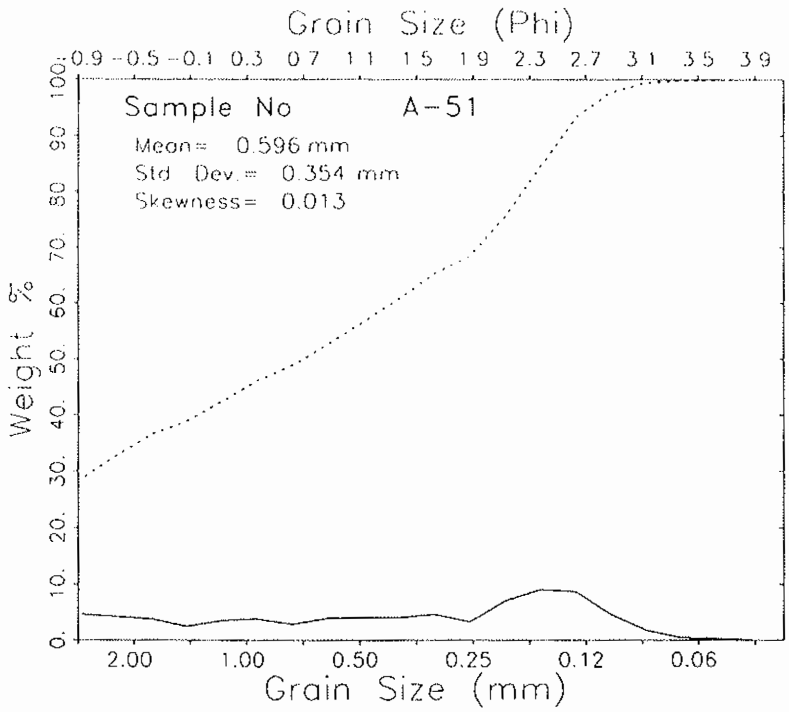
MOMENT MEASURES:

MEAN = 2.413 STANDARD DEVIATION = 1.160 SKEWNESS = -.999 KURTOSIS = 3.199
DISPERSION = .394 STANDARD DEVIATION = .600 DEVIATION FROM NORMAL DISTR. = -48.32%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.201	-1.004	2.005	2.372	2.782	3.018	3.158	3.490	3.812

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.582	2.648	FINE SAND
STANDARD DEVIATION	.576	.969	MODERATELY SORTED
SKEWNESS(1)	-.347	-.516	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-2.670		
KURTOSIS	2.900	2.850	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT / WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-51	111199					
Bogue Banks - Borrow A						
		-1.125	24.400	24.002	-1.000	24.002
		-.875	4.660	4.584	-.750	28.585
		-.625	4.170	4.102	-.500	32.687
		-.375	3.820	3.758	-.250	36.445
		-.125	2.440	2.400	.000	38.845
		.125	3.560	3.502	.250	42.347
		.375	3.750	3.689	.500	46.036
		.625	2.880	2.833	.750	48.869
		.875	3.940	3.876	1.000	52.744
		1.125	4.050	3.984	1.250	56.728
		1.375	4.050	3.984	1.500	60.712
		1.625	4.670	4.594	1.750	65.306
		1.875	3.280	3.226	2.000	68.532
		2.125	7.100	6.984	2.250	75.516
		2.375	9.100	8.951	2.500	84.468
		2.625	8.760	8.617	2.750	93.085
		2.875	4.620	4.545	3.000	97.629
		3.125	1.760	1.731	3.250	99.361
		3.375	.370	.364	3.500	99.725
		3.625	.220	.216	3.750	99.941
		3.875	.060	.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.660

PERCENT FINER THAN 4.00 PHI = .10 PERCENT COARSER THAN -1.00 PHI = .00

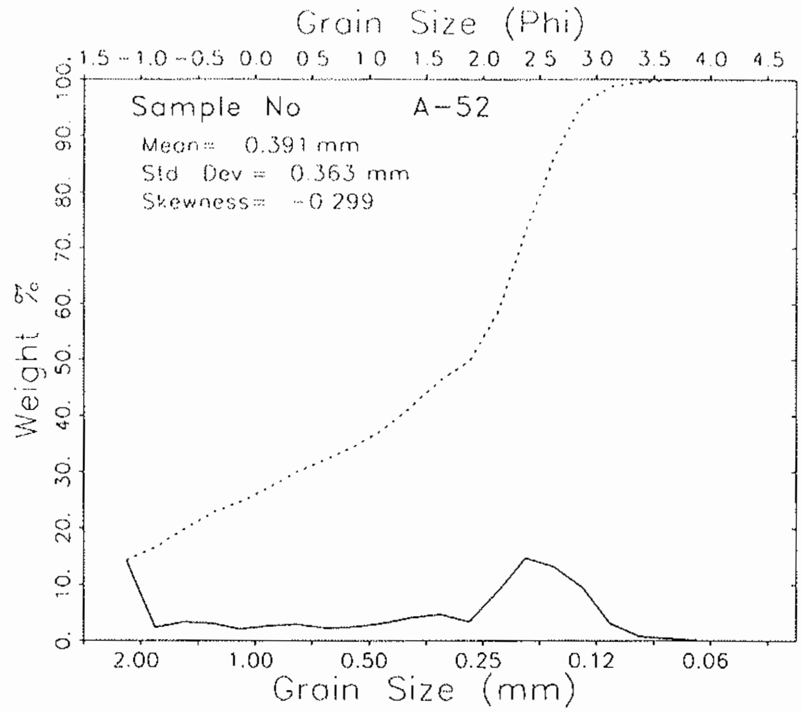
MOMENT MEASURES:

MEAN = .746 STANDARD DEVIATION = 1.499 SKEWNESS = .013 KURTOSIS = -1.538
DISPERSION = .555 STANDARD DEVIATION = .869 DEVIATION FROM NORMAL DISTR. = -42.05%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.198	-1.083	-.946	.823	2.232	2.487	2.855	3.198

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.702	.742	COARSE SAND
STANDARD DEVIATION	1.785	1.507	POORLY SORTED
SKEWNESS(1)	-.068	-.033	NEAR SYMMETRICAL
SKEWNESS(2)	.003		
KURTOSIS	.135	.523	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-52	111199					
Borrow A - A52						
		-1.125	15.520	14.203	-1.000	14.203
		-.875	2.450	2.242	-.750	16.446
		-.625	3.530	3.231	-.500	19.676
		-.375	3.280	3.002	-.250	22.678
		-.125	2.150	1.968	.000	24.645
		.125	2.790	2.553	.250	27.199
		.375	3.060	2.800	.500	29.999
		.625	2.370	2.169	.750	32.168
		.875	2.570	2.352	1.000	34.520
		1.125	3.380	3.093	1.250	37.613
		1.375	4.460	4.082	1.500	41.695
		1.625	5.060	4.631	1.750	46.326
		1.875	3.620	3.313	2.000	49.639
		2.125	9.530	8.722	2.250	58.360
		2.375	15.980	14.624	2.500	72.984
		2.625	14.400	13.178	2.750	86.163
		2.875	10.410	9.527	3.000	95.690
		3.125	3.250	2.974	3.250	98.664
		3.375	.820	.750	3.500	99.414
		3.625	.450	.412	3.750	99.826
		3.875	.190	.174	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.270

PERCENT FINER THAN 4.00 PHI = .36 PERCENT COARSER THAN -1.00 PHI = .00

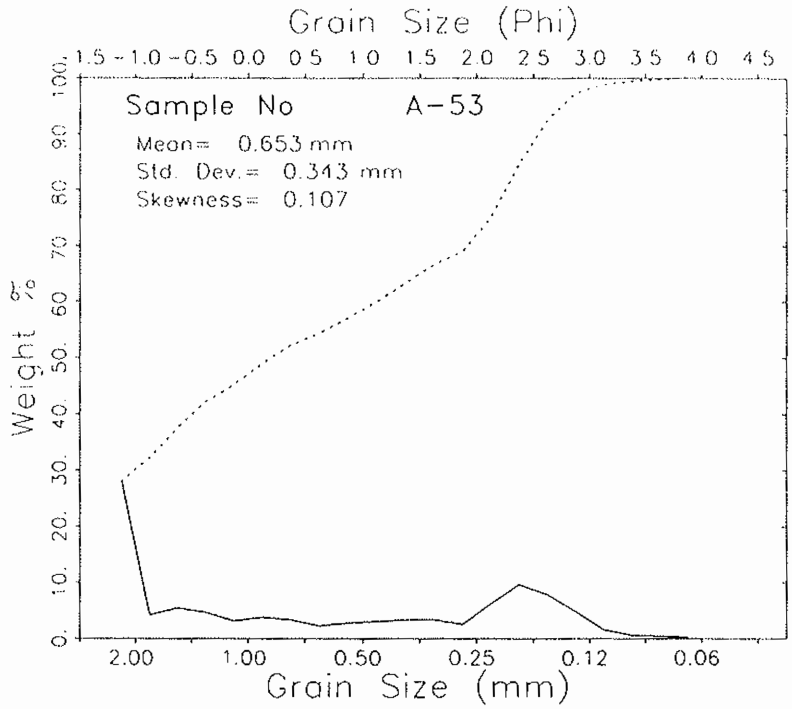
MOMENT MEASURES:

MEAN = 1.355 STANDARD DEVIATION = 1.461 SKEWNESS = -.299 KURTOSIS = -1.129
DISPERSION = .559 STANDARD DEVIATION = .877 DEVIATION FROM NORMAL DISTR. = -39.96%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.232	-1.162	-.800	.035	2.010	2.538	2.709	2.982	3.362

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.955	1.307	MEDIUM SAND
STANDARD DEVIATION	1.754	1.505	POORLY SORTED
SKEWNESS(1)	-.602	-.566	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.627		
KURTOSIS	.181	.678	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-53	111199					
Borrow A - A53						
		-1.125	30.830	27.987	-1.000	27.987
		-.875	4.540	4.121	-.750	32.108
		-.625	5.910	5.365	-.500	37.473
		-.375	5.140	4.666	-.250	42.139
		-.125	3.370	3.059	.000	45.198
		.125	4.100	3.722	.250	48.920
		.375	3.660	3.322	.500	52.242
		.625	2.410	2.188	.750	54.430
		.875	2.960	2.687	1.000	57.117
		1.125	3.250	2.950	1.250	60.067
		1.375	3.630	3.295	1.500	63.362
		1.625	3.610	3.277	1.750	66.639
		1.875	2.680	2.433	2.000	69.072
		2.125	6.728	6.100	2.250	75.172
		2.375	10.510	9.541	2.500	84.713
		2.625	8.620	7.825	2.750	92.538
		2.875	5.250	4.766	3.000	97.304
		3.125	1.730	1.570	3.250	98.874
		3.375	.570	.517	3.500	99.392
		3.625	.400	.363	3.750	99.755
		3.875	.270	.245	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.160

PERCENT FINER THAN 4.00 PHI = .51   PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

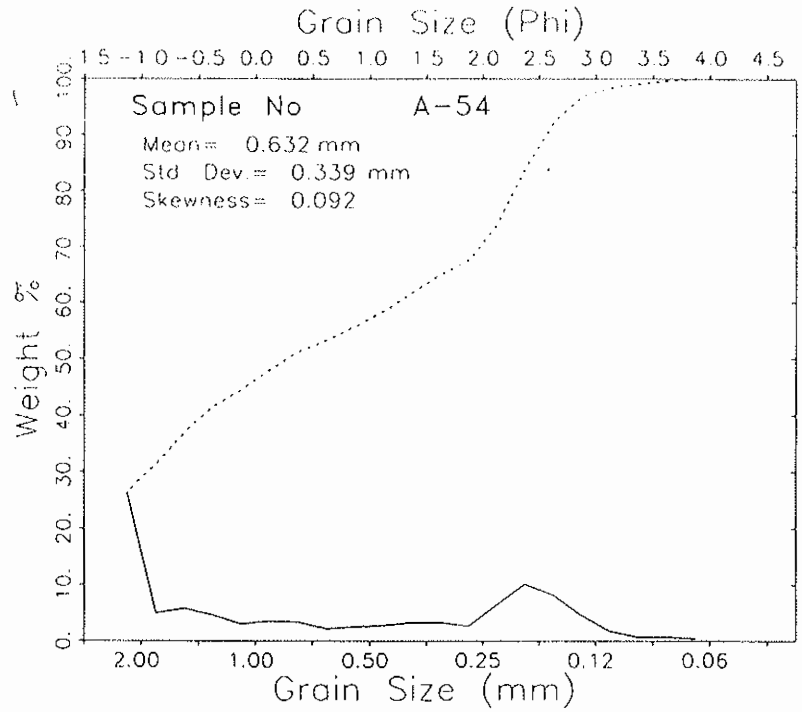
MEAN = .614   STANDARD DEVIATION = 1.545   SKEWNESS = .107   KURTOSIS = -1.540

DISPERSION = .526   STANDARD DEVIATION = .812   DEVIATION FROM NORMAL DISTR. = -47.47%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.205	-1.107	-1.027	.331	2.243	2.481	2.879	3.311

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.687	.569	COARSE SAND
STANDARD DEVIATION	1.794	1.516	POORLY SORTED
SKEWNESS(1)	.198	.223	FINE-SKEWED
SKEWNESS(2)	.282		
KURTOSIS	.138	.512	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-54	111199					
Borrow A - A54						
		-1.125	27.370	26.305	-1.000	26.305
		-.875	5.090	4.892	-.750	31.197
		-.625	5.940	5.709	-.500	36.905
		-.375	4.770	4.584	-.250	41.490
		-.125	3.090	2.970	.000	44.459
		.125	3.640	3.498	.250	47.958
		.375	3.410	3.277	.500	51.235
		.625	2.210	2.124	.750	53.359
		.875	2.540	2.441	1.000	55.800
		1.125	2.800	2.691	1.250	58.491
		1.375	3.390	3.258	1.500	61.749
		1.625	3.330	3.200	1.750	64.950
		1.875	2.700	2.595	2.000	67.544
		2.125	6.660	6.401	2.250	73.945
		2.375	10.440	10.034	2.500	83.979
		2.625	8.490	8.160	2.750	92.138
		2.875	4.710	4.527	3.000	96.665
		3.125	1.760	1.691	3.250	98.357
		3.375	.650	.625	3.500	98.981
		3.625	.640	.615	3.750	99.596
		3.875	.420	.404	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.050

PERCENT FINER THAN 4.00 PHI = .89 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

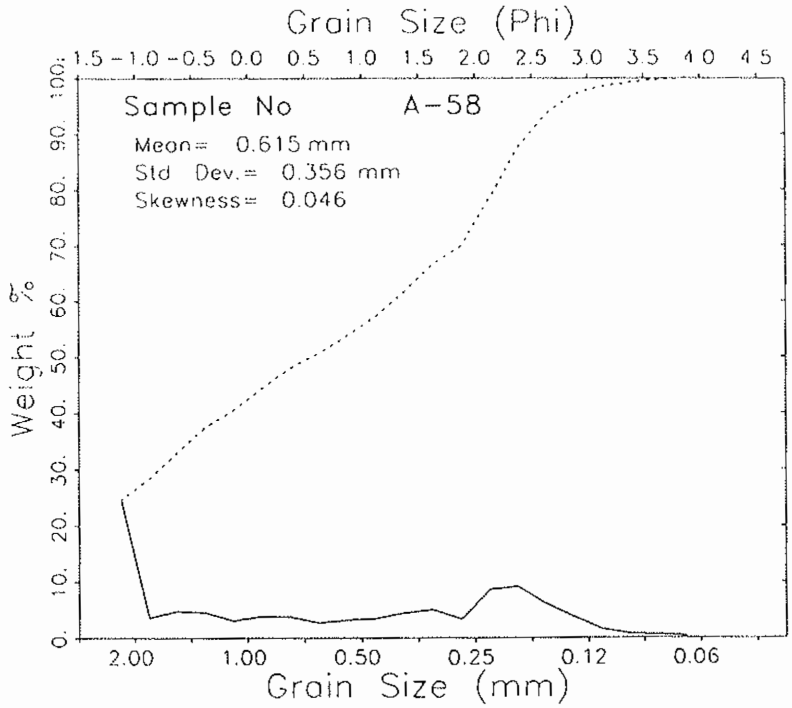
MEAN = .662 STANDARD DEVIATION = 1.560 SKEWNESS = .092 KURTOSIS = -1.549

DISPERSION = .540 STANDARD DEVIATION = .839 DEVIATION FROM NORMAL DISTR. = -46.25%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.202	-1.098	-1.012	.406	2.276	2.501	2.908	3.508

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.701	.603	COARSE SAND
STANDARD DEVIATION	1.799	1.522	POORLY SORTED
SKEWNESS(1)	.164	.191	FINE-SKEWED
SKEWNESS(2)	.248		
KURTOSIS	.142	.512	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT / CLASS LIMITS (PHI)	CUM PERCENT
A-58 Borrow A - A58	111199					
		-1.125	26.050	24.655	-1.000	24.655
		-.875	3.770	3.568	-.750	28.223
		-.625	4.970	4.704	-.500	32.926
		-.375	4.760	4.505	-.250	37.431
		-.125	3.250	3.076	.000	40.507
		.125	4.010	3.795	.250	44.302
		.375	3.920	3.710	.500	48.012
		.625	2.820	2.669	.750	50.681
		.875	3.290	3.114	1.000	53.795
		1.125	3.610	3.417	1.250	57.212
		1.375	4.640	4.391	1.500	61.603
		1.625	5.210	4.931	1.750	66.534
		1.875	3.510	3.322	2.000	69.856
		2.125	9.070	8.584	2.250	78.440
		2.375	9.580	9.067	2.500	87.507
		2.625	6.280	5.944	2.750	93.451
		2.875	3.830	3.625	3.000	97.076
		3.125	1.540	1.458	3.250	98.533
		3.375	.690	.653	3.500	99.186
		3.625	.560	.530	3.750	99.716
		3.875	.300	.284	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.660

PERCENT FINER THAN 4.00 PHI = .70 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

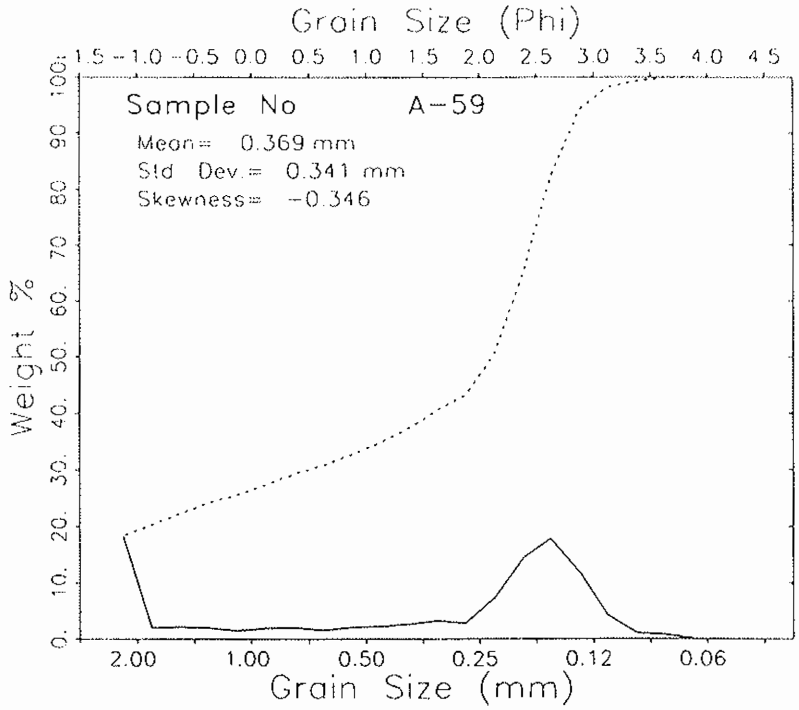
MEAN = .701 STANDARD DEVIATION = 1.491 SKEWNESS = .046 KURTOSIS = -1.484

DISPERSION = .560 STANDARD DEVIATION = .878 DEVIATION FROM NORMAL DISTR. = -41.12%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.199	-1.088	-.976	.686	2.150	2.403	2.857	3.429

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.658	.667	COARSE SAND
STANDARD DEVIATION	1.746	1.487	POORLY SORTED
SKEWNESS(1)	-.016	.027	NEAR SYMMETRICAL
SKEWNESS(2)	.082		
KURTOSIS	.162	.532	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-59	111199						
Borrow A - A59							
		-1.125	20.330	18.291	-1.000	18.291	
		-.875	2.130	1.916	-.750	20.207	
		-.625	2.290	2.060	-.500	22.267	
		-.375	2.130	1.916	-.250	24.184	
		-.125	1.510	1.359	.000	25.542	
		.125	2.000	1.799	.250	27.341	
		.375	2.110	1.898	.500	29.240	
		.625	1.650	1.484	.750	30.724	
		.875	2.170	1.952	1.000	32.677	
		1.125	2.360	2.123	1.250	34.800	
		1.375	2.880	2.591	1.500	37.391	
		1.625	3.470	3.122	1.750	40.513	
		1.875	3.010	2.708	2.000	43.221	
		2.125	7.930	7.135	2.250	50.355	
		2.375	15.780	14.197	2.500	64.552	
		2.625	19.680	17.706	2.750	82.258	
		2.875	13.210	11.885	3.000	94.143	
		3.125	4.520	4.067	3.250	98.210	
		3.375	1.100	.990	3.500	99.199	
		3.625	.800	.720	3.750	99.919	
		3.875	.090	.081	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 111.150

PERCENT FINER THAN 4.00 PHI = .44 PERCENT COARSER THAN -1.00 PHI = .00

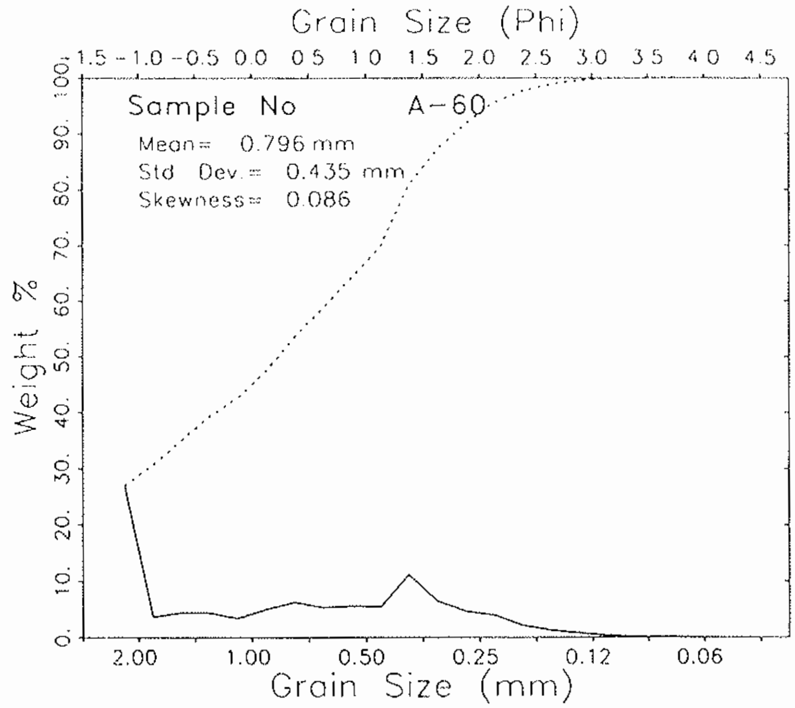
MOMENT MEASURES:

MEAN = 1.437 STANDARD DEVIATION = 1.552 SKEWNESS = -.346 KURTOSIS = -1.136
DISPERSION = .489 STANDARD DEVIATION = .746 DEVIATION FROM NORMAL DISTR. = -51.94%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.182	-1.031	-.100	2.238	2.648	2.787	3.053	3.450

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.878	1.331	MEDIUM SAND
STANDARD DEVIATION	1.909	1.596	POORLY SORTED
SKEWNESS(1)	-.712	-.664	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.682		
KURTOSIS	.109	.632	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-60	111199					
Borrow A - A60						
		-1.125	32.260	26.946	-1.000	26.946
		-.875	4.260	3.558	-.750	30.505
		-.625	5.130	4.285	-.500	34.790
		-.375	5.190	4.335	-.250	39.125
		-.125	4.000	3.341	.000	42.466
		.125	5.880	4.911	.250	47.377
		.375	7.320	6.114	.500	53.491
		.625	6.270	5.237	.750	58.729
		.875	6.550	5.471	1.000	64.200
		1.125	6.490	5.421	1.250	69.621
		1.375	13.300	11.109	1.500	80.730
		1.625	7.670	6.407	1.750	87.137
		1.875	5.420	4.527	2.000	91.664
		2.125	4.620	3.859	2.250	95.523
		2.375	2.490	2.080	2.500	97.603
		2.625	1.480	1.236	2.750	98.839
		2.875	.900	.752	3.000	99.591
		3.125	.350	.292	3.250	99.883
		3.375	.080	.067	3.500	99.950
		3.625	.060	.050	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 119.720

PERCENT FINER THAN 4.00 PHI = .03 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

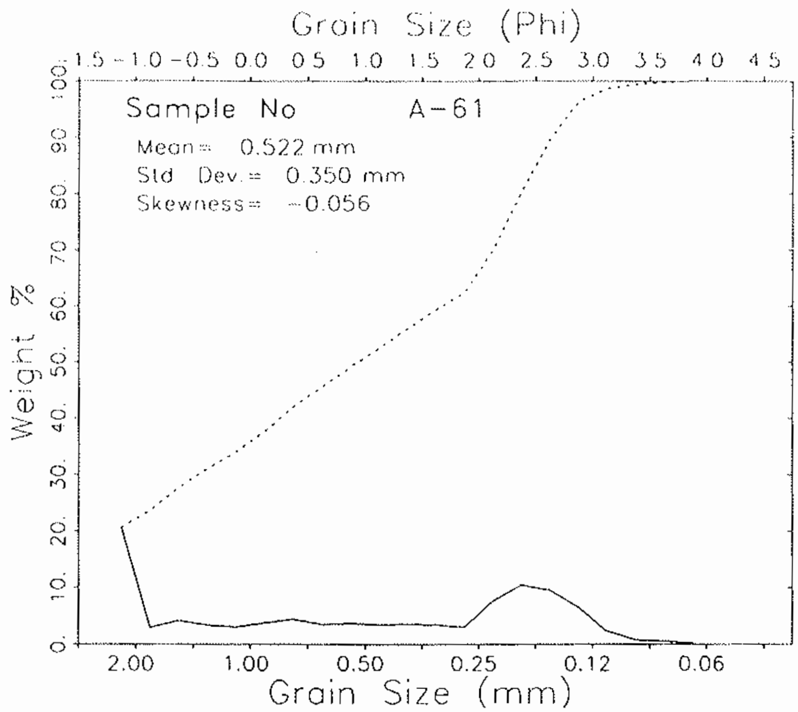
MEAN = .330 STANDARD DEVIATION = 1.201 SKEWNESS = .086 KURTOSIS = -1.250

DISPERSION = .497 STANDARD DEVIATION = .760 DEVIATION FROM NORMAL DISTR. = -36.78%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.204	-1.102	-1.018	.357	1.371	1.628	2.216	2.804

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.263	.294	COARSE SAND
STANDARD DEVIATION	1.365	1.200	POORLY SORTED
SKEWNESS(1)	-.069	.009	NEAR SYMMETRICAL
SKEWNESS(2)	.109		
KURTOSIS	.253	.587	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-61	111199						
Bogue Banks - Borrow A							
		-1.125	23.790	20.635		-1.000	20.635
		-.875	3.330	2.888		-.750	23.523
		-.625	4.730	4.103		-.500	27.626
		-.375	3.820	3.313		-.250	30.939
		-.125	3.400	2.949		.000	33.888
		.125	4.270	3.704		.250	37.592
		.375	5.100	4.424		.500	42.016
		.625	4.020	3.487		.750	45.503
		.875	4.160	3.608		1.000	49.111
		1.125	3.910	3.391		1.250	52.502
		1.375	3.980	3.452		1.500	55.955
		1.625	3.930	3.409		1.750	59.363
		1.875	3.470	3.010		2.000	62.373
		2.125	8.710	7.555		2.250	69.928
		2.375	11.960	10.374		2.500	80.302
		2.625	10.910	9.463		2.750	89.765
		2.875	7.580	6.575		3.000	96.340
		3.125	2.650	2.299		3.250	98.638
		3.375	.840	.729		3.500	99.367
		3.625	.510	.442		3.750	99.809
		3.875	.220	.191		4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.290

PERCENT FINER THAN 4.00 PHI = .71 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

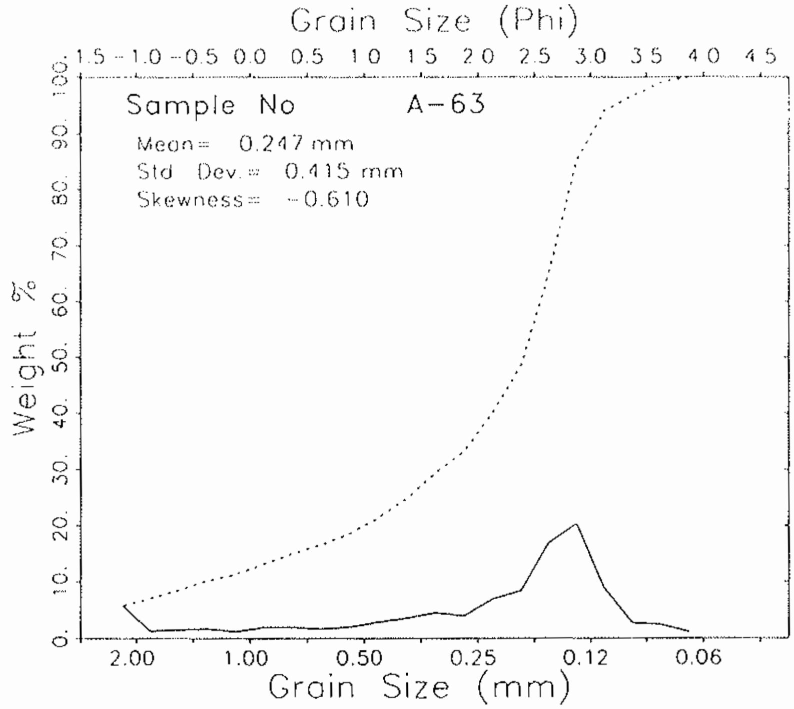
MEAN = .937 STANDARD DEVIATION = 1.515 SKEWNESS = -.056 KURTOSIS = -1.495

DISPERSION = .577 STANDARD DEVIATION = .914 DEVIATION FROM NORMAL DISTR. = -39.67%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.189	-1.056	-.660	1.066	2.372	2.598	2.949	3.374

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.771	.869	COARSE SAND
STANDARD DEVIATION	1.827	1.541	POORLY SORTED
SKEWNESS(1)	-.161	-.126	COARSE-SKEWED
SKEWNESS(2)	-.102		
KURTOSIS	.133	.559	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-63	111199						
Borrow A - A63							
		-1.125	5.920	5.713		-1.000	5.713
		-.875	1.280	1.235		-.750	6.948
		-.625	1.540	1.486		-.500	8.434
		-.375	1.710	1.650		-.250	10.084
		-.125	1.190	1.148		.000	11.232
		.125	1.920	1.853		.250	13.085
		.375	1.920	1.853		.500	14.938
		.625	1.660	1.602		.750	16.540
		.875	2.070	1.997		1.000	18.537
		1.125	2.880	2.779		1.250	21.316
		1.375	3.560	3.435		1.500	24.752
		1.625	4.630	4.468		1.750	29.219
		1.875	4.040	3.898		2.000	33.118
		2.125	7.090	6.842		2.250	39.959
		2.375	8.610	8.308		2.500	48.268
		2.625	17.380	16.771		2.750	65.039
		2.875	20.960	20.226		3.000	85.265
		3.125	9.030	8.714		3.250	93.979
		3.375	2.690	2.596		3.500	96.574
		3.625	2.470	2.383		3.750	98.958
		3.875	1.080	1.042		4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.630

PERCENT FINER THAN 4.00 PHI = 1.50 PERCENT COARSER THAN -1.00 PHI = .00

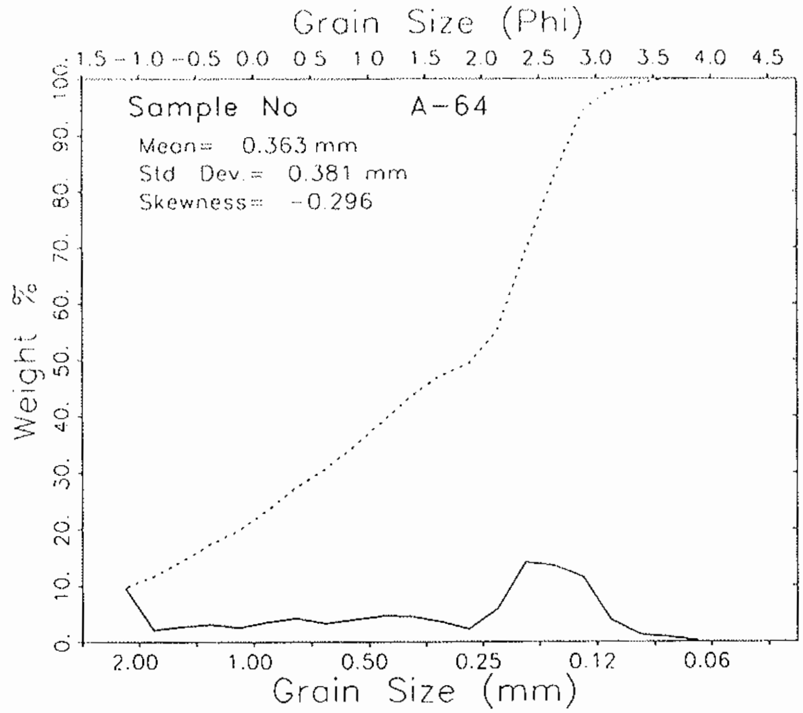
MOMENT MEASURES:

MEAN = 2.020 STANDARD DEVIATION = 1.269 SKEWNESS = -.610 KURTOSIS = .508
DISPERSION = .540 STANDARD DEVIATION = .839 DEVIATION FROM NORMAL DISTR. = -33.91%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.206	-1.031	.666	1.514	2.526	2.873	2.984	3.348	3.760

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.825	2.059	FINE SAND
STANDARD DEVIATION	1.159	1.243	POORLY SORTED
SKEWNESS(1)	-.604	-.614	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.179		
KURTOSIS	.889	1.321	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-64	111199						
Borrow A - A64							
		-1.125	9.970		9.608	-1.000	9.608
		-.875	2.120		2.043	-.750	11.651
		-.625	2.760		2.660	-.500	14.310
		-.375	3.160		3.045	-.250	17.356
		-.125	2.580		2.486	.000	19.842
		.125	3.590		3.460	.250	23.302
		.375	4.280		4.125	.500	27.426
		.625	3.310		3.190	.750	30.616
		.875	4.070		3.922	1.000	34.538
		1.125	4.720		4.549	1.250	39.086
		1.375	4.610		4.443	1.500	43.529
		1.625	3.710		3.575	1.750	47.104
		1.875	2.280		2.197	2.000	49.301
		2.125	5.920		5.705	2.250	55.006
		2.375	14.600		14.070	2.500	69.076
		2.625	13.970		13.462	2.750	82.538
		2.875	12.000		11.564	3.000	94.102
		3.125	3.940		3.797	3.250	97.899
		3.375	1.240		1.195	3.500	99.094
		3.625	.820		.790	3.750	99.884
		3.875	.120		.116	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.770

PERCENT FINER THAN 4.00 PHI = 1.28 PERCENT COARSER THAN -1.00 PHI = .00

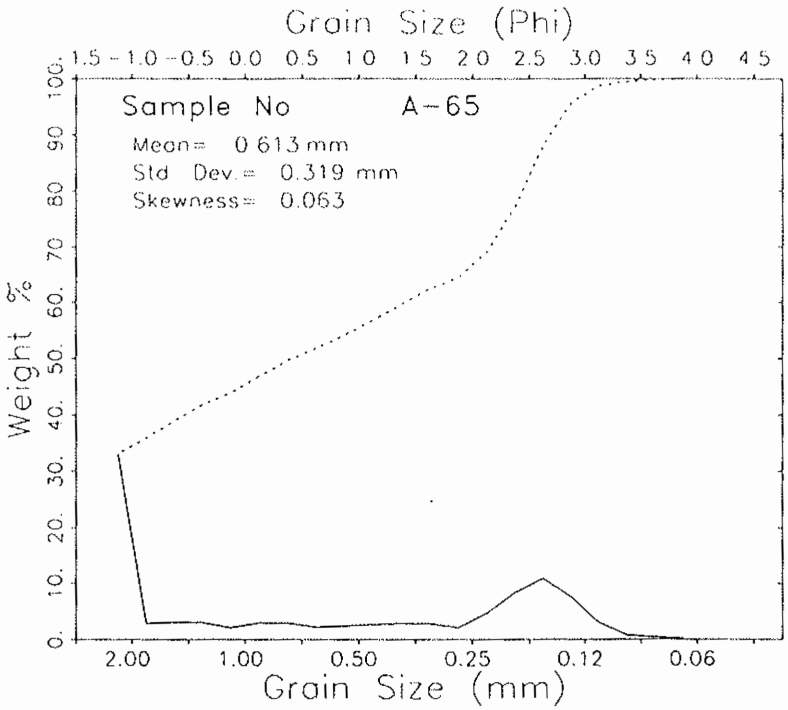
MOMENT MEASURES:

MEAN = 1.462 STANDARD DEVIATION = 1.393 SKEWNESS = -.296 KURTOSIS = -.984
DISPERSION = .591 STANDARD DEVIATION = .944 DEVIATION FROM NORMAL DISTR. = -32.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.120	-.361	.353	2.031	2.610	2.782	3.059	3.480

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.210	1.484	MEDIUM SAND
STANDARD DEVIATION	1.571	1.419	POORLY SORTED
SKEWNESS(1)	-.522	-.515	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.675		
KURTOSIS	.330	.759	PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-65 111199					
Borrow A - A65					
	-1.125	35.900	33.030	-1.000	33.030
	-.875	3.070	2.825	-.750	35.854
	-.625	3.330	3.064	-.500	38.918
	-.375	3.200	2.944	-.250	41.862
	-.125	2.220	2.043	.000	43.905
	.125	3.150	2.898	.250	46.803
	.375	3.150	2.898	.500	49.701
	.625	2.340	2.153	.750	51.854
	.875	2.550	2.346	1.000	54.200
	1.125	2.850	2.622	1.250	56.822
	1.375	3.020	2.779	1.500	59.601
	1.625	3.020	2.779	1.750	62.379
	1.875	2.260	2.079	2.000	64.459
	2.125	5.050	4.646	2.250	69.105
	2.375	8.990	8.271	2.500	77.376
	2.625	11.750	10.811	2.750	88.187
	2.875	8.170	7.517	3.000	95.703
	3.125	3.230	2.972	3.250	98.675
	3.375	.790	.727	3.500	99.402
	3.625	.460	.423	3.750	99.825
	3.875	.190	.175	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.690

PERCENT FINER THAN 4.00 PHI = .30 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

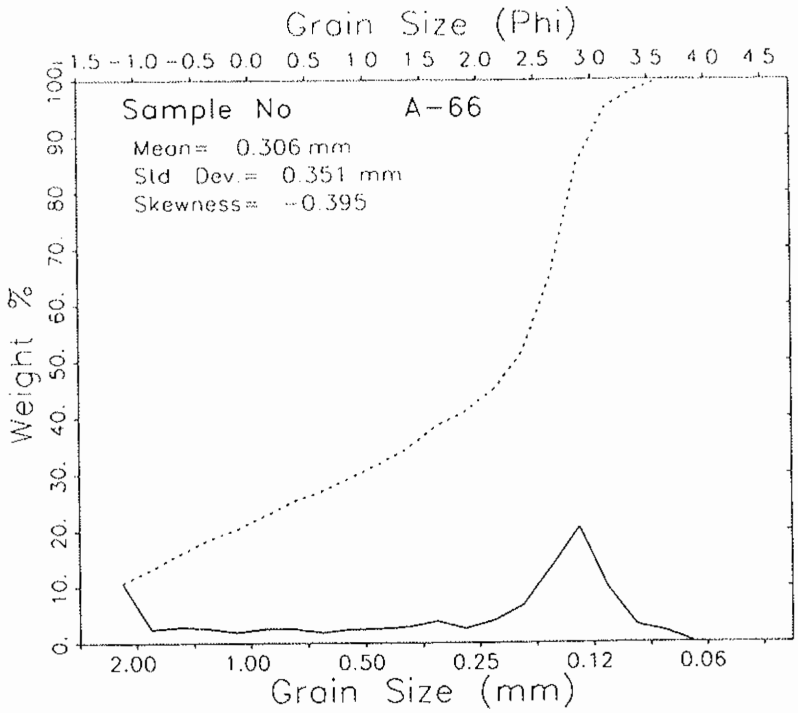
MEAN = .706 STANDARD DEVIATION = 1.649 SKEWNESS = .063 KURTOSIS = -1.656

DISPERSION = .469 STANDARD DEVIATION = .712 DEVIATION FROM NORMAL DISTR. = -56.79%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.212	-1.129	-1.061	.535	2.428	2.653	2.977	3.362

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.762	.686	COARSE SAND
STANDARD DEVIATION	1.891	1.580	POORLY SORTED
SKEWNESS(1)	.120	.143	FINE-SKEWED
SKEWNESS(2)	.184		
KURTOSIS	.108	.492	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-66	111199					
Borrow A - ATH814						
		-1.125	11.040	10.673	-1.000	10.673
		-.875	2.490	2.407	-.750	13.080
		-.625	2.890	2.794	-.500	15.874
		-.375	2.610	2.523	-.250	18.397
		-.125	1.940	1.875	.000	20.273
		.125	2.520	2.436	.250	22.709
		.375	2.550	2.465	.500	25.174
		.625	1.880	1.817	.750	26.991
		.875	2.480	2.398	1.000	29.389
		1.125	2.520	2.436	1.250	31.825
		1.375	2.880	2.784	1.500	34.609
		1.625	3.970	3.838	1.750	38.447
		1.875	2.520	2.436	2.000	40.884
		2.125	3.990	3.857	2.250	44.741
		2.375	6.770	6.545	2.500	51.286
		2.625	13.880	13.418	2.750	64.704
		2.875	21.270	20.563	3.000	85.267
		3.125	10.070	9.735	3.250	95.002
		3.375	3.140	3.036	3.500	98.038
		3.625	2.000	1.933	3.750	99.971
		3.875	.030	.029	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.440

PERCENT FINER THAN 4.00 PHI = 1.24 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

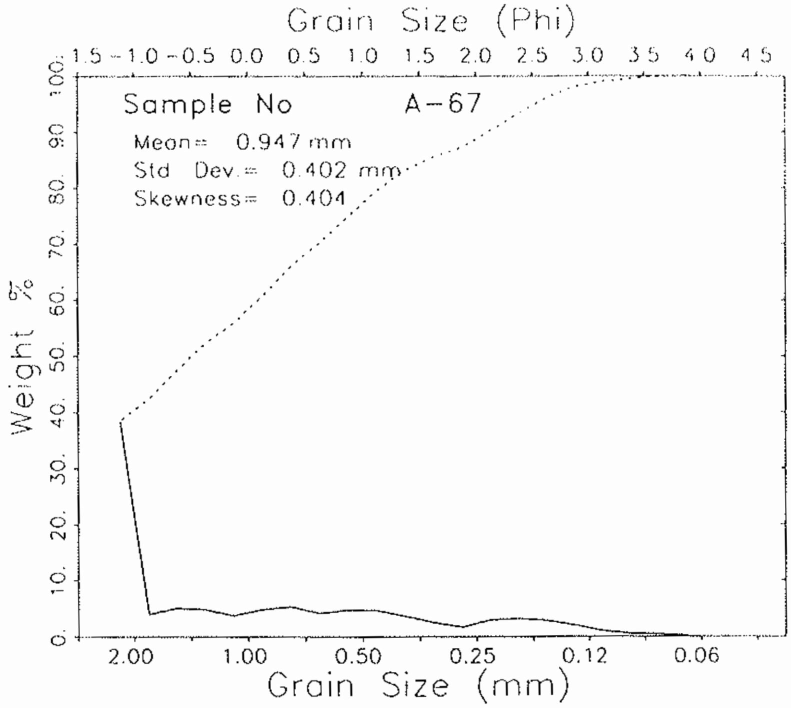
MEAN = 1.707 STANDARD DEVIATION = 1.509 SKEWNESS = -.395 KURTOSIS = -.860

DISPERSION = .551 STANDARD DEVIATION = .861 DEVIATION FROM NORMAL DISTR. = -42.92%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.133	-.488	.482	2.451	2.875	2.985	3.250	3.624

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.249	1.649	MEDIUM SAND
STANDARD DEVIATION	1.736	1.532	POORLY SORTED
SKEWNESS(1)	-.693	-.664	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.802		
KURTOSIS	.262	.751	PLATYKURTIC



SAMPLE NO. DATE

A-67 111199
Borrow A - A67

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	41.550	38.316	-1.000	38.316
-.875	4.280	3.947	-.750	42.263
-.625	5.510	5.081	-.500	47.344
-.375	5.210	4.805	-.250	52.149
-.125	4.000	3.689	.000	55.837
.125	5.210	4.805	.250	60.642
.375	5.760	5.312	.500	65.954
.625	4.520	4.168	.750	70.122
.875	5.130	4.731	1.000	74.852
1.125	5.040	4.648	1.250	79.500
1.375	3.930	3.624	1.500	83.124
1.625	2.650	2.444	1.750	85.568
1.875	1.780	1.641	2.000	87.210
2.125	3.200	2.951	2.250	90.160
2.375	3.410	3.145	2.500	93.305
2.625	3.020	2.785	2.750	96.090
2.875	2.160	1.992	3.000	98.082
3.125	1.010	.931	3.250	99.013
3.375	.480	.443	3.500	99.456
3.625	.400	.369	3.750	99.825
3.875	.190	.175	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.440

PERCENT FINER THAN 4.00 PHI = .18 PERCENT COARSER THAN -1.00 PHI = .00

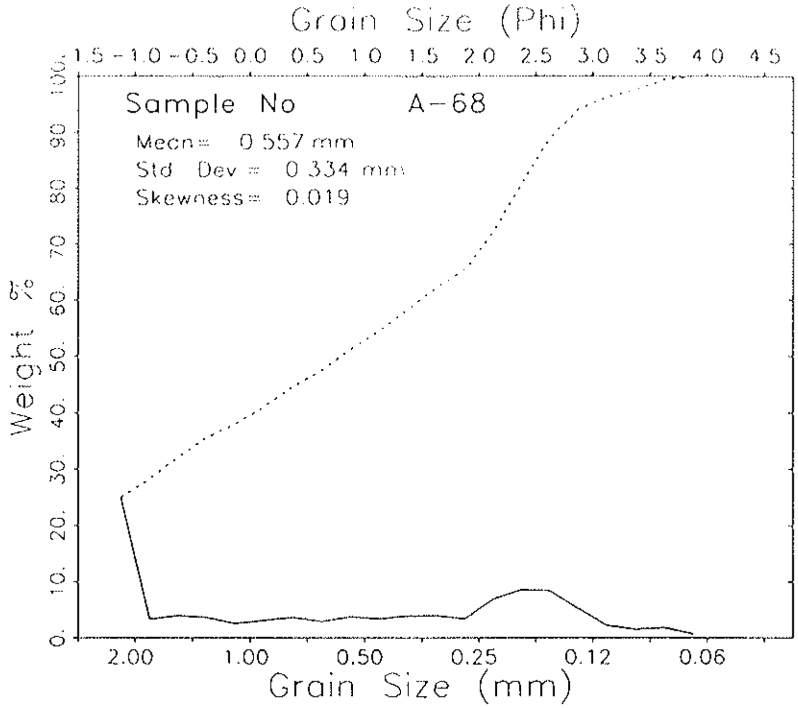
MOMENT MEASURES:

MEAN = .078 STANDARD DEVIATION = 1.315 SKEWNESS = .404 KURTOSIS = -.527
DISPERSION = .442 STANDARD DEVIATION = .669 DEVIATION FROM NORMAL DISTR. = -49.12%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.243	-1.217	-1.146	-1.087	-.362	1.008	1.590	2.652	3.246

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.222	.027	COARSE SAND
STANDARD DEVIATION	1.368	1.270	POORLY SORTED
SKEWNESS(1)	.427	.492	STRONGLY FINE-SKEWED
SKEWNESS(2)	.789		
KURTOSIS	.415	.757	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-68	111199					
Borrow A - A68						
		-1.125	25.940	24.930	-1.000	24.930
		-.875	3.370	3.239	-.750	28.169
		-.625	4.010	3.854	-.500	32.023
		-.375	3.700	3.556	-.250	35.579
		-.125	2.550	2.451	.000	38.030
		.125	3.160	3.037	.250	41.067
		.375	3.700	3.556	.500	44.623
		.625	2.960	2.845	.750	47.468
		.875	3.800	3.652	1.000	51.120
		1.125	3.440	3.306	1.250	54.426
		1.375	3.940	3.787	1.500	58.212
		1.625	4.040	3.883	1.750	62.095
		1.875	3.410	3.277	2.000	65.372
		2.125	7.070	6.795	2.250	72.167
		2.375	8.830	8.486	2.500	80.654
		2.625	8.610	8.275	2.750	88.928
		2.875	5.350	5.142	3.000	94.070
		3.125	2.210	2.124	3.250	96.194
		3.375	1.450	1.394	3.500	97.588
		3.625	1.820	1.749	3.750	99.337
		3.875	.690	.663	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.050

PERCENT FINER THAN 4.00 PHI = 1.18 PERCENT COARSER THAN -1.00 PHI = .00

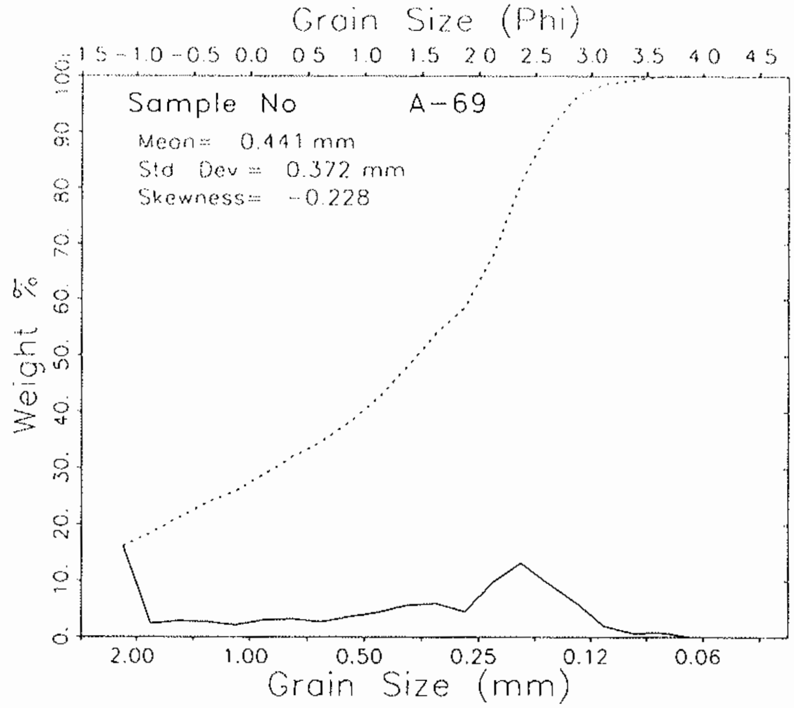
MOMENT MEASURES:

MEAN = .845 STANDARD DEVIATION = 1.581 SKEWNESS = .019 KURTOSIS = -1.481
DISPERSION = .575 STANDARD DEVIATION = .910 DEVIATION FROM NORMAL DISTR. = -42.46%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.200	-1.090	-.995	.923	2.333	2.601	3.109	3.702

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.756	.812	COARSE SAND
STANDARD DEVIATION	1.845	1.576	POORLY SORTED
SKEWNESS(1)	-.091	-.038	NEAR SYMMETRICAL
SKEWNESS(2)	.017		
KURTOSIS	.168	.531	VERY PLATYKURTIC



SAMPLE NO. DATE

A-69 111199

Borrow A - A69

MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
-1.125	18.280	16.150	-1.000	16.150
-.875	2.570	2.271	-.750	18.420
-.625	3.200	2.827	-.500	21.247
-.375	2.950	2.606	-.250	23.854
-.125	2.350	2.076	.000	25.930
.125	3.400	3.004	.250	28.934
.375	3.510	3.101	.500	32.035
.625	3.020	2.668	.750	34.703
.875	3.980	3.516	1.000	38.219
1.125	4.900	4.329	1.250	42.548
1.375	6.280	5.548	1.500	48.096
1.625	6.690	5.910	1.750	54.007
1.875	5.060	4.470	2.000	58.477
2.125	10.890	9.621	2.250	68.098
2.375	14.920	13.181	2.500	81.279
2.625	10.620	9.382	2.750	90.662
2.875	6.780	5.990	3.000	96.652
3.125	2.180	1.926	3.250	98.578
3.375	.730	.645	3.500	99.223
3.625	.800	.707	3.750	99.929
3.875	.080	.071	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.190

PERCENT FINER THAN 4.00 PHI = 1.04 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

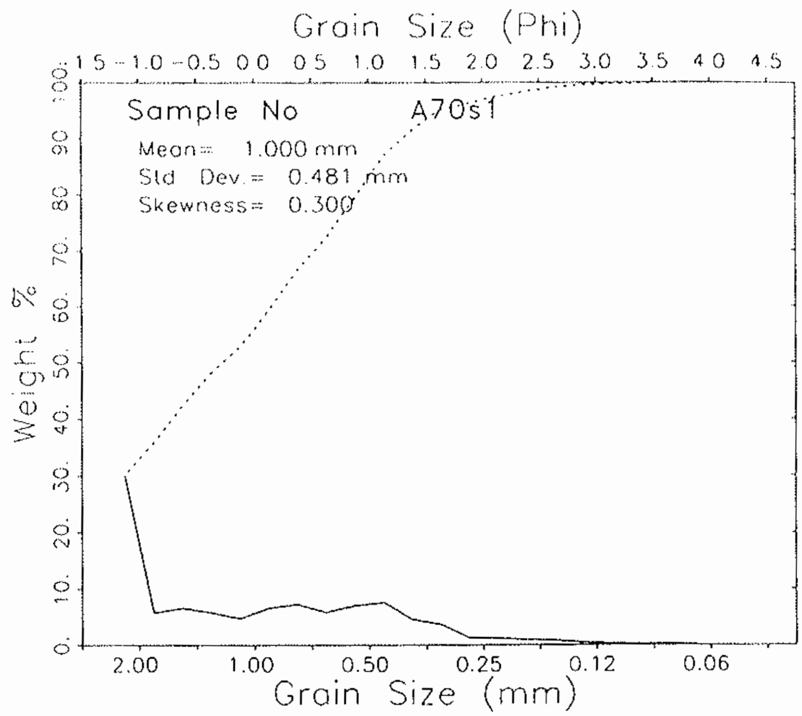
MEAN = 1.182 STANDARD DEVIATION = 1.428 SKEWNESS = -.228 KURTOSIS = -1.190

DISPERSION = .578 STANDARD DEVIATION = .917 DEVIATION FROM NORMAL DISTR. = -35.79%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.173	-1.002	-.112	1.581	2.381	2.572	2.931	3.414

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.705	1.050	MEDIUM SAND
STANDARD DEVIATION	1.787	1.515	POORLY SORTED
SKEWNESS(1)	-.445	-.393	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.392		
KURTOSIS	.148	.675	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A70s1	111199					
Bogue Banks - Borrow A						
		-1.125	30.670	30.101	-1.000	30.101
		-.875	5.790	5.683	-.750	35.784
		-.625	6.660	6.536	-.500	42.320
		-.375	5.850	5.741	-.250	48.062
		-.125	4.820	4.731	.000	52.792
		.125	6.680	6.556	.250	59.348
		.375	7.320	7.184	.500	66.533
		.625	5.910	5.800	.750	72.333
		.875	7.090	6.958	1.000	79.291
		1.125	7.690	7.547	1.250	86.839
		1.375	4.660	4.574	1.500	91.412
		1.625	3.690	3.622	1.750	95.034
		1.875	1.230	1.207	2.000	96.241
		2.125	1.200	1.178	2.250	97.419
		2.375	.870	.854	2.500	98.273
		2.625	.850	.834	2.750	99.107
		2.875	.430	.422	3.000	99.529
		3.125	.190	.186	3.250	99.715
		3.375	.110	.108	3.500	99.823
		3.625	.120	.118	3.750	99.941
		3.875	.060	.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.890

PERCENT FINER THAN 4.00 PHI = .33 PERCENT COARSER THAN -1.00 PHI = .00

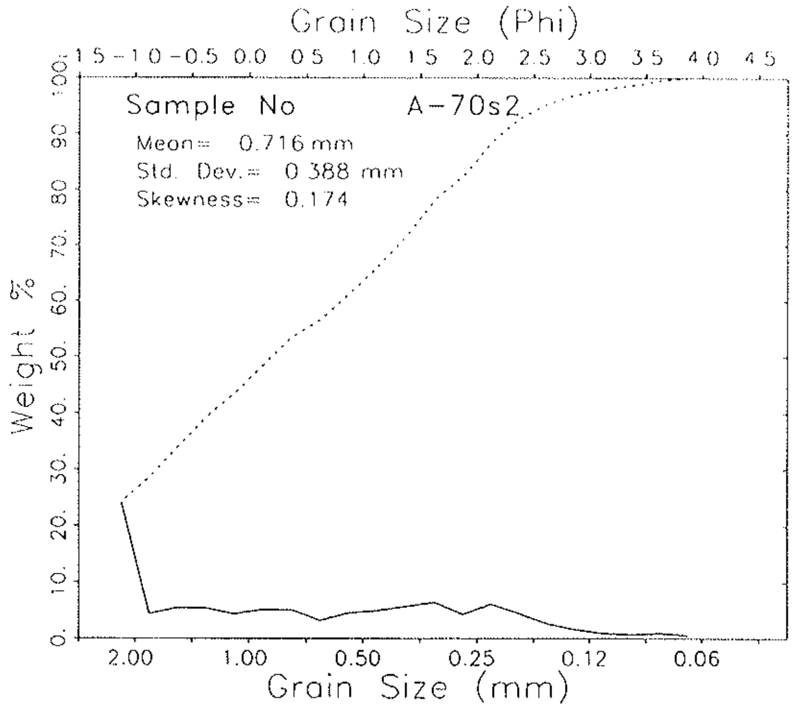
MOMENT MEASURES:

MEAN = .000 STANDARD DEVIATION = 1.056 SKEWNESS = .300 KURTOSIS = -.493
DISPERSION = .452 STANDARD DEVIATION = .685 DEVIATION FROM NORMAL DISTR. = -35.14%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.208	-1.117	-1.042	-.148	.846	1.156	1.748	2.718

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.019	-.036	VERY COARSE SAND
STANDARD DEVIATION	1.137	1.016	POORLY SORTED
SKEWNESS(1)	.147	.215	FINE-SKEWED
SKEWNESS(2)	.367		
KURTOSIS	.300	.642	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-70s2	111199					
Bogue Banks - Borrow A						
		-1.125	11.030	24.242	-1.000	24.242
		-.875	1.960	4.308	-.750	28.549
		-.625	2.440	5.363	-.500	33.912
		-.375	2.420	5.319	-.250	39.231
		-.125	1.950	4.286	.000	43.516
		.125	2.310	5.077	.250	48.593
		.375	2.260	4.967	.500	53.560
		.625	1.440	3.165	.750	56.725
		.875	2.050	4.505	1.000	61.231
		1.125	2.210	4.857	1.250	66.088
		1.375	2.570	5.648	1.500	71.736
		1.625	2.920	6.418	1.750	78.154
		1.875	1.930	4.242	2.000	82.396
		2.125	2.760	6.066	2.250	88.462
		2.375	1.990	4.374	2.500	92.835
		2.625	1.180	2.593	2.750	95.429
		2.875	.720	1.582	3.000	97.011
		3.125	.420	.923	3.250	97.934
		3.375	.290	.637	3.500	98.571
		3.625	.420	.923	3.750	99.495
		3.875	.230	.505	4.000	100.000

TOTAL WEIGHT (GRAMS) = 45.500

PERCENT FINER THAN 4.00 PHI = 1.11 PERCENT COARSER THAN -1.00 PHI = .00

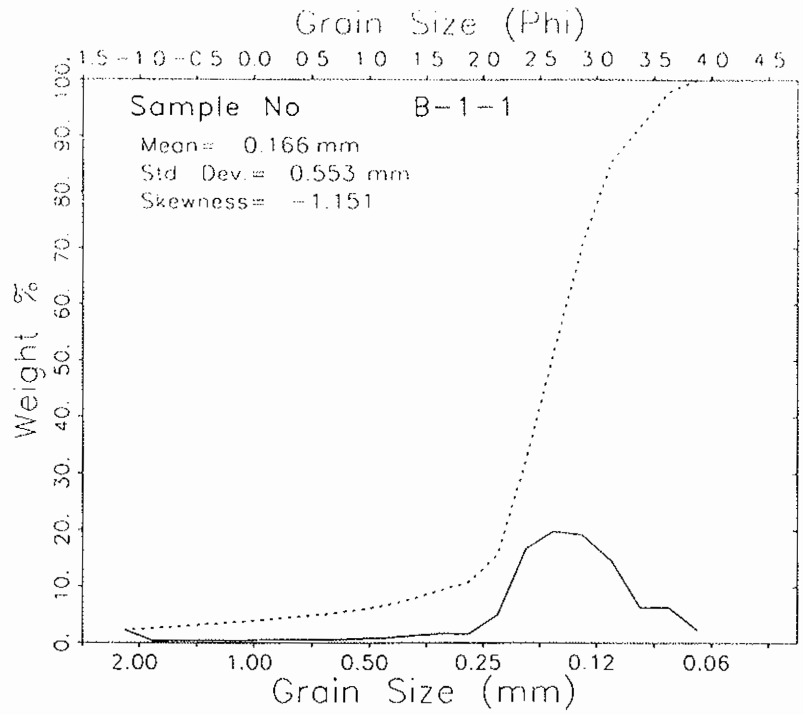
MOMENT MEASURES:

MEAN = .481 STANDARD DEVIATION = 1.367 SKEWNESS = .174 KURTOSIS = -1.073
DISPERSION = .574 STANDARD DEVIATION = .908 DEVIATION FROM NORMAL DISTR. = -33.60%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.198	-1.085	-.956	.321	1.627	2.066	2.709	3.616

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.491	.434	COARSE SAND
STANDARD DEVIATION	1.576	1.380	POORLY SORTED
SKEWNESS(1)	.108	.165	FINE-SKEWED
SKEWNESS(2)	.276		
KURTOSIS	.240	.620	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-1-1	111199					
Borrow B1 - 01						
		-1.125	2.500	2.202	-1.000	2.202
		-.875	.370	.326	-.750	2.528
		-.625	.400	.352	-.500	2.880
		-.375	.420	.370	-.250	3.250
		-.125	.390	.344	.000	3.594
		.125	.500	.440	.250	4.034
		.375	.530	.467	.500	4.501
		.625	.560	.493	.750	4.994
		.875	.710	.625	1.000	5.620
		1.125	.950	.837	1.250	6.456
		1.375	1.370	1.207	1.500	7.663
		1.625	1.780	1.568	1.750	9.231
		1.875	1.660	1.462	2.000	10.693
		2.125	5.410	4.765	2.250	15.458
		2.375	18.820	16.577	2.500	32.036
		2.625	22.290	19.634	2.750	51.669
		2.875	21.670	19.087	3.000	70.757
		3.125	16.630	14.648	3.250	85.405
		3.375	6.990	6.157	3.500	91.562
		3.625	7.080	6.236	3.750	97.798
		3.875	2.500	2.202	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.530

PERCENT FINER THAN 4.00 PHI = 2.31 PERCENT COARSER THAN -1.00 PHI = .00

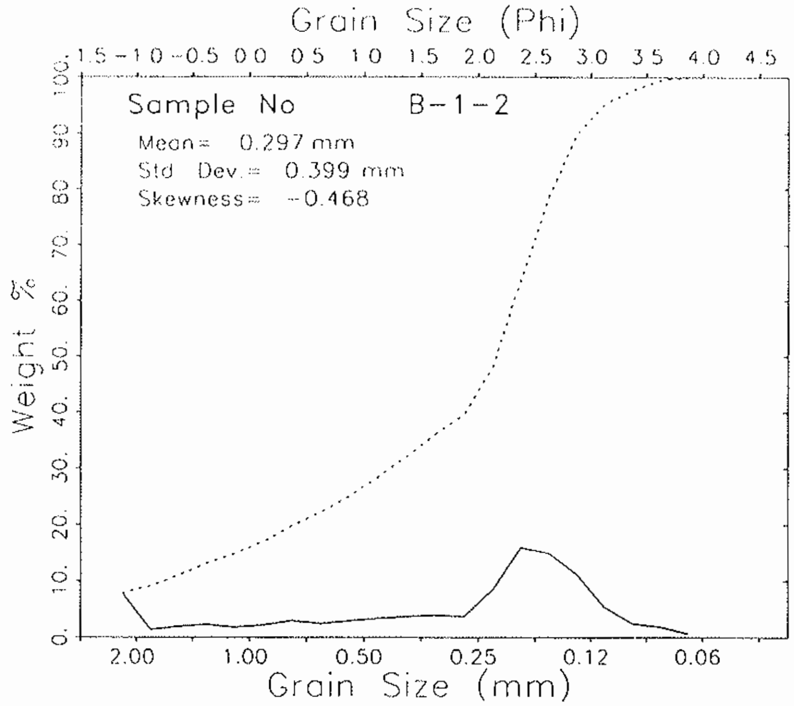
MOMENT MEASURES:

MEAN = 2.594 STANDARD DEVIATION = .894 SKEWNESS = -1.151 KURTOSIS = 6.706
DISPERSION = .388 STANDARD DEVIATION = .591 DEVIATION FROM NORMAL DISTR. = -33.92%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.136	.752	2.250	2.394	2.729	3.072	3.226	3.638	3.886

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.742	2.738	FINE SAND
STANDARD DEVIATION	.484	.679	MODERATELY WELL SORTED
SKEWNESS(1)	.028	-.171	COARSE-SKEWED
SKEWNESS(2)	-1.103		
KURTOSIS	1.981	1.743	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-1-2	111199						
Borrow B1 - 2							
		-1.125	8.010	7.762		-1.000	7.762
		-.875	1.330	1.289		-.750	9.051
		-.625	1.910	1.851		-.500	10.902
		-.375	2.270	2.200		-.250	13.102
		-.125	1.790	1.735		.000	14.837
		.125	2.200	2.132		.250	16.969
		.375	2.940	2.849		.500	19.818
		.625	2.460	2.384		.750	22.202
		.875	2.970	2.878		1.000	25.080
		1.125	3.430	3.324		1.250	28.404
		1.375	3.770	3.653		1.500	32.057
		1.625	4.030	3.905		1.750	35.963
		1.875	3.750	3.634		2.000	39.597
		2.125	8.670	8.402		2.250	47.999
		2.375	16.370	15.864		2.500	63.863
		2.625	15.410	14.934		2.750	78.796
		2.875	11.480	11.125		3.000	89.922
		3.125	5.500	5.330		3.250	95.251
		3.375	2.460	2.384		3.500	97.635
		3.625	1.880	1.822		3.750	99.457
		3.875	.560	.543		4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.190

PERCENT FINER THAN 4.00 PHI = 1.30 PERCENT COARSER THAN -1.00 PHI = .00

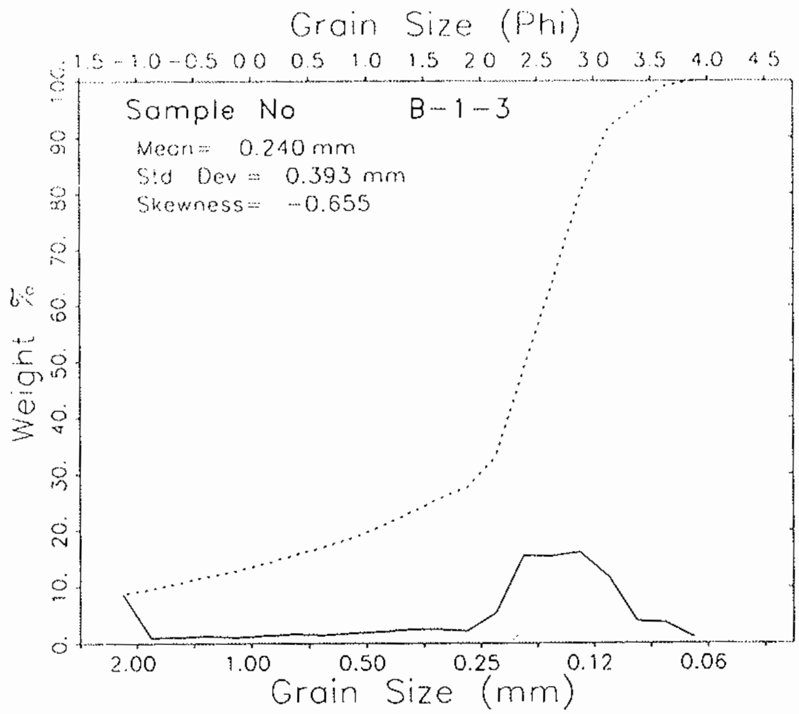
MOMENT MEASURES:

MEAN = 1.753 STANDARD DEVIATION = 1.326 SKEWNESS = -.468 KURTOSIS = -.252
DISPERSION = .576 STANDARD DEVIATION = .912 DEVIATION FROM NORMAL DISTR. = -31.19%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.089	.136	.993	2.282	2.686	2.867	3.238	3.687

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.502	1.762	MEDIUM SAND
STANDARD DEVIATION	1.365	1.338	POORLY SORTED
SKEWNESS(1)	-.571	-.565	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.884		
KURTOSIS	.585	1.047	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
B-1-3 Borrow 81 - 3	111199					
		-1.125	9.930	8.654	-1.000	8.654
		-.875	1.010	.880	-.750	9.535
		-.625	1.240	1.081	-.500	10.615
		-.375	1.400	1.220	-.250	11.835
		-.125	1.150	1.002	.000	12.838
		.125	1.480	1.290	.250	14.128
		.375	1.760	1.534	.500	15.661
		.625	1.560	1.360	.750	17.021
		.875	1.930	1.682	1.000	18.703
		1.125	2.270	1.978	1.250	20.682
		1.375	2.760	2.405	1.500	23.087
		1.625	2.760	2.405	1.750	25.492
		1.875	2.460	2.144	2.000	27.636
		2.125	6.010	5.238	2.250	32.874
		2.375	17.730	15.452	2.500	48.327
		2.625	17.670	15.400	2.750	63.727
		2.875	18.380	16.019	3.000	79.746
		3.125	13.580	11.835	3.250	91.581
		3.375	4.470	3.896	3.500	95.477
		3.625	4.120	3.591	3.750	99.067
		3.875	1.070	.933	4.000	100.000

TOTAL WEIGHT (GRAMS) = 114.740

PERCENT FINER THAN 4.00 PHI = .87 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

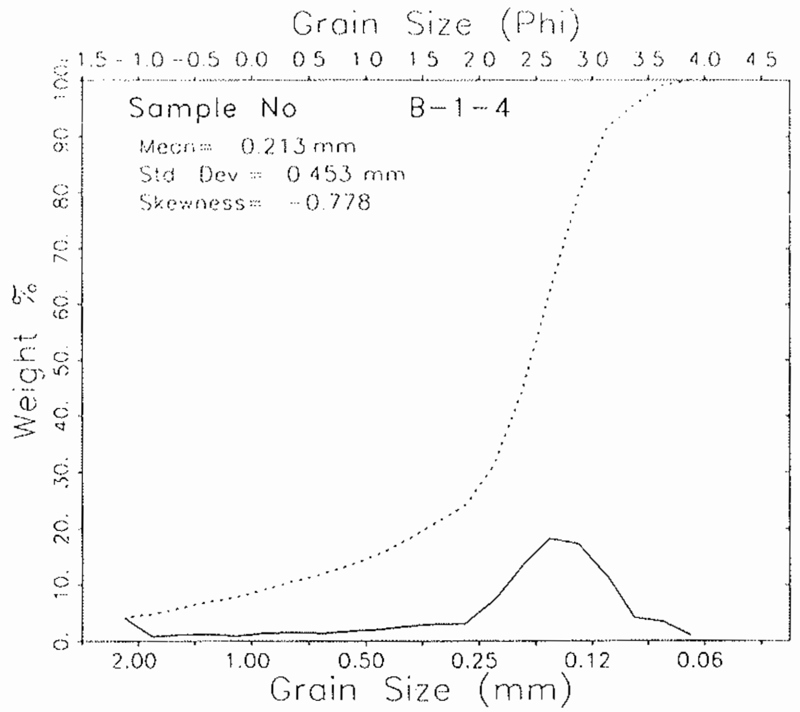
MEAN = 2.058 STANDARD DEVIATION = 1.349 SKEWNESS = -.655 KURTOSIS = .574

DISPERSION = .508 STANDARD DEVIATION = .779 DEVIATION FROM NORMAL DISTR. = -42.27%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.221	-1.106	.562	1.699	2.527	2.926	3.090	3.469	3.745

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.826	2.060	FINE SAND
STANDARD DEVIATION	1.264	1.325	POORLY SORTED
SKEWNESS(1)	-.555	-.571	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.064		
KURTOSIS	.810	1.528	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-1-4 Borrow B1 - 4	111199						
		-1.125	4.690	4.068	-1.000	4.068	
		-.875	.810	.703	-.750	4.771	
		-.625	1.210	1.050	-.500	5.821	
		-.375	1.290	1.119	-.250	6.940	
		-.125	.940	.815	.000	7.755	
		.125	1.560	1.353	.250	9.108	
		.375	1.690	1.466	.500	10.574	
		.625	1.510	1.310	.750	11.884	
		.875	1.950	1.692	1.000	13.576	
		1.125	2.240	1.943	1.250	15.519	
		1.375	2.920	2.533	1.500	18.052	
		1.625	3.460	3.001	1.750	21.053	
		1.875	3.420	2.967	2.000	24.020	
		2.125	8.230	7.139	2.250	31.159	
		2.375	15.210	13.194	2.500	44.353	
		2.625	20.940	18.164	2.750	62.517	
		2.875	19.840	17.210	3.000	79.728	
		3.125	13.550	11.754	3.250	91.482	
		3.375	4.720	4.094	3.500	95.576	
		3.625	3.950	3.426	3.750	99.002	
		3.875	1.150	.998	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 115.280

PERCENT FINER THAN 4.00 PHI = 1.30 PERCENT COARSER THAN -1.00 PHI = .00

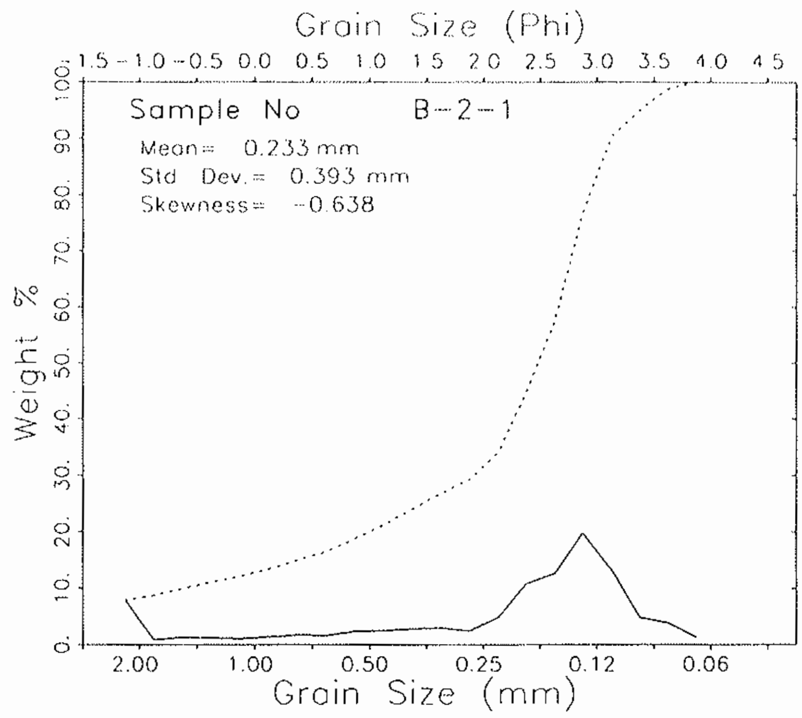
MOMENT MEASURES:

MEAN = 2.233 STANDARD DEVIATION = 1.144 SKEWNESS = -.778 KURTOSIS = 1.845
DISPERSION = .501 STANDARD DEVIATION = .767 DEVIATION FROM NORMAL DISTR. = -32.97%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.189	-.695	1.298	2.034	2.578	2.931	3.091	3.465	3.750

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.194	2.322	FINE SAND
STANDARD DEVIATION	.897	1.079	POORLY SORTED
SKEWNESS(1)	-.428	-.501	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.330		
KURTOSIS	1.320	1.901	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-1	111199					
Bogue Banks - Borrow 82						
		-1.125	7.920	7.827	-1.000	7.827
		-.875	.800	.791	-.750	8.617
		-.625	1.250	1.235	-.500	9.853
		-.375	1.190	1.176	-.250	11.029
		-.125	.980	.968	.000	11.997
		.125	1.320	1.304	.250	13.302
		.375	1.660	1.640	.500	14.942
		.625	1.530	1.512	.750	16.454
		.875	2.350	2.322	1.000	18.777
		1.125	2.410	2.382	1.250	21.158
		1.375	2.770	2.737	1.500	23.896
		1.625	2.940	2.905	1.750	26.801
		1.875	2.420	2.392	2.000	29.193
		2.125	4.810	4.753	2.250	33.946
		2.375	10.870	10.742	2.500	44.688
		2.625	12.650	12.501	2.750	57.189
		2.875	19.950	19.715	3.000	76.905
		3.125	13.490	13.331	3.250	90.236
		3.375	4.810	4.753	3.500	94.990
		3.625	3.810	3.765	3.750	98.755
		3.875	1.260	1.245	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.190

PERCENT FINER THAN 4.00 PHI = .07 PERCENT COARSER THAN -1.00 PHI = .00

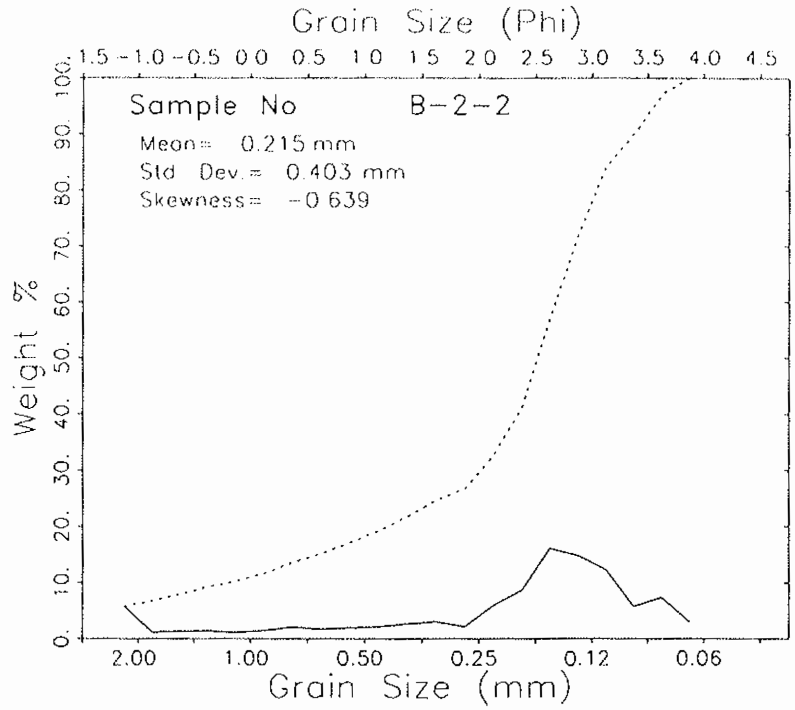
MOMENT MEASURES:

MEAN = 2.099 STANDARD DEVIATION = 1.347 SKEWNESS = -.638 KURTOSIS = .531
DISPERSION = .527 STANDARD DEVIATION = .814 DEVIATION FROM NORMAL DISTR. = -39.54%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.090	.675	1.595	2.606	2.976	3.133	3.501	3.799

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.904	2.138	FINE SAND
STANDARD DEVIATION	1.229	1.310	POORLY SORTED
SKEWNESS(1)	-.571	-.591	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.140		
KURTOSIS	.868	1.363	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-2 Borrow 82 - 2	111199					
		-1.125	5.840	5.627	-1.000	5.627
		-.875	1.080	1.041	-.750	6.668
		-.625	1.240	1.195	-.500	7.863
		-.375	1.360	1.310	-.250	9.173
		-.125	1.080	1.041	.000	10.214
		.125	1.470	1.416	.250	11.630
		.375	2.030	1.956	.500	13.586
		.625	1.680	1.619	.750	15.205
		.875	1.990	1.918	1.000	17.123
		1.125	2.170	2.091	1.250	19.214
		1.375	2.620	2.525	1.500	21.738
		1.625	3.050	2.939	1.750	24.677
		1.875	2.120	2.043	2.000	26.720
		2.125	6.050	5.830	2.250	32.550
		2.375	8.880	8.557	2.500	41.106
		2.625	16.670	16.063	2.750	57.169
		2.875	15.360	14.801	3.000	71.970
		3.125	12.740	12.276	3.250	84.246
		3.375	5.890	5.675	3.500	89.921
		3.625	7.460	7.188	3.750	97.109
		3.875	3.000	2.891	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.780

PERCENT FINER THAN 4.00 PHI = 3.08 PERCENT COARSER THAN -1.00 PHI = .00

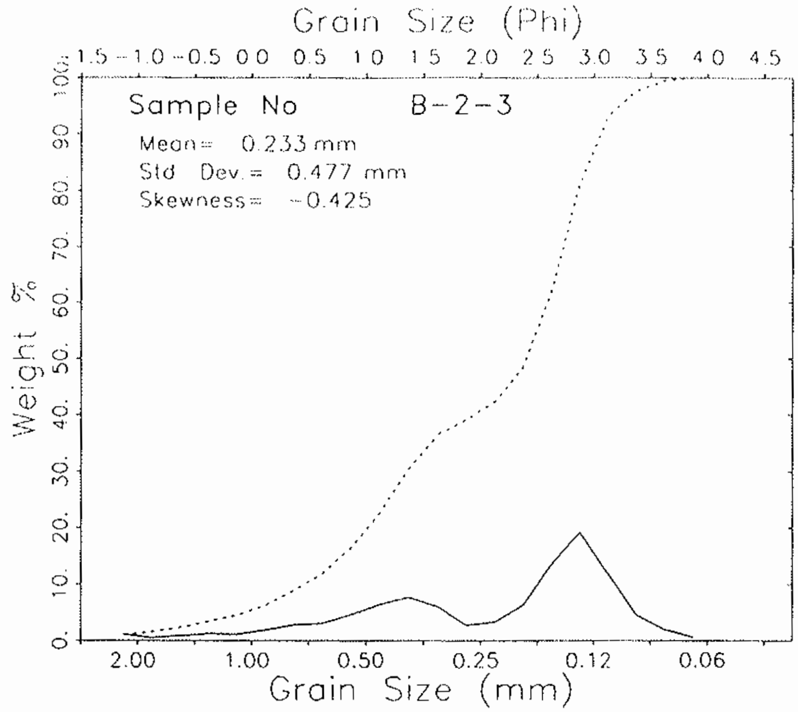
MOMENT MEASURES:

MEAN = 2.216 STANDARD DEVIATION = 1.312 SKEWNESS = -.639 KURTOSIS = .735
DISPERSION = .557 STANDARD DEVIATION = .872 DEVIATION FROM NORMAL DISTR. = -33.57%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.206	-1.028	.854	1.790	2.638	3.062	3.245	3.677	3.914

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.049	2.246	FINE SAND
STANDARD DEVIATION	1.196	1.311	POORLY SORTED
SKEWNESS(1)	-.493	-.526	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.099		
KURTOSIS	.967	1.516	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-3 Borrow B2 - 3	111199					
		-1.125	1.140	1.025	-1.000	1.025
		-.875	.480	.432	-.750	1.456
		-.625	.900	.809	-.500	2.266
		-.375	1.220	1.097	-.250	3.362
		-.125	1.180	1.061	.000	4.423
		.125	1.980	1.780	.250	6.203
		.375	3.050	2.742	.500	8.945
		.625	3.350	3.012	.750	11.957
		.875	5.070	4.558	1.000	16.515
		1.125	7.070	6.356	1.250	22.872
		1.375	8.520	7.660	1.500	30.531
		1.625	6.660	5.988	1.750	36.519
		1.875	2.900	2.607	2.000	39.126
		2.125	3.590	3.228	2.250	42.354
		2.375	6.910	6.212	2.500	48.566
		2.625	15.000	13.486	2.750	62.052
		2.875	21.310	19.158	3.000	81.210
		3.125	13.270	11.930	3.250	93.140
		3.375	4.990	4.486	3.500	97.627
		3.625	2.060	1.852	3.750	99.479
		3.875	.580	.521	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.230

PERCENT FINER THAN 4.00 PHI = .30 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

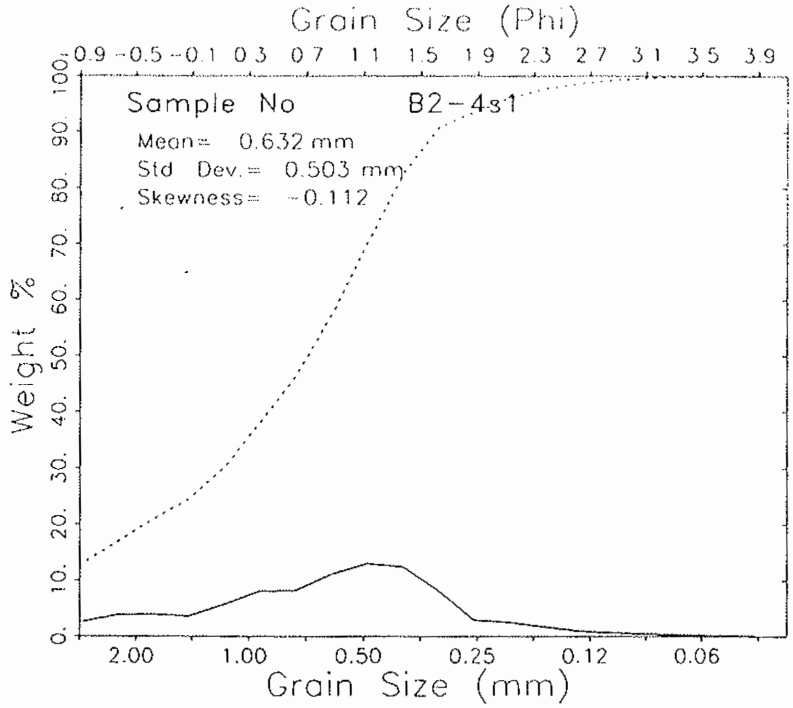
MEAN = 2.101 STANDARD DEVIATION = 1.068 SKEWNESS = -.425 KURTOSIS = -.005

DISPERSION = .537 STANDARD DEVIATION = .834 DEVIATION FROM NORMAL DISTR. = -21.88%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.006	.081	.972	1.319	2.527	2.919	3.058	3.354	3.685

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.015	2.186	FINE SAND
STANDARD DEVIATION	1.043	1.018	POORLY SORTED
SKEWNESS(1)	-.490	-.492	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.776		
KURTOSIS	.568	.839	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-4	111199						
Borrow B2 - 4 S1 ToP							
		-1.125	11.400	10.570		-1.000	10.570
		-.875	2.770	2.568		-.750	13.139
		-.625	4.090	3.792		-.500	16.931
		-.375	4.230	3.922		-.250	20.853
		-.125	3.820	3.542		.000	24.395
		.125	6.050	5.610		.250	30.005
		.375	8.680	8.048		.500	38.053
		.625	8.780	8.141		.750	46.194
		.875	11.950	11.080		1.000	57.274
		1.125	13.960	12.944		1.250	70.218
		1.375	13.330	12.360		1.500	82.578
		1.625	8.780	8.141		1.750	90.719
		1.875	3.070	2.847		2.000	93.565
		2.125	2.680	2.485		2.250	96.050
		2.375	1.790	1.660		2.500	97.710
		2.625	.940	.872		2.750	98.581
		2.875	.660	.612		3.000	99.193
		3.125	.430	.399		3.250	99.592
		3.375	.260	.241		3.500	99.833
		3.625	.140	.130		3.750	99.963
		3.875	.040	.037		4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.850

PERCENT FINER THAN 4.00 PHI = .04 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

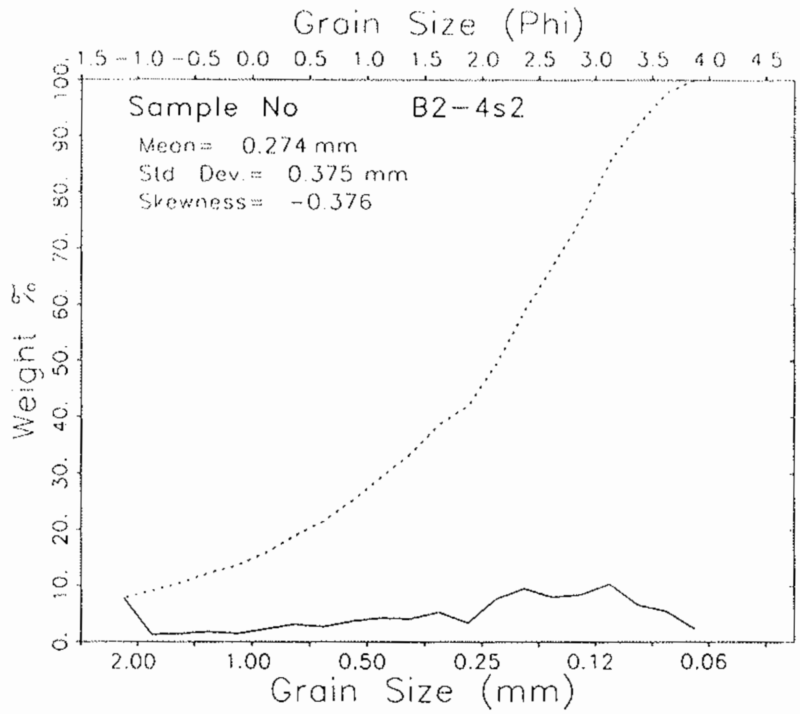
MEAN = .661 STANDARD DEVIATION = .992 SKEWNESS = -.112 KURTOSIS = -.407

DISPERSION = .537 STANDARD DEVIATION = .833 DEVIATION FROM NORMAL DISTR. = -16.02%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.226	-1.132	-.561	.027	.836	1.347	1.544	2.144	2.921

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.491	.606	COARSE SAND
STANDARD DEVIATION	1.053	1.023	POORLY SORTED
SKEWNESS(1)	-.328	-.264	COARSE-SKEWED
SKEWNESS(2)	-.313		
KURTOSIS	.556	1.017	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-4s	111199						
Borrow B2 - 4s2 Bottom							
		-1.125	8.260	7.793		-1.000	7.793
		-.875	1.300	1.227		-.750	9.020
		-.625	1.510	1.425		-.500	10.444
		-.375	1.850	1.745		-.250	12.190
		-.125	1.480	1.396		.000	13.586
		.125	2.360	2.227		.250	15.813
		.375	3.230	3.047		.500	18.860
		.625	2.800	2.642		.750	21.502
		.875	3.860	3.642		1.000	25.144
		1.125	4.440	4.189		1.250	29.333
		1.375	4.270	4.029		1.500	33.362
		1.625	5.540	5.227		1.750	38.589
		1.875	3.490	3.293		2.000	41.881
		2.125	8.080	7.623		2.250	49.505
		2.375	10.000	9.435		2.500	58.940
		2.625	8.480	8.001		2.750	66.940
		2.875	8.890	8.388		3.000	75.328
		3.125	10.880	10.265		3.250	85.593
		3.375	6.980	6.586		3.500	92.179
		3.625	5.820	5.491		3.750	97.670
		3.875	2.470	2.330		4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.990

PERCENT FINER THAN 4.00 PHI = 2.84 PERCENT COARSER THAN -1.00 PHI = .00

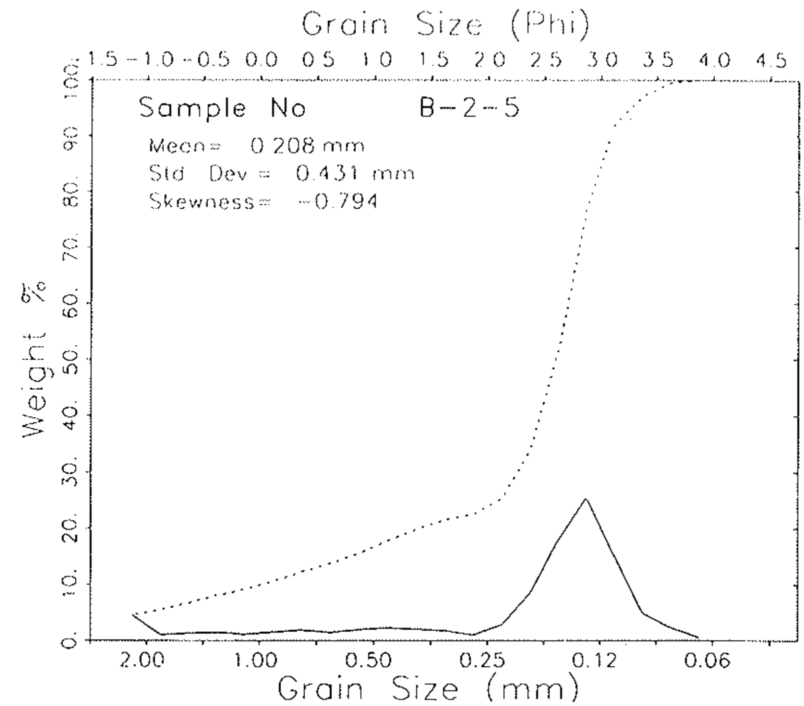
MOMENT MEASURES:

MEAN = 1.866 STANDARD DEVIATION = 1.416 SKEWNESS = -.376 KURTOSIS = -.458
DISPERSION = .644 STANDARD DEVIATION = 1.066 DEVIATION FROM NORMAL DISTR. = -24.74%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.090	.265	.990	2.263	2.990	3.211	3.628	3.893

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.738	1.913	MEDIUM SAND
STANDARD DEVIATION	1.473	1.451	POORLY SORTED
SKEWNESS(1)	-.356	-.389	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.675		
KURTOSIS	.602	.967	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-5	111199					
Borrow B2 - 5						
		-1.125	4.720	4.427	-1.000	4.427
		-.875	1.050	.985	-.750	5.412
		-.625	1.290	1.210	-.500	6.622
		-.375	1.500	1.407	-.250	8.029
		-.125	1.150	1.079	.000	9.108
		.125	1.570	1.473	.250	10.581
		.375	1.880	1.763	.500	12.344
		.625	1.520	1.426	.750	13.770
		.875	1.970	1.848	1.000	15.618
		1.125	2.380	2.232	1.250	17.850
		1.375	2.110	1.979	1.500	19.829
		1.625	1.870	1.754	1.750	21.583
		1.875	1.050	.985	2.000	22.568
		2.125	2.930	2.748	2.250	25.317
		2.375	9.010	8.451	2.500	33.768
		2.625	19.070	17.888	2.750	51.656
		2.875	27.130	25.448	3.000	77.103
		3.125	16.110	15.111	3.250	92.215
		3.375	5.180	4.859	3.500	97.073
		3.625	2.490	2.336	3.750	99.409
		3.875	.630	.591	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.610

PERCENT FINER THAN 4.00 PHI = .53 PERCENT COARSER THAN -1.00 PHI = .00

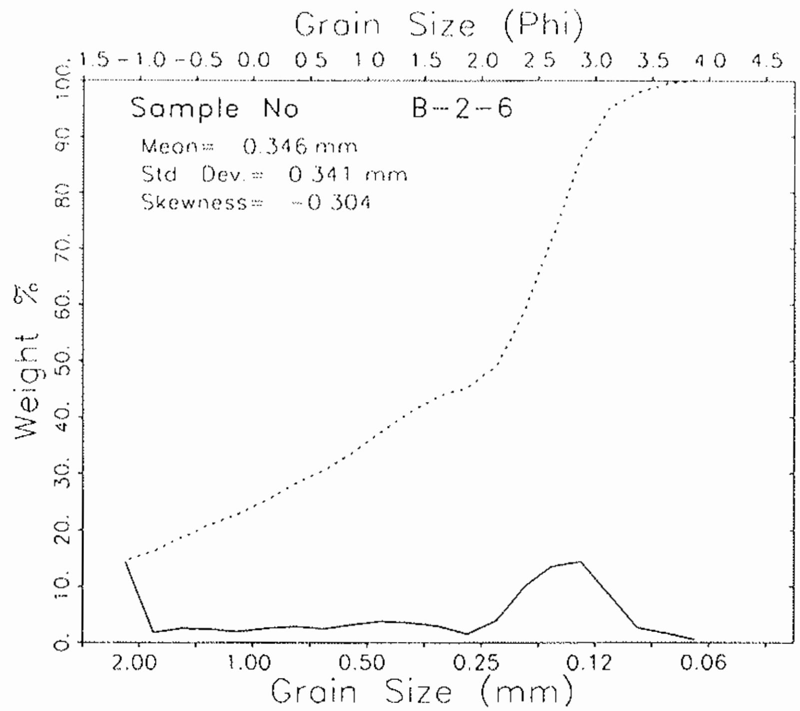
MOMENT MEASURES:

MEAN = 2.264 STANDARD DEVIATION = 1.214 SKEWNESS = -.794 KURTOSIS = 1.487
DISPERSION = .443 STANDARD DEVIATION = .671 DEVIATION FROM NORMAL DISTR. = -44.71%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.194	-.855	1.043	2.221	2.727	2.979	3.114	3.393	3.706

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.078	2.295	FINE SAND
STANDARD DEVIATION	1.036	1.161	POORLY SORTED
SKEWNESS(1)	-.626	-.656	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.407		
KURTOSIS	1.051	2.296	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-6	111199					
Borrow B2 - 6						
		-1.125	15.020	14.409	-1.000	14.409
		-.875	1.830	1.756	-.750	16.165
		-.625	2.580	2.475	-.500	18.640
		-.375	2.420	2.322	-.250	20.961
		-.125	1.960	1.880	.000	22.842
		.125	2.570	2.465	.250	25.307
		.375	2.940	2.820	.500	28.127
		.625	2.480	2.379	.750	30.507
		.875	3.240	3.108	1.000	33.615
		1.125	3.890	3.732	1.250	37.347
		1.375	3.610	3.463	1.500	40.810
		1.625	2.970	2.849	1.750	43.659
		1.875	1.570	1.506	2.000	45.165
		2.125	3.970	3.809	2.250	48.974
		2.375	10.310	9.891	2.500	58.864
		2.625	14.080	13.507	2.750	72.371
		2.875	14.880	14.275	3.000	86.646
		3.125	8.980	8.615	3.250	95.261
		3.375	2.710	2.600	3.500	97.861
		3.625	1.700	1.631	3.750	99.492
		3.875	.530	.508	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.240

PERCENT FINER THAN 4.00 PHI = .66 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

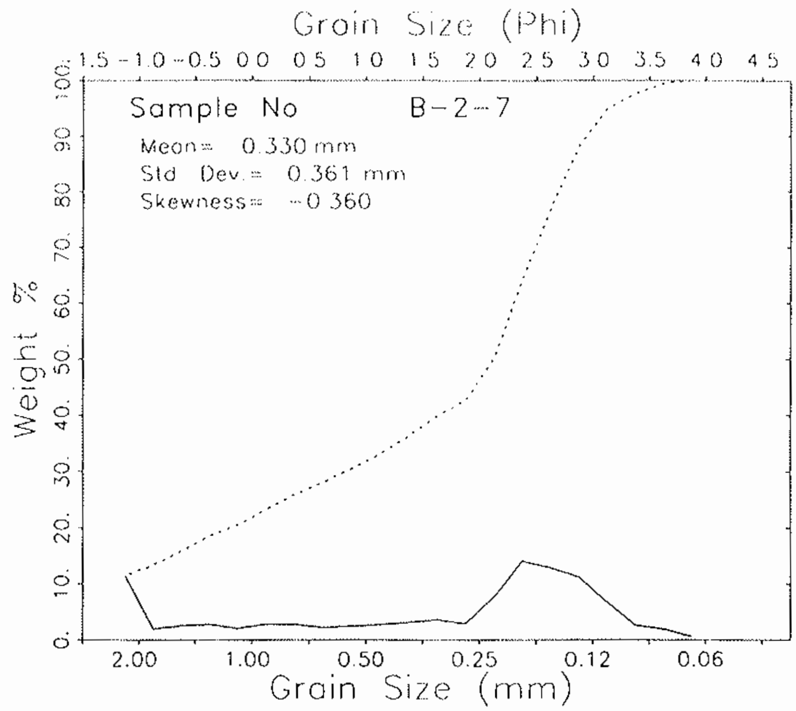
MEAN = 1.532 STANDARD DEVIATION = 1.552 SKEWNESS = -.304 KURTOSIS = -1.109

DISPERSION = .570 STANDARD DEVIATION = .898 DEVIATION FROM NORMAL DISTR. = -42.11%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.233	-1.163	-.773	.219	2.276	2.796	2.954	3.242	3.675

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.090	1.485	MEDIUM SAND
STANDARD DEVIATION	1.864	1.599	POORLY SORTED
SKEWNESS(1)	-.636	-.599	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.663		
KURTOSIS	.182	.701	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-7	111199					
Borrow B2 - 7						
		-1.125	12.960	11.425	-1.000	11.425
		-.875	2.170	1.913	-.750	13.337
		-.625	2.770	2.442	-.500	15.779
		-.375	3.060	2.697	-.250	18.477
		-.125	2.220	1.957	.000	20.434
		.125	3.100	2.733	.250	23.166
		.375	3.130	2.759	.500	25.926
		.625	2.460	2.169	.750	28.094
		.875	2.740	2.415	1.000	30.510
		1.125	3.010	2.653	1.250	33.163
		1.375	3.490	3.077	1.500	36.239
		1.625	4.030	3.553	1.750	39.792
		1.875	3.180	2.803	2.000	42.595
		2.125	8.610	7.590	2.250	50.185
		2.375	15.980	14.087	2.500	64.272
		2.625	14.490	12.773	2.750	77.045
		2.875	12.690	11.187	3.000	88.232
		3.125	7.660	6.752	3.250	94.984
		3.375	2.890	2.548	3.500	97.532
		3.625	2.150	1.895	3.750	99.427
		3.875	.650	.573	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.440

PERCENT FINER THAN 4.00 PHI = .85 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

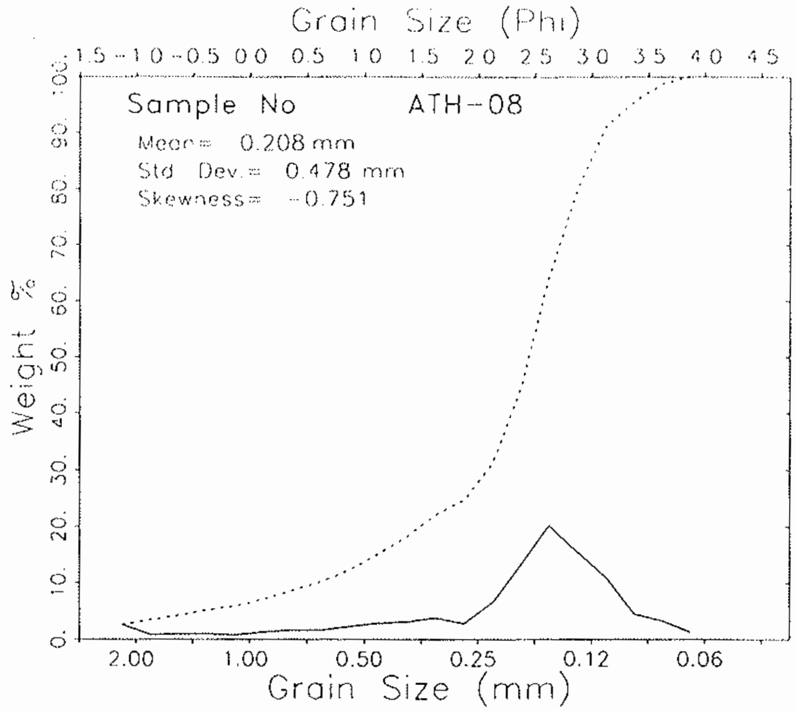
MEAN = 1.598 STANDARD DEVIATION = 1.470 SKEWNESS = -.360 KURTOSIS = -.859

DISPERSION = .508 STANDARD DEVIATION = .938 DEVIATION FROM NORMAL DISTR. = -36.18%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.228	-1.141	-.480	.416	2.244	2.710	2.905	3.252	3.694

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.213	1.557	MEDIUM SAND
STANDARD DEVIATION	1.692	1.512	POORLY SORTED
SKEWNESS(1)	-.609	-.575	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.702		
KURTOSIS	.298	.785	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-08	111199						
Borrow B1 - ATH08							
		-1.125	2.810		2.563	-1.000	2.563
		-.875	.860		.784	-.750	3.347
		-.625	.940		.857	-.500	4.204
		-.375	.960		.876	-.250	5.080
		-.125	.830		.757	.000	5.837
		.125	1.320		1.204	.250	7.041
		.375	1.730		1.578	.500	8.618
		.625	1.700		1.550	.750	10.169
		.875	2.410		2.198	1.000	12.367
		1.125	3.080		2.809	1.250	15.176
		1.375	3.370		3.073	1.500	18.249
		1.625	4.120		3.757	1.750	22.006
		1.875	2.960		2.699	2.000	24.706
		2.125	7.100		6.475	2.250	31.181
		2.375	14.520		13.242	2.500	44.423
		2.625	22.100		20.155	2.750	64.578
		2.875	17.000		15.504	3.000	80.082
		3.125	12.140		11.072	3.250	91.154
		3.375	4.870		4.441	3.500	95.595
		3.625	3.510		3.201	3.750	98.796
		3.875	1.320		1.204	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.650

PERCENT FINER THAN 4.00 PHI = .75 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

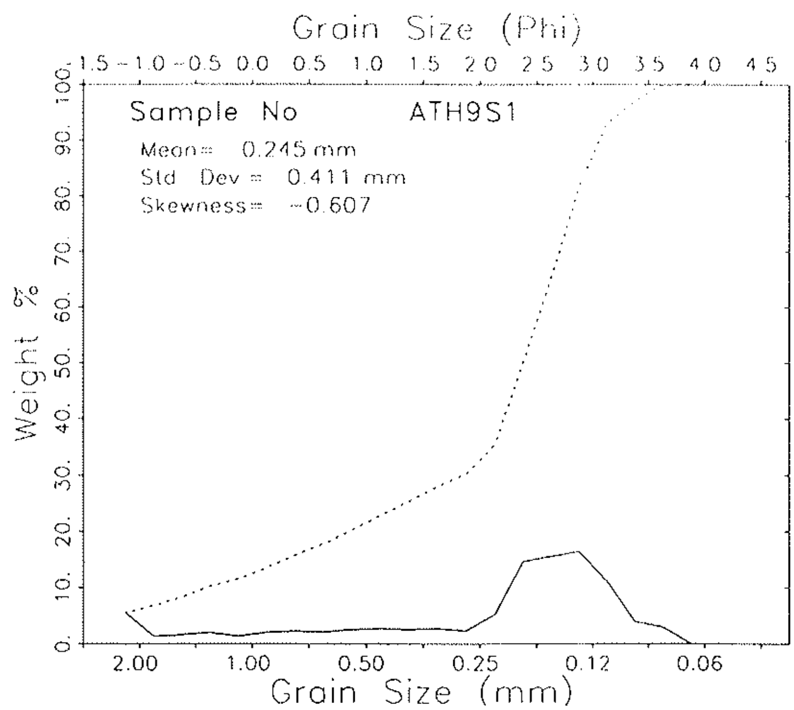
MEAN = 2.262 STANDARD DEVIATION = 1.066 SKEWNESS = -.751 KURTOSIS = 1.994

DISPERSION = .505 STANDARD DEVIATION = .774 DEVIATION FROM NORMAL DISTR. = -27.45%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.152	-.273	1.317	2.011	2.569	2.918	3.088	3.467	3.792

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.203	2.325	FINE SAND
STANDARD DEVIATION	.886	1.009	POORLY SORTED
SKEWNESS(1)	-.414	-.467	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.098		
KURTOSIS	1.111	1.690	VERY LEPTOKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT / WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-09 111199					
Borrow B1 - ATH09s1					
	-1.125	5.940	5.465	-1.000	5.465
	-.875	1.380	1.270	-.750	6.735
	-.625	1.650	1.518	-.500	8.253
	-.375	2.110	1.941	-.250	10.194
	-.125	1.430	1.316	.000	11.510
	.125	2.170	1.997	.250	13.506
	.375	2.420	2.227	.500	15.733
	.625	2.230	2.052	.750	17.785
	.875	2.660	2.447	1.000	20.232
	1.125	2.840	2.613	1.250	22.845
	1.375	2.680	2.466	1.500	25.311
	1.625	2.880	2.650	1.750	27.960
	1.875	2.380	2.190	2.000	30.150
	2.125	5.600	5.152	2.250	35.302
	2.375	15.860	14.592	2.500	49.894
	2.625	16.830	15.484	2.750	65.379
	2.875	17.800	16.377	3.000	81.755
	3.125	12.240	11.261	3.250	93.017
	3.375	4.270	3.929	3.500	96.945
	3.625	3.260	2.999	3.750	99.945
	3.875	.060	.055	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.690

PERCENT FINER THAN 4.00 PHI = 1.33 PERCENT COARSER THAN -1.00 PHI = .00

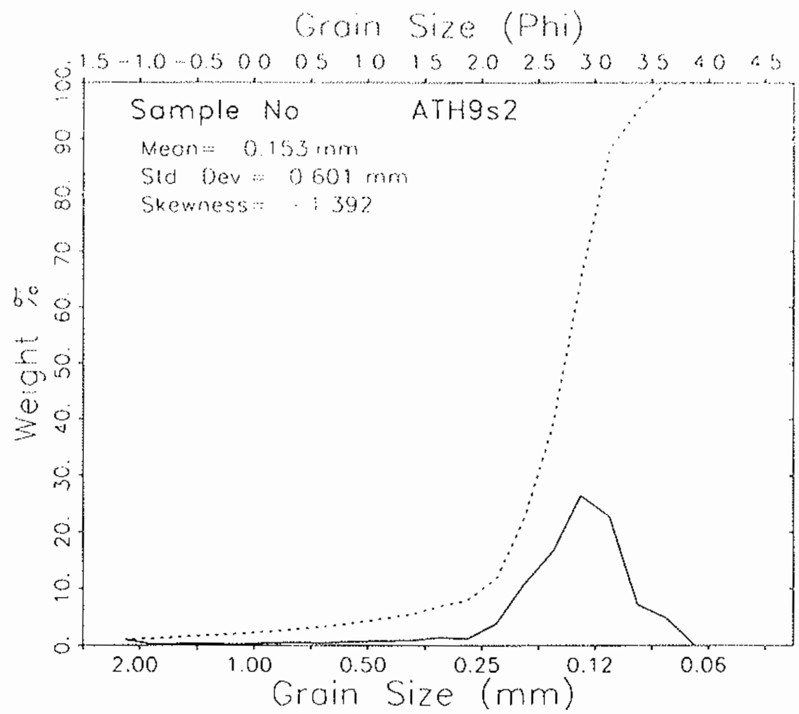
MOMENT MEASURES:

MEAN = 2.030 STANDARD DEVIATION = 1.284 SKEWNESS = -.607 KURTOSIS = .377
DISPERSION = .532 STANDARD DEVIATION = .825 DEVIATION FROM NORMAL DISTR. = -35.78%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.204	-1.021	.533	1.469	2.502	2.897	3.050	3.376	3.671

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.791	2.028	FINE SAND
STANDARD DEVIATION	1.259	1.296	POORLY SORTED
SKEWNESS(1)	-.565	-.583	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.052		
KURTOSIS	.747	1.262	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-09	111199					
Borrow 81 - ATH09s2						
		-1.125	1.010	.999	-1.000	.999
		-.875	.170	.168	-.750	1.167
		-.625	.300	.297	-.500	1.463
		-.375	.310	.307	-.250	1.770
		-.125	.240	.237	.000	2.007
		.125	.370	.366	.250	2.373
		.375	.450	.445	.500	2.818
		.625	.400	.395	.750	3.213
		.875	.640	.633	1.000	3.846
		1.125	.730	.722	1.250	4.568
		1.375	.840	.831	1.500	5.398
		1.625	1.360	1.345	1.750	6.743
		1.875	1.170	1.157	2.000	7.900
		2.125	3.740	3.698	2.250	11.598
		2.375	10.910	10.787	2.500	22.385
		2.625	16.660	16.472	2.750	38.857
		2.875,	26.730	26.429	3.000	65.286
		3.125	23.050	22.790	3.250	88.076
		3.375	7.170	7.089	3.500	95.165
		3.625	4.830	4.776	3.750	99.941
		3.875	.060	.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.140

PERCENT FINER THAN 4.00 PHI = 2.31 PERCENT COARSER THAN -1.00 PHI = .00

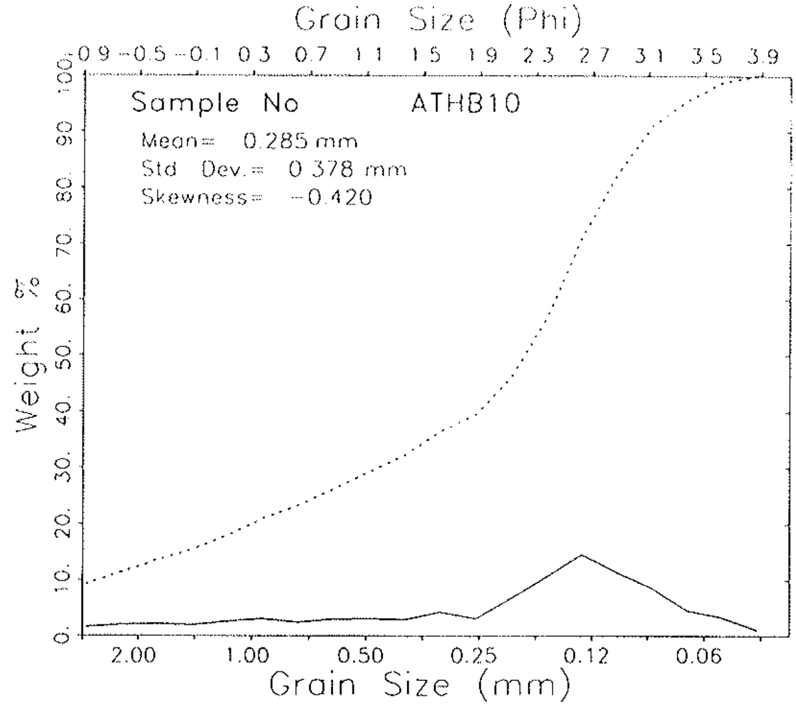
MOMENT MEASURES:

MEAN = 2.711 STANDARD DEVIATION = .734 SKEWNESS = -1.392 KURTOSIS = 10.252
DISPERSION = .299 STANDARD DEVIATION = .482 DEVIATION FROM NORMAL DISTR. = -34.35%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.998	1.380	2.352	2.540	2.855	3.107	3.205	3.494	3.701

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.779	2.804	FINE SAND
STANDARD DEVIATION	.427	.534	MODERATELY WELL SORTED
SKEWNESS(1)	-.180	-.288	COARSE-SKEWED
SKEWNESS(2)	-.980		
KURTOSIS	1.478	1.528	VERY LEPTOKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-B1 111199					
Borrow B1 - ATHB10					
	-1.125	9.050	7.744	-1.000	7.744
	-.875	1.820	1.557	-.750	9.302
	-.625	2.330	1.994	-.500	11.296
	-.375	2.540	2.174	-.250	13.469
	-.125	2.160	1.848	.000	15.317
	.125	2.950	2.524	.250	17.842
	.375	3.530	3.021	.500	20.863
	.625	2.830	2.422	.750	23.284
	.875	3.450	2.952	1.000	26.237
	1.125	3.610	3.089	1.250	29.326
	1.375	3.360	2.875	1.500	32.201
	1.625	4.950	4.236	1.750	36.437
	1.875	3.540	3.029	2.000	39.466
	2.125	7.860	6.726	2.250	46.192
	2.375	12.280	10.508	2.500	56.700
	2.625	16.950	14.505	2.750	71.205
	2.875	13.180	11.278	3.000	82.483
	3.125	10.020	8.574	3.250	91.058
	3.375	5.350	4.578	3.500	95.636
	3.625	3.830	3.277	3.750	98.913
	3.875	1.270	1.087	4.000	100.000

TOTAL WEIGHT (GRAMS) = 116.860

PERCENT FINER THAN 4.00 PHI = .79 PERCENT COARSER THAN -1.00 PHI = .00

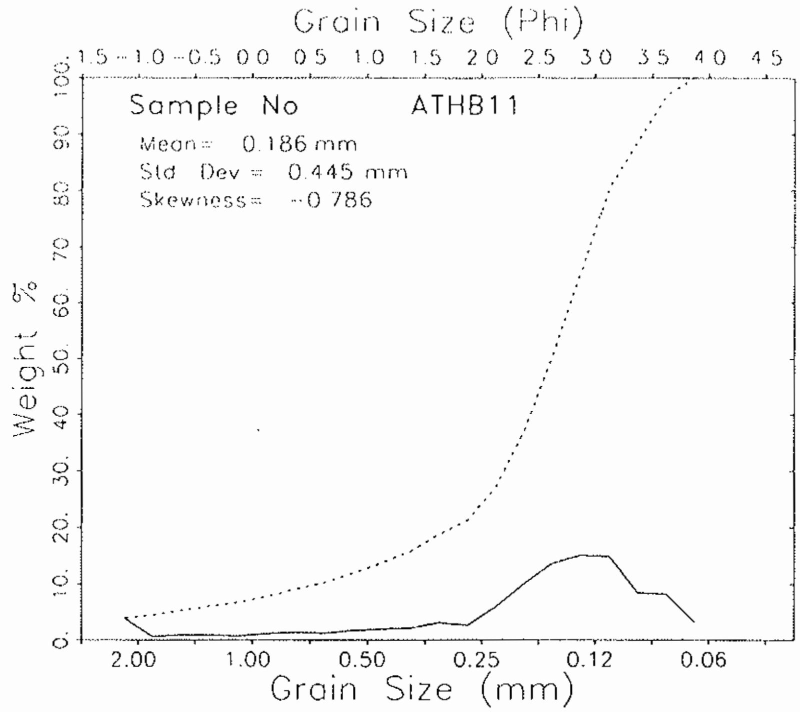
MOMENT MEASURES:

MEAN = 1.813 STANDARD DEVIATION = 1.402 SKEWNESS = -.420 KURTOSIS = -.475
DISPERSION = .613 STANDARD DEVIATION = .992 DEVIATION FROM NORMAL DISTR. = -29.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.089	.068	.895	2.341	2.834	3.044	3.465	3.770

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.556	1.817	MEDIUM SAND
STANDARD DEVIATION	1.488	1.434	POORLY SORTED
SKEWNESS(1)	-.527	-.517	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.774		
KURTOSIS	.530	.963	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-B-	111199						
Borrow B1 - B11							
		-1.125	4.000		3.868	-1.000	3.868
		-.875	.530		.512	-.750	4.380
		-.625	.830		.803	-.500	5.183
		-.375	.860		.832	-.250	6.014
		-.125	.640		.619	.000	6.633
		.125	1.070		1.035	.250	7.668
		.375	1.360		1.315	.500	8.983
		.625	1.210		1.170	.750	10.153
		.875	1.710		1.653	1.000	11.806
		1.125	1.940		1.876	1.250	13.682
		1.375	2.090		2.021	1.500	15.703
		1.625	3.120		3.017	1.750	18.720
		1.875	2.620		2.533	2.000	21.253
		2.125	6.120		5.918	2.250	27.171
		2.375	10.310		9.969	2.500	37.140
		2.625	14.020		13.556	2.750	50.696
		2.875	15.470		14.958	3.000	65.655
		3.125	15.300		14.794	3.250	80.449
		3.375	8.600		8.316	3.500	88.764
		3.625	8.380		8.103	3.750	96.867
		3.875	3.240		3.133	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.420

PERCENT FINER THAN 4.00 PHI = 2.22 PERCENT COARSER THAN -1.00 PHI = .00

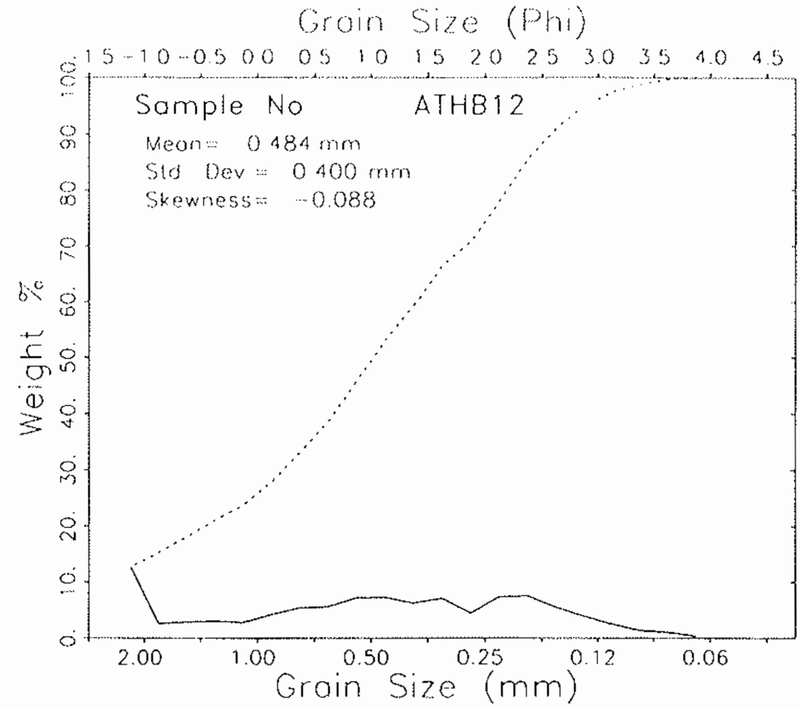
MOMENT MEASURES:

MEAN = 2.423 STANDARD DEVIATION = 1.168 SKEWNESS = -.786 KURTOSIS = 2.083
DISPERSION = .524 STANDARD DEVIATION = .809 DEVIATION FROM NORMAL DISTR. = -30.73%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.185	-.557	1.525	2.158	2.737	3.158	3.357	3.692	3.920

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.441	2.540	FINE SAND
STANDARD DEVIATION	.916	1.102	POORLY SORTED
SKEWNESS(1)	-.324	-.437	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.277		
KURTOSIS	1.319	1.742	VERY LEPTOKURTIC



SAMPLE NO. DATE

ATH-B- 111199
Borrow B1 - ATHB12

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	13.920	12.663	-1.000	12.663
-.875	2.780	2.529	-.750	15.191
-.625	3.080	2.802	-.500	17.993
-.375	3.300	3.002	-.250	20.995
-.125	2.970	2.702	.000	23.697
.125	4.540	4.130	.250	27.827
.375	5.810	5.285	.500	33.112
.625	6.130	5.576	.750	38.688
.875	7.880	7.168	1.000	45.856
1.125	7.980	7.259	1.250	53.116
1.375	6.870	6.249	1.500	59.365
1.625	7.760	7.059	1.750	66.424
1.875	4.830	4.394	2.000	70.818
2.125	8.030	7.305	2.250	78.122
2.375	8.180	7.441	2.500	85.564
2.625	6.010	5.467	2.750	91.031
2.875	4.280	3.893	3.000	94.924
3.125	2.720	2.474	3.250	97.398
3.375	1.430	1.301	3.500	98.699
3.625	1.110	1.010	3.750	99.709
3.875	.320	.291	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.930

PERCENT FINER THAN 4.00 PHI = .44 PERCENT COARSER THAN -1.00 PHI = .00

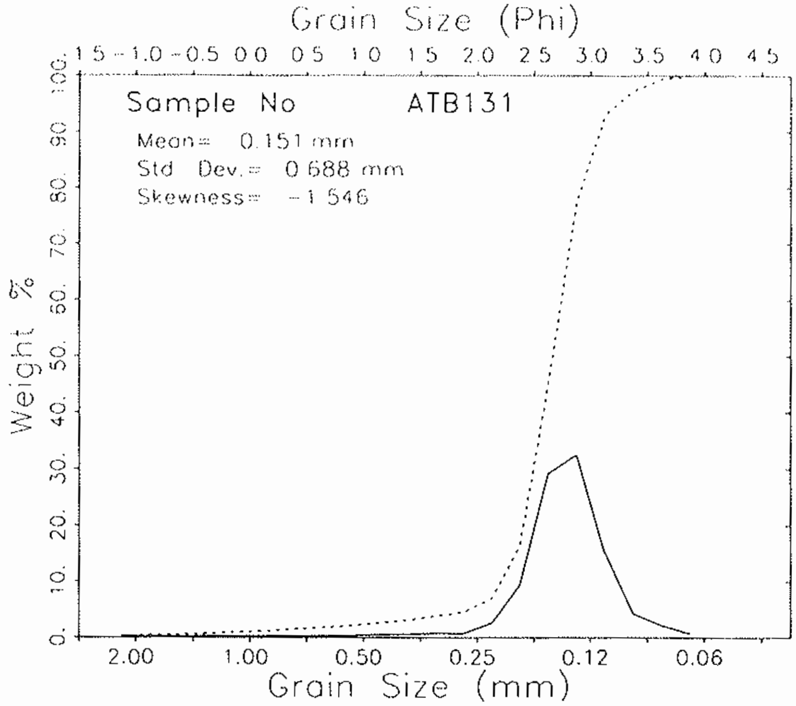
MOMENT MEASURES:

MEAN = 1.047 STANDARD DEVIATION = 1.322 SKEWNESS = -.088 KURTOSIS = -.971
DISPERSION = .642 STANDARD DEVIATION = 1.060 DEVIATION FROM NORMAL DISTR. = -19.82%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.230	-1.151	-.678	.079	1.143	2.143	2.447	3.008	3.574

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.885	.971	COARSE SAND
STANDARD DEVIATION	1.563	1.411	POORLY SORTED
SKEWNESS(1)	-.165	-.134	COARSE-SKEWED
SKEWNESS(2)	-.137		
KURTOSIS	.331	.826	PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-B-1361 111199					
Borrow B1 - ATHB1361					
	-1.125	.240	.228	-1.000	.228
	-.875	.140	.133	-.750	.361
	-.625	.150	.142	-.500	.503
	-.375	.210	.199	-.250	.702
	-.125	.190	.180	.000	.883
	.125	.230	.218	.250	1.101
	.375	.340	.323	.500	1.424
	.625	.280	.266	.750	1.689
	.875	.360	.342	1.000	2.031
	1.125	.510	.484	1.250	2.515
	1.375	.490	.465	1.500	2.980
	1.625	.800	.759	1.750	3.739
	1.875	.710	.674	2.000	4.413
	2.125	2.590	2.458	2.250	6.871
	2.375	9.840	9.339	2.500	16.210
	2.625	30.670	29.107	2.750	45.317
	2.875	34.180	32.438	3.000	77.755
	3.125	16.040	15.223	3.250	92.977
	3.375	4.460	4.233	3.500	97.210
	3.625	2.240	2.126	3.750	99.336
	3.875	.700	.664	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.370

PERCENT FINER THAN 4.00 PHI = .27 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

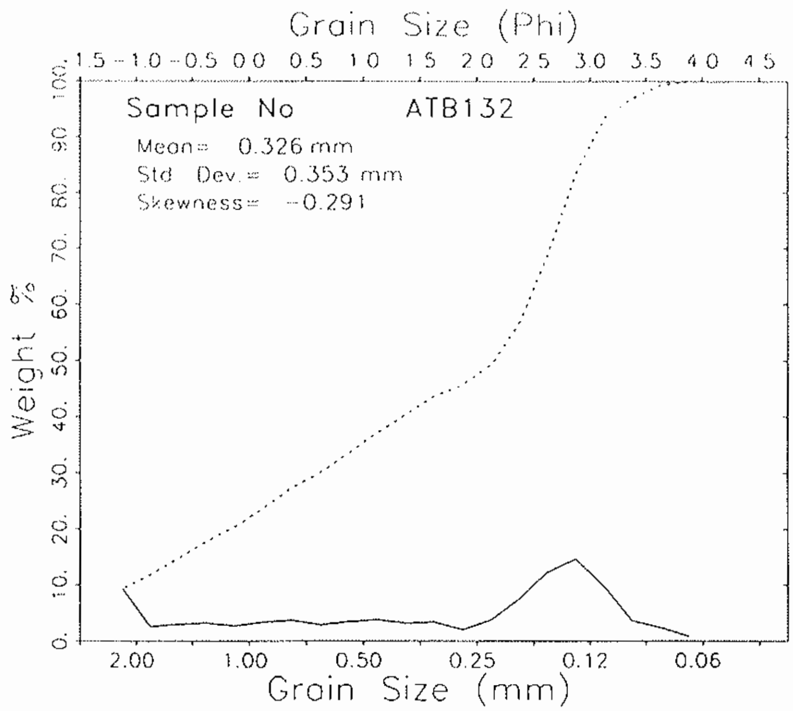
MEAN = 2.729 STANDARD DEVIATION = .539 SKEWNESS = -1.546 KURTOSIS = 16.067

DISPERSION = .187 STANDARD DEVIATION = .372 DEVIATION FROM NORMAL DISTR. = -30.93%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.134	2.060	2.494	2.576	2.786	2.979	3.103	3.369	3.711

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.798	2.794	FINE SAND
STANDARD DEVIATION	.304	.350	WELL SORTED
SKEWNESS(1)	.041	-.034	NEAR SYMMETRICAL
SKEWNESS(2)	-.235		
KURTOSIS	1.154	1.331	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATHB13	111199					
Borrow B1 - ATHB13-s2						
		-1.125	10.280	9.265	-1.000	9.265
		-.875	2.760	2.487	-.750	11.752
		-.625	3.250	2.929	-.500	14.681
		-.375	3.450	3.109	-.250	17.790
		-.125	2.880	2.596	.000	20.386
		.125	3.640	3.280	.250	23.666
		.375	4.000	3.605	.500	27.271
		.625	3.070	2.767	.750	30.038
		.875	3.790	3.416	1.000	33.453
		1.125	4.090	3.686	1.250	37.140
		1.375	3.520	3.172	1.500	40.312
		1.625	3.630	3.271	1.750	43.583
		1.875	2.140	1.929	2.000	45.512
		2.125	4.150	3.740	2.250	49.252
		2.375	8.290	7.471	2.500	56.723
		2.625	13.600	12.257	2.750	68.980
		2.875,	16.170	14.573	3.000	83.553
		3.125	10.830	9.760	3.250	93.313
		3.375	3.940	3.551	3.500	96.864
		3.625	2.610	2.352	3.750	99.216
		3.875	.870	.784	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.960

PERCENT FINER THAN 4.00 PHI = .45 PERCENT COARSER THAN -1.00 PHI = .00

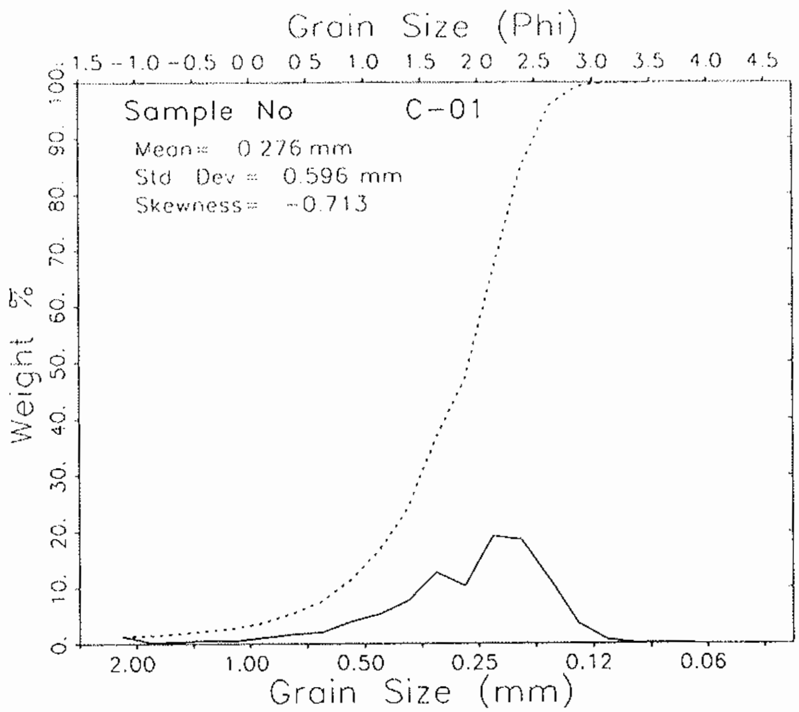
MOMENT MEASURES:

MEAN = 1.618 STANDARD DEVIATION = 1.504 SKEWNESS = -.291 KURTOSIS = -1.062
DISPERSION = .619 STANDARD DEVIATION = 1.005 DEVIATION FROM NORMAL DISTR. = -33.15%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.223	-1.115	-.394	.343	2.275	2.853	3.011	3.369	3.727

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.309	1.631	MEDIUM SAND
STANDARD DEVIATION	1.703	1.531	POORLY SORTED
SKEWNESS(1)	-.567	-.540	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.674		
KURTOSIS	.317	.732	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-01	111199						
Borrow C - 01							
		-1.125	1.130	1.263		-1.000	1.263
		-.875	.170	.190		-.750	1.453
		-.625	.280	.313		-.500	1.765
		-.375	.460	.514		-.250	2.279
		-.125	.430	.480		.000	2.760
		.125	.930	1.039		.250	3.799
		.375	1.500	1.676		.500	5.475
		.625	1.790	2.000		.750	7.475
		.875	3.450	3.855		1.000	11.330
		1.125	4.670	5.218		1.250	16.547
		1.375	6.770	7.564		1.500	24.112
		1.625	11.210	12.525		1.750	36.637
		1.875	9.170	10.246		2.000	46.883
		2.125	17.150	19.162		2.250	66.045
		2.375	16.540	18.480		2.500	84.525
		2.625	10.060	11.240		2.750	95.765
		2.875	3.130	3.497		3.000	99.263
		3.125	.540	.603		3.250	99.866
		3.375	.080	.089		3.500	99.955
		3.625	.020	.022		3.750	99.978
		3.875	.020	.022		4.000	100.000

TOTAL WEIGHT (GRAMS) = 89.500

PERCENT FINER THAN 4.00 PHI = .02 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

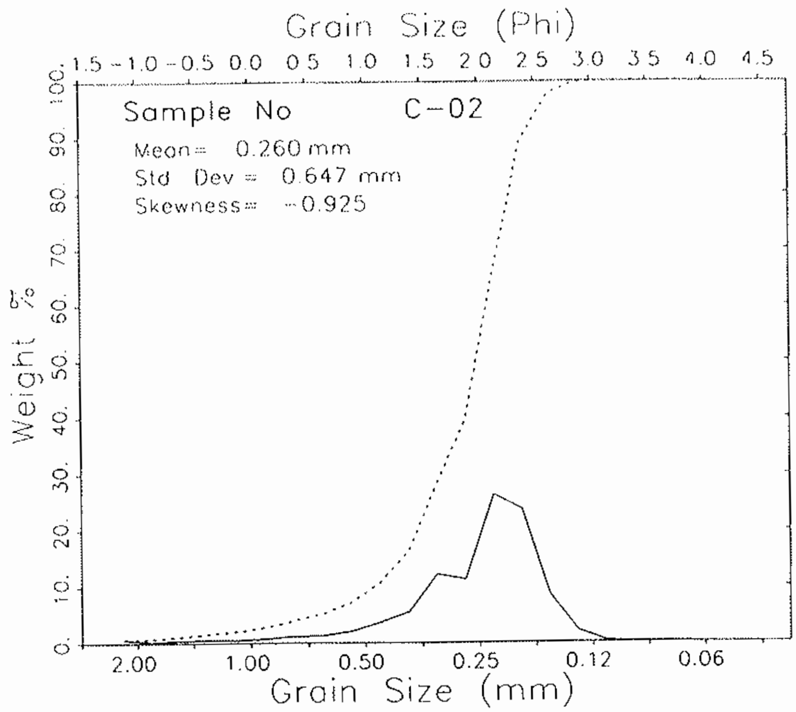
MEAN = 1.857 STANDARD DEVIATION = .747 SKEWNESS = -.713 KURTOSIS = 2.853

DISPERSION = .411 STANDARD DEVIATION = .624 DEVIATION FROM NORMAL DISTR. = -16.46%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.052	.429	1.224	1.518	2.041	2.371	2.493	2.733	2.981

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.858	1.919	MEDIUM SAND
STANDARD DEVIATION	.635	.666	MODERATELY WELL SORTED
SKEWNESS(1)	-.287	-.343	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.724		
KURTOSIS	.815	1.106	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-02	111199						
Borrown C - 02							
		-1.125	.530		.530	-1.000	.530
		-.875	.160		.160	-.750	.690
		-.625	.380		.380	-.500	1.071
		-.375	.460		.460	-.250	1.531
		-.125	.450		.450	.000	1.981
		.125	.760		.760	.250	2.741
		.375	1.140		1.141	.500	3.882
		.625	1.240		1.241	.750	5.123
		.875	1.990		1.991	1.000	7.114
		1.125	3.530		3.532	1.250	10.645
		1.375	5.410		5.413	1.500	16.058
		1.625	12.120		12.126	1.750	28.184
		1.875	11.200		11.206	2.000	39.390
		2.125	26.300		26.313	2.250	65.703
		2.375	23.680		23.692	2.500	89.395
		2.625	8.390		8.394	2.750	97.789
		2.875	1.940		1.941	3.000	99.730
		3.125	.220		.220	3.250	99.950
		3.375	.030		.030	3.500	99.980
		3.625	.010		.010	3.750	99.990
		3.875	.010		.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.950

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

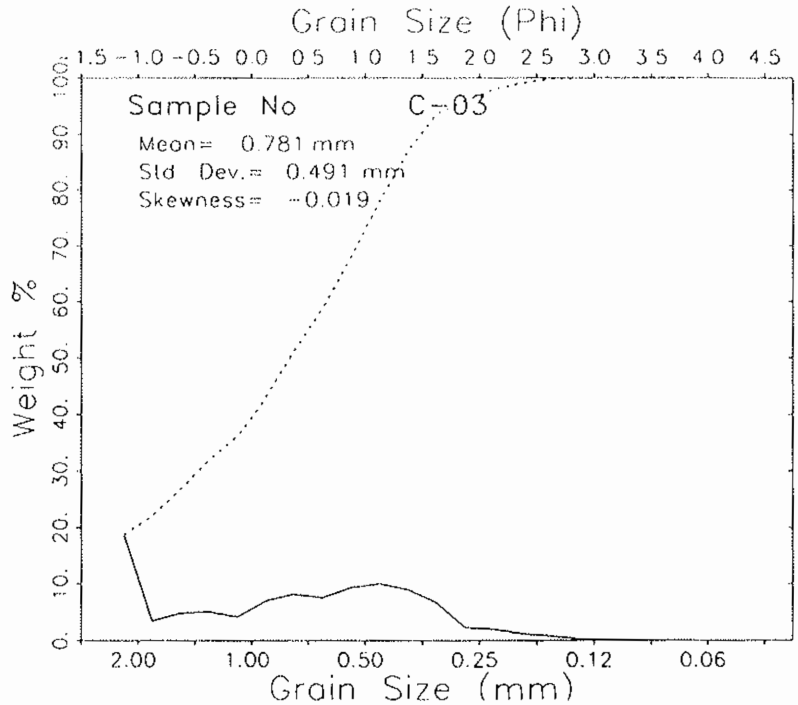
MEAN = 1.946 STANDARD DEVIATION = .629 SKEWNESS = -.925 KURTOSIS = 4.930

DISPERSION = .310 STANDARD DEVIATION = .494 DEVIATION FROM NORMAL DISTR. = -21.46%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.546	.725	1.497	1.684	2.101	2.348	2.443	2.667	2.906

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.970	2.014	FINE SAND
STANDARD DEVIATION	.473	.531	MODERATELY WELL SORTED
SKEWNESS(1)	-.276	-.347	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.856		
KURTOSIS	1.053	1.199	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-03	111199					
Borrow C - 03						
		-1.125	19.210	18.634	-1.000	18.634
		-.875	3.470	3.366	-.750	22.000
		-.625	4.990	4.840	-.500	26.841
		-.375	5.200	5.044	-.250	31.885
		-.125	4.290	4.161	.000	36.046
		.125	7.200	6.984	.250	43.030
		.375	8.380	8.129	.500	51.159
		.625	7.820	7.586	.750	58.745
		.875	9.590	9.303	1.000	68.047
		1.125	10.260	9.952	1.250	78.000
		1.375	9.290	9.012	1.500	87.011
		1.625	6.870	6.664	1.750	93.675
		1.875	2.330	2.260	2.000	95.936
		2.125	2.060	1.998	2.250	97.934
		2.375	1.160	1.125	2.500	99.059
		2.625	.710	.689	2.750	99.748
		2.875	.210	.204	3.000	99.951
		3.125	.040	.039	3.250	99.990
		3.375	.010	.010	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.090

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

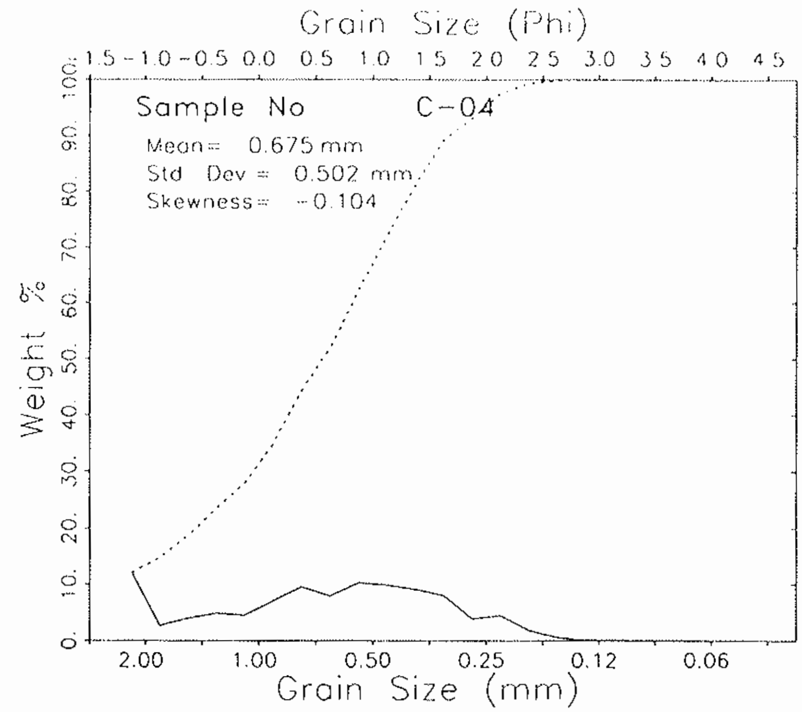
MEAN = .356 STANDARD DEVIATION = 1.025 SKEWNESS = -.019 KURTOSIS = -1.053

DISPERSION = .508 STANDARD DEVIATION = .779 DEVIATION FROM NORMAL DISTR. = -23.97%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.237	-1.183	-1.035	-.595	.464	1.175	1.416	1.897	2.487

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.191	.282	COARSE SAND
STANDARD DEVIATION	1.226	1.080	POORLY SORTED
SKEWNESS(1)	-.223	-.147	COARSE-SKEWED
SKEWNESS(2)	-.008		
KURTOSIS	.256	.713	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-04	111199					
Borrow C - 04						
		-1.125	12.040	12.038	-1.000	12.038
		-.875	2.630	2.629	-.750	14.667
		-.625	3.930	3.929	-.500	18.596
		-.375	4.800	4.799	-.250	23.395
		-.125	4.440	4.439	.000	27.834
		.125	7.010	7.009	.250	34.843
		.375	9.450	9.448	.500	44.291
		.625	7.890	7.888	.750	52.180
		.875	10.260	10.258	1.000	62.438
		1.125	9.840	9.838	1.250	72.276
		1.375	9.070	9.068	1.500	81.344
		1.625	7.970	7.968	1.750	89.312
		1.875	3.790	3.789	2.000	93.101
		2.125	4.410	4.409	2.250	97.510
		2.375	1.800	1.800	2.500	99.310
		2.625	.550	.550	2.750	99.860
		2.875	.090	.090	3.000	99.950
		3.125	.050	.050	3.250	100.000
		3.375	.000	.000	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.020

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

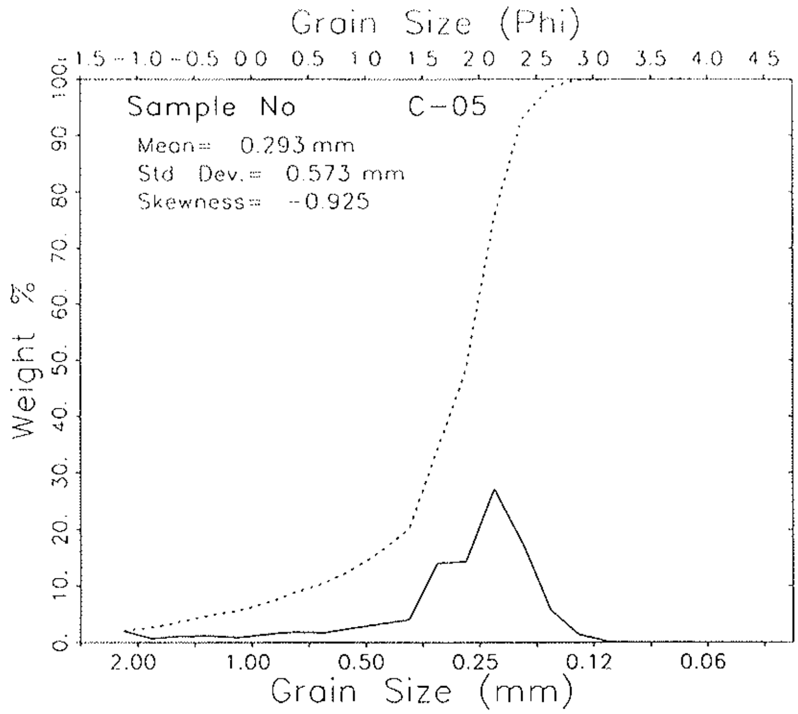
MEAN = .568 STANDARD DEVIATION = .994 SKEWNESS = -.104 KURTOSIS = -.857

DISPERSION = .538 STANDARD DEVIATION = .835 DEVIATION FROM NORMAL DISTR. = -15.96%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.229	-1.146	-.665	-.160	.681	1.325	1.583	2.108	2.457

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.459	.533	COARSE SAND
STANDARD DEVIATION	1.124	1.055	POORLY SORTED
SKEWNESS(1)	-.197	-.160	COARSE-SKEWED
SKEWNESS(2)	-.170		
KURTOSIS	.447	.898	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-05	111199						
Borrow C - 05							
		-1.125	2.110	2.004		-1.000	2.004
		-.875	.630	.598		-.750	2.603
		-.625	1.080	1.026		-.500	3.628
		-.375	1.160	1.102		-.250	4.730
		-.125	.860	.817		.000	5.547
		.125	1.460	1.387		.250	6.934
		.375	1.910	1.814		.500	8.748
		.625	1.700	1.615		.750	10.363
		.875	2.570	2.441		1.000	12.804
		1.125	3.420	3.248		1.250	16.052
		1.375	4.160	3.951		1.500	20.004
		1.625	14.700	13.963		1.750	33.967
		1.875	14.950	14.200		2.000	48.167
		2.125	28.600	27.166		2.250	75.332
		2.375	18.520	17.591		2.500	92.924
		2.625	5.960	5.661		2.750	98.585
		2.875	1.350	1.282		3.000	99.867
		3.125	.130	.123		3.250	99.991
		3.375	.010	.009		3.500	100.000
		3.625	.000	.000		3.750	100.000
		3.875	.000	.000		4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.280

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

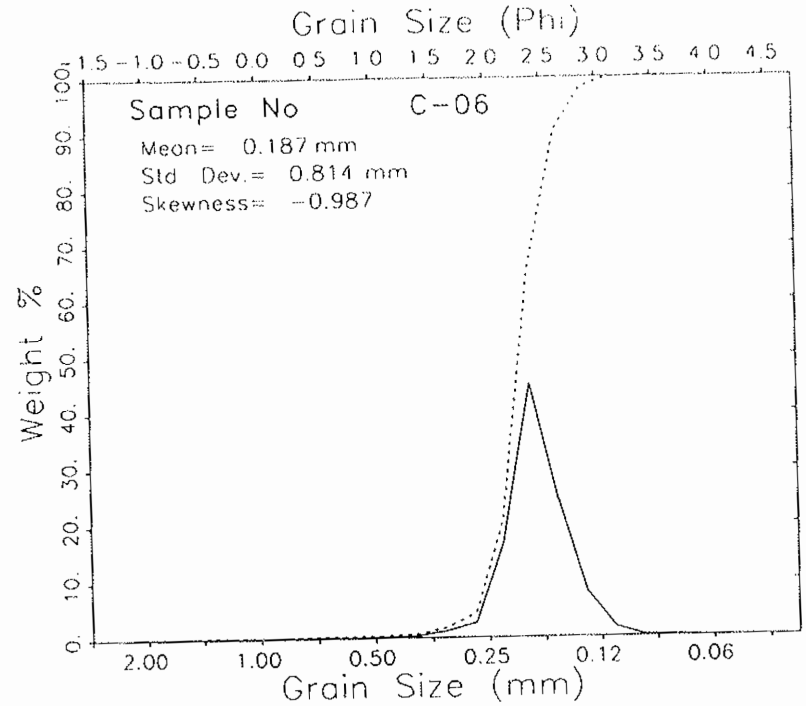
MOMENT MEASURES:

MEAN = 1.769 STANDARD DEVIATION = .803 SKEWNESS = -.925 KURTOSIS = 3.442
DISPERSION = .359 STANDARD DEVIATION = .553 DEVIATION FROM NORMAL DISTR. = -31.14%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.125	-.167	1.246	1.589	2.017	2.247	2.373	2.592	2.831

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.810	1.879	MEDIUM SAND
STANDARD DEVIATION	.564	.700	MODERATELY WELL SORTED
SKEWNESS(1)	-.368	-.476	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.428		
KURTOSIS	1.448	1.720	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-06	111199					
Borrow C - 06						
		-1.125	.050	.048	-1.000	.048
		-.875	.010	.010	-.750	.058
		-.625	.030	.029	-.500	.086
		-.375	.030	.029	-.250	.115
		-.125	.020	.019	.000	.135
		.125	.030	.029	.250	.163
		.375	.020	.019	.500	.183
		.625	.020	.019	.750	.202
		.875	.050	.048	1.000	.250
		1.125	.100	.096	1.250	.346
		1.375	.290	.279	1.500	.625
		1.625	1.140	1.095	1.750	1.720
		1.875	2.570	2.469	2.000	4.189
		2.125	17.460	16.777	2.250	20.967
		2.375	46.890	45.056	2.500	66.023
		2.625	25.250	24.263	2.750	90.285
		2.875	8.250	7.927	3.000	98.213
		3.125	1.660	1.595	3.250	99.808
		3.375	.180	.173	3.500	99.981
		3.625	.020	.019	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.070

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.417 STANDARD DEVIATION = .297 SKEWNESS = -.987 KURTOSIS = 19.712

DISPERSION = .035 STANDARD DEVIATION = .262 DEVIATION FROM NORMAL DISTR. = -11.73%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.586	2.012	2.176	2.272	2.411	2.592	2.685	2.899	3.123

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	2.431	2.424	FINE SAND
STANDARD DEVIATION	.255	.262	VERY WELL SORTED
SKEWNESS(1)	.077	.088	NEAR SYMMETRICAL
SKEWNESS(2)	.174		
KURTOSIS	.741	1.135	LEPTOKURTIC

ATHENA CORE LOG

CORE ID
ATH-01

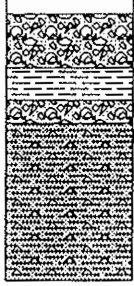
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 0810
PENETRATION LENGTH 6'
RECOVERY 2.83'
WATER DEPTH 49'
WEATHER Clear 45F, Lt Breeze
GPS-LAT 34 38'59.9"
GPS-LON 76 53'29.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER JNW/WJS
DATE LOGGED 8 NOV 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

0-0.58 Coarse grained, poorly sorted Sand mixed with up to 50% shell fragments (<1mm-7mm) (SW) CX, SH

0.58-0.92 Grey silty Mud, soft high water content (CH) MU

0.92-1.17 Coarse grained, poorly sorted Sand mixed with up to 50% shell fragments (<1mm-7mm) (SW) CX, SH

1.17-2.83 Gray Mud and fine Sand mixed with abundant shells from 0.1-7cm Large clam shells at base Occasional fine Sand lens (SC) FX, MU, SH

ATHENA CORE LOG

CORE ID
ATH-02

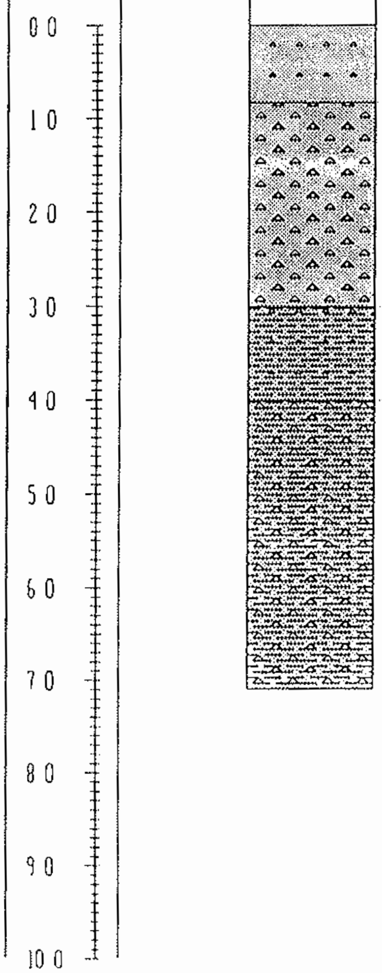
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 0847
PENETRATION LENGTH 8'
RECOVERY 7.08'
WATER DEPTH 46'
WEATHER Clear 45F
GPS-LAT 34 39'29.9"
GPS-LON 76' 53'29.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 8 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-0 83 Fine grained well sorted Sand Grey/tan Abundant small black grains and fine shell fragments (SP) FX SL

0 83-3 0 Fine grained Sand mixed with abundant shell fragments (0 1-5 0cm) Shell content varies with depth minor mud content (SW) FX SH

3 0-4 0 Shell content decreases Fine Sand mixed with Mud (SC) FX MU SL

4 0-7 08 Fine Sand and Mud mixed with abundant shell material that increases with depth (SC) FX MU SH

ATHENA CORE LOG

	CORE ID
	ATH-03

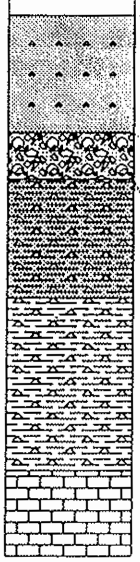
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 0940
PENETRATION LENGTH 7'
RECOVERY 5.75'
WATER DEPTH 48'
WEATHER Clear 50F
GPS-LAT 34 39'15.1"
GPS-LON 76 53'59.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 8 Nov 99
PAGE 1 OF 1

KEY

Fine Sand		Carbonate		Mud	
Med Sand		Shell Hash		Peat	
Crs Sand		Muddy Sand		Burrows	

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



Depth scale: 1 0, 2 0, 3 0, 4 0, 5 0, 6 0, 7 0, 8 0, 9 0, 10 0

0-1 25 Fine grained, well sorted Sand Abundant fine black grains and fine to medium shell fragments (SP) FX SL

1 25-1 75 Mixed fine to coarse sand with abundant shell fragments (SW) CX SH

1 25-3 0 Grey mixed fine Sand and Mud with abundant shell fragments (1-15mm) (SC) FX MU SH

3 0-4 83 Mud content increases, several large thick clam shells (SC) MU SH

4 83-5 75 Tight dewatered mud Grainy texture, heavy reaction to HCL Tan in color (ML) LS

ATHENA CORE LOG

CORE ID
ATH-09

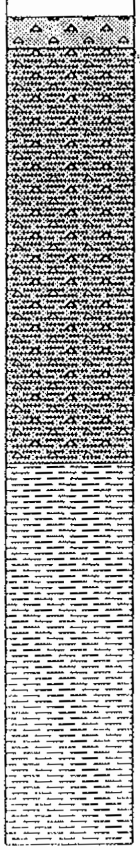
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 1115
PENETRATION LENGTH 10'
RECOVERY 8.83'
WATER DEPTH 50'
WEATHER CLEAR 55F
GPS-LAT 54 38'44.9"
GPS-LON 76 54'59.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 9 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-0 33 Fine to medium Sand mixed with abundant randomly size shell fragments (SW) FX SH
1 0			0 33-4 75 Gray fine Sand and Mud mixed with abundant shell fragments Intact 3cm olive shells at 0 83 and 1 25' Shell size and content varies with depth Mild HCl reaction (SC) FX MU SH
2 0			
3 0			
4 0			
5 0			4 75-8 83 Olive, silty Mud Very mild HCl reaction Occasional pockets of gray sediments similar to above unit Water content decreases, becomes tighter with depth (OL) MU
6 0			
7 0			
8 0			
9 0			
10 0			



ATHENA CORE LOG

CORE ID
ATH-05

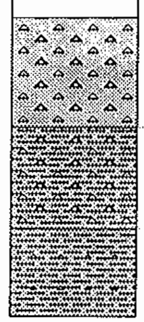
PROJECT Bogue Bonk Sond Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 1210
PENETRATION LENGTH 7'
RECOVERY 3'2"
WATER DEPTH 47
WEATHER Clear 60F
GPS-LAT 34 39'59.9"
GPS-LON 76 54'29.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 8 Nov 99
PAGE 1 OF 1

KEY

Fine Sond		Carbonote		Mud	
Med Sond		Shell Hosh		Peat	
Crs Sond		Muddy Sond		Burrows	

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-1 17 Fine to medium grained Sand mixed with abundant small shell fragments (SW) FX SH

1 17-2 25 Fine grained Sand and Mud mixed with abundant shell fragments (SW) FX MU SH

2 25-3 17 Shell and sand content decreases, mud content decreases (SW) FX MU SL

1 0
2 0
3 0
4 0
5 0
6 0
7 0
8 0
9 0
10 0

ATHENA CORE LOG

CORE ID
ATH-06

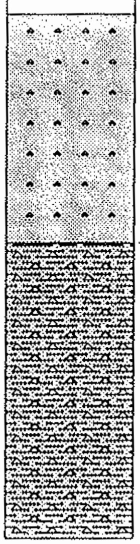
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 1301
PENETRATION LENGTH 6.5'
RECOVERY 5.58'
WATER DEPTH 49'
WEATHER Clear 60F
GPS-LAT 34 39'29.9"
GPS-LON 76 54'29.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 9 Nov 99
PAGE 1 OF 1

KEY

Fine Sand		Carbonate		Mud	
Med Sand		Shell Hash		Peat	
Crs Sand		Muddy Sand		Burrows	

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-2 43 Gray, well sorted, fine grained Sand mixed with moderate fine to medium shell fragments Abundant fine black grains throughout Coarse shell layer (lag?) at base of unit (SP) FX SL
1 0			
2 0			2 43-5 58 Olive gray fine Sand and Mud mix with shell content increasing with depth intact olive shell (2cm) at 3 0' Mild reaction with HCl Large intact shells at 3 5' and 4 08' Becomes light gray after 4 08' Mild HCl reaction Shell assemblage varies in size and type (SC) FX MU SH
3 0			
4 0			
5 0			
6 0			
7 0			
8 0			
9 0			
10 0			



ATHENA CORE LOG

CORE ID
ATH-07

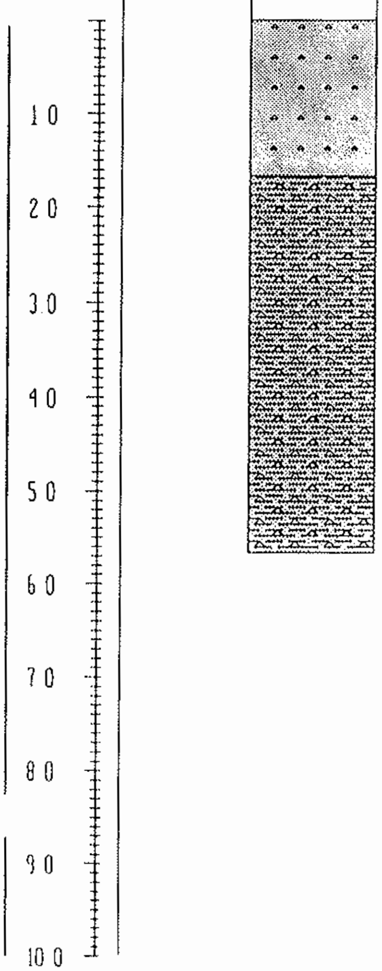
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 1437
PENETRATION LENGTH 9'
RECOVERY 5.67'
WATER DEPTH 47'
WEATHER Clear 65F
GPS-LAT 34 39'15.0"
GPS-LON 76 54'59.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 9 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-1.67 Olive/gray, fine grained, well sorted Sand. Low fine shell content. (SP) FX, SL

1.67-5.67 Fine grained Sand and Mud mixed with abundant shell fragments. Shells vary in type and size (2mm-60mm). Mild HCl reaction. Shell content increases and becomes more uniform below 3.0' (3-10mm). (SC) FX MU SH

ATHENA CORE LOG

CORE ID
ATH-B08

PROJECT Bogue Bonk Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 0755
PENETRATION LENGTH 13′
RECOVERY 11 25′
WATER DEPTH 35′
WEATHER Cleor 45F
GPS-LAT 34 41′12.5"
GPS-LON 76 48′07.8"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 10 Nov 99
PAGE 1 OF 2

KEY

Fine Sond	Corbonote	Mud
Med Sond	Shell Hosh	Peot
Crs Sond	Muddy Sond	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-4 08 Groy, fine groined, well sorted Sond minor shell frogments throughout Very thin muddy loyers between 0 5-1 43′ Shell content increoses ot 2 5′ (SP) FX SL
1 0			
2 0			
3 0			
4 0			4 08-7 17 Slightly muddy, fine groined Sond Medium shell frogments throughout Mud content increoses with depth (SC) FX
5 0			
6 0			
7 0			7 17-9 33 Slightly muddy fine to medium Sond ond shell frogments ronging from 1mm-40mm Shells ore of vorying types ond sizes (GM) MS SH
8 0			
9 0			9 33-11 25 Shell ossembloge becomes oll oyster Sond motrix becomes finer ond muddy (GC) FX MU SH
10 0			

ATHENA CORE LOG

CORE ID: ATH-B09

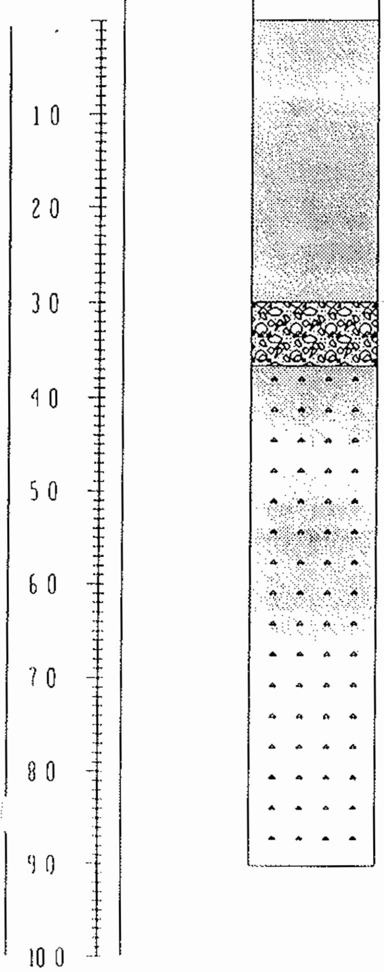
PROJECT Bogue Bonk Sand Seorch
CLIENT CSE
CORE DATE 5 Nov 99
TIME 0850
PENETRATION LENGTH 10′
RECOVERY 9′
WATER DEPTH 32′
WEATHER Clear, 50F
GPS-LAT 34 41′10.3"
GPS-LON 76 49′10.7"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 9 Nov 99
PAGE 1 OF 1

KEY

Fine Sond		Corbonote		Mud	
Med Sond		Shell Hosh		Peot	
Crs Sond		Muddy Sond		Burrows	

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-3 0 Fine grained, well sorted gray Sand, low shell content 2" shell/fine to coarse sand horizon at 1 25′ (SP) FX

3 0-3 67 Shell rich horizon, coarse Sand mixed with abundant shell fragments ranging from 1mm-50mm (SW) CX SH

3 67-9 0 Olive gray very fine Sand Low to moderate fine shell content Reacts with HCl Becomes muddies with depth Shell fragments up to 1cm between 8 25-8 58′ (SP) FX SL

	# ATHENA CORE LOG	CORE ID
		ATH-B10

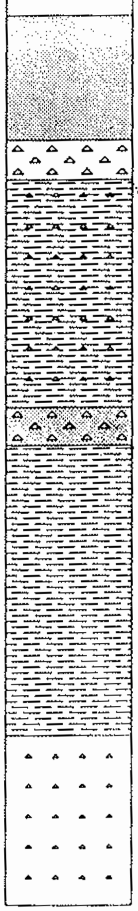
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 1000
PENETRATION LENGTH 10 5'
RECOVERY 7 5'
WATER DEPTH 37'
WEATHER Clear 60F
GPS-LAT 34 40'56.7"
GPS-LON 76 50'10.8"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 9 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0 0, 1 0, 2 0, 3 0, 4 0, 5 0, 6 0, 7 0, 8 0, 9 0, 10 0

0-1 33 Fine grained, well sorted sand Very low shell content Black Mud lenses at 0 83' and 1 33' (SP) FX

1 33-1 75 Coarse grained, poorly sorted Sand mixed with abundant, randomly sized shell fragments (SW) LX SH

1 75-4 17 Gray, muddy, very fine sand with shell fragments present Mild HCl reaction (MH) MU SL

4 17-4 58 Very fine sandy/mud mixed with abundant shell fragments (SC) FX SH

4 58-7 67 Olive Mud Soft and moldable, moderate HCl reaction Appears burrowed in some areas Minor small shell fragments throughout (CH) MU

7 67-9 5 Muddy, fine grained Sand mixed with moderate amounts of shell fragments (SC) FX SL

ATHENA CORE LOG

CORE ID
ATH-B11

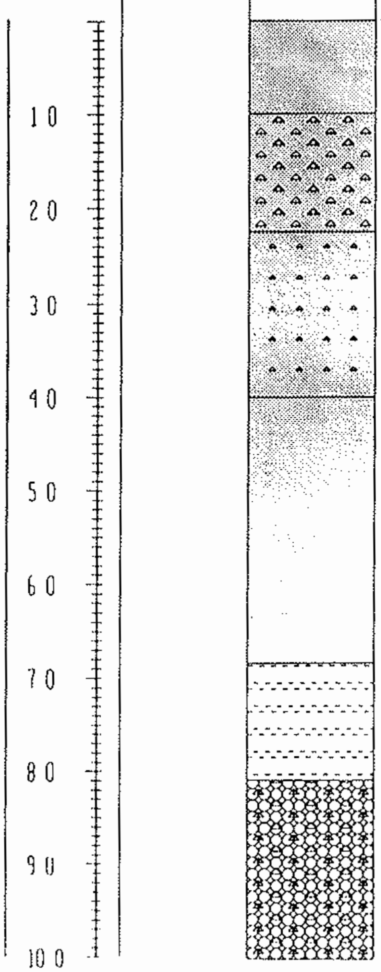
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 1055
PENETRATION LENGTH 11.5'
RECOVERY 10.0'
WATER DEPTH 35'
WEATHER Clear, 65F
GPS-LAT 34 40'33.7"
GPS-LON 76 53'50.6"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 10 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-1.0 Fine grained, well sorted, dark gray Sand Soft Mud lens from 0.08-0.17' Fine to medium shell fragments present throughout (SP) FX

1.0-2.25 Gray, fine grained, slightly muddy Sand mixed with moderate shell fragments (1-20mm) (SW) FX SH

2.25-4.0 Gray, muddy, very fine sand, low shell content Sand slightly coarsens with depth (MH) FX SL

4.0-6.83 Olive gray, fine to very fine grained, slightly muddy Sand Occasional random large shell fragment Medium to fine shell fragments throughout Small mud lenses appear between 5' and 6' Coarsens with depth after 5.5' (SP) FX

6.83-8.08 Gray Mud interbedded with fine grained Sand Low shell content (SC) FB

8.08-10.0 Fine to medium grained, Sand mixed with abundant shell fragments Shell fragments coarsen downcore (SW) MX SH

ATHENA CORE LOG

CORE ID
ATH-B12

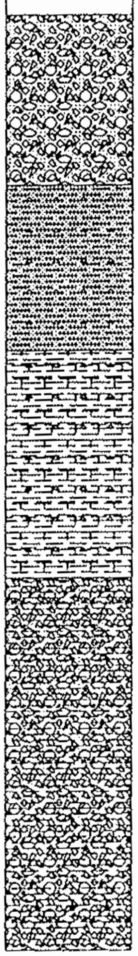
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 1147
PENETRATION LENGTH 10 5'
RECOVERY 10 25'
WATER DEPTH 37'
WEATHER Clear 65F
GPS-LAT 34 40'22.5"
GPS-LON 76 54'52.4"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 10 Nov 99
PAGE 1 OF 1

KEY

Fine Sand		Carbonate		Mud	
Med Sand		Shell Hash		Peat	
Crs Sand		Muddy Sand		Burrows	

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-1 83 Fine to coarse grained, poorly sorted Sand with abundant small shell fragments Mud lenses present at 0 67' and 1 25' (SW) CX SH
1 0			
2 0			1 83-3 58 Olive, fine to very fine grained Sand, slightly muddy moderate shell content (SC) FX MU SL
3 0			
4 0			3 58-6 0 Soft mud Occasional fine sand pockets (burrows?) Reacts with HCl (OH) MU SL BR
5 0			
6 0			6 0-10 25 Gray fine to coarse, poorly sorted Sand and mud mixed with abundant shell fragments of various types and sizes (GC) MU CX SH
7 0			
8 0			
9 0			
10 0			



ATHENA CORE LOG

CORE ID: ATH-B13

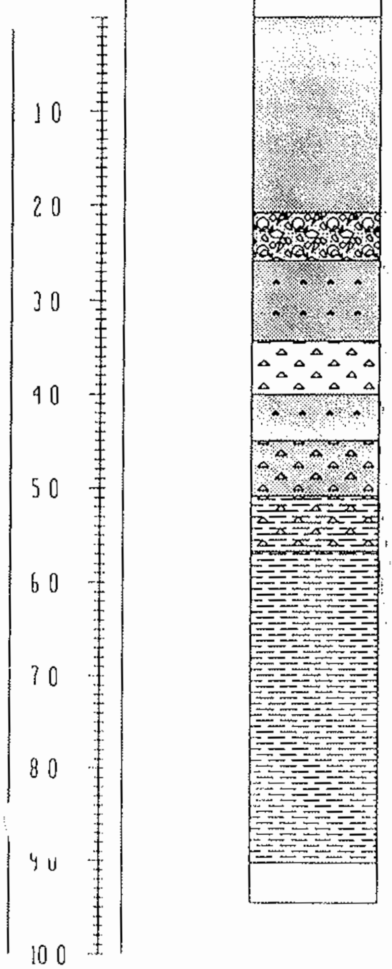
PROJECT Bogue Bonk Sond Seorch
CLIENT CSE
CORE DATE 5 Nov 99
TIME 1242
PENETRATION LENGTH 10'
RECOVERY 9 58'
WATER DEPTH 29'
WEATHER cleor, 65-70F
GPS-LAT 34 40'22.609"
GPS-LON 76 55'59.563"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 10 Nov 99
PAGE 1 OF 1

KEY

Fine Sond	Corbonote	Mud
Med Sond	Shell Hosh	Peot
Crs Sond	Muddy Sond	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-2 08 Ton, fine groined, well sorted Sond
Very fine shell debris throughout, reocts with HCl (SP) FX

2 08-2 58 Shell hosh mixed with fine to coorse Sond ond shell mix Shell frogments ronge from 1mm to 20mm (SW) CX SH

2.58-3 43 Very fine sond Groy in color
Moderote omount of smoll shell frogments (SW) FX SL

3 43-4 0 Fine to coorse groined Sond mixed with obundont shell frogments Shell frogments 1-3mm ot 3 43-3 75, 1-30mm from 3 75-4 0' (SW) CS SH

4 0-4 50 Fine to medium Sond mixed with moderote omount of smoll shell frogments (1-10mm size) (SN) FX SL

4 50-5 08 Shell loyer similor to 3 43 to 4 0'unit Fine to medium Sond mixed with obundont shell frogments of rondom size (SW) FX SH

5 08-5 67 Silty, Mud High omount of intoct oyster shells
(OH) MU SH

5 67-9 0 Olive, soft Mud High woter content, moldoble Minor unidentifioble plont frogments present Some fine sond infilled burrows present Unit becomes silty down core (OH) MU

9 0-9 43 Fine groined well sorted Sond 3mm white corbonote lenses present Becomes finer with depth (SN) FX

ATHENA CORE LOG

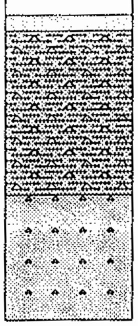
CORE ID	ATH-14

PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 1355
PENETRATION LENGTH 6'
RECOVERY 3 33'
WATER DEPTH 43
WEATHER Clear 65F
GPS-LAT 34 40'14.9"
GPS-LON 76 54'59.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 8 Nov 99
PAGE 1 OF 1

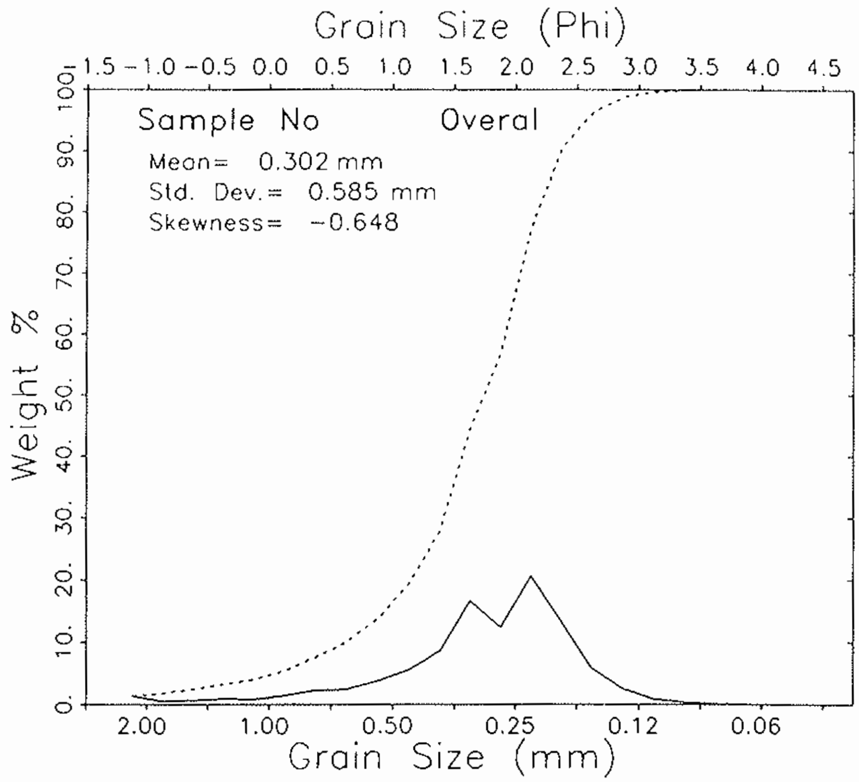
KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-0 17 Fine well sorted Sand (SP)FX
1 0			0 17-1 93 Fine Sand and Mud mixed with abundant randomly sized shell fragments High water content, dark grey (SC)FX MU SH
2 0			1 93-3 25 Mud and water content decreases as does shell content Mostly Fx sand and silt (SC) FX SL
3 0			
4 0			
5 0			
6 0			
7 0			
8 0			
9 0			
10 0			

ANNEX E-3

Beach Composite Sediment Sample Results
Phase I Borrow Area Composites



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
AllCmp	070699						
Bogue Banks - Overall Beach Composite -							
		-1.125	1.370		1.280	-1.000	1.280
		-.875	.470		.439	-.750	1.719
		-.625	.720		.673	-.500	2.392
		-.375	.910		.850	-.250	3.242
		-.125	.840		.785	.000	4.027
		.125	1.460		1.364	.250	5.391
		.375	2.350		2.196	.500	7.587
		.625	2.590		2.420	.750	10.007
		.875	3.970		3.709	1.000	13.716
		1.125	5.900		5.512	1.250	19.228
		1.375	9.080		8.484	1.500	27.712
		1.625	17.820		16.650	1.750	44.361
		1.875	13.240		12.370	2.000	56.732
		2.125	22.070		20.620	2.250	77.352
		2.375	14.190		13.258	2.500	90.610
		2.625	6.080		5.681	2.750	96.291
		2.875	2.650		2.476	3.000	98.767
		3.125	.900		.841	3.250	99.608
		3.375	.310		.290	3.500	99.897
		3.625	.100		.093	3.750	99.991
		3.875	.010		.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.030

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

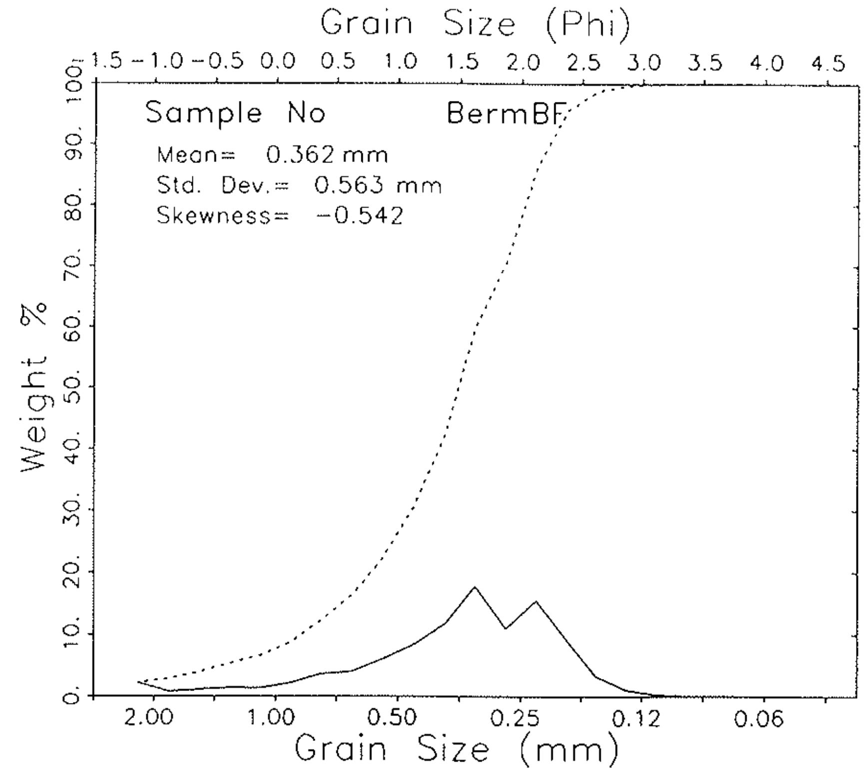
MOMENT MEASURES:

MEAN = 1.725 STANDARD DEVIATION = .773 SKEWNESS = -.648 KURTOSIS = 2.366
DISPERSION = .434 STANDARD DEVIATION = .657 DEVIATION FROM NORMAL DISTR. = -14.96%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.055	.178	1.104	1.420	1.864	2.221	2.375	2.693	3.069

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.739	1.781	MEDIUM SAND
STANDARD DEVIATION	.636	.699	MODERATELY WELL SORTED
SKEWNESS(1)	-.196	-.268	COARSE-SKEWED
SKEWNESS(2)	-.673		
KURTOSIS	.977	1.286	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BERMBF	070699					
Bogue Banks Berm & Beach Face Composite						
		-1.125	2.300	2.145	-1.000	2.145
		-.875	.770	.718	-.750	2.862
		-.625	1.160	1.082	-.500	3.944
		-.375	1.470	1.371	-.250	5.315
		-.125	1.360	1.268	.000	6.583
		.125	2.310	2.154	.250	8.737
		.375	3.820	3.562	.500	12.298
		.625	4.240	3.953	.750	16.252
		.875	6.370	5.939	1.000	22.191
		1.125	8.880	8.280	1.250	30.471
		1.375	12.480	11.636	1.500	42.107
		1.625	19.060	17.772	1.750	59.879
		1.875	11.780	10.984	2.000	70.862
		2.125	16.590	15.469	2.250	86.331
		2.375	9.820	9.156	2.500	95.487
		2.625	3.460	3.226	2.750	98.713
		2.875	1.000	.932	3.000	99.646
		3.125	.250	.233	3.250	99.879
		3.375	.090	.084	3.500	99.963
		3.625	.030	.028	3.750	99.991
		3.875	.010	.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.250

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

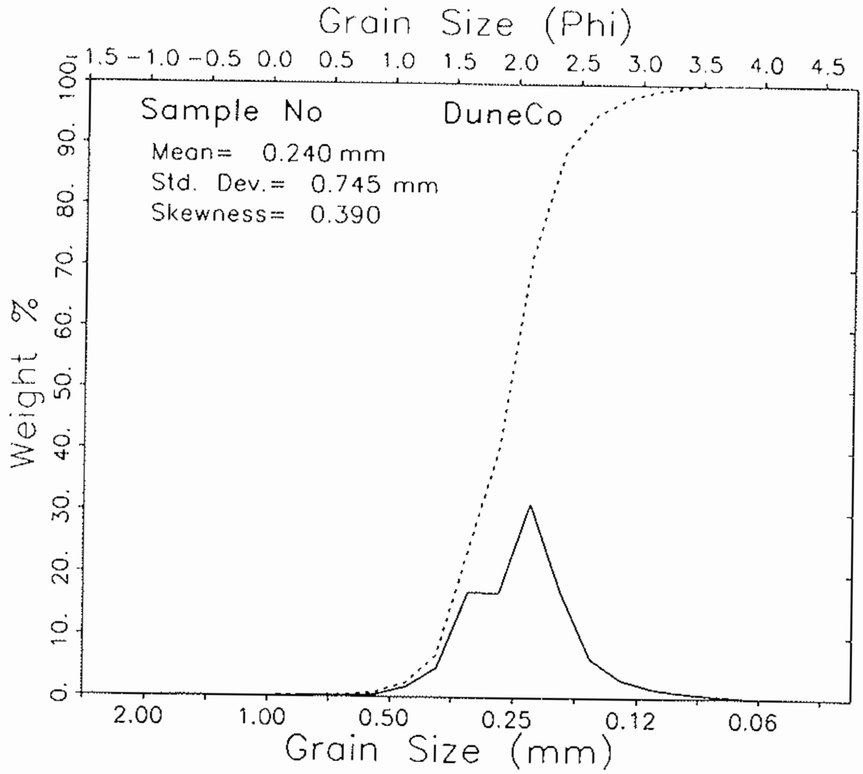
MOMENT MEASURES:

MEAN = 1.466 STANDARD DEVIATION = .830 SKEWNESS = -.542 KURTOSIS = 1.227
DISPERSION = .470 STANDARD DEVIATION = .715 DEVIATION FROM NORMAL DISTR. = -13.87%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.133	-.307	.734	1.085	1.611	2.067	2.212	2.487	2.827

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.473	1.519	MEDIUM SAND
STANDARD DEVIATION	.739	.793	MODERATELY SORTED
SKEWNESS(1)	-.186	-.280	COARSE-SKEWED
SKEWNESS(2)	-.705		
KURTOSIS	.890	1.166	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Dune-C	070699					
Bogue Banks - Dune Composite BB30 & BB90						
		-1.125	.000	.000	-1.000	.000
		-.875	.010	.010	-.750	.010
		-.625	.020	.020	-.500	.029
		-.375	.020	.020	-.250	.049
		-.125	.010	.010	.000	.059
		.125	.050	.049	.250	.108
		.375	.110	.108	.500	.216
		.625	.140	.137	.750	.353
		.875	.350	.343	1.000	.696
		1.125	1.550	1.519	1.250	2.214
		1.375	4.620	4.526	1.500	6.740
		1.625	17.260	16.910	1.750	23.650
		1.875	17.140	16.792	2.000	40.443
		2.125	31.940	31.292	2.250	71.735
		2.375	17.310	16.959	2.500	88.694
		2.625	6.290	6.162	2.750	94.856
		2.875	2.820	2.763	3.000	97.619
		3.125	1.390	1.362	3.250	98.981
		3.375	.740	.725	3.500	99.706
		3.625	.270	.265	3.750	99.971
		3.875	.030	.029	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.070

PERCENT FINER THAN 4.00 PHI = .01 PERCENT COARSER THAN -1.00 PHI = .00

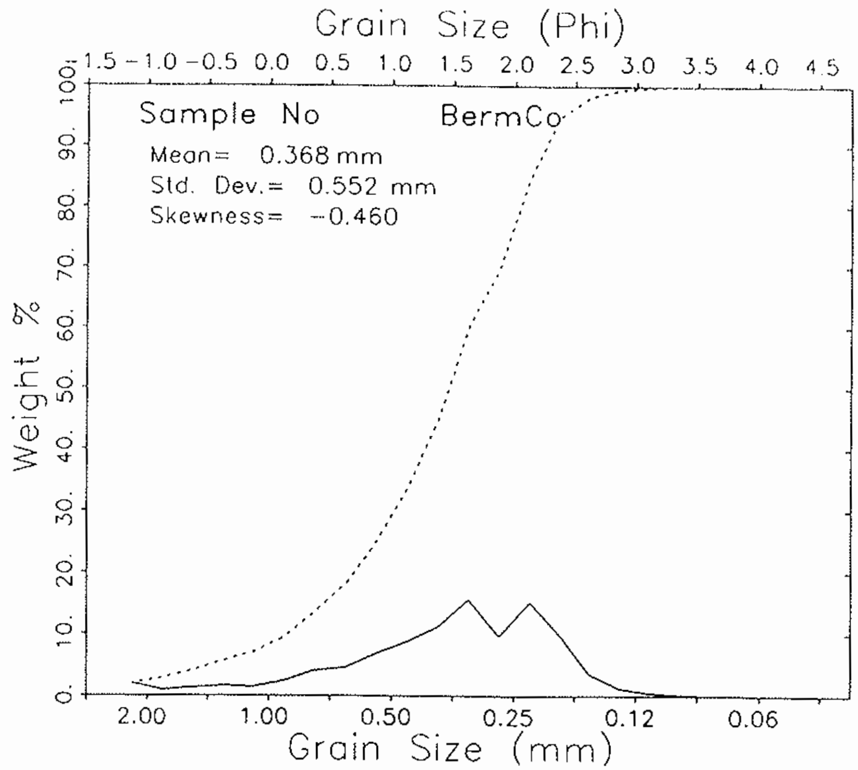
MOMENT MEASURES:

MEAN = 2.060 STANDARD DEVIATION = .425 SKEWNESS = .039 KURTOSIS = 1.952
DISPERSION = .221 STANDARD DEVIATION = .403 DEVIATION FROM NORMAL DISTR. = -5.10%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.050	1.404	1.637	1.770	2.076	2.298	2.431	2.763	3.257

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.034	2.040	FINE SAND
STANDARD DEVIATION	.397	.404	WELL SORTED
SKEWNESS(1)	-.107	-.048	NEAR SYMMETRICAL
SKEWNESS(2)	.018		
KURTOSIS	.712	1.055	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Berm C	070699					
Bogue Banks - Berm Composite - 6 Station						
		-1.125	2.070	1.962	-1.000	1.962
		-.875	.900	.853	-.750	2.815
		-.625	1.330	1.261	-.500	4.076
		-.375	1.620	1.536	-.250	5.612
		-.125	1.500	1.422	.000	7.034
		.125	2.520	2.389	.250	9.423
		.375	4.280	4.057	.500	13.480
		.625	4.800	4.550	.750	18.030
		.875	7.220	6.844	1.000	24.874
		1.125	9.160	8.683	1.250	33.558
		1.375	11.640	11.034	1.500	44.592
		1.625	16.410	15.556	1.750	60.148
		1.875	10.130	9.603	2.000	69.751
		2.125	16.000	15.167	2.250	84.918
		2.375	10.430	9.887	2.500	94.805
		2.625	3.640	3.451	2.750	98.256
		2.875	1.210	1.147	3.000	99.403
		3.125	.400	.379	3.250	99.782
		3.375	.160	.152	3.500	99.934
		3.625	.060	.057	3.750	99.991
		3.875	.010	.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.490

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

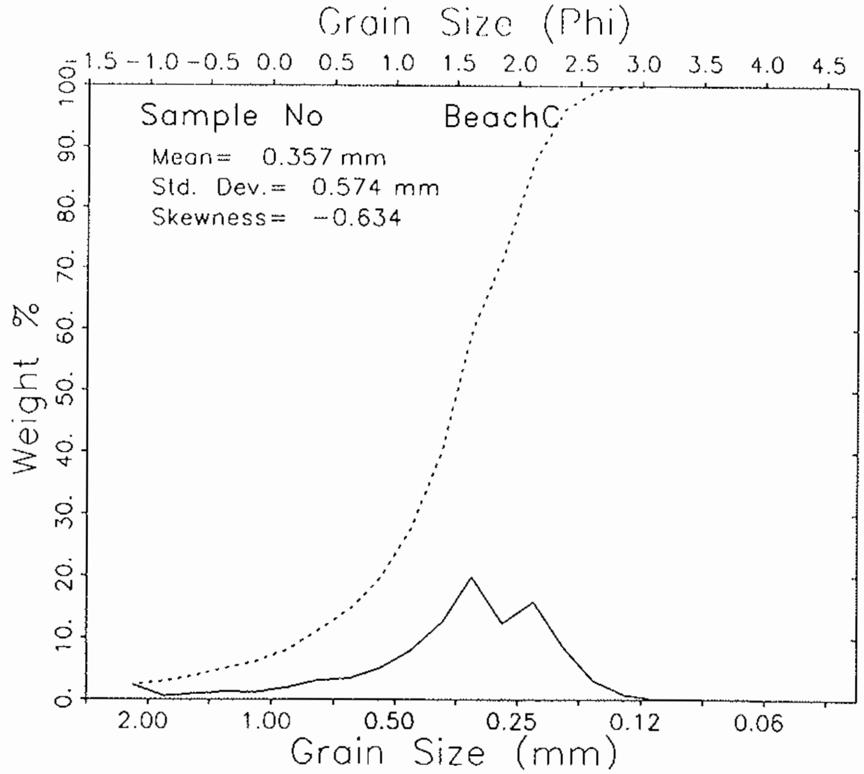
MEAN = 1.444 STANDARD DEVIATION = .858 SKEWNESS = -.460 KURTOSIS = .760

DISPERSION = .496 STANDARD DEVIATION = .759 DEVIATION FROM NORMAL DISTR. = -11.52%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.123	-.350	.638	1.004	1.587	2.087	2.235	2.514	2.912

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.437	1.487	MEDIUM SAND
STANDARD DEVIATION	.798	.833	MODERATELY SORTED
SKEWNESS(1)	-.188	-.270	COARSE-SKEWED
SKEWNESS(2)	-.632		
KURTOSIS	.794	1.084	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BFComp	070699						
Bogue Banks - Beach Face Composite - 6 S							
		-1.125	2.540		2.330	-1.000	2.330
		-.875	.630		.578	-.750	2.908
		-.625	.990		.908	-.500	3.816
		-.375	1.320		1.211	-.250	5.027
		-.125	1.220		1.119	.000	6.146
		.125	2.090		1.917	.250	8.063
		.375	3.360		3.082	.500	11.146
		.625	3.690		3.385	.750	14.531
		.875	5.530		5.073	1.000	19.604
		1.125	8.590		7.880	1.250	27.484
		1.375	13.320		12.219	1.500	39.703
		1.625	21.720		19.925	1.750	59.628
		1.875	13.430		12.320	2.000	71.948
		2.125	17.190		15.769	2.250	87.717
		2.375	9.210		8.449	2.500	96.165
		2.625	3.270		3.000	2.750	99.165
		2.875	.780		.716	3.000	99.881
		3.125	.100		.092	3.250	99.972
		3.375	.020		.018	3.500	99.991
		3.625	.000		.000	3.750	99.991
		3.875	.010		.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.010

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

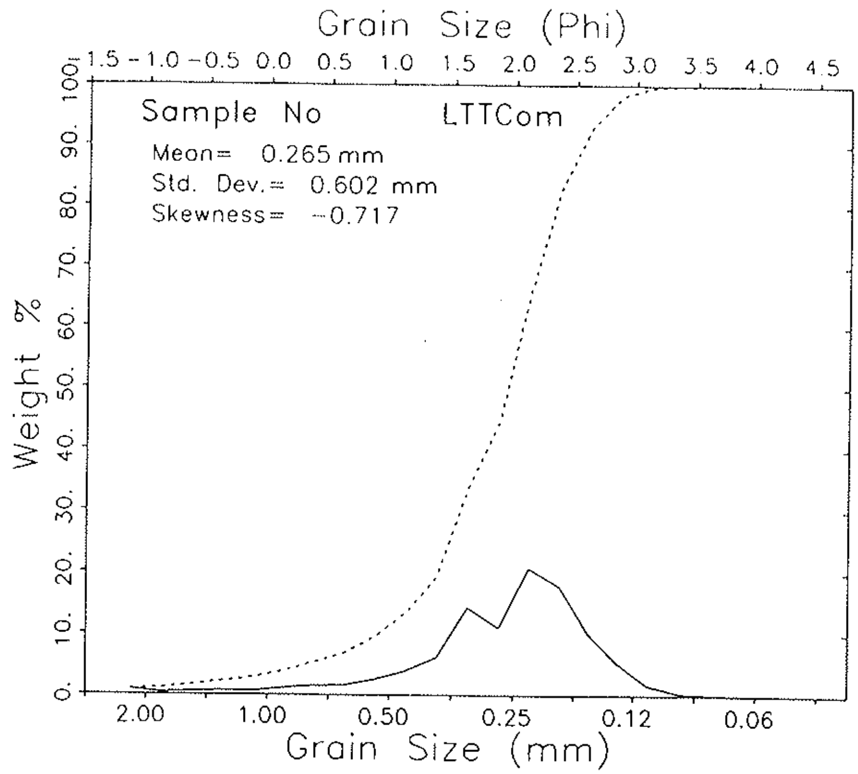
MEAN = 1.487 STANDARD DEVIATION = .801 SKEWNESS = -.634 KURTOSIS = 1.798

DISPERSION = .440 STANDARD DEVIATION = .666 DEVIATION FROM NORMAL DISTR. = -16.88%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.143	-.256	.822	1.171	1.629	2.048	2.191	2.466	2.736

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.507	1.548	MEDIUM SAND
STANDARD DEVIATION	.684	.754	MODERATELY SORTED
SKEWNESS(1)	-.179	-.282	COARSE-SKEWED
SKEWNESS(2)	-.766		
KURTOSIS	.988	1.271	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
LTTCmp	070699					
Bogue Banks - Low Tide Terrace - 6 Stati						
		-1.125	.870	.780	-1.000	.780
		-.875	.330	.296	-.750	1.075
		-.625	.560	.502	-.500	1.577
		-.375	.680	.609	-.250	2.187
		-.125	.650	.582	.000	2.769
		.125	1.170	1.048	.250	3.818
		.375	1.650	1.479	.500	5.296
		.625	1.720	1.541	.750	6.838
		.875	2.780	2.491	1.000	9.329
		1.125	4.300	3.853	1.250	13.182
		1.375	6.730	6.031	1.500	19.213
		1.625	15.910	14.258	1.750	33.471
		1.875	12.260	10.987	2.000	44.457
		2.125	23.170	20.764	2.250	65.221
		2.375	19.820	17.761	2.500	82.982
		2.625	11.110	9.956	2.750	92.938
		2.875	5.780	5.180	3.000	98.118
		3.125	1.690	1.514	3.250	99.633
		3.375	.320	.287	3.500	99.919
		3.625	.080	.072	3.750	99.991
		3.875	.010	.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.590

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

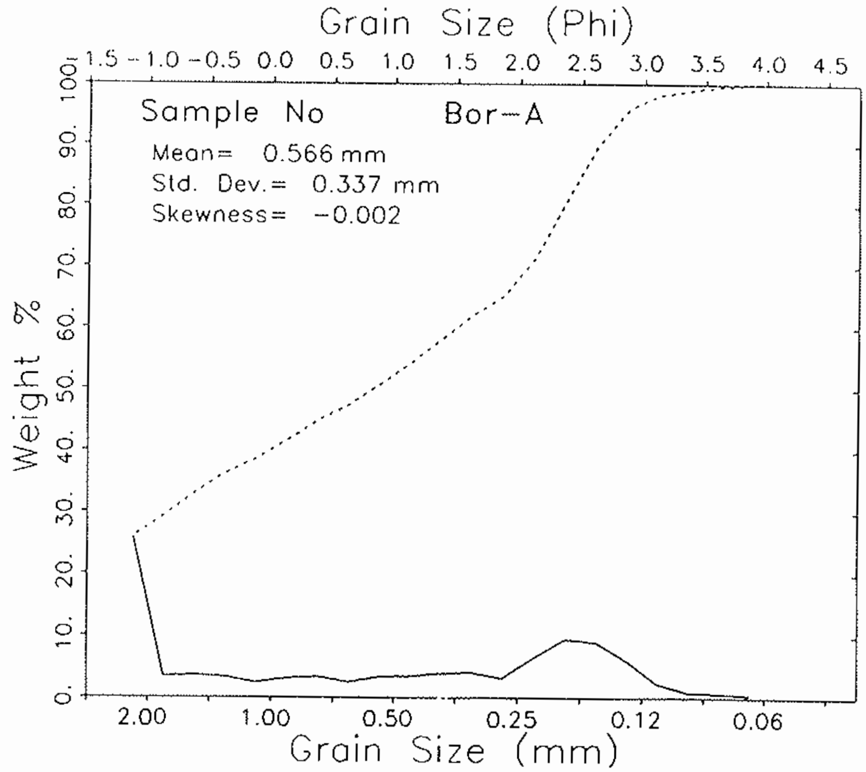
MEAN = 1.918 STANDARD DEVIATION = .731 SKEWNESS = -.717 KURTOSIS = 3.112

DISPERSION = .409 STANDARD DEVIATION = .620 DEVIATION FROM NORMAL DISTR. = -15.19%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.814	.450	1.367	1.601	2.067	2.388	2.526	2.850	3.146

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.946	1.986	MEDIUM SAND
STANDARD DEVIATION	.579	.653	MODERATELY WELL SORTED
SKEWNESS(1)	-.208	-.278	COARSE-SKEWED
SKEWNESS(2)	-.720		
KURTOSIS	1.071	1.251	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bor-A	070699					
Bogue Banks - Borrow Area A						
		-1.125	27.420	25.856	-1.000	25.856
		-.875	3.610	3.404	-.750	29.260
		-.625	3.810	3.593	-.500	32.852
		-.375	3.520	3.319	-.250	36.172
		-.125	2.520	2.376	.000	38.548
		.125	3.230	3.046	.250	41.594
		.375	3.460	3.263	.500	44.856
		.625	2.580	2.433	.750	47.289
		.875	3.490	3.291	1.000	50.580
		1.125	3.630	3.423	1.250	54.003
		1.375	4.120	3.885	1.500	57.888
		1.625	4.310	4.064	1.750	61.952
		1.875	3.370	3.178	2.000	65.130
		2.125	6.830	6.440	2.250	71.570
		2.375	10.010	9.439	2.500	81.009
		2.625	9.490	8.949	2.750	89.958
		2.875	6.350	5.988	3.000	95.945
		3.125	2.350	2.216	3.250	98.161
		3.375	.850	.802	3.500	98.963
		3.625	.680	.641	3.750	99.604
		3.875	.420	.396	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.050

PERCENT FINER THAN 4.00 PHI = 1.20 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

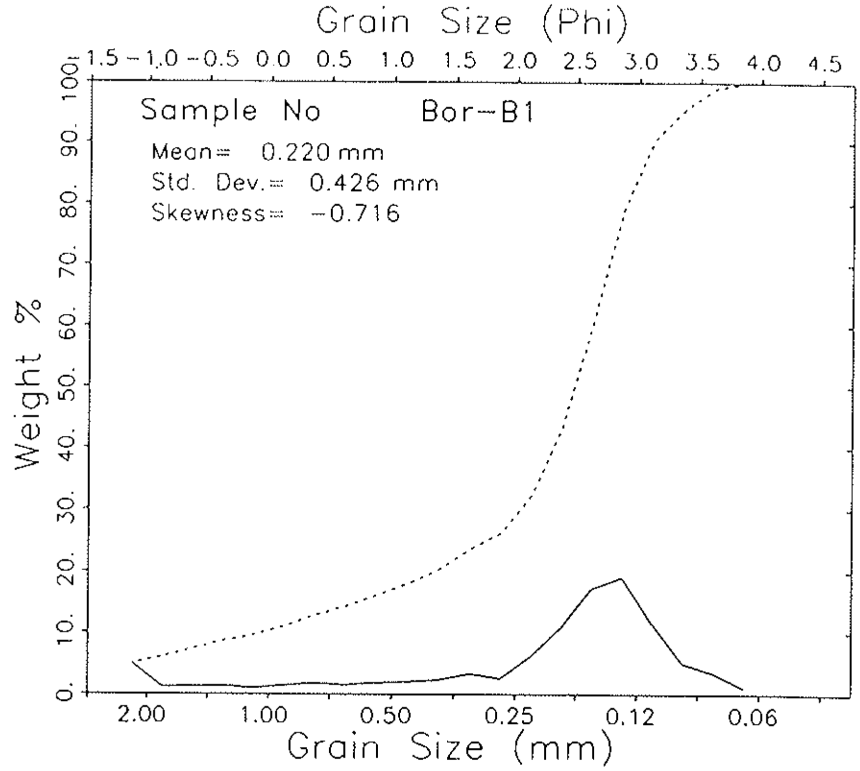
MEAN = .822 STANDARD DEVIATION = 1.568 SKEWNESS = -.002 KURTOSIS = -1.551

DISPERSION = .549 STANDARD DEVIATION = .856 DEVIATION FROM NORMAL DISTR. = -45.40%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.202	-1.095	-1.008	.956	2.341	2.584	2.961	3.515

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.744	.815	COARSE SAND
STANDARD DEVIATION	1.839	1.550	POORLY SORTED
SKEWNESS(1)	-.115	-.076	NEAR SYMMETRICAL
SKEWNESS(2)	-.042		
KURTOSIS	.131	.509	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bor-B1	070699					
Bogue Banks - Borrow Area B1						
		-1.125	5.050	4.952	-1.000	4.952
		-.875	1.130	1.108	-.750	6.060
		-.625	1.270	1.245	-.500	7.305
		-.375	1.310	1.285	-.250	8.590
		-.125	.950	.932	.000	9.521
		.125	1.440	1.412	.250	10.934
		.375	1.750	1.716	.500	12.650
		.625	1.540	1.510	.750	14.160
		.875	1.840	1.804	1.000	15.964
		1.125	1.990	1.951	1.250	17.915
		1.375	2.370	2.324	1.500	20.239
		1.625	3.330	3.265	1.750	23.505
		1.875	2.640	2.589	2.000	26.093
		2.125	6.240	6.119	2.250	32.212
		2.375	10.900	10.688	2.500	42.901
		2.625	17.500	17.160	2.750	60.061
		2.875	19.330	18.955	3.000	79.015
		3.125	11.720	11.492	3.250	90.508
		3.375	5.170	5.070	3.500	95.578
		3.625	3.520	3.452	3.750	99.029
		3.875	.990	.971	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.980

PERCENT FINER THAN 4.00 PHI = 1.71 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

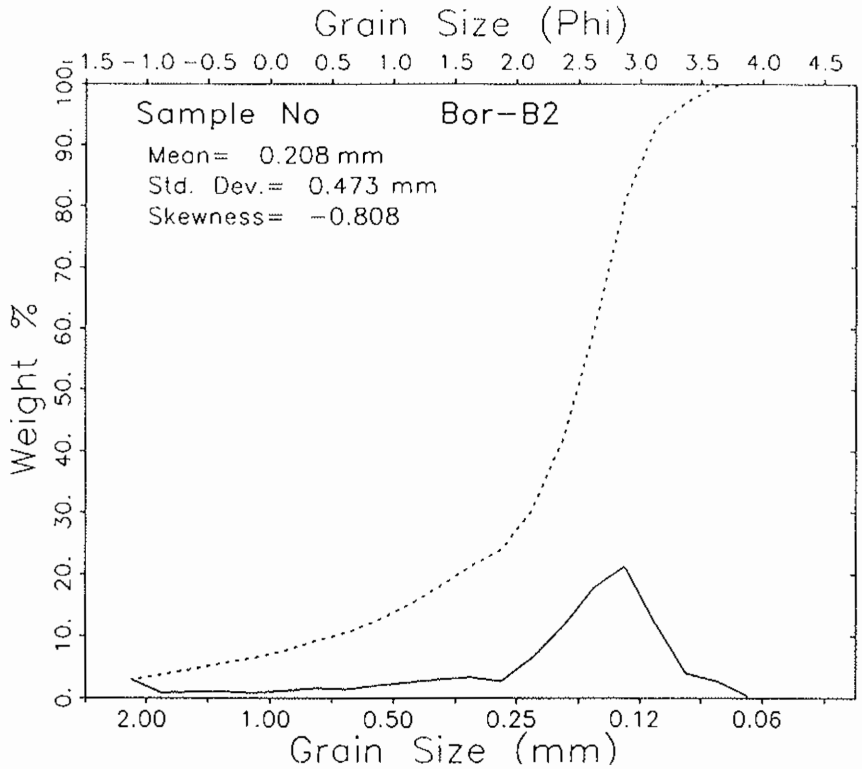
MEAN = 2.182 STANDARD DEVIATION = 1.230 SKEWNESS = -.716 KURTOSIS = 1.181

DISPERSION = .517 STANDARD DEVIATION = .797 DEVIATION FROM NORMAL DISTR. = -35.23%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.200	-.989	1.005	1.894	2.603	2.947	3.108	3.472	3.748

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.057	2.239	FINE SAND
STANDARD DEVIATION	1.052	1.202	POORLY SORTED
SKEWNESS(1)	-.520	-.565	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.295		
KURTOSIS	1.120	1.737	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bor-B2	070699					
Bogue Banks - Borrow Area B2						
		-1.125	3.110	2.979	-1.000	2.979
		-.875	.800	.766	-.750	3.746
		-.625	.970	.929	-.500	4.675
		-.375	1.020	.977	-.250	5.652
		-.125	.840	.805	.000	6.457
		.125	1.210	1.159	.250	7.616
		.375	1.600	1.533	.500	9.149
		.625	1.470	1.408	.750	10.558
		.875	2.100	2.012	1.000	12.569
		1.125	2.570	2.462	1.250	15.032
		1.375	3.070	2.941	1.500	17.973
		1.625	3.450	3.305	1.750	21.278
		1.875	2.820	2.702	2.000	23.980
		2.125	6.750	6.467	2.250	30.446
		2.375	12.150	11.640	2.500	42.087
		2.625	18.550	17.772	2.750	59.858
		2.875	22.060	21.134	3.000	80.993
		3.125	12.510	11.985	3.250	92.978
		3.375	4.140	3.966	3.500	96.944
		3.625	2.880	2.759	3.750	99.703
		3.875	.310	.297	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.380

PERCENT FINER THAN 4.00 PHI = .63 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

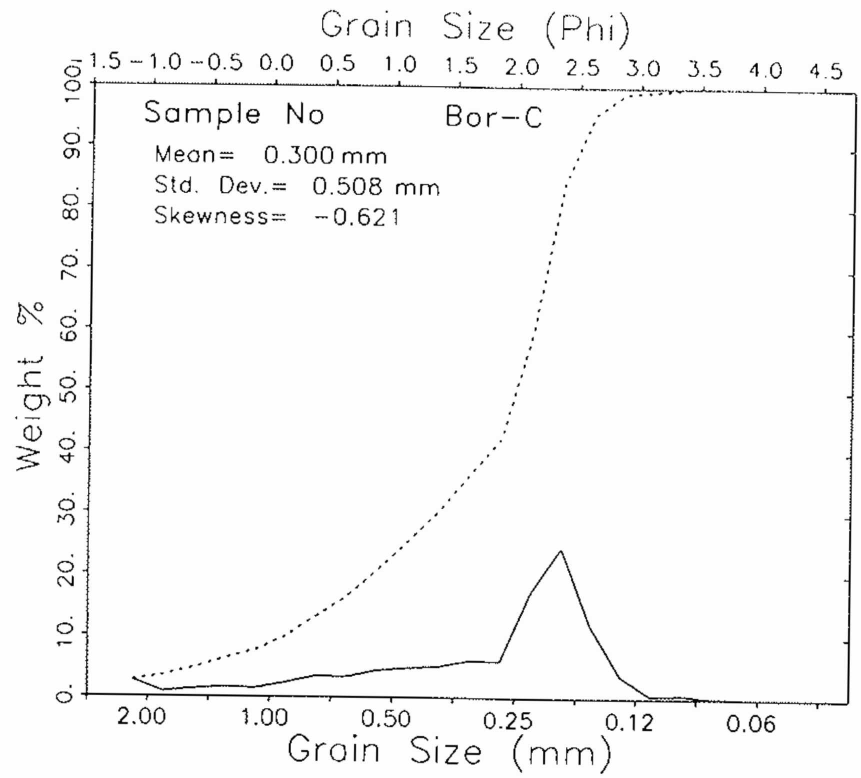
MEAN = 2.263 STANDARD DEVIATION = 1.081 SKEWNESS = -.808 KURTOSIS = 2.137

DISPERSION = .480 STANDARD DEVIATION = .730 DEVIATION FROM NORMAL DISTR. = -32.44%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.166	-.417	1.332	2.039	2.611	2.929	3.063	3.377	3.686

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.198	2.335	FINE SAND
STANDARD DEVIATION	.865	1.008	POORLY SORTED
SKEWNESS(1)	-.478	-.537	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.307		
KURTOSIS	1.193	1.748	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bor-C	070699						
Bogue Inlet Shoal							
		-1.125	2.800		2.616	-1.000	2.616
		-.875	.850		.794	-.750	3.410
		-.625	1.300		1.214	-.500	4.624
		-.375	1.630		1.523	-.250	6.147
		-.125	1.420		1.327	.000	7.474
		.125	2.400		2.242	.250	9.716
		.375	3.550		3.317	.500	13.033
		.625	3.450		3.223	.750	16.256
		.875	4.650		4.344	1.000	20.600
		1.125	5.040		4.709	1.250	25.308
		1.375	5.330		4.979	1.500	30.288
		1.625	6.430		6.007	1.750	36.295
		1.875	6.320		5.904	2.000	42.199
		2.125	18.470		17.255	2.250	59.454
		2.375	26.150		24.430	2.500	83.885
		2.625	12.330		11.519	2.750	95.404
		2.875	3.790		3.541	3.000	98.944
		3.125	.430		.402	3.250	99.346
		3.375	.600		.561	3.500	99.907
		3.625	.100		.093	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.040

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

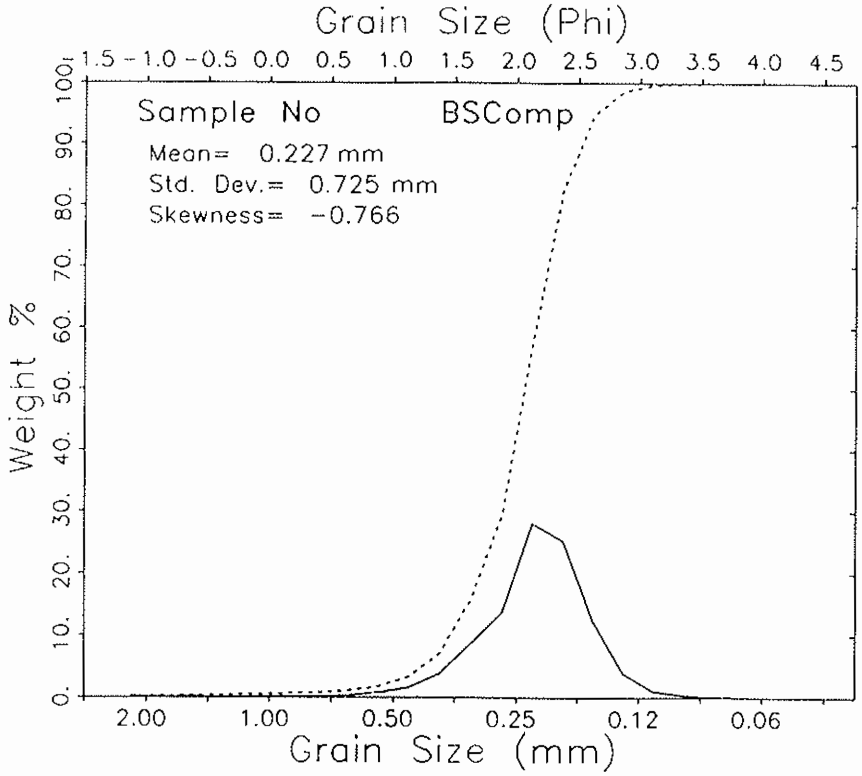
MOMENT MEASURES:

MEAN = 1.738 STANDARD DEVIATION = .978 SKEWNESS = -.621 KURTOSIS = .890
DISPERSION = .464 STANDARD DEVIATION = .705 DEVIATION FROM NORMAL DISTR. = -27.95%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.154	-.438	.730	1.234	2.113	2.409	2.503	2.741	3.035

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.616	1.782	MEDIUM SAND
STANDARD DEVIATION	.886	.925	MODERATELY SORTED
SKEWNESS(1)	-.560	-.583	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.085		
KURTOSIS	.794	1.109	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BSComp	070699						
Bogue Sound - 3 Samples							
		-1.125	.150		.140	-1.000	.140
		-.875	.070		.065	-.750	.205
		-.625	.120		.112	-.500	.317
		-.375	.080		.075	-.250	.391
		-.125	.080		.075	.000	.466
		.125	.140		.130	.250	.596
		.375	.190		.177	.500	.773
		.625	.280		.261	.750	1.034
		.875	.760		.708	1.000	1.742
		1.125	1.630		1.519	1.250	3.261
		1.375	3.960		3.690	1.500	6.951
		1.625	9.260		8.628	1.750	15.580
		1.875	14.680		13.679	2.000	29.258
		2.125	30.150		28.094	2.250	57.352
		2.375	27.100		25.252	2.500	82.603
		2.625	13.100		12.206	2.750	94.810
		2.875	4.170		3.886	3.000	98.695
		3.125	1.030		.960	3.250	99.655
		3.375	.290		.270	3.500	99.925
		3.625	.080		.075	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.320

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

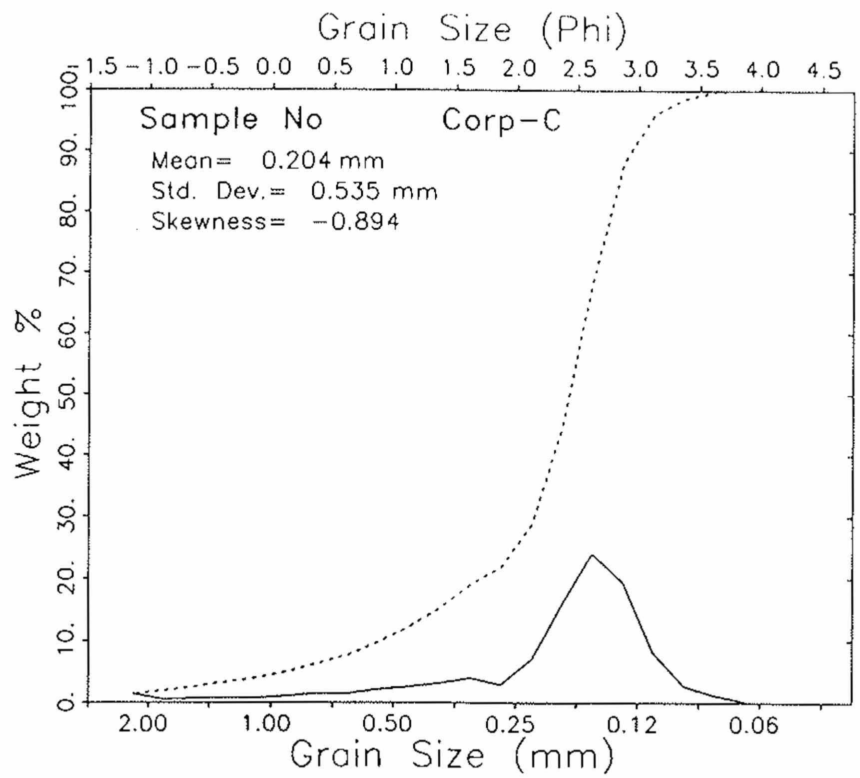
MOMENT MEASURES:

MEAN = 2.141 STANDARD DEVIATION = .463 SKEWNESS = -.766 KURTOSIS = 7.247
DISPERSION = .234 STANDARD DEVIATION = .415 DEVIATION FROM NORMAL DISTR. = -10.50%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.717	1.368	1.758	1.922	2.185	2.425	2.529	2.762	3.079

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.143	2.157	FINE SAND
STANDARD DEVIATION	.385	.404	WELL SORTED
SKEWNESS(1)	-.107	-.139	COARSE-SKEWED
SKEWNESS(2)	-.310		
KURTOSIS	.809	1.137	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
CorpC	070699					
Corps Disposal Area - Eastern Bogue Bank						
		-1.125	1.430	1.368	-1.000	1.368
		-.875	.500	.478	-.750	1.847
		-.625	.660	.631	-.500	2.478
		-.375	.760	.727	-.250	3.205
		-.125	.690	.660	.000	3.865
		.125	1.010	.966	.250	4.832
		.375	1.420	1.359	.500	6.190
		.625	1.430	1.368	.750	7.558
		.875	2.160	2.067	1.000	9.625
		1.125	2.560	2.449	1.250	12.074
		1.375	3.200	3.062	1.500	15.136
		1.625	4.030	3.856	1.750	18.992
		1.875	2.940	2.813	2.000	21.804
		2.125	7.190	6.879	2.250	28.684
		2.375	16.590	15.873	2.500	44.556
		2.625	25.030	23.948	2.750	68.504
		2.875	20.380	19.499	3.000	88.002
		3.125	8.370	8.008	3.250	96.010
		3.375	2.790	2.669	3.500	98.680
		3.625	1.200	1.148	3.750	99.828
		3.875	.180	.172	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.520

PERCENT FINER THAN 4.00 PHI = .24 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.292 STANDARD DEVIATION = .903 SKEWNESS = -.894 KURTOSIS = 3.329

DISPERSION = .418 STANDARD DEVIATION = .634 DEVIATION FROM NORMAL DISTR. = -29.79%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.067	.281	1.556	2.116	2.557	2.833	2.949	3.218	3.570

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.252	2.354	FINE SAND
STANDARD DEVIATION	.696	.793	MODERATELY SORTED
SKEWNESS(1)	-.437	-.493	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.159		
KURTOSIS	1.109	1.679	VERY LEPTOKURTIC

APPENDIX F

APPENDIX F

ECONOMIC STUDIES

LIST OF TABLES

APPENDIX F

Supporting Computations for Section 4.3 "Retreat/Relocate Alternative"

The first three tables in this Appendix are the calculations for the summarized numbers in Section 4.3. Table F-1 breaks down the costs for relocating a house on the same lot, Table F-2 the same computations but for moving to a different lot (insufficient room remains on the same lot), and Table F-3 shows the cost breakdown by municipality.

In the analyses of the retreat/relocate alternative it is assumed that costs occur equally in each year of the 10 year study period; that construction costs escalate at 3 percent per year; that real estate costs escalate at 4.8 percent per year. Final costs for comparison with project costs are normalized to present value based on the discount factor for 30 year Treasury bonds as of February 24, 2000 as published in the Wall Street Journal.

The relocation costs used in the previous tables are supported in detail in Table F-9, showing the different relocation costs by community. The accumulation of these costs by year and type of relocation are further broken down in Table F-10. Thus F-10 feeds the supporting data into F-9, which then provides supporting data for the first three Tables F-1 through F-3.

Finally, the net present worth of all these relocation costs are summed in Table F-11 over the ten years.

Supporting Computations for Section 4.2 "Do-Nothing Alternative"

Impacts on Property Values

The number of oceanfront properties that will be lost under the 10-year project life are totaled in Table F-4 and the values totaled. The appropriate tax rates are then applied to determine the total property tax losses, broken down by community in each section of Table F-4. This is a government loss.

Table F-5 shows the lost property values by year and by community. These are losses to those in the special tax districts.

The present worth of the property tax losses are computed in Table F-6. **This value of $6.3 million is reported in the summary table in Section 4.2.**

In addition to the actual loss of property, there is a loss to the appreciated values, had the structures remained. The present worth of all lost properties, taking into account appreciation, are totaled by community in Table F-7. The listed property losses are losses in the Special Tax Districts, and the listed property tax losses are government losses.

All types of property loss are summarized in Table F-8. These include lost property, lost taxes, beach scraping, property repairs, and debris removal.

The relocation costs used in the previous tables are supported in detail in Table F-9, showing the different relocation costs by community.

Impacts to the Community (Carteret County) Economy

Tourist Expenditures -- Total revenues generated from domestic tourism in Carteret County has been estimated by Carteret County Economic Development Council to be $208.55 million (1998) in "Facts on Carteret County Tourism" based on statistics provided by NC Department of Commerce. The proportion of tourist revenues in Carteret County that are generated on Bogue Banks has been estimated by the same sources as 84 percent. The proportion of recreational beaches on Bogue Banks that this beach-nourishment project is planned to improve is the ratio of this project length to the total beach length or 78 percent. Thus the maximum tourist expenditures that are in jeopardy if there is no recreational beach over the proposed project length is 0.84 x 0.78 x $208.55 million = $136.64 million annually or $1,366.4 million over the ten-year lifetime of the project. The prime tourist attraction in Bogue Banks is the beach. It is difficult to estimate the percent of tourists who would not come to Bogue Banks if the proposed project beach has little or no beach above high tide. Some tourists who come to the area do not use the beach. Those who do use the beach will increasingly crowd onto remaining healthy beach areas such as Atlantic Beach. However, a range of possibilities can be considered. For inclusion in the high and low estimates in Section 4.2, we propose a low limit of 10 percent and a high limit of 25 percent proportion of tourist population that will elect to go elsewhere. Thus the total lost tourist revenues over ten years would range between $136.64 million and $341.61 million. For the purpose of ascertaining who will experience these losses, lost tourism is broken down into the following categories.

Occupancy Tax – There is a 3 percent occupancy tax on all short-term (visitor) rentals. In fiscal year 1998-99 this generated $1,706,788 in Carteret County. Using the numbers in Tourist Expenditures above, losses of occupancy tax for one year would be 10-25 percent of 0.84 x 0.78 x $1,706,788. So the loss range over ten years is $1,118,287 to $2,795,718. This is a governmental loss.

Sales Tax – There is a 6 percent sales tax on non-housing expenditures. The Economic Development Council (reference publication listed above under Tourism Expenditures) estimates $20.05 million of these annual revenues are generated by tourists in Carteret County. Using the numbers in Tourist Expenditures above, losses of sales tax for one year would be 10-25 percent of 0.84 x 0.78 x $20,050,000. So the loss range over ten years is $13,136,000 to $32,840,000. This is a governmental loss.

Payroll – The tourism industry is Carteret County's largest industry. The Economic Development Council estimates this annual payroll at $48.99 million. Using the numbers in Tourist Expenditures above, losses of payroll in one year would be 10-25 percent of 0.84 x 0.78 x $48,990,000. So the loss range over ten years is $32,098,000 to $80,245,000. This is a private loss.

Other Tourist Expenditures – The remaining tourist expenditures (total minus tax and payroll) over the project portion of Bogue Banks are annually 0.84 x 0.78 x ($208.55 - $1.71 - $20.05 - $48.99). So the range of possible losses (10-25 percent of this value multiplied over ten years) is $90.287 million to $225.718 million. This is a private loss.

Recreational Losses – Losses to the environment are more difficult to quantify than economic losses. However, the Corps of Engineers has established procedures for estimating the value of a recreational beach to the general public. Procedures outlined in Engineering Regulation 1105-2-100 were followed. Some choice of methods is allowed under the regulation, but most nourishment projects designed by the Corps use example surveys of the beach-going public that have resulted in "use curves" based on surveys conducted in Florida that were later updated in the Myrtle Beach, SC, project (USACE, 1993). These studies compute the number of beach visits annually by each person (P) as P = A exp (B x) where A and B are empirical coefficients determined by surveys, and x is the travel distance between a community and the beach. The Florida study generated values of A = 6.8 and B = -0.03, and Myrtle Beach updated these to A = 8 and B = -0.04. The A value represents the annual number of beach visits made by a resident who is within walking distance of the beach. Using these values the annual number of beach visits made by residents of Carteret County was computed in Table F-12.

The annual visits total 310,181. To translate this into a dollar value, procedures are available for assigning "point" values to various recreational experiences associated with the amenities at a particular beach. Rather than follow these complex procedures which tends to result in variation in the final number of only 10-20 percent, we simply used the value computed in another study for Folly Beach, SC (USACE, 1991) which produced a value per visit of $3.44. Multiplying the number of annual visits by this value results in an annual recreational value to County residents of $1,067,022. The portion of Bogue Banks represented by this project is 78 percent, so the annual recreational value to residents is 0.78 x $1,067,022 or $832,277. Following the same logic outlined above for Tourist Expenditures, we propose that 10-25 percent of these visits will not occur because of the degraded beach. Ten to 25 percent of the above value multiplied over the ten-year project results in value of $832,277 to $2,080,693. This is an environmental/quality-of-life impact to the county.

Impacts to Owners in Special Tax Districts

Beach Scraping – Since Hurricane *Floyd* (September 1999), an estimated 80 percent of oceanfront properties in the proposed project area have scraped the beach and restored the foredune. Scraping was continuing on 1 March 2000, nearly six months after *Floyd.* Typical dimensions of scraping are 10-15 cubic yards per linear foot. Scraping is performed by skimming the upper 2-4 ft of dry beach by bulldozer and pushing it into a steep sloping dune (typically 1 on 4 seaward slope). Elevation of the top of the scraped dune generally coincides with the backshore escarpment elevation (typically 15-20 ft NGVD). Typical range of expenditures per 100-ft oceanfront lot have been $500–3000 per incident. Some owners have scraped nearly every year since 1995. While the crest elevation of the scraped dune is well above the 10-year or 25-year surge elevation, the protection is not equivalent because the remaining beach after scraping is narrower and less able to absorb wave energy. As a result, the scraped dune is exposed at the toe and vulnerable to scarping. This, in turn, leads to mass wasting of the scraped dune and the need to rescrape. As erosion continues under the no action alternative, the frequency of erosion and undermining of the artificial dunes will increase. For purposes of cost estimating, we assume that 50 percent of the beach will require scraping in any given year. Scraping 50 percent each year results in an annual cost of $250,000. Escalating and normalizing to present value is $ 2.2 million over ten (10) years: (Table F-8).

Reconstruction of Dune Walkovers – An estimated 80 percent of existing dune walkovers in the project area have been rebuilt since Hurricane *Floyd.* Many of these same property owners had to replace their walkovers after *Fran* and the other hurricanes of the late 1990s. The nature of repairs ranges from replacement of just a few steps at the base to entire reconstruction of support piles, observation decks and handicapped ramps. A majority of walkovers extend from relatively high backshore elevations (typically 15–20 ft NGVD), thus the support systems are elaborate in many cases. With increasing frequency of runup to the base of structures, repaired walkovers are usually improved and more expensive compared to the destroyed walkover. We estimate a range of expenditures per property is ~$200 to $10,000 after *Floyd*, with a typical cost around $3000, or approximately $2.2 million. Thus, the ten-year cost of walkover replacement due to storm erosion has a present value of $19.1 million (Table F-8). This is an impact to oceanfront property owners.

TABLE F-1

BOGUE BANKS BEACH NOURISHMENT
RETREAT/RELOCATE ALTERNATIVE
RELOCATE HOUSE ON EXISTING LOT

CSE Baird
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

Date: Feb. 28, 2000
By: J.W. Forman, Jr., P.E.

COST OPINION FOR RELOCATION OF BEACHFRONT RESIDENTIAL STRUCTURE
BASED ON TYPICAL HOUSE, 1350 S.F. FOOTPRINT
STRUCTURE MOVED ON EXISTING LOT

#	Item	Quant.	Unit	Unit Cost	Total Costs OH&P
A.	ADMINISTRATIVE				
A.	SITE WORK AND GENERAL CONSTRUCTION				
1.0	Fees and Permits	1	l.s.	$500.00	$500.00
2.0	Site Grading	1	l.s.	$2,000.00	$2,000.00
3.0	Demolition and Removal of Old Slab	1	l.s.	$300.00	$300.00
4.0	Abandon Old & Install New Septic System	1	l.s.	$3,000.00	$3,000.00
5.0	Water & Sewer Plumbing to New Structure	1	l.s.	$2,000.00	$2,000.00
SITE WORK & GENERAL CONSTRUCTION TOTAL					$7,800
B	MOVE AND RECONSTRUCT STRUCTURE				
1.0	House Preparation & Moving	1350	s.f.	$22.50	$30,375.00
2.0	Pile Driving Mobilization	1	l.s.	$1,000.00	$1,000.00
3.0	Treated Timber Piles 8x8x25	500	v.l.f.	$10.00	$5,000.00
4.0	Drive Timber Piles	500	v.l.f.	$12.50	$6,250.00
5.0	300 s.f. Conc. Slab 4" thk.	4	c.y.	$125.00	$500.00
6.0	Underhouse Construction	300	s.f.	$25.00	$7,500.00
7.0	Porch Replacement, Piles	125	v.l.f.	$22.50	$2,812.50
8.0	Timber Decking, Min. Framing, No Piles	540	s.f.	$25.00	$13,500.00
9.0	Electrical Wiring and Service	1	l.s.	$1,500.00	$1,500.00
10.0	HVAC Reinstallation	1	l.s.	$1,500.00	$1,500.00
MOVE AND RECONSTRUCT STRUCTURE TOTAL					$68,437.50
CONSTRUCTION TOTAL					$0.00
				USE	$78,000.00

TABLE F-2

BOGUE BANKS BEACH NOURISHMENT
RETREAT/RELOCATE ALTERNATIVE
RELOCATE HOUSE TO NON-OCEANFRONT LOT

CSE BAIRD
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

By: **J.W. Forman, Jr., P.E.** **Date:** **February 28, 2000**

COST OPINION FOR RELOCATION OF BEACHFRONT RESIDENTIAL STRUCTURE
BASED ON TYPICAL HOUSE, 1350 S.F. HEATED FOOTPRINT, 1890 S.F. TOTAL ELEVATED
RELOCATE STRUCTURE TO OFF-SITE LOT, ABANDON EXISTING LAND

#	Item	Quant.	Unit		Unit Cost		Total Costs
A.	LAND PURCHASE AND ABANDONMENT						
Emerald Isle							
1.0	Cost for Abandonment of Exist Lot*	L.S.	1		$264,000.00		
	Purchase of New Lot**	L.S.	1		$126,000.00		**$390,000.00**
Pine Knoll Shores and Indian Beach							
	Cost for Abandonment of Exist Lot*	L.S.	1		$264,000.00		
	Purchase of New Lot**	L.S.	1		$175,000.00		**$439,000.00**
B.	SITE WORK AND GENERAL CONSTRUCTION, FOUNDATION RETROFIT						
1.0	Fees and Permits	1	l.s.	$	500.00	$	500.00
2.0	Site Grading	1	l.s.	$	1,000.00	$	1,000.00
3.0	Demolition and Removal of Old Slab	1	l.s.	$	300.00	$	300.00
4.0	Abandon Old & Install New Septic System	1	l.s.	$	3,000.00	$	3,000.00
5.0	Water & Sewer Plumbing to New Structure	1	l.s.	$	2,000.00	$	2,000.00
6.0	Electrical Wiring and Service	1	l.s.	$	1,500.00	$	1,500.00
7.0	HVAC Reinstallation	1	l.s.	$	1,500.00	$	1,500.00
8.0	Pile Driving Mobilization	1	l.s.	$	1,000.00	$	1,000.00
9.0	Treated Timber Piles 8x8x25	625	v.l.f.	$	10.00	$	6,250.00
10.0	Drive Timber Piles	400	v.l.f.	$	12.50	$	5,000.00
11.0	300 s.f. Conc. Slab 4" thk.	4	c.y.	$	125.00	$	500.00
12.0	Underhouse Construction	300	s.f.	$	25.00	$	7,500.00
13.0	Timber Decking, Min. Framing, No Piles	540	s.f.	$	25.00	$	13,500.00
SITE WORK AND GENERAL CONSTRUCTION, FOUNDATION RETROFIT TOTAL						**$**	**44,000.00**
		Cost per Sq. Ft.				$	32.59
C.	PREPARE AND MOVE STRUCTURE						
1.0	House Preparation & Moving	1350	s.f.	$	25.00	$	33,750.00
2.0	Electrical Secondary Power Temp Move	1	l.s.	$	8,000.00	$	8,000.00
PREPARE AND MOVE STRUCTURE TOTAL						**$**	**42,000.00**
		Cost per Sq. Ft.				$	31.11
CONSTRUCTION TOTAL						**$**	**86,000.00**

COST SUMMARY

Emerald Isle - Relocate House to Non-Oceanfront Lot	**$ 390,000.00**
Pine Knoll Shores - Relocate House to Non-Oceanfront Lot	**$ 439,000.00**

* Abandonment Cost is Lost Value of Existing Homesite
** Based on assumption that replacement oceanfront lots are not available able for purchase. Owner would have to purchase replacement lot in intereior of island at market prices.

TABLE F-3

BOGUE BANKS BEACH NOURISHMENT
RETREAT/RELOCATE ALTERNATIVE
PROPERTY VALUE DATA

STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

By: J.W. Forman, Jr., P.E. Date: 28-Feb-00

Values for Existing Properties
Based on data provided by Carteret County Tax Office

Property	Type	Muni	Land Value	Building Value	Total Value	% Land	%Building	Sq. Ft. Land	Land Value per Sq. Ft
Bryant	S.F.	PKS	$ 218,500	$ 115,080	$ 333,580	65.5%	34.5%	27,929	$ 7.82
Oakley	S.F.	PKS	$ 255,200	$ 176,397	$ 431,597	59.1%	40.9%	47,808	$ 5.34
Zwerling	S.F.	S.P.	$ 153,450	$ 95,663	$ 249,113	61.6%	38.4%	32,536	$ 4.72
Zoeller	S.F.	E.I.	$ 261,660	$ 170,375	$ 432,035	60.6%	39.4%	19,822	$ 13.20
Nobles	S.F.	E.I.	$ 244,575	$ 75,148	$ 319,723	76.5%	23.5%	15,202	$ 16.09
Murphrey	S.F.	E.I.	$ 152,550	$ 56,919	$ 209,469	72.8%	27.2%	11,533	$ 13.23
Averages			**$ 214,323**	**$ 114,930**	**$ 329,253**	**66.02%**	**33.98%**		**$ 10.07**
Std. Deviations			**$ 49,700**	**$ 49,300**	**$ 91,600**	**7.12%**	**7.12%**		**$ 4.73**
		Use	**$ 264,000**	**$ 136,000**	**$ 400,000**	**66%**	**34%**		
<u>DELETED FROM SAMPLE</u>									
LAND ONLY PROPERTIES									
Barnett	L	PKS-C	$ 249,900.00		$ 249,900.00	100.0%		42,164	$ 5.93
Nassau Corp.	L	E.I.	$ 272,204.00		$ 272,204.00	100.0%		28,449	$ 9.57
EXTRAORDINARILY HIGH VALUE BUILDINGS									
Best	S.F.	PKS-C	$ 186,520.00	$ 286,762.00	$ 473,282.00	39.4%	60.6%	27,544	$ 6.77
Guthrie	S.F.	PKS-W	$ 241,595.00	$ 383,497.00	$ 625,092.00	38.6%	61.4%	37,100	$ 6.51

TABLE F-3

Off Beachfront Vacant Lot Values (Researched by Ron Martin, Appraiser, Allen Shelor Real Estate, Atlantic Beach, NC)

Emerald Isle		**Use**	**Average Costs**
Second Row lots	$ 200,000.00	$ 200,000	
Third Row	$102,000 to $125,000	$ 114,000	$ 126,333
Interior	$60,000 to $70,000	$ 65,000	
Pine Knoll Shores			
Interior	$40,000 to $60,000	$ 50,000	
Interior Canal	$150,000	$ 150,000	$ 175,000
Beachfront	$300,000 to $350,000	$ 325,000	

Abbreviations

Muni - Municipality

Salter Path	S.P.	**Type**	
Emerald Isle	E.I.	Single Family	S.F.
Pine Knoll Shores	PKS	Land Only	L

BOGUE BANKS BEACH NOURISHMENT
PROJECT ALTERNATIVE ANALYSES
DO-NOTHING ALTERNATIVE
Date: 28-Feb-00
By: J.W. Forman, Jr., P.E.

TABLE F-4

CSE BAIRD
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

TAX REVENUE LOSSES ASSOCIATED WITH LOSS OF OCEANFRONT PROPERTIES FOR DO-NOTHING ALTERNATIVE

Emerald Isle	Units	Property Values Land	Property Values Structure	Unit Value	Total Value
Single Family	156	$264,000	$136,000	$400,000	$62,400,000
Condominium	36		$150,000	$150,000	$5,400,000
Mobile Home Lots	17		$20,000	$20,000	$340,000

	Tax Rates/$100 Value Town	Tax Rates/$100 Value County	Unit Tax Revenues Town	Unit Tax Revenues County	Per Annum Total Tax Rev. Value Town	Per Annum Total Tax Rev. Value County
	$0.195	$0.50	$780	$2,000	$121,680	$312,000
	$0.195	$0.50	$293	$750	$10,530	$27,000
	$0.195	$0.50	$39	$100	$663	$1,700

Salter Path	Units	Property Values Land	Property Values Structure	Unit Value	Total Value
Single Family	15	$264,000	$136,000	$400,000	$6,000,000
Condominium	45		$150,000	$150,000	$6,750,000
Mobile Home Lots	7		$20,000	$20,000	$140,000

	Tax Rates/$100 Value Town	Tax Rates/$100 Value County	Unit Tax Revenues Town	Unit Tax Revenues County	Per Annum Total Tax Rev. Value Town	Per Annum Total Tax Rev. Value County
	$0.00	$0.50	$0	$2,000	$0	$30,000
	$0.00	$0.50	$0	$750	$0	$33,750
	$0.00	$0.50	$0	$100	$0	$700

Indian Beach	Units	Property Values Land	Property Values Structure	Unit Value	Total Value
Single Family	10	$264,000	$136,000	$400,000	$4,000,000
Condominium	32		$150,000	$150,000	$4,800,000
Mobile Home Lots	15		$20,000	$20,000	$300,000

	Tax Rates/$100 Value Town	Tax Rates/$100 Value County	Unit Tax Revenues Town	Unit Tax Revenues County	Per Annum Total Tax Rev. Value Town	Per Annum Total Tax Rev. Value County
	$0.170	$0.50	$680	$2,000	$6,800	$20,000
	$0.170	$0.50	$255	$750	$8,160	$24,000
	$0.170	$0.50	$34	$100	$510	$1,500

Pine Knoll Shores	Units	Property Values Land	Property Values Structure	Unit Value	Total Value
Single Family	4	$264,000	$136,000	$400,000	$1,600,000
Condominium	58		$150,000	$150,000	$8,700,000
Mobile Home Lots	0		$20,000	$20,000	$0

	Tax Rates/$100 Value Town	Tax Rates/$100 Value County	Unit Tax Revenues Town	Unit Tax Revenues County	Per Annum Total Tax Rev. Value Town	Per Annum Total Tax Rev. Value County
	$0.16	$0.50	$640	$2,000	$2,560	$8,000
	$0.16	$0.50	$240	$750	$13,920	$43,500
	$0.16	$0.50	$32	$100	$0	$0

TABLE F-5

BOGUE BANKS BEACH RENOURISHMENT
PROJECT LTERNATIVE ANALYSIS
DO-NOTHING ALTERNATIVE

CSE BAIRD
STROUD ENGINEERING, P.A.

BY: J.W. Forman, Jr., P.E.
DATE: 28-Feb-00

ANNUAL PROPERTY VALUE LOSS FOR LOST OCEANFRONT PROPERTIES ADJUSTED FOR INFLATION

Annual Real Estate Appreciation Rate* 4.8%

Year	Emerald Isle Property Value Per Year	Indian Beach	Salter Path	Pine Knoll Shores Property Value Per Year	County Property Value Per Year
1	$68,140,000	$12,890,000	$9,100,000	$10,300,000	$100,430,000
2	$71,410,720	$13,508,720	$9,536,800	$10,794,400	$105,250,640
3	$74,838,435	$14,157,139	$9,994,566	$11,312,531	$110,302,671
4	$78,430,679	$14,836,681	$10,474,306	$11,855,533	$115,597,199
5	$82,195,352	$15,548,842	$10,977,072	$12,424,598	$121,145,864
6	$86,140,729	$16,295,186	$11,503,972	$13,020,979	$126,960,866
7	$90,275,484	$17,077,355	$12,056,162	$13,645,986	$133,054,988
8	$94,608,707	$17,897,068	$12,634,858	$14,300,993	$139,441,627
9	$99,149,925	$18,756,128	$13,241,331	$14,987,441	$146,134,825
10	$103,909,121	$19,656,422	$13,876,915	$15,706,838	$153,149,297

*From County Tax Valuation for 1987 and 1997 Reassessments
** "Inflation is Not Dead Yet", Tim Grogan, Engineering News Record, Cost Report Summary, 9/27/99

TABLE F-6

BOGUE BANKS BEACH RENOURISHMENT
PROJECT LTERNATIVE ANALYSIS
DO-NOTHING ALTERNATIVE
BY: J.W. Forman, Jr., P.E.
DATE: 28-Feb-00

CSE BAIRD
STROUD ENGINEERING, P.A.

SUMMARY OF LOST PRESENT WORTH OF TAX REVENUES ASSOCIATED WITH DO-NOTHING ALTERNATIVE

Discount Rate** 6.125%

Tax Rate/$100 Cash Flow Year	Emerald Isle 0.195 Tax Revenues Per Year	Salter Path In County	Indian Beach 0.17	Pine Knoll Shores 0.16 Tax Revenues Per Year	County 0.5 Tax Revenues Per Year
1	$132,873	$0	$21,913	$16,480	$502,150
2	$139,251	$0	$18,597	$17,271	$526,253
3	$145,935	$0	$19,489	$18,100	$551,513
4	$152,940	$0	$20,425	$18,969	$577,986
5	$160,281	$0	$21,405	$19,879	$605,729
6	$167,974	$0	$22,433	$20,834	$634,804
7	$176,037	$0	$23,510	$21,834	$665,275
8	$184,487	$0	$24,638	$22,882	$697,208
9	$193,342	$0	$25,821	$23,980	$730,674
10	$202,623	$0	$27,060	$25,131	$765,746
Present Value	**$1,256,509**		**$171,973**	**$155,843**	**$4,748,564**
TOTAL NPV	**$6,332,889**				

**Discount Rate is Yield on 30 Year Treasury Bond, Latest Auction reported in Wall Street Journal, 2/24/2000

TABLE F-7

BOGUE BANKS BEACH NOURISHMENT
PROJECT ALTERNATIVE ANALYSES
DO-NOTHING ALTERNATIVE
Date: 28-Feb-00
By: J.W. Forman, Jr., P.E.

CSE BAIRD
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

Annual and Present Value Associated with
Reduced Appreciation and Tax Revenue Losses due to Reduced Appreciation

Discount Rate 6.125% Reduced Real Estate Appreciation Rate 2.00%

Emerald Isle

	Historic Appreciation Rate 4.580%	Reduced Appreciation Rate 2.580%	Value Difference	Revenue Loss 0.195	Pres. Worth Tax Val. Loss	Present Worth Value Loss
1	1,095,105,083	1,095,105,083	0	0	$0	$0
2	1,145,260,896	1,123,358,794	21,902,102	42,709	$40,244	$20,638,023
3	1,197,713,845	1,152,341,451	45,372,394	88,476	$78,558	$40,286,198
4	1,252,569,139	1,182,071,860	70,497,278	137,470	$115,015	$58,981,966
5	1,309,936,805	1,212,569,314	97,367,491	189,867	$149,685	$76,761,449
6	1,369,931,911	1,243,853,603	126,078,308	245,853	$182,636	$93,659,505
7	1,432,674,793	1,275,945,026	156,729,767	305,623	$213,934	$109,709,761
8	1,498,291,298	1,308,864,407	189,426,891	369,382	$243,642	$124,944,662
9	1,566,913,040	1,342,633,109	224,279,931	437,346	$271,821	$139,395,511
10	1,638,677,657	1,377,273,043	261,404,614	509,739	$298,530	$153,092,501
				Pres. Worth	$1,594,066	$817,469,576

Indian Beach

	Historic Appreciation Rate 4.580%	Reduced Appreciation Rate 2.580%	Value Difference	Revenue Loss 0.170	Pres. Worth Tax Val. Loss	Present Worth Value Loss
1	133,575,597	133,575,597	0	0	$0	$0
2	139,693,359	137,021,847	2,671,512	4,542	$4,279	$2,517,326
3	146,091,315	140,557,011	5,534,304	9,408	$8,354	$4,913,915
4	152,782,297	144,183,382	8,598,915	14,618	$12,230	$7,194,334
5	159,779,727	147,903,313	11,876,413	20,190	$15,917	$9,362,989
6	167,097,638	151,719,219	15,378,419	26,143	$19,421	$11,424,131
7	174,750,710	155,633,575	19,117,135	32,499	$22,749	$13,381,864
8	182,754,292	159,648,921	23,105,372	39,279	$25,908	$15,240,143
9	191,124,439	163,767,863	27,356,576	46,506	$28,905	$17,002,787
10	199,877,938	167,993,074	31,884,865	54,204	$31,745	$18,673,479
				Pres. Worth	$169,509	$99,710,967

TABLE F-7

Pine Knoll Shores

	Historic Appreciation Rate	Reduced Appreciation Rate	Value Difference	Revenue Loss	Pres. Worth Tax Val. Loss	Present Worth Value Loss
	4.580%	2.580%		0.160		
1	444,345,692	444,345,692	0	0	$0	$0
2	464,696,725	455,809,811	8,886,914	14,219	$13,398	$8,374,006
3	485,979,835	467,569,704	18,410,131	29,456	$26,154	$16,346,375
4	508,237,711	479,633,002	28,604,709	45,768	$38,292	$23,932,299
5	531,514,998	492,007,534	39,507,464	63,212	$49,834	$31,146,435
6	555,858,385	504,701,328	51,157,057	81,851	$60,805	$38,002,926
7	581,316,699	517,722,622	63,594,077	101,751	$71,225	$44,515,417
8	607,941,004	531,079,866	76,861,138	122,978	$81,115	$50,697,073
9	635,784,702	544,781,727	91,002,975	145,605	$90,497	$56,560,595
10	664,903,641	558,837,095	106,066,546	169,706	$99,389	$62,118,234
				Pres. Worth	$530,709	$331,693,360

Carteret County

	Historic Appreciation Rate	Reduced Appreciation Rate	Value Difference	Revenue Loss	Pres. Worth Tax Val. Loss	Present Worth Value Loss
	4.800%	2.800%		0.500		
1	1,673,026,372	1,673,026,372	0	0	$0	
2	1,753,331,638	1,719,871,110	33,460,527	167,303	$157,647	
3	1,837,491,556	1,768,027,502	69,464,055	347,320	$308,386	
4	1,925,691,151	1,817,532,272	108,158,880	540,794	$452,459	
5	2,018,124,326	1,868,423,175	149,701,151	748,506	$590,098	
6	2,114,994,294	1,920,739,024	194,255,270	971,276	$721,530	
7	2,216,514,020	1,974,519,717	241,994,303	1,209,972	$846,972	
8	2,322,906,693	2,029,806,269	293,100,424	1,465,502	$966,635	
9	2,434,406,214	2,086,640,844	347,765,370	1,738,827	$1,080,724	
10	2,551,257,713	2,145,066,788	406,190,925	2,030,955	$1,189,435	
				Pres. Worth	$6,313,886	

Total Revenue Loss Present Value	$8,608,170	
Total Value Loss Present Worth		$1,248,873,903

TABLE F-8

BOGUE BANKS BEACH NOURI CSE BAIRD
PROJECT ALTERNATIVE ANAL STROUD ENGINEERING, P.A.
DO-NOTHING ALTERNATIVE MOREHEAD CITY, NC

Date: 28-Feb-00
By: J.W. Forman, Jr., P.E.

CSE BAIRD
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

Summary of Annual and Present Value of Beach Scaping, Beach Access Structure Repair, and Property Values and Lost Revenues due to Reduced Property Value Appreciation

Discount Rate **6.125%**

Year	Beach Scraping Annual Costs	Structure Repair Annual Costs	Debris Removal Annual Costs	Lost Property Values	Lost Revenues Due to Lower Apprec.
1	$250,000	$2,184,000	$400,000	$0	$0
2	$257,500	$2,249,520	$412,000	$3,941,169	$26,946
3	$265,225	$2,317,006	$424,360	$7,758,301	$53,126
4	$273,182	$2,386,516	$437,091	$11,454,328	$78,556
5	$281,377	$2,458,111	$450,204	$15,032,122	$103,252
6	$289,819	$2,531,855	$463,710	$18,494,494	$127,230
7	$298,513	$2,607,810	$477,621	$21,844,196	$150,506
8	$307,468	$2,686,045	$491,950	$25,083,921	$173,094
9	$316,693	$2,766,626	$506,708	$28,216,305	$195,010
10	$326,193	$2,849,625	$521,909	$31,243,929	$216,269
Pres. Worth	**$2,193,446**	**$19,161,948**	**$3,509,514**	**$163,068,766**	**$1,123,988**
Total Present Worth		**$189,057,663**			

TABLE F-9

BOGUE BANKS BEACH NOURISHMENT				CSE BAIRD			
PROJECT ALTERNATIVE ANALYSES				STROUD ENGINEERING			
RETREAT / RELOCATION ALTERNATIVE							
Date:	2/28/00		By:	J.W. Forman, Jr., P.E.			
SUMMARY OF RELOCATION COSTS (YEAR 2000 DOLLARS)							
		House Moving	Abandon Ex. Lot	Buy New Lot	Site and Constr.	Unit Relocation	Total Relocation
Emerald Isle	Units	Costs	Value	Value	Costs	Costs	Costs
Single Family							
Move On Existing Lot	26	$ 34,000			$ 44,000	$ 78,000	$ 2,028,000
Relocate to New Lot	148	$ 42,000	$ 264,000	$ 136,000	$ 44,000	$ 486,000	$ 71,928,000
Condominium	0				$ -	$ -	$ -
M. H. Replacement							
		House Moving	Existing Land	New Land	Site and Constr.	Unit Relocation	Total Relocation
Indian Beach	Units	Costs	Value	Value	Costs	Costs	Costs
Single Family							
Move On Existing Lot	0	$ 34,000			$ 44,000	$ 78,000	$ -
Relocate to New Lot	0	$ 42,000	$ 264,000	$ 136,000	$ 44,000	$ 486,000	$ -
Condominium	0				$ -	$ -	$ -
M. H. Replacement							
		House Moving	Existing Land	New Land	Site and Constr.	Unit Relocation	Total Relocation
Pine Knoll Shores	Units	Costs	Value	Value	Costs	Costs	Costs
Single Family							
Move On Existing Lot	19	$ 34,000			$ 44,000	$ 78,000	$ 1,482,000
Relocate to New Lot	3	$ 42,000	$ 264,000	$ 175,000	$ 44,000	$ 525,000	$ 1,575,000
Condominium	51				$ 135,500	$ 135,500	$ 6,910,500
M. H. Replacement							
					PROJECT TOTALS		**$ 77,013,000**

BOGUE BANKS BEACH RENOURISHME CSE BAIRD TABLE F-10
PROJECT LTERNATIVE ANALYSIS STROUD ENGINEERING, P.A.
RELOCATE/RRETREAT ALTERNATIVE
DATE: 28-Feb-00 BY: J.W. Forman, Jr., P.E.

ANNUAL COSTS ASSOCIATED WITH RETREAT / RELOCATION ALTERNATIVE

Cost of Moving On-Site	$ 78,000	Condo Rebuild Costs	$127,500	Mobile Home Spaces Replacem	$40,000
Cost of Moving Off-Site	$ 86,000	Annual Land Appreciation Rate*	4.8%	Commercial Spaces Replaceme	$300,000
Abandoned Land value	$ 264,000	Annual Inflation Rate for Construc	3.0%	Mobile Home Inflation	3.0%
New Lot Value	$ 136,000				

	Emerald Isle				Pine Knoll Shores			
Units	**91**	**156**	**36**	**17**	**37**	**4**	**58**	**0**
Year	Move on Lot	Move Off Site	Rebuild Condo	M.H. Spaces	Move on Lot	Move Off Site	Rebuild Condo	M.H. Spaces
1	$709,800	$7,581,600	$459,000	$68,000	$288,600	$194,400	$739,500	$0
2	$731,094	$7,921,368	$472,770	$70,040	$297,258	$203,112	$761,685	$0
3	$753,027	$8,261,136	$486,953	$72,141	$306,176	$211,824	$784,536	$0
4	$775,618	$8,600,904	$501,562	$74,305	$315,361	$220,536	$808,072	$0
5	$798,886	$8,940,672	$516,609	$76,535	$324,822	$229,248	$832,314	$0
6	$822,853	$9,280,440	$532,107	$78,831	$334,566	$237,960	$857,283	$0
7	$847,538	$9,620,208	$548,070	$81,196	$344,603	$246,672	$883,002	$0
8	$872,964	$9,959,976	$564,512	$83,631	$354,942	$255,384	$909,492	$0
9	$899,153	$10,299,744	$581,447	$86,140	$365,590	$264,096	$936,776	$0
10	$926,128	$10,639,512	$598,891	$88,725	$376,558	$272,808	$964,880	$0
	Indian Beach				**Salter Path**			
	0	**10**	**32**	**15**	**10**	**15**	**45**	**7**
	Move on Lot	Move Off Site	Rebuild Condo	M.H. Spaces	Move on Lot	Move Off Site	Rebuild Condo	M.H. Spaces
1	$0	$486,000	$408,000	$60,000	$78,000	$729,000	$573,750	$28,000
2	$0	$507,780	$420,240	$61,800	$80,340	$761,670	$590,963	$28,840
3	$0	$529,560	$432,847	$63,654	$82,750	$794,340	$608,691	$29,705
4	$0	$551,340	$445,833	$65,564	$85,233	$827,010	$626,952	$30,596
5	$0	$573,120	$459,208	$67,531	$87,790	$859,680	$645,761	$31,514
6	$0	$594,900	$472,984	$69,556	$90,423	$892,350	$665,134	$32,460
7	$0	$616,680	$487,173	$71,643	$93,136	$925,020	$685,088	$33,433
8	$0	$638,460	$501,789	$73,792	$95,930	$957,690	$705,640	$34,436
9	$0	$660,240	$516,842	$76,006	$98,808	$990,360	$726,809	$35,470
10	$0	$682,020	$532,347	$78,286	$101,772	$1,023,030	$748,614	$36,534

*Valuations from County Tax Office for Years 1989 and 1997
** "Inflation is Not Dead Yet", Tim Grogan, Engineering News Record, Cost Report Summary, 9/27/99

TABLE F-11

BOGUE BANKS BEACH RENOURISHMENT
PROJECT LTERNATIVE ANALYSIS
RELOCATE/RRETREAT ALTERNATIVE
DATE: 28-Feb-00

CSE BAIRD
STROUD ENGINEERING, P.A.

BY: J.W. Forman, Jr., P.E.

NET PRESENT WORTH OF RELOCATION/RETREAT ALTERNATIVE

Discount Rate** **6.125%**

	ANNUAL COSTS OF RELOCATION, RECONSTRUCTION*			
Cash Flow Year	Single Family Relocate on Site	Relocate Off site	Condominiums Rebuild on Site	Rebuild M.H. Sites
1	$1,076,400	$8,991,000	$2,180,250	$156,000
2	$1,108,692	$9,393,930	$2,245,658	$160,680
3	$1,141,953	$9,796,860	$2,313,027	$165,500
4	$1,176,211	$10,199,790	$2,382,418	$170,465
5	$1,211,498	$10,602,720	$2,453,891	$175,579
6	$1,247,843	$11,005,650	$2,527,507	$180,847
7	$1,285,278	$11,408,580	$2,603,333	$186,272
8	$1,323,836	$11,811,510	$2,681,432	$191,860
9	$1,363,551	$12,214,440	$2,761,875	$197,616
10	$1,404,458	$12,617,370	$2,844,732	$203,545
Present Value	$9,444,103	$82,367,407	$19,129,046	$1,368,711
TOTAL NPV	$110,940,556			

**Discount Rate is Yield on 30 Year Treasury Bond, Latest Auction reported in Wall Street Journal, 2/24/2000

TABLE F-12. Estimates of beach visits by Carteret County residents. [P is the number of annual visits made by each person to the beach.]

Town	Distance (miles)	P	x	Population (1998)	=	Annual Visits
Atlantic	40	1.615		812		1311
Beaufort	6	6.923		10,820		68,090
Cedar Island	island	0		407		0
Davis	25	2.943		430		1265
Harkers Island	15	4.390		1363		5984
Harlowe	15	4.390		1289		5659
Marshallberg	25	2.943		621		1828
Merrimon	10	5.363		591		3170
Morehead City	6	6.293		16,283		102,649
Atlantic Beach not in project		0		2308		0
Indian Beach	0	8		177		1416
Pink Knoll Shores	0	8		1543		12,344
Newport	15	4.390		18,135		79,613
Sea Level	35	0.247		649		160
Smyrna	20	3.595		843		3031
Stacy	32	2.224		434		965
Straits	30?	2.410		2129		5131
White Oak	30?	2.410		1179		2841
Williston	30?	2.410		288		694
Swansboro	35	0.247		7391		1826
Emerald Isle	0	8		1548		12,384
				68,833		310,181

APPENDIX G

APPENDIX G — LITTORAL PROCESSES

APPENDIX G1. PREVIOUS STUDIES

A substantial amount of literature exists on Outer Banks beaches, some of it specific to Bogue Banks. Generally there are two types of data that are fairly plentiful: monitoring studies of Beaufort Inlet by the Corps of Engineers and geological studies of the Outer Banks as student theses at various universities.

The Corps of Engineers studies on Beaufort Inlet are so numerous that Beaufort is used as the Corps' example of how to evaluate inlets in their Engineering Manual "Coastal Inlet Hydraulics and Sedimentation" (USACE, 1995). There is a substantial amount of bathymetric profile data for the inlet, and more recently, beach profiles for Atlantic Beach. What is generally missing are "coastal process" measurements, that is, waves, currents, tides, and sediment transport.

The student theses from Duke University, North Carolina State University, and University of North Carolina are rich in information about the geology of the islands themselves (hundreds of core samples taken on various barrier islands and sometimes profiles of the beach), but they are quite sparse in information for the underwater portion of the beach. Core samples and beach profiles generally end at the water line.

Many of the findings in the literature relevant to a Bogue Banks beach-nourishment project are listed in Table G1.

TABLE G1. Literature Summary — Historical Documents

Thesis on relict inlet locations — 1962. UNC. Fisher, J.J., Geomorphic expression of former inlets along the Outer Banks of North Carolina, 120 pp.

- Summary of former inlets in NC, as detected by geomorphology
- Distribution of relict inlets for entire outer banks shown in Figure 4
- Aerial photo of 3 Atlantic Beach relict inlets in Figure 5
- 1860 map of Atlantic Beach relict channels, Figure 6
- Opening history of Beaufort Inlet, p. 88
- Opening history of Bogue Inlet, pp. 88-89
- Opening history of Bogue relict inlet #1, pp. 89-90
- Opening history of Bogue relict inlet #2, p. 90

Study on hurricane impacts on Bogue Banks — 1966. USACE. Beaufort Inlet to Bogue Inlet, North Carolina. US House Document No. 479, 89th Congress.

- Survey of hurricane damages
- Recommends flood dike for west side of New River. Other protections not economically feasible
- 8 hurricanes listed, 1953-60, p. 16
- Hurricane surges, 1953-60, p. 17
- Hurricane tracks, 1953-60, p. 18
- Hurricane damages, 1953-60, p. 19

Dissertation on geologic history of Bogue Banks (UNC Chapel Hill) — 1967. UNC. Fisher, J.J. Development pattern of relict beach ridges, Outer Banks barrier chain, North Carolina, 247 pp.

- Maps of 300+ relict beach ridges on Bogue Banks, with 7 sequences (Fig. 53)
- Sequential development of Bogue Banks, Fig. 57
- Soil map for Bogue Banks, Fig. 58

NCSU study on North Carolina beach erosion — 1973. NCSU. Knowles, C.E., J. Langfelder, and R. McDonald. A preliminary study of storm-induced beach erosion for North Carolina. NCSU Rept. No. 73-5, 14 pp. + figs.

- Topographic surveys along each fishing pier
- Storm surge levels recorded and plotted as function of return frequency
- Design surge levels and breaking-wave depths, Table 1
- Estimated beach recession for 25 yr storm (21 ft), 50 yr (162 ft), 100 yr (220 ft) at Bogue Banks, Table 2
- Plot of storm surge versus return period (Fig. 1)

Thesis on Shackleford Banks geology and subsurface sediments — 1975. Duke. Susman, K.R. Post-Miocene subsurface stratigraphy of Shackleford Banks, Carteret County, North Carolina, 70 pp + app.

- Sediment-size statistics, radiocarbon dates, and fauna count for core samples within Shackleford Banks (Tables 1-3)
- Schematic cross-section of Shackleford, Fig. 4

Morehead City harbor general design memorandum — 1976. USACE. Morehead City Harbor, North Carolina, General Design Memorandum, USACE-Wilmington, 41 pp. + app A-F.

- Recommended increasing navigation channel depth to 40 ft in harbor and inlet and 42 ft in ocean approach.
- Proposed disposing of sediment along 4000 ft of Shackleford by hopper, initial disposal via pipeline dredge on the eastern 5000 ft of Atlantic Beach, and later disposal via pipeline for additional 25,000 ft west of the 5000 ft
- Inlet migration and throat width, pp. B2-3
- Table of dredging volumes through 1974, pp. B5-6
- Hurricane surge and winds for *Donna*, 1960, table, p. B8
- Table of tidal currents, p. B10
- Cumulative dune-line location for entire island, p. B17
- Hydrographic surveys since 1839 showing channel, plate B1
- 8 beach profile transect taken well offshore in 1958 and 1972, plates B6-B9
- Appendix C: longshore transport analysis from ship-based winds
- Attachment D1: boring logs
- D6-D7: grain-size information. **Reaches shown on Plate D-3. Reach P (inner harbor) has retention of 60% (Ra of 1.67); Outermost (ocean) Reach Hc has retention of 68% (Ra of 1.47); composite retention for all of H(a-c) is 80% (Ra of 1.25). Thus 1.25 is best estimate of beach-fill material Ra. Native material is rather fine, with mean of 2.52 phi (0.17 mm) and standard deviation of 0.77 phi.**
- Sediment transport conclusions: (1) transport is to the east (75%), (2) shoaling occurs more on the west side of the channel (68% of the channel shoaling), (3) bypassing efficiency of the inlet dropped from 52% to 28% after dredging, (4) net transport is about 14% of the gross

Thesis study of sediments and geology of Bogue Banks — 1977. UNC, Goff, W.T. Sedimentation in a modern tidal inlet: Bogue Inlet, North Carolina, 117 pp + app.

- Analysis of 244 bottom samples, 20 can cores, 9 trenches in Bogue Inlet
- Sketch of inlet geomorphics compared to Hayes' model, Fig. 2 and 3
- Mean tide range at Bogue (71 cm) and Beaufort (96 cm), p. 11
- Bathymetric map, Fig. 5
- Inlet migration maps, Fig. 7
- Sediment size-distribution map, Fig. 8
- Percentage shell content, Fig. 13
- Transport paths inferred from ripple/sand-wave geometry, Fig. 18
- Sediment environment map, Fig. 26
- Sediment environment vertical cross-section Fig. 28 (cross-shore)
- Fig. 29 (longshore)

Thesis on geology and sediments of Outer Banks — 1977. Duke. Moslow, T.F. Quaternary evolution of Core Banks, North Carolina, from Cape Lookout to New Drum Inlet, 171 pp.

- Analysis of many core samples from within Core Banks, nothing south of Cape Lookout
- Radiocarbon dating, macrofauna counts, and analysis of each depositional environment

- Comparison of relict and modern inlets, p. 108
- Rates of landward migration of Core Banks, 50-100 m/century, p. 102

Thesis on coastal process measurements in Beaufort Inlet — 1977. Duke. Sarle, L.L. Processes and resulting morphology of sand deposits within Beaufort Inlet, Carteret County, North Carolina, 152 pp.

- Storm frequencies, p. 14, 1.64 hurricanes per year for Bogue Banks
- Monthly wind roses, p. 19
- Data collected: surveys, fathometer, tidal currents, and grab samples
- Fathometer traverses all in Sound, locations p. 27, results, p. 98
- Tide measurement locations, p. 29
- Sediment sample locations, p. 31
- Tidal velocity data summary, p. 34
- Average curves for spring, neap, mean tides, p. 36
- Sedimentary structure flow-indicator classification, p. 40
- Tidal velocity curves for each station, p. 45-54
- Sketch of pre-dredging model of Beaufort Inlet, p. 57
- Western growth rate of Shackleford Spit, p. 66
- Morphological classifications of underwater topography: map p. 74, sketch p. 84
- Aerial photo with tidal current directions superimposed, p. 135
- Conclusion: tidal current velocities increased because of narrowing of inlet by stabilizing Fort Macon State Park and western growth of Shackleford, p. 139
- Conclusion: dredging causes sediment to be transported seaward and deposited in deeper water, where it is not available for beaches, p. 139

Thesis on geology and sediments for Core Banks — 1978. Duke. Herbert, J.R. Post-Miocene stratigraphy and evolution of northern Core Banks, North Carolina, 140 pp.

- Sediment size analysis, geological history, and inlet cross-sections, all north of New Drum Inlet

Thesis on sedimentation of Shackleford Banks — 1979. Duke. Berelson, W.M. Barrier island evolution and its effect on lagoonal sedimentation; Shackleford Banks, Back Sound, and Harkers Island: Cape Lookout National Seashore, 220 pp.

- Textural and size analysis of core samples throughout and landward of Shackleford, but no data offshore

Thesis on sediments in Bogue Banks — 1980. Duke. Steele, G.A. Stratigraphy and depositional history of Bogue Banks, North Carolina, 220 pp.

- 42 bore-hole locations on Bogue, p. 10 (none offshore)
- No prevailing longshore transport direction, except at eastern end, where sand accumulates on west side of jetty (p. 13)
- Monthly wind roses, p. 15
- Tide discussion, p. 16; maximum ebb in Beaufort 116 cm/s, flood 106 cm/s; tidal prism of Bogue Sound 80 million cubic meters
- Dune-line change along entire island, 1964-71, p. 18
- Sediment analyses: faunal counts, lithology, radiocarbon dating, size
- Detailed discussion of geologic history, by community, pp. 91-142
- Summary of Bogue Banks forming, pp. 165-167

Planning brochure on options for stabilizing Bogue Inlet — 1980. USACE. Planning Brochure for Bogue Banks Stage II Study, 21 pp.

- Summarizes Phase II study for inlet stabilization
- p. 20 summarizes plans; bottom line is that only channel deepening (by only 2 ft from 6 ft to 8 ft) is economically justified; all structural alternatives examined were not econonical

North Carolina erosion task force report — 1984. NCDNRCD. Coastal Resources Commission's Outer Banks Erosion Task Force Report, 29 pp.

- Evaluated the following alternatives for responding to coastal erosion: (1) hardening (seawalls), (2) trapping (groins), (3) nourishment, (4) dune building, (5) beach pushing (scraping), and (6) relocating threatened buildings. General cost comparisons were made:

Sandbags	$125-250/ft/yr
Bulkheads	$25-50/ft/yr
Revetments	$5-15/ft/yr
Groins	$12-25/ft/yr
Breakwaters	$60+/ft/yr
Beach pushing	$200/ft/yr
Nourishment	$240/ft/yr

- Determined that federal nourishment projects have taken 15-18 years to authorize, with a minimum of eight years.
- Conclusions: an unobstructed public beach is essential to the continued vitality of the tourism industry.
- Beach nourishment is the preferred response to erosion.

Sedimentation study of Shackleford Banks/Cape Lookout — 1984. Marine Geology. Heron, S.D., T.F. Moslow, W.M. Berelson, J.R. Herbert, G.A. Steele, and K.R. Susman. Holocene sedimentation of a wave-dominated barrier-island shoreline: Cape Lookout, North Carolina, Vol. 60, pp. 413-434.
- Process/response model of wave-dominated barrier islands in sand-rich environments with 5 parts of model in Fig. 8
- Per Nummedal et al. (1977) classification, area has relative to the rest of the southeastern United States: high waves, small tidal range, little ebb-tidal delta, and large inner shoal area
- Waves average 1.7 m height with 2 m exceeded 30% of the year, more than anywhere else in southeastern United States (Nummedal, Fig. 2)
- Bogue summarized in section lower-energy depositional limb with vertical sequence of sediments in Fig. 15

Vibracore data and interpretation for Bogue Banks — 1985. Marine Geology. Hine, A.C. and S.W. Snyder. Coastal lithosome preservation: evidence from the shoreface and inner continental shelf off Bogue Banks, North Carolina, Vol. 63, pp. 307-330.
- Analysis of Bogue shelf based on drill holes on Bogue Banks, 125 vibracores on shelf, and seismic data
- Much of sand deposits removed from shelf, but paleochannels with sand identified (fig. 2)
- Isopach map of Quaternary deposit thicknesses, fig 6, shows sands confined very close to shore and within the paleochannels
- Shoreface is narrow, generally 12 m deep and 500-800 m wide

Morehead City harbor improvement feasibility report and environmental assessment — 1990. USACE. Feasibility report and environmental assessment: Morehead City harbor improvement, Morehead City, North Carolina, App. A-F.
- Coastal engineering information in Appendix C contains:
  - Tides (IIB)
  - Changes in shoreline volumes (IID), including historical rates (Table 20) and recent (since dredging) rates (Table 21); Fort Macon recent erosion is explained as erosion of the large (1.2 million cy) nourishment placed in 1978
  - Longshore transport calculations in Section IIE and later are all based on wind hindcasts and are thus suspect
- Channel boring logs are in Appendix D

Morehead City general design memorandum (updated) — 1992. USACE. Design memorandum and environmental assessment: Harbor improvement, Morehead City, North Carolina, 50 pp. + App. A-M.
- Project encompasses deepening of outer harbor, extending ocean approach dredging, and enlarging harbor
- Proposed disposal for inner harbor is via pipeline to Brand Island, with pumpout to Atlantic Beach every 8-10 years; deposit outer harbor material on nearshore berm at 20 ft contour
- Disposal alternatives and their unit costs in Table 15, p. 37
- Analyzed potential for nearshore berm to move using Hands/Allison figure and WIS hindcast data to determine currents (p. C12); results suggest active motion; also applied LTD program, which also suggested active motion of berm (p. C13).
- Appendix D contains bore logs and sieve analyses, but no computation of composite size and overfill ratios

Shoreline erosion methods and maps — 1997. NCDEHNR. Benton, S.B., C.J. Bellis, M.F. Overton, J.S. Fisher, J.L. Hench, and R. Dolan. North Carolina long term average annual rates of shoreline change: methods report 1992 update, 20 pp. + app A-F.

- Uses both wet/dry line and vegetation line to estimate shoreline changes; latest update is 1992; previous updates in 1986 and 1980
- Bogue USGS maps are Q19-Q22 and SNC54-65; SNC photogrammetry available for Bogue in 1943, 1959, 1980, 1986, and 1992

Preliminary 111 evaluation on causes of erosion at Pine Knoll Shores — 1998. USACE. Preliminary Section 111 evaluation, Morehead City Harbor/Pine Knoll Shores, North Carolina, 15 pp. + figs.

- Lists dredging history in Tables 1 and 2
- Beach disposal volumes and locations, p. 3
- Pine Knoll Shores interests claim disruption of westerly LST by navigation channel and also increased flow (and thus sediment) into harbor because of increased tidal prism
- The results of the two previous LST studies are summarized below:
  1) The Corps of Engineers 1976 study compared two time periods relative to navigation-channel maintenance, before (1854-1936) and after (1960-1974) and concluded: (a) sediment transport is to the east (75%), (b) shoaling occurs more on the west side of the channel (68% of the channel shoaling), (c) bypassing efficiency of the inlet dropped from 52% to 28% after dredging, and (d) the net transport is about 14% of the gross.
  2) The Corps of Engineers 1990 study concluded that (a) the gross transport rate was about 600,000 cy/yr greater than shown in the 1976 study, but (b) the net transport proportion was about the same as in the previous study, in this case 78% of the total.
- The current study uses updated 1993 WIS hindcasts that show sufficiently changed wave-direction predictions from the past studies, that the transport direction may be from west to east. The use of the updated hindcasts in LST equations was not performed in this preliminary phase of the study, but postponed till the next phase.
- Tidal ranges increased 0.1-0.4 ft in the Sound after the 40 ft project deepening, thus increasing the tidal prism and flow rates.
- Analysis of Corps profiles uses both wet/dry line and vegetation line demarcations to examine shoreline erosion rates
- Conclusions: (1) Pine Knoll Shores has higher erosion rates than areas further west along Bogue. (2) WIS hindcast updates suggest the possibility of westward LST. (3) Tidal prism has increased, suggesting the possibility of increased sediment trapping in the inlet. These three factors plus annual removal of 325,500 cy by the harbor project suggest a possible impact on the beach. Further study was recommended.

Wave hindcast study on erosion impacts of Morehead City navigation channel maintenance — 1998. UNC. Roessler, T.S. Effects of offshore geology and the Morehead City Harbor project on Eastern Bogue Banks, North Carolina, 112 pp.

- General conclusion: dredging has increased the tidal prism, thereby increasing tidal velocities and ebb-tidal delta to move seaward. This increases gradients in longshore currents during storms and thus increases erosion.
- Maps of Beaufort Inlet channel since 1850, Fig. 2
- Inlet location now stable, since western side is jettied
- Dredging has occurred since 1911; inner harbor now dredged every two years, outer channel every year
- Dredging location and disposal sites, Fig. 4; volumes, Table 1
- Beach profiles collected monthly over two years on 13 transects in AB and PKS
- Longshore currents computed from offshore winds, RCPWAVE wave model, and Komar's longshore current equation
- Erosion for AB 1958-1972, Fig. 7
- Beach nourishment volumes changes, 1986 and 1994, Fig. 9
- Measured erosion rates of nourishment sand, 1996-1998, Fig. 10
- Volumetric and linear erosion rates from this study and NCDCM, Fig. 14
- Hurricane-induced erosion, Fig. 23
- Recent bathymetric map, Fig. 31; maps from 1854, 1925, and recent, Fig. 34

- Summary of effects of dredging, p. 860
- Conclusions:
  - Net longshore sediment transport is to the west
  - During hurricanes disposal area decreased longshore currents on beach
  - Progradation of ebb-tidal delta caused by dredging increases erosion at PKS
  - Dredging alters longshore currents from large storms and may increase erosion

Historical beach profile data set

- 1998. UNC. Bogue Banks historical beach profile data set; digital files provided by T.S. Roessler.
- 1978. USACE (Wilmington). Bogue Banks historical beach profile data set provided by Tom Jarrett

USACE/Pine Knoll Shores (PKS) — series of correspondence (various dates) — USACE. Correspondence between USACE-Wilmington, Pine Knoll Shores, Carteret County, and NCDEHNR contain the following relevant information.

- Cost-sharing documents provided by County show annual estimated cost of harbor-depth maintenance of $5,000,000 federal and $50,000 state. Sand is piped to Brandt Island, and is periodically pumped to nourish Atlantic Beach.
- Federal feasibility study is underway to determine whether federal navigation maintenance is eroding Bogue Banks (specifically Pine Knoll Shores). Expenditures on study to date total $54,000. Completion of study to cost $400,000 more, 50/50 federal/state cost split. Nourishment project estimated at $1,678,000 federal and $904,000 state costs.
- Proposed plastic pipeline plan for nourishing Bogue submitted by Bill Price to Carteret County. Feasibility of using small-diameter plastic pipe was evaluated by a rental company that has not performed beach nourishment. Phone check with a company specializing in beach nourishment confirms that the material and diameter would not withstand required pressure and stresses imposed by sand slurry.
- Series of correspondence between USACE-Wilmington, Pine Knoll Shores, and Sen. Helms provides the following information regarding possible use by PKS of sand dredged from the harbor and navigation channel:
  1) Option 1 is for direct pumping from Beaufort Inlet via ocean-certified dredge. Additional cost for 1 million cubic yards is estimated at $2.75-$4 million
  2) Option 2 is hoppers with direct pumpout capability with additional cost for 1 millon cubic yards at $4 million
  3) Option 3 is transport by pumpout hopper and later redistribution by dredge and pipeline, additional cost at $5-6 million
  4) Total available sand in harbor and range A (approach channel) is typically 1.6 millon cubic yards
  5) Corps says their surveys show stable or accretionary beaches for 6.5 miles west of Beaufort Inlet, since beach has been nourished
  6) PKS does not have full public beach access and is thus not currently eligible for 50/50 cost sharing of the additional costs under WRDA 1986
  7) Brandt Island disposal reaches capacity every 8-10 years and is not expected to be used as nourishment source again until 2002-4.
- State DEHNR cost-sharing with local governments for areas allowing public access can be up to 75% of non-federal costs for construction and 50% for preliminary studies and engineering. Typical state contributions in other NC beach nourishment projects ranged from $105,000 to $6,000,000. Detailed cost-sharing breakdowns with these other local governments are enclosed in the gathered materials.

APPENDIX G2. DIMENSIONS OF LITTORAL ZONE (Depth of Closure)

The dimensions of the active area of the littoral zone are of interest, since nourishment projects are supposed to move sediment from regions where it is not part of the beach system to locations where it will help build the active beach. If the nourishment sand were to simply be moved from one location to another within the beach system, then it is questionable whether such a project has a significant net value. To answer this question, standard coastal engineering practice is to determine the "depth of closure" where sequential beach profiles at the same location "close" to the same offshore location, indicating very infrequent motion.

Closure depth is sometimes erroneously referred to as the "depth of no motion" in some publications. The standard definition (Hallermeier, 1978) is the depth beyond which there is active seabed motion for an average of only 12 hours per year. This standard definition has been incorporated into the standard texts, such as the Shore Protection Manual (CERC, 1984).

To be confident of the results, we used several different methods of determining depth of closure. Described below are six methods, three of them computational methods using different wave databases, and three of them empirical geological evidence specific to this site.

1. From Nearshore Hindcast Wave Data

Closure depth is supposed to be computed from wave databases **nearshore**, that is in the general vicinity or depth at which closure is often found, typically in the 30 to 50 ft range. A de facto standard that has arisen is the 10-meter depth, for two reasons. The Corps of Engineers has its Phase III Wave Information Study stations at 10m depth. Also, the national field testing center for coastal engineering, the USACE Field Research Facility in Duck, North Carolina, has its permanent wave-measuring array at 10m depth. That station makes measurements of both waves and the resulting changes in beach topography, so tests of depth-of-closure methods are made with those data.

The data used in these computations were the Phase III 10m-depth hindcast waves at Stations 96 and 97 (USACE, 1983). Stations 95-97 are along Bogue Banks, with Station 97 for the western third, 96 the middle third, and 95 the eastern. Our project does not encompass nourishment for the eastern third. The 12-hour-per-year data were selected as the 80 highest readings out of the 58,440 predictions each year. This database averages all years during 1956-75, but does not include hurricanes. The 80th highest wave height was selected by interpolation between the tabulated bands and was determined to be 2.63m for Station 96 (mid-Bogue) and 2.47m for Station 97 (western Bogue). Wave periods were computed by weighting the periods in each height band by the number of occurrences in each band and produced 8.82 sec for #96 and 8.74 sec for #97.

There are two accepted equations for computing depth-of-closure:

(Hallermeier, 1978) $d_l = 2.28\ H_e - 68.5\ (H_e^2 / g\ T_e^2)$

(Birkemeier, 1985) $d_l = 1.75\ H_e - 57.9\ (H_e^2 / g\ T_e^2)$

where d_l is closure depth, H_e the extreme wave height (12 hrs/yr), T_e the associated wave period, and g the acceleration of gravity.

The latter method was determined from a study correlating measured waves with depth of observed motion at the North Carolina FRF site. Considering the proximity of that site to Bogue Banks suggests it is more appropriate for this project. Furthermore, the measurement methods were cruder and less accurate in the earlier study. The results from both equations in feet below MLW are:

Mid-Bogue:	Hallermeier 17.6 ft (5.38m)	Birkemeier 13.4 ft (4.08m)
Western Bogue:	Hallermeier 16.6 ft (5.07m)	Birkemeier 12.6 ft (3.85m)

2. From UNC Measured and Modeled Storm Waves

A University of North Carolina study (Roessler, 1998) shoaled the deep-water WIS database (Station 46, 1975-93) over bathymetry with the model RefDif. That work examined the resulting currents and potential sediment transport for the **average** wave conditions in that database. In addition to that main part of the study, certain storm wave conditions were modeled using brief visual measurements of the waves. The storm-wave input data were H = 3.0 m, D = 158 TN, and T = 15 sec. These storm waves were generated by the simultaneous combined distant departure of Hurricane *Bonnie* and approach of Hurricane *Fran*. Inserting these numbers in the two equations yields depth of closure of 21.5 ft (6.56m) (Hallermeier) and 16.4 ft (5.01 m) (Birkemeier).

3. From UNC Modeled Hurricane Waves

The same UNC study (Roessler, 1998) modeled the direct effects of Hurricanes *Bertha* and *Fran* for the conditions when they were in the immediate vicinity of Bogue Banks. These very brief extreme conditions produced results that varied somewhat along the study area, but which were fairly unvarying for the study area west of Atlantic Beach, with wave heights of about 7 m and period of 15 sec. (This result of 7m wave height is expected for the most extreme condition possible, because it is the highest wave that can possibly exist in the depths modeled, referred to as "depth limited".) The results from the two equations are 47 ft (14.44m) (Hallermeier) and 36 ft (10.96m) (Birkemeier).

4. Measured Closure Depths at Duck

The results presented thus far are predictions from equations, whereas measurements of both waves and resulting seabed motion were made at the reasonably close site of Duck, North Carolina (on the exposed open-coast Outer Banks close to the Virginia border). The results are reproduced here as Table G2-1 and Figure G2-1. Equation (1) in the table is Hallermeier and (2) is Birkemeier. Equation (3) is a simpler less accurate version of the Birkemeier equation. The results indicate a range of depths between 3.9 and 6.4m. These "ground truth" measurements appear to validate use of the Birkemeier equation results computed in Section 1 above for Bogue of 3.8 to 4.1m. It is expected that results for Bogue would be on the low end of the measured values at Duck, since Bogue is a south-facing beach protected from more of the wave climate than the east-facing Outer Banks site at Duck.

TABLE G2-1. Wave and limit depth data (from Birkemeier, 1985). [Note: 1 m = 3.281 ft]

Closure Estimate (1)	Wave Data: Date (2)	Wave Data: H (m) (3)	Wave Data: T (sec) (4)	Limit Depth (d_l) in Meters Below MLW: Measured (5)	Limit Depth: Predicted (Eq. 1) (6)	Limit Depth: Best Fit (Eq. 2) (7)	Limit Depth: Best Fit (Eq. 3) (8)
1	08/20/81	3.3	10.2	4.0	6.8	5.2	5.2
2	10/12/81	2.7	6.8	3.9	5.1	3.8	4.2
3	10/31/81	2.3	9.3	4.3	4.8	3.7	3.6
4	11/14/81	3.9	12.9	6.4	8.3	6.3	6.1
5	11/25/81	3.0	8.4	5.0	6.0	4.5	4.7
6	01/01/82	2.9	10.9	4.8	6.1	4.7	4.5
7	10/12/82	2.4	12.0	4.2	5.2	4.0	3.8
8	10/24/82	3.8	10.8	5.2	7.8	5.9	6.0
9	11/23/82	2.5	14.0	4.3	5.5	4.2	3.9
10	12/13/82	3.7	10.0	6.1	7.5	5.7	5.8

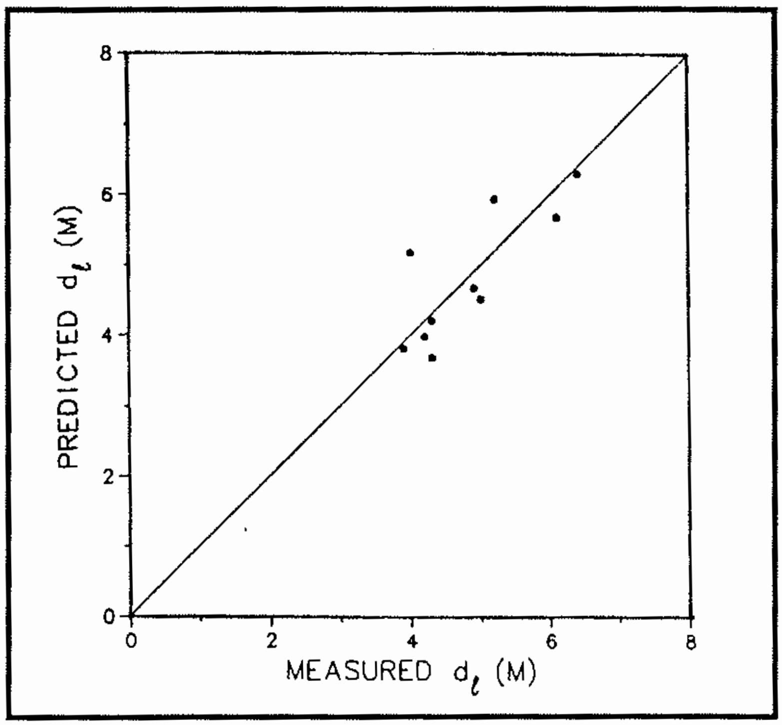


FIGURE G2-1. Best-fit comparison between predicted (Eq. 2) and measured d_l (from Birkemeier, 1985).

5. UNC Sediment Texture Study (Reed, 1997)

For this thesis, measurements were made of the color, texture, and size distribution of beach sand, shelf sand, and nourishment sand from Pine Knoll Shores to Shackleford Banks. The nourishment sand was from navigation-channel and harbor dredging projects by the Corps of Engineers. The excavation and delivery methods of the nourishment sand were similar to those proposed for this project, although the sand in the Corps project was significantly finer than that proposed in this project. Numerous surface grab samples enabled classification of sand type on the bed, and the results are reproduced here as Figure G2-2. The important point for this project is the solid line separating the native or replenishment sands from the shelf sands. The fact that the shelf sands are staying in place and not moving onto the beach in any quantifiable amounts suggests that the bounding line is one measure of the depth of closure.

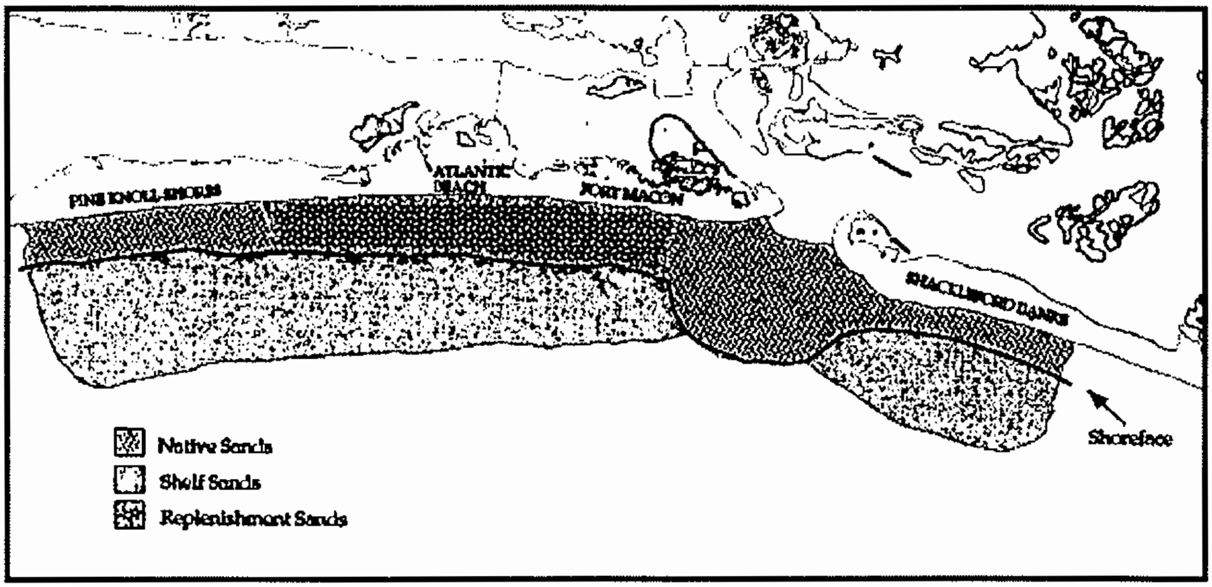


FIGURE G2-2. Interpretive map of offshore sediment distribution during the spring 1997 sampling period.

The figures in the thesis do not show bathymetric contours, so to estimate the bounding depths from the figures, we computed a scale conversion factor between the thesis figures and NOAA Chart #11543. Each 1.4 unit of distance on the NOAA chart equals 1 in the thesis figures, and this enabled us to determine depths of the solid bounding line at the following locations alongshore:

At the western end of the study area, d_l = 33 ft.
At the Pine Knoll Shores/Atlantic Beach border, d_l = 33 ft.
Along the line formed by the causeway to the mainland, d_l = 32 ft.
At the Atlantic Beach/Fort Macon border, d_l = 24 ft.

The latter two sites are east of and outside of the proposed project area.

The appropriateness of the contour data presented in Figure G2-2 for use in determining depth of closure is addressed in the thesis. Our professional opinion is that the data presented in the thesis are valid and useful and that the following opinions regarding their usefulness are incorrect and the result of misinterpretation of valid data (Reed, 1997, p. 66):

"The interpretive maps of offshore sediment distribution (Figures 17 A and B) may appear to indicate a closure depth, however this is only a result of the limitations of contour maps. . . . the stratigraphy of the cores (Cores #1-6), are better able to represent the history of sediment transport. Also, most sediment is transported offshore, past the designated "closure depth" during brief, but significant, storm events that are best recorded in the shallow stratigraphy and rippled scour depressions features."

In rebuttal to the three sentences above:

1) No evidence is presented in the thesis invalidating the results in the contour maps. Great care was taken in classifying the sediment types, and large numbers of grab samples allowed detailed delineation of sediment boundaries.

2) In three of the very small number of six cores taken, there are coarse shelly layers that are properly classified as to type of sediment, but their source is identified as "storm event" with no evidence to support that cause. Similar deposits were found in many of our core samples, which previous studies (Hine and Snyder, 1985) correctly identify as lag deposits from relict inlets and times of lowered sea level. No mechanism is identified in the thesis (e.g., computation of threshold velocities) for producing these deposits with current conditions.

3) The final sentence refers to sidescan sonar images collected by Thieler (1997), which identify linear ridges of coarser deposits. Those images of sand waves are consistent with the relict flows and conditions identified by Hine and Snyder (1985). Again, no mechanism is proposed in the thesis for causing these features under current conditions.

6. Non-motion of Nearshore Berm

The most conclusive hard evidence of the depth at which significant seabed motion occurs is the lack of motion of the Corps of Engineers' nearshore berm, a mound of dredged sediment disposed offshore of Atlantic Beach. The intended concept was to use the Beaufort Inlet navigation channel's dredged sediments for a beneficial purpose of feeding the beaches, rather than dumping the materials offshore in much deeper water where they would not move. Unfortunately, the originally intended placement depth of 18ft MLW was changed to 25-30 ft (USACE, 1994, p. 11), and the result from the monitoring survey is little motion, "little" meaning less than the error in survey methods. This confirms that **sediment deeper than 30 ft will not contribute to the beach system**.

Conclusions

1) Hindcast data of extreme (12hr/yr) conditions produce depths of closure between 13 and 18 ft MLW.

2) Measured storm conditions produce closure depths between 16 and 22 ft.

3) During the few hours that hurricanes are present in the immediate vicinity, closure depth has been computed as 36 ft.

4) The limit of sediment activity was measured at a nearby but more open-coast site at between 3.9 m and 6.4 m (13-21 ft).

5) Mapping sediment types by color, texture, and size result in a boundary between beach and shelf sands between 32 and 33 ft depths.

6) The Corps of Engineers nearshore berm off of Atlantic Beach in 25-30 ft depths has not exhibited significant motion and has not contributed sediment to the beach.

APPENDIX G3. WAVES

Databases of wave climate were utilized for the purposes of (1) characterizing the site, (2) use in final design of beach fill sections and berm heights, (3) use in computing potential longshore sediment transport (summarized in the next Appendix G4), and (4) changes in waves on the beach caused by dredging the borrow sites. Only the last item will be detailed here.

Several different estimates of the wave climate have been computed by the US Army Corps of Engineers over the years. All of these data have come from models relating offshore winds to the waves that they create. There is no wave database for the Bogue Banks area. As a measure of how inaccurate this method of computing waves from winds is, note that the resulting annual average sum of wave energy flux along the beach has changed direction, as the Corps uses different methods over the years for estimating the winds. Thus the current methods are incapable of resolving the question of total longshore wave-energy flux. Nevertheless, this database is thought to be somewhat more reliable for relative changes. That is, comparisons of percent changes in the same database under different scenarios are likely to be more accurate than the actual values of wave-energy flux.

The Corps' Wave Information Study data of waves computed from wind models is divided into separate data sets by: (1) location or "Station," (2) depth or "Phase," and (3) time period.

1) For the computations below, we used Station 45, which is the station directly south of Bogue (at 34° 15' latitude, 77° 00' longitude and 27 m depth). The next closest station, #46, is offshore of Atlantic Beach.

2) WIS data appear in three Phases. Phase I is in deep water. These waves are then refracted in to form the databases at the Phase II stations, typically in 20-30 m depths. Along some coasts data are refracted into Phase III stations at 10m depth. Up-to-date Phase III data for the Atlantic Coast do not exist. (The only Phase III data are in old reports using hindcast methods that are no longer used.) Thus we used the Phase II data for wave-energy computations.

3) Data have been hindcast for two time periods: 1956-75 and 1976-95. The two databases are not directly comparable, since different methods for estimating the winds and shoaling the waves were used. Furthermore, a statistical average of hurricane-generated waves were included in the 1976-95 database, but not in the earlier one. The wave-energy comparisons we made used the more recent 1976-95 database. We used this database to compare before-and-after dredging scenarios for the **relative** change in wave heights and energies. However, caution should be used in accepting the longshore energy fluxes computed from this database, since independent analyses (Reed, 1997; CERC, 1984, Table 4-7) suggest the longshore fluxes are unrealistically high.

The Automated Coastal Engineering System (ACES) program was used to shoal the waves from the offshore Phase II station 45 into the borrow areas. The subroutine "Linear Wave Theory with Snell's Law" was used. The main limitation of this program is that it assumes depth contours are straight and parallel. For the depths offshore of borrow area A this is a reasonable assumption, but is less so the closer to shore one approaches. The other main assumption is that wave data of different periods (or wavelengths) and direction can be shoaled separately and then recombined ("linear superposition"). Compared to the other assumption of parallel contours, this assumption is quite good for the depths we used in the model, since we did not shoal waves inshore of the innermost borrow area B. A graphical representation of the shoaling process is illustrated in Figure G3-1. Note that as the waves cross various depth contours as they approach the coast, the wave crests turn to become more parallel with the coast. As this happens, the wave heights (and energies), wave angles, and energy fluxes change.

Borrow area A is between depths 50 ft and 40 ft, and B is between 40 ft and 30 ft. Thus the first step was to shoal the WIS wave data from 27m (88.6 ft) to 50 ft. From CERC's website, the WIS datafile "au2percnt.045" was used as input. Only the directional bands from which it is possible for waves to approach Bogue Banks were used. WIS uses numbered bands to identify directions. Bands 6 through 12 produce waves that are within the half of the compass facing the beach. The angle of the shoreline for this application was measured as 171d for "shore normal" for the section of Bogue at borrow areas A and B-1 (approximately at the Salter Path/Emerald Isle border). Inputs into the shoaling model were the WIS statistics of mean wave height and period (Hmo and Tp), depth, wave directions, shoreline angle, and bottom slope from NOAA charts. Outputs for the wave conditions at the seaward side of borrow area A (depth of 50 ft) are shown in Table G3-1. As expected in these still relatively deep depths, wave heights decrease slightly, and energy flux remains constant.

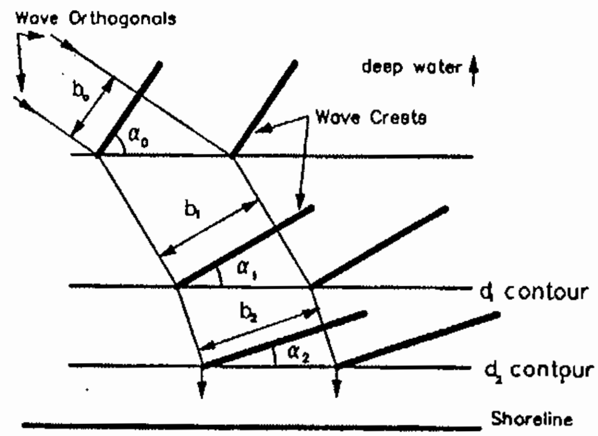


Figure 3-1-1. Snell's Law and Wave Refraction

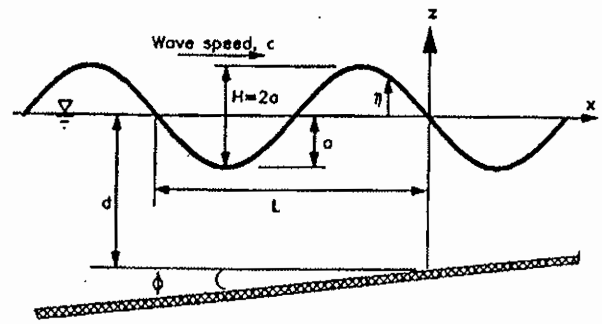


Figure 3-1-2. Progressive Wave on a Nearshore Slope

FIGURE G3-1.

The next step was to shoal waves over the existing topography in borrow area A. The results in Table G3-2 still show little change in total wave heights and energy flux.

The change in conditions if 6 ft of borrow area A is dredged is shown in Table G3-3. The results show a wave height increase of 0.2 ft, an increase in height of 2%, an increase in energy of 4%, and an increase in longshore energy flux of 9%.

The maximum dredging of borrow area A is not expected to be as large as 6 ft. That case was computed to show an extreme condition. The maximum anticipated dredging of the borrow area is 4 ft. The results for that scenario are listed in Table G3-4 and show a 1% increase in wave height of 0.1 ft, an energy increase of 2.5%, and an energy flux increase of 6%. Like the 6 ft scenario, this one should be viewed as unrealistically extreme, since the entire borrow area will not be dredged to this depth. Only localized areas within the delineated borrow area limits would experience this extreme of sediment removal.

The most realistic scenario for dredging is a 2 ft cut in borrow area A. The results in Table G3-5 show a 0.6% increase in wave height of 0.1 ft, a 1% increase in energy, and a 3% increase in energy flux.

To examine the effects of dredging the nearshore borrow areas B, the existing conditions in borrow area B1 were first computed and are listed in Table G3-6. Since the waves are now shoaling over shallower water, energy is being used in the shoaling process, and there are decreases in all relevant quantities of height, energy, and flux.

The maximum expected cut in borrow area B is 4 feet. The scenario of dredging B but not dredging A is investigated in Table G3-7. Results show less than 1% increase in wave height of less than 0.1 ft, a 1.5% increase in energy, and a 9% increase in energy flux.

The combined effect of dredging both borrow areas A and B is investigated in Table G3-8. The most likely scenario of dredging 2 ft in A and 4 ft in B was computed, and results show only 0.7% increase in wave height of less than 0.1 ft, a 1.5% increase in energy, and an 8% to 9% increase in energy flux. Note that the combined effect of dredging both borrow areas is **less** than the effect of dredging B alone. The reason for this is that the changes in topography caused by the dredging are spread out over a longer distance. The less abrupt change felt by the waves results in less change to the waves.

The final conclusions to this investigation are that:

1) Maximum anticipated dredging of the borrow areas will result in a **temporary** increase in wave heights at the landward edge of the borrow areas of somewhat less than 1% or less than 0.1 ft. The potential for longshore transport of sediment will also temporarily increase by several percent. The reason that these changes are temporary is that currents will smooth out the changes in topography by moving sand in the longshore direction to "even out" the changes.

2) Conclusions regarding the several percent increase in longshore sediment transport are suspect, because of the poor quality of the model wave data, illustrated by enormous changes in the wave database for different time periods and methods used by the Corps of Engineers in producing the Wave Information Study hindcast databases.

TABLE G3-1. Waves at the seaward edge of borrow area A (depth = 50 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right, the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 88.6 ft to 50 ft depth. 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename SEA45U.OUT

Waves outside borrow area A

WIS Band		6 (112.5°)		7 (135°)		8 (157.5°)	
Period (sec)		8.9		7.3		8.0	
% Occurrence		22.8		6.1		15.0	
% within 90°		34.9		9.3		22.9	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	3.281	2.836	3.281	3.095	4.921	4.693
Energy	E (ft-lb/ft²)	86.093	64.318	86.093	76.624	193.708	176.153
Energy Flux	P (ft-lb/ft-s)	2304	1735	1999	1882	3955	3933
	% E	8.3	7.2	8.3	8.6	18.6	19.8
Wave Angle	α (°)	58.5	46.051	36	30.733	13.5	12.054

WIS Band		9 (180°)		10 (202.5°)		11 (225°)	
Period (sec)		6.8		5.9		5.5	
% Occurrence		7.7		6.1		4.8	
% within 90°		11.8		9.3		7.3	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.921	4.666	4.265	4.027	4.593	4.277
Energy	E (ft-lb/ft²)	193.708	174.098	145.497	129.702	168.742	146.288
Energy Flux	P (ft-lb/ft-s)	-3582	-3575	-2241	-2205	-2376	-2253
	% E	18.6	19.6	14.0	14.6	16.2	16.2
Wave Angle	α (°)	-9	-8.234	-31.5	-29.954	-54	-51.697

WIS Band		12 (247.5°)		Totals	
Period (sec)		5.2			
% Occurrence		2.9		65.4	
% within 90°		4.4			
		In	Out	In	Out
Wave Height	H (ft)	4.593	3.911	11.418	10.546
Energy	E (ft-lb/ft²)	168.742	122.329	1042.583	889.512
Energy Flux	P (ft-lb/ft-s)	-2246	-1742	-2187	-2225
	% E	16.2	13.8		
Wave Angle	α (°)	-76.5	-72.476		

TABLE G3-2. Existing conditions in borrow area A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 40 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right, the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 50 ft to 40 ft depth over borrow area A. 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 4045U.OUT

Borrow area A existing condition

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.4		5.2		6.3	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.836	2.774	3.095	3.080	4.693	4.680
Energy	E (ft-lb/ft^2)	64.318	61.565	76.624	75.862	176.153	175.164
Energy Flux	P (ft-lb/ft-s)	1735	1608	1882	1837	3933	3922
	%E	7.2	7.4	8.6	9.1	19.8	21.0
Wave Angle	α (°)	46.051	41.529	30.733	28.310	12.054	11.267

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.3		5.1		5.2	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.666	4.626	4.027	3.924	4.277	4.083
Energy	E (ft-lb/ft^2)	174.098	171.141	129.702	123.143	146.288	133.343
Energy Flux	P (ft-lb/ft-s)	-3575	-3571	-2205	-2177	-2253	-2147
	%E	19.6	20.5	14.6	14.7	16.4	16.0
Wave Angle	α (°)	-8.234	-7.758	-29.954	-28.609	-51.697	-49.428

WIS Band		12		Totals	
Period (sec)		5.2			
H_b (ft)		5.1			
		In	Out	In	Out
Wave Height	H (ft)	3.911	3.457	10.546	10.223
Energy	E (ft-lb/ft^2)	122.329	95.605	889.512	835.823
Energy Flux	P (ft-lb/ft-s)	-1742	-1424	-2225	-1952
	%E	13.8	11.4		
Wave Angle	α (°)	-72.476	-68,396		

TABLE G3-3. 6 ft cut in borrow area A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 40 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 50 ft to 46 ft depth (6 ft cut). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 4645U.OUT

6 ft dredging borrow area A

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.4		5.2		6.6	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.836	2.807	3.095	3.085	4.693	4.682
Energy	E (ft-lb/ft^2)	64.318	63.025	76.624	76.139	176.153	175.351
Energy Flux	P (ft-lb/ft-s)	1735	1683	1882	1865	3933	3929
	% E	7.2	7.3	8.6	8.8	19.8	20.2
Wave Angle	α (°)	46.051	44.324	30.733	29.834	12.054	11.769

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.3		5.1		5.2	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.66	4.645	4.027	3.986	4.277	4.206
Energy	E (ft-lb/ft^2)	174.098	172.594	129.702	127.072	146.288	141.485
Energy Flux	P (ft-lb/ft-s)	-3575	-3574	-2205	-2196	-2253	-2217
	% E	19.6	19.9	14.6	14.6	16.4	16.3
Wave Angle	α (°)	-8.234	-8.064	-29.954	-29.498	-51.697	-50.949

WIS Band		12		Totals		
Period (sec)		5.2				
H_b (ft)		5.1				
		In	Out	In	Out	Percent Change
Wave Height	H (ft)	3.911	3.741	10.546	10.415	+1.9% (+0.19 ft)
Energy	E (ft-lb/ft^2).	122.329	111.923	889.512	867.589	+3.8%
Energy Flux	P (ft-lb/ft-s)	-1742	-1620	-2225	-2130	+9.1%
	% E	13.8	12.9			
Wave Angle	α (°)	-72.476	-71.113			

TABLE G3-4. 4 ft cut in borrow area A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 40 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 50 ft to 44 ft depth (4 ft cut). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 4445U.OUT

4 ft dredging of borrow area A

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.4		5.2		6.6	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.836	2.795	3.095	3.082	4.693	4.679
Energy	E (ft-lb/ft^2)	64.318	62.467	76.624	75.982	176.153	175.135
Energy Flux	P (ft-lb/ft-s)	1735	1658	1882	1856	3933	3926
	% E	7.2	7.3	8.6	8.9	19.8	20.4
Wave Angle	α (°)	46.051	43.421	30.733	29.351	12.054	11.612

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.3		5.1		5.2	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.666	4.637	4.027	3.965	4.277	4.167
Energy	E (ft-lb/ft^2)	174.098	171.977	129.702	125.746	146.288	138.875
Energy Flux	P (ft-lb/ft-s)	-3575	-3573	-2205	-2190	-2253	-2196
	% E	19.6	20.1	14.6	14.7	16.4	16.2
Wave Angle	α (°)	-8.234	-7.970	-29.954	-29.232	-51.697	-50.500

WIS Band		12		Totals		
Period (sec)		5.2				
H_b (ft)		5.1				
		In	Out	In	Out	Percent Change
Wave Height	H (ft)	3.911	3.649	10.546	10.350	+1.2% (+0.13 ft)
Energy	E (ft-lb/ft^2),	122.329	106.509	889.512	856.691	+2.5%
Energy Flux	P (ft-lb/ft-s)	-1742	-1556	-2225	-2075	+6.3%
	% E	13.8	12.4			
Wave Angle	α (°)	-72.476	-70.303			

TABLE G3-5. 2 ft cut in borrow area A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 40 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 50 ft to 42 ft depth (2 ft cut). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 4245U.OUT

2 ft dredging of borrow area A

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.4		5.2		6.6	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.836	2.784	3.095	3.080	4.693	4.678
Energy	E (ft-lb/ft^2)	64.318	61.979	76.624	75.887	176.153	175.066
Energy Flux	P (ft-lb/ft-s)	1735	1633	1882	1847	3933	3924
	% E	7.2	7.3	8.6	9.0	19.8	20.7
Wave Angle	α (°)	46.051	42.490	30.733	28.843	12.054	11.445

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.3		5.1		5.2	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.666	4.630	4.027	3.944	4.277	4.126
Energy	E (ft-lb/ft^2)	174.098	171.486	129.702	124.431	146.288	136.155
Energy Flux	P (ft-lb/ft-s)	-3575	-3572	-2205	-2184	-2253	-2173
	% E	19.6	20.3	14.6	14.7	16.4	16.1
Wave Angle	α (°)	-8.234	-7.868	-29.954	-28.936	-51.697	-49.995

WIS Band		12		Totals		
Period (sec)		5.2				
H_b (ft)		5.1				
		In	Out	In	Out	Percent Change
Wave Height	H (ft)	3.911	3.554	10.546	10.285	+0.6% (+0.06 ft)
Energy	E (ft-lb/ft^2).	122.329	101.048	889.512	846.052	+1.2%
Energy Flux	P (ft-lb/ft-s)	-1742	-1490	-2225	-2015	+3.2%
	% E	13.8	11.9			
Wave Angle	α (°)	-72.476	-69.399			

TABLE G3-6. Existing conditions in borrow area B1. "In" statistics are the waves at the landward edge of borrow area A (depth = 40 ft), and "Out" are the waves at the landward edge of borrow area B1 (depth = 30 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 40 ft to 30 ft depth. 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 3045U.OUT (uses borrow area A existing conditions' output as input)

Borrow area B1 (existing conditions)

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.9		5.6		7.1	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.774	2.759	3.080	3.107	4.680	4.733
Energy	E (ft-lb/ft^2)	61.575	60.868	75.862	77.225	175.164	179.182
Energy Flux	P (ft-lb/ft-s)	1608	1492	1837	1788	3922	3908
	%E	7.4	7.6	9.1	9.7	21.0	22.5
Wave Angle	α (°)	41.529	36.212	28.310	25.197	11.267	10.184

WIS Band		9		10		11	
Period (sec)		6.8					
H_b (ft)		6.7					
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.626	4.645	3.924	3.838	4.083	3.855
Energy	E (ft-lb/ft^2)	171.141	172.607	123.143	117.826	133.343	118.881
Energy Flux	P (ft-lb/ft-s)	-3517	-3566	-2177	-2134	-2147	-1992
	%E	20.5	21.6	14.7	14.8	16.0	14.9
Wave Angle	α (°)	-7.758	-7.069	-28.609	-26.397	-49.428	-45.473

WIS Band		12		Totals	
Period (sec)		5.2			
H_b (ft)					
		In	Out	In	Out
Wave Height	H (ft)	3.457	2.974	10.233	9.985
Energy	E (ft-lb/ft^2)	95.605	70.725	835.823	797.314
Energy Flux	P (ft-lb/ft-s)	-1424	-1107	-1952	-1611
	%E	11.4	8.9		
Wave Angle	α (°)	-68.396	-61.729		

TABLE G3-7. 4 ft cut in borrow area B, with no dredging in A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 34 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right, the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 40 ft to 34 ft depth (4 ft cut). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 3445U.OUT (uses borrow area A's existing condition output as input)

Dredging borrow area B (4 ft cut)

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.8		5.5		6.9	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.774	2.758	3.080	3.089	4.680	4.701
Energy	E (ft-lb/ft^2)	61.575	60.822	75.862	76.333	175.164	176.740
Energy Flux	P (ft-lb/ft-s)	1608	1537	1837	1808	3922	3914
	% E	7.4	7.5	9.1	9.4	21.0	21.8
Wave Angle	α (°)	41.529	38.451	28.310	26.540	11.267	10.660

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.6		5.5		5.5	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.626	4.627	3.924	3.868	4.083	3.947
Energy	E (ft-lb/ft^2)	171.141	171.260	123.143	119.642	133.343	124.613
Energy Flux	P (ft-lb/ft-s)	-3571	-3569	-2177	-2153	-2147	-2060
	% E	20.5	21.2	14.7	14.8	16.0	15.4
Wave Angle	α (°)	-7.758	-7.375	-28.609	-27.410	-49.428	-47.302

WIS Band		12		Totals		
Period (sec)		5.2				
H_b (ft)						
		In	Out	In	Out	Percent Change
Wave Height	H (ft)	3.457	3.163	10.233	10.060	+0.8% (+0.075 ft)
Energy	E (ft-lb/ft^2)	95.605	79.998	835.823	809.408	+0.8%
Energy Flux	P (ft-lb/ft-s)	-1424	-1229	-1952	-1752	+8.8%
	% E	11.4	9.9			
Wave Angle	α (°)	-68.396	-64.745			

TABLE G3-8. 4 ft cut in borrow area B, with 2 ft cut in A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge of borrow area B (depth = 34 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right, the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 42 ft to 34 ft depth (2 ft cut in A and 4 ft cut in B). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 34AB45U.OUT (uses borrow area A's 2-ft-cut output as input)

Dredging both borrow areas A (2 ft cut) and B (4 ft cut)

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.9		5.6		7.0	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.784	2.758	3.080	3.089	5.678	4.700
Energy	E (ft-lb/ft^2)	61.979	60.853	75.887	76.309	175.066	176.688
Energy Flux	P (ft-lb/ft-s)	1633	1538	1847	1808	3924	3913
	% E	7.3	7.5	9.0	9.4	20.7	21.8
Wave Angle	α (°)	42.490	38.452	28.843	26.539	11.445	10.660

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.7		5.5		5.6	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.630	4.627	3.944	3.867	4.126	3.947
Energy	E (ft-lb/ft^2)	171.486	171.212	124.431	119.614	136.155	124.624
Energy Flux	P (ft-lb/ft-s)	-3572	-3568	-2184	-2152	-2173	-2060
	% E	20.3	21.2	14.7	14.8	16.1	15.4
Wave Angle	α (°)	-7.868	-7.375	-28.936	-27.410	-49.995	-47.302

WIS Band		12		Totals		
Period (sec)		5.2				
H_b (ft)						
		In	Out	In	Out	Percent Change
Wave Height	H (ft)	3.554	3.163	10.285	10.059	+0.7% (+0.074 ft)
Energy	E (ft-lb/ft^2)	101.048	79.996	846.052	809.296	+1.5%
Energy Flux	P (ft-lb/ft-s)	-1490	-1229	-2015	-1750	+8.6%
	% E	11.9	9.9			
Wave Angle	α (°)	-69.399	-64.745			

APPENDIX G4. LITTORAL TRANSPORT

Previous Transport Studies

Several studies have been performed by both the Corps of Engineers and the University of North Carolina to estimate the potential for longshore sediment-transport:

1) The Corps of Engineers 1976 study compared two time periods relative to Beaufort Inlet navigation-channel maintenance, before (1854-1936) and after (1960-1974). The results vary considerably over time, as shown in Table G4-1. But the overall results from the study concluded: (a) sediment transport is to the east (75%), (b) shoaling occurs more on the west side of the channel (68% of the channel shoaling), (c) bypassing efficiency of the inlet dropped from 52% to 28% after dredging, and (d) the net transport is about 14% of the gross. These results suggest that the dredged channel at Beaufort Inlet is blocking some (about half) of the longshore transport and that this impact should be felt more on Shackleford than Bogue, since net transport is to the east. The dataset used for these computations was a series of shipboard observations of winds, which in turn were used in models to predict the waves they create. The fact that this dataset was abandoned by the Corps several years later is an indication of its quality.

2) In 1990, the Corps of Engineers updated its previous study with a different set of wind data, but from the same time period of 1956-1975. That study concluded that (a) the gross transport rate was about 600,000 cy/yr greater than shown in the 1976 study, but (b) the net transport proportion was about the same as in the previous study, in this case 78% of the total or gross transport, and still to the east. Results are summarized below in Table G4-2.

TABLE G4-1. Results of the 1976 sediment budget analysis. [*Negative transport quantities indicate drift moving in opposite direction from assumed in the analysis. **Negative bypassing quantities indicate transport into the inlet by tidal currents. [From USACE, 1999]

Time Period	Easterly Sand Trans. from Bogue Banks (cy/yr)	Westerly Sand Trans. from Shackleford Banks (cy/yr)	Bypassing to the East (cy/yr)	Bypassing to the West (cy/yr)
1854-1936	702,000	239,000	492,000	133,000
1936-1952	1,720,000	584,000	1,241,000	234,000
1952-1960	*-400,000	**-136,000	-518,000	88,000
1960-1974	641,000	218,000	238,000	121,000
1936-1974	378,000	128,000	60,000	-66,000

TABLE G4-2. Results of the 1990 sediment budget analysis. [From USACE, 1999]

Time Period	Easterly Sand Trans. from Bogue Banks (cy/yr)	Westerly Sand Trans. from Shackleford Banks (cy/yr)	Bypassing to the East (cy/yr)	Bypassing to the West (cy/yr)
1980-1988	1,130,000	328,000	898,000	-113,000

3) The Corps is currently performing an updated hindcast study, and results are not yet available.

4) Roessler (1998) performed a very similar study as the Corps, but used a very different set of wind data (the 1976-1993 Station 46 WIS dataset), a different wave-shoaling model (REF/DIF), and a slightly different set of digitized topographic data (UNC, 1998). He reached the following conclusions:

- "**Net longshore current velocity (and hence transport) in the study area is to the west.** Modeled fairweather and storm wave conditions based on USACE Hindcast Wave data indicated that the net longshore transport at eastern Bogue Banks is to the west."

- "**Although approximately 17 million cubic meters of sediment were removed from the active littoral system by offshore disposal, the offshore disposal area appeared to actually decrease both velocities and gradients in longshore current velocity during simulations of Hurricanes *Bertha* and *Fran* and potentially decrease erosion rates.** The offshore disposal area actually decreased longshore current velocities in some locations by up to 50 percent during Hurricane *Bertha* and up to 65 percent during Hurricane *Fran*."

- "**According to model results, the nearshore berm had a minimal effect on the refraction and diffraction of fairweather waves; however, during storm events the potential for cross-shore transport (perpendicular to the shoreline) was much greater.** REF/DIF results agree with USACE predictions that the nearshore berm will have a very limited effect on fairweather waves."

- "**Inlet orientation had only minor effects on wave refraction/diffraction processes during fair weather and storm conditions.**"

- "**Although the offshore disposal area decreased gradients in longshore current velocity, the overall effect of dredging Beaufort Inlet, which caused the ebb tidal delta to prograde seaward, was to increase gradients in longshore current velocity during simulations of Hurricanes *Bertha* and *Fran*.** REF/DIF results suggested that the progradation of the ebb tidal delta of Beaufort Inlet caused by dredging likely increases erosion rates in certain locations of the study area including Pine Knoll Shores. During storm conditions, steeper gradients in longshore current velocity were predicted for the recent bathymetry when compared to model runs for bathymetry from 1854 and 1925. These steep gradients in longshore current velocities were reflected in the erosion and accretion patterns following Hurricanes *Bertha* and *Fran*."

- "**Eastern Bogue Banks is susceptible to high erosion from storm waves approaching from the south, and longshore current velocities are altered by the progradation of the ebb tidal delta of Beaufort Inlet when simulated storm waves approach from the southeast.** When large storm waves (greater than 4.5 m) approach Bogue Banks from a direction less than 137 degrees, calculated longshore current velocities are altered throughout most of the study area which can potentially lead to higher erosion rates. When storms waves approach Bogue Banks from between 140 and 179 degrees, calculated longshore current velocities are changed in the vicinity of Atlantic Beach and Fort Macon State Park which can also potentially increase erosion rates especially at eastern Atlantic Beach and Fort Macon State Park."

Transport Computations for This EIS

We performed a similar type of analysis of potential longshore sediment transport along Bogue Banks to:

1) Investigate the variation of the transport along the entire island. (The Corps and UNC studies were for Atlantic Beach, Beaufort Inlet, and Shackleford Banks, since those were the areas being considered for Corps dredging and nourishment projects.)

2) Determine the sensitivity of the results to data source. We compared the variation in transport results for the different WIS time periods (1956-75 and 1976-95) and for different stations (45 and 46), by using exactly the same procedures for both time periods and both stations.

3) Determine the sensitivity of the results to wave shoaling method (i.e., simple linear shoaling vs. models such as RCPWave that account for the effects of nonparallel seabed contours).

We calculated potential for longshore sediment transport for both time periods and both wind-data stations. In addition, computations were performed at several different stations along the island listed in Table G4-3. The angle of "shore normal" was measured from NOAA charts for each location. "Shore normal" is the azimuth angle perpendicular to the beach, as illustrated in Figure G4-1. We did not perform wave-shoaling computations as a part of these longshore transport computations, since the Corps had already done so, and our intention was to determine how much the results depended on whether the waves were shoaled. Longshore sediment-transport theory says that if the seabed contours are straight and parallel, then no shoaling is necessary, because the longshore energy flux will remain the same. The transports were computed using the Longshore Sediment Transport module in the Automated Coastal Engineering System (ACES). The wave data inputs were in "CEDRS" format as obtained from the WIS datasets on the US Army Corps of Engineers' Coastal Engineering Research Center's website.

TABLE G4-3 Shore normal from NOAA chart 11543.

	Longitude	Normal Azimuth
West end of Emerald Isle west	77°04.5'	162°
Mid Emerald Isle west	77°02.0'	165°
Mid Emerald Isle central	76°59.0'	169°
Mid Emerald Isle east	76°56.0'	169°
Salter Path/Emerald Isle boundary	76°54.0'	169°
Mid Salter Path/Indian Beach	76°53.0'	171°
Salter Path/Indian Beach/Pine Knoll Shores boundary	76°52.0'	170°
Mid Pine Knoll Shores West	76°51.0'	172°
Mid Pine Knoll Shores East	76°49.0'	172°
Pine Knoll Shores/Atlantic Beach boundary	76°47.0'	173°
Mid Atlantic Beach	76°45.0'	180°
Atlantic Beach/Fort Macon boundary	76°42.0'	187°

The results for each combination of ten locations along the island, two time periods, and two WIS stations are listed as the 40 longshore transport rates in Table G4-4. Using the standard sign convention for transport, for an observer standing on the beach, transport to his right is positive, to his left negative. For Bogue Banks, this means positive transport is to the west. The **results** can be summarized as follows:

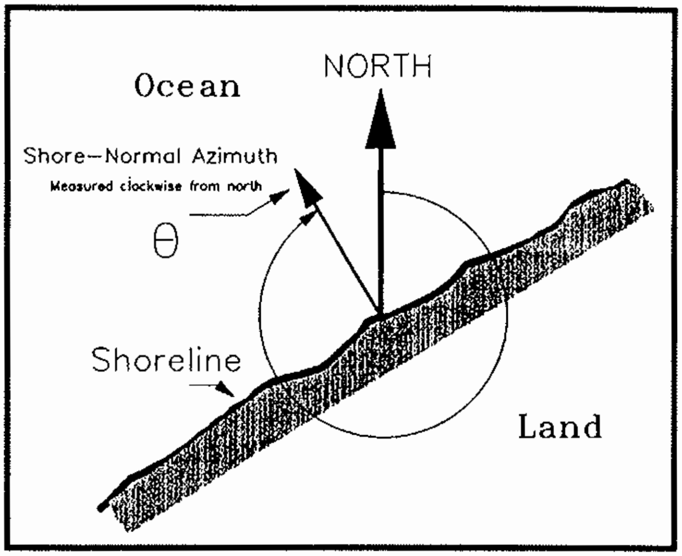


FIGURE G4-1. Definition diagram for shore-normal azimuth.

1) The results for the 1956-75 time period are directly comparable to the second Corps of Engineers study, which used the same input data. As found in the Corps study, the Station 45 data (directly south of Bogue Banks) generate longshore sediment transport **toward the east at every station** along the island. Numerical values decrease from a maximum 560,000 cy/yr at the west end of the island to 260,000 cy/yr at the eastern border of Atlantic Beach (next to Fort Macon).

TABLE G4-4. Longshore sediment transport rates from WIS hindcast data. Positive transport is to the west, negative to the east. Longitudes are in Table G4-3. [*No hurricanes. **Includes hurricanes.]

	Station 46		Station 45	
Location along Bogue Banks	**1956-1975***	**1976-1995****	**1956-1975***	**1976-1995****
West end of Emerald Isle	-450,446	550,895	-560,710	349,854
Emerald Isle west	-398,140	618,708	-552,180	424,298
Emerald Isle central	-319,330	700,821	-546,002	509,601
Emerald Isle east	-285,766	724,094	-543,051	538,883
Salter Path/Emerald Isle boundary	-300,105	716,366	-547,583	520,170
Mid Salter Path/Indian Beach	-269,473	734,851	-533,379	562,452
Salter Path/Indian Beach/Pine Knoll Shores boundary	-242,748	755,330	-523,024	582,884
Pine Knoll Shores West	-129,940	841,233	-471,172	670,450
Pine Knoll Shores East .	-7,927	934,084	-405,011	750,221
Pine Knoll Shores/Atlantic Beach boundary	285,997	1,186,473	-258,183	938,429

2) For the same 1956-75 time period Station 46 data (southeast of Bogue Banks) generate transport which has **somewhat smaller transport values (about 20% less)** until a point in the middle of Atlantic Beach is reached. At that point the transport is essentially zero. East of that point the data generate results that are geologically impossible: transport is to the west. This would require sediment to be piling up in the middle of Atlantic Beach, which it is not. Most likely, the model is generating unrealistic results for eastern Atlantic Beach and Fort Macon, because of the nonlinear bathymetric topography in that area, which violates the basic assumption of the shoaling model. For

this station, the values range from a high of 450,000 cy/yr at the west end of Bogue Banks to zero in the middle of Atlantic Beach. [For the record, the results that we do not believe show: to the east of that point, transport is back to the west, increasing from the mid-Atlantic Beach nodal point of zero transport to 286,000 cy/yr westward transport at the border with Fort Macon.]

3) The computations for the time period 1975-95 are directly comparable to the University of North Carolina study, which used essentially the same database. (Since that study, the WIS data were changed only slightly by adding two more years of data during 1994-95.) As found in the UNC study, transport is **to the west everywhere** along the island (although the UNC study was only for the eastern half of Bogue). Our values of longshore transport for Station 46 (the same as used by UNC) ranged from a minimum of 551,000 cy/yr at the western end of Bogue to a maximum of 1,186,000 cy/yr at the Fort Macon border.

4) The results for the 1975-95 time using Station 45, directly south of Bogue, were qualitatively similar to the Station 46 runs, but the values **(all transport to the west)** ranged from a minimum of 350,000 cy/yr at the west end of the island to 938,000 cy/yr at the Fort Macon border.

Conclusions which can be made from these results include:

1) Error in the wave data results in inability to predict even the direction of longshore transport, since opposite directions are predicted for all locations, depending on which datasets are used.

2) Because of change in beach orientation, transport necessarily becomes more and more westward-directed as one progresses to the east end of Bogue.

3) Results are far more dependent on input wave data than on what wave-shoaling model is used, or even if a shoaling model is used at all.

4) Although different methods were used to determine the WIS wave data for the two time periods, the only significant difference in which winds were "counted" in modeling the waves was the presence of hurricanes. The 1956-75 datasets do not include hurricanes, whereas the 1976-95 datasets do. This may account for the change in predicted net transport direction for most of the island from eastward (1956-75, no hurricanes) to westward (1976-95, with hurricanes).

5) Other independent methods of determining longshore sediment transport, such as measuring dispersal of nourishment sand (Reed, 1997) show small values of net transport in the Atlantic Beach area. This places doubt on all the WIS hindcast results, which tend to show high transports.

APPENDIX G5. EROSION RATES

Erosion rates are important in determining environmental impacts for the following reasons:

- Nourishment volumes are computed so as to counteract the natural erosion for a specified number of years. Erosion rates are used in computing the needed nourishment volumes.
- The severity of erosion is the most important indicator of how fast detrimental impacts will occur to the economy and infrastructure, if the "no action" option continues.
- The rate of erosion will determine how long beneficial impacts will last for both humans and plant/animals (e.g., increased dry beach width for turtle nesting).

Estimates of erosion rates have been obtained from two types of data analysis: linear retreat of shorelines seen in aerial photographs, and comparisons of profile surveys of the beach. The latter method is far more accurate, but also far more expensive. The available data from both methods on Bogue Banks will be described below, but the best method of determining erosion (a comparison of two comprehensive surveys) is not possible, since there have not been multiple surveys of most of the island.

Most of the studies described below are comparisons of "lines" on aerial photographs. Typically, there are two such lines that are identifiable: a high-tide or "wet/dry" line and a dune or "vegetation" line. Regardless of which line is identified and compared between successive photograph dates, this linear shoreline change (ft/yr) must then be translated into a volumetric erosion/accretion rate in cubic yards per year (cy/yr). There are various rules of thumb for doing so, but site-specific determination of the conversion factor is more accurate than rules of thumb. The site-specific conversions are computed by comparing the two types of rates (linear and volumetric) for that site and then dividing the results to determine the conversion factor. This exercise was performed by the Corps of Engineers (USACE, 1976, p. C-10), and for Bogue Banks 1 ft/yr equates to 1.3 cy/yr.

Long-Term Linear Erosion Rates (COE & NCSU)

Several recent studies of aerial photography have been performed to determine recent erosion rates, but for long-term erosion there are two important studies, one conducted by an agency of the Corps of Engineers called the Beach Erosion Board in 1948, and a study conducted by North Carolina State University. The BEB study determined erosion along the entire island between the dates 1854 and 1933. Of course, this study did not use aerial photography, but instead relied on surveys by the National Ocean Survey of certain topographic contour lines. Starting from the eastern end of Bogue at Beaufort Inlet, the BEB measured erosion averaging 0.14 ft/yr for the first mile, 0.90 ft/yr of accretion for the next two miles, and 1.14 ft/yr erosion for the remaining 7 miles. The Corps of Engineers uses different rates from the BEB study, depending on the location of the proposed project. But clearly the most appropriate number for this EIS is the 1.14 ft/yr erosion for the island west of Atlantic Beach. Using the USACOE conversion factor of 1.3 over our project length of 88,760 feet results in an **erosion rate of 132,000 cy/yr during 1854-1933.**

NCSU measured locations of vegetation lines and wet/dry lines on aerial photographs from 1939, 1953, 1958, 1964, and 1971. The vegetation or dune-line results (USACE, 1976, p. B-15) for the long-term period of 1939-71 were 4.2 ft/yr erosion for the easternmost 32,000 feet of Bogue and 2.9 ft/yr for the remainder. Multiplying the latter rate by 1.3 and our project length of 88,760 feet produces an **erosion rate of 335,000 cy/yr during 1939-1971.**

Beach Erosion from Aerial Photos (COE & NCDCM)

North Carolina's Division of Coastal Management updates shoreline erosion rates from aerial photographs about every 6 years. Erosion maps for Bogue Banks are available for 1980, 1986, and 1992. The resulting erosion rates are computed as changes from the baseline set of photos from 1938. So the results are averages from 1938 until the update. We tabulated the 1980 and 1992 erosion rates for each of our beach-profile stations along the island for comparison. The plotted erosion/accretion values for the two time periods (1938-80 and 1938-92) are shown in the upper half of Figure G5-1.

The Corps of Engineers performed similar analyses in a study of effects of their dredging projects (USACE, 1999). They measured the changes in both types of linear indicators: the wet/dry line and the vegetation line. We tabulated these results alongside our survey results for use in computing nourishment volumes. The Corps' rates are plotted in the lower half of Figure G5-1.

Beach Erosion from Comparison of Surveys (COE & CSE)

Repetitive beach surveys, encompassing the entire littoral zone, are the best means of determining how much sand is lost or gained along the beach (NAS, 1995). Bogue Banks, unfortunately, does not have an extensive data base of historical surveys. One island-wide survey by the USACE in 1978 allowed comparisons to low-tide wading depth (~−4 ft NGVD) with 60 of our profile lines. USACE profiles were superimposed on our present surveys and analyzed for changes. By extrapolating profile cross-sections over one foot of shoreline ("unit width") or from one profile to the next, a measure of the sand volume change can be obtained. The two sets of profiles, plotted for the entire island, are presented at the end of this appendix.

Figure G5-2 presents our summary of **estimated volumetric rates**, based on best-available data (bold-faced values in Table G5-1).

All five of the methods described above were tabulated for each profile line (1-111) shown in Figures G5-1 and G5-2. Starting with profile line 1 at the western end of Bogue Banks and working east, we tabulate below the results for each of the island "reaches" (separated by solid vertical lines on both figures). Since volumetric methods are considered more accurate, the numbers from that method were generally selected as most appropriate. When those values differed drastically from the other methods, the method which most closely matched the volumetric method, namely the Corps wet/dry line, was selected. The selected value for each reach is in boldface in Table G5-1.

Clearly there are large discrepancies between individual methods and reaches. However, there are some trends. Generally, the Volume Change method and the COE Wet/Dry Line methods were consistent. The two methods that used vegetation lines over roughly the same time period were also consistent: the NCDCM 1992 and COE vegetation lines. Some choice had to be made as to the most reliable estimates for each reach.

The computed **volumes on each of the 111 profile lines are in Table G5-2**. The volumes are all relative to the Stroud survey baseline. Each profile volume computation was started at the listed "offset" distance from the baseline and ended at the listed "cutoff" distance from the baseline.

Plots of each profile are included at the end of this appendix in Annex G1.

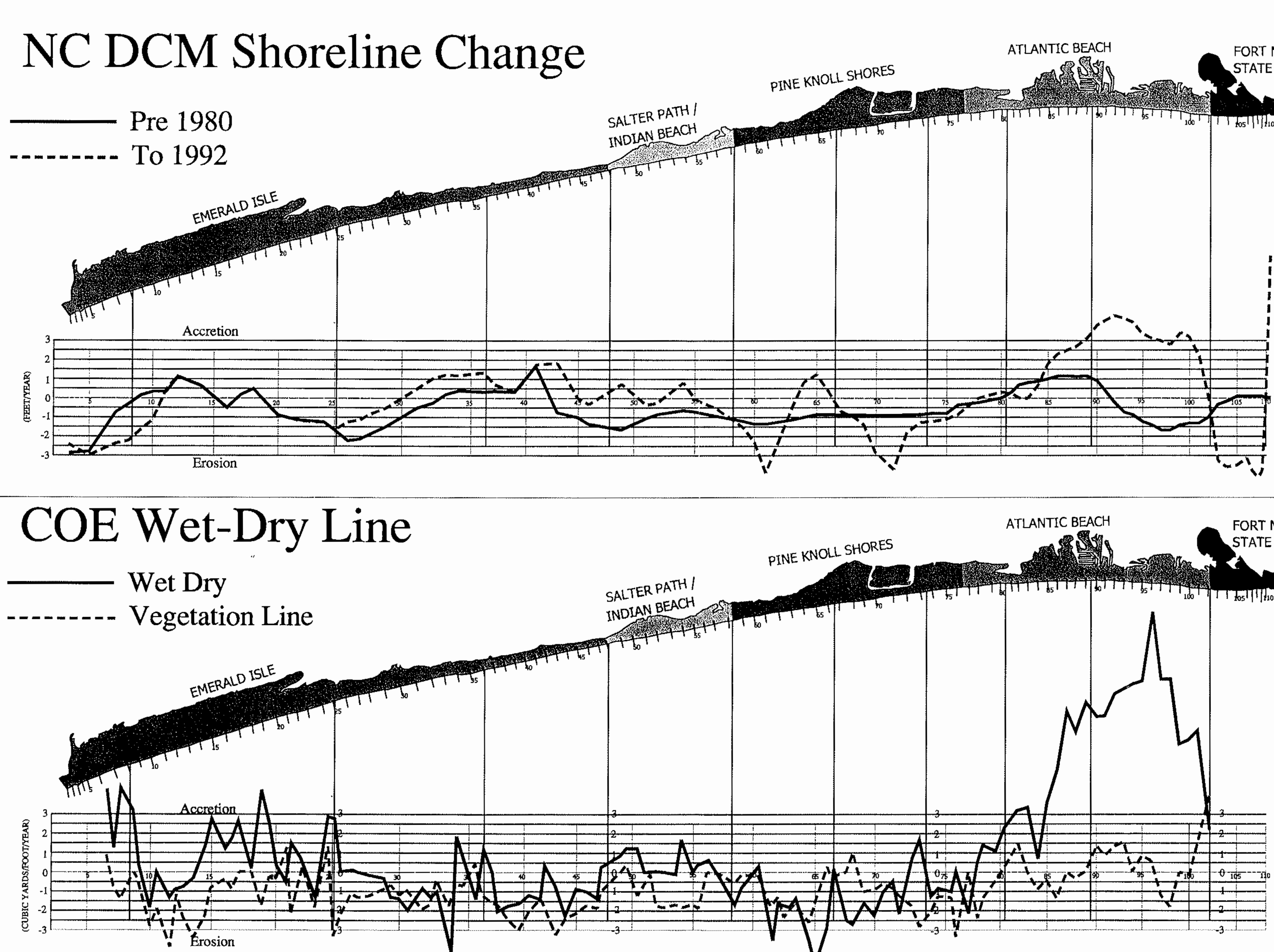


FIGURE G5-1. Linear shoreline change rates for Bogue Banks compiled by the State of North Carolina (upper) and the USACE (lower), based on analysis of aerial photography.

Coastal Science & Engineering, LLC

STROUD ENGINEERING
151A HIGHWAY 24
MOREHEAD CITY, N.C. 28557
(252) 247-7479

Surveyed By:
Drawn By: PAM TWK
Checked By: TWK
Approved By: TEW

REVISIONS:

Date

PROJECT NORTH
0 5000 10000

Bogue Banks
Beach Nourishment
North Carolina

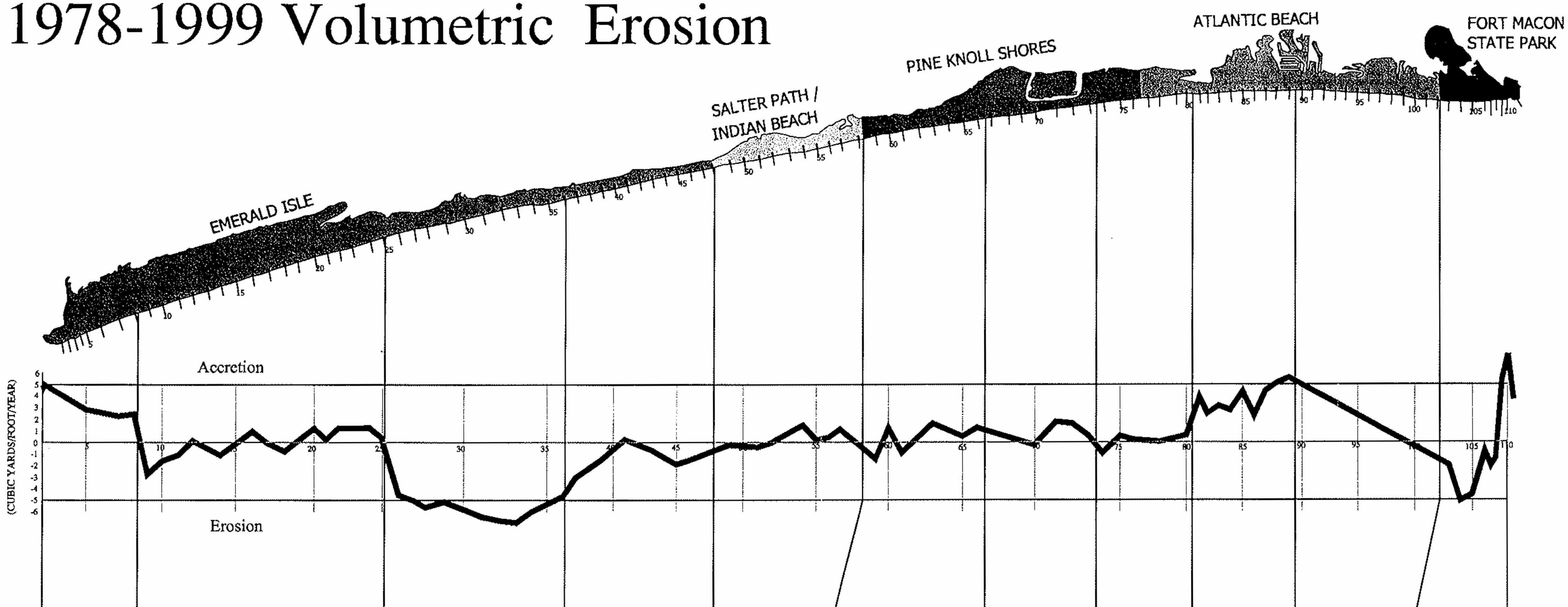
Prepared For:
Carteret County
North Carolina

Drawing Title:

Fig G5-1

CSE Project Number: 9853-04
Date: February 2000
Printed: 2/11/00
Drawing Number: Fig. G5-1.dwg
Sheet Number:

1978-1999 Volumetric Erosion



Accreting 3.15 cy/ft/yr	Very Slow Erosion 0.11 cy/ft/yr	Slow Erosion 0.78 cy/ft/yr	Moderate Erosion 1.62 cy/ft/yr	Stable	Slow Erosion 0.34 cy/ft/yr Note: Used NCDENR pre 1992 rates.	Stable	Moderate Erosion 1.87 ct/ft/yr	Very Slow Erosion 0.40 cy/ft/yr	Stable	Slow Erosion 0.88 cy/ft/yr Note: Used NCDENR pre 1980 rates.	Rapid Erosion 2.62 cy/ft/yr	Accretion
								With Continuing Corps Nourishment				
		Note: Difference in Corps baseline in this reach gives high erosion rates (above). Corps Wet/Dry line analysis used instead.						Stable	Accreting 3.79 cy/ft/yr	Accreting 3 to 9 cy/ft/yr		

Volume Change Rates 1978 - 1999 (to 4 ft depth, from comparison of 1978 COE profiles and 1999 CSE profiles)

KEY

<0.5 cy/ft/yr	Very Slow Erosion
0.5-1.0 cy/ft/yr	Slow Erosion
1-2 cy/ft/yr	Moderate Erosion
>2 cy/ft/yr	Rapid Erosion

FIGURE G5-2. Volumetric erosion rates estimated to the outer bar, based on (1) extrapolation of comparative wading depth profiles and (2) extrapolation of linear shoreline movement (vegetation lines and dry-sand/wet-sand lines on aerial photography).

CSE
Coastal Science & Engineering, LLC.

STROUD ENGINEERING
151A HIGHWAY 24
MOREHEAD CITY, N.C. 28557
(252) 247-7479

Surveyed By:
Drawn By: PAM TMK
Checked By: TMK
Approved By: TEW

REVISIONS:

Date

PROJECT NORTH

0 5000 10000

Bogue Banks Beach Nourishment North Carolina

Prepared For:
Carteret County
North Carolina

Drawing Title:

Fig. G5-2

CSE Project Number: 9853-04
Date: February 2000
Printed: 2/11/00
Drawing Number: fig_g5-2.dwg
Sheet Number:

TABLE G5-1. Summary of Bogue Banks erosion rates. (Positive values are accretion, negative erosion. "Best" values are in boldface.) The boldface values for Atlantic Beach are postnourishment. For prenourishment rates, use the 1938-80 NCDCM study numbers. [*Variable low erosion rates resulted in selection of "zero" rate or a stable beach.]

Project	Reach	COE/CSE Volume Change 1978-99 (cy/ft/yr)	NCDCM Shoreline Change 1938-92 (ft/yr)	USACE NCDCM Shoreline Change 1938-80 (ft/yr)	USACE Shoreline Change 1978-93 Wet-Dry (ft/yr)	Shoreline Change 1978-93 Vegetation (ft/yr)
1-8	Emerald Isle-Inlet	**3.15**	−2.48	−1.68	3.93	−0.03
9-25	Emerald Isle-West	**−0.11**	−0.47	−0.65	0.82	−1.21
26-36	Emerald Isle-Central	−5.67	0.16	−0.82	**−0.78**	−1.06
37-48	Emerald Isle-East	**−1.62**	0.68	−0.28	−1.09	−2.01
49-58	Salter Path/Indian Bch*	0.21	0.01	−0.91	−0.09	−1.23
59-66	PineKnollShores West	0.38	−2.60	−1.27	**−0.57**	−0.94
67-73	PineKnollShores East	1.05	−1.87	−0.90	**−1.84**	−0.96
74-80	PKS/AB border*	0.09	−0.56	−0.40	−0.07	−1.64
81-89	Atlantic Beach West	**3.79**	1.48	0.94	4.52	−0.10
90-102	Atlantic Beach East	No 1978 Data	3.19	-0.88	**9.85**	0.73
103-108	Fort Macon	**−2.62**	−3.63	0.00	7.37	0.53
109-111	Beaufort Inlet	**5.18**	1.13	0.03	11.10	1.03

Table G6-2. Profile Volumes for 1999 CSE/Stroud Survey of Bogue Banks on 111 Lines

(page 2 of 2)

Station	Baseline Offset	Cutoff	Distance to Next	Top to 9 ft. Unit Volume	9 to 2 Volume	2.0 to -4.0 Volume	-4.0 to -11 Volume	+9 to -11 Volume	Normalized Unit Volume	Normalized +9 to -4
	(ft)	(ft)	(ft)	(cy/ft)	(cy/ft)	(cy/ft)	(cy/ft)	(cy/ft)	vol/avg vol	vol/avg vol
80	75	None	1097	0.00	15.73	47.60	125.85	189.18	1.12	1.18
81	71	None	707	0.00	18.82	48.96	132.09	199.87	1.18	1.26
82	74	None	998	0.00	11.37	41.07	120.29	172.73	1.02	0.98
83	77	None	1012	0.00	12.35	38.37	121.92	172.64	1.02	0.94
84	77	None	1000	0.00	14.92	48.05	120.86	183.83	1.09	1.17
85	74	None	1001	0.00	17.50	51.05	123.51	192.06	1.13	1.28
86	52	None	1000	0.00	21.43	53.60	125.74	200.77	1.19	1.40
87	85	None	994	0.00	18.92	54.38	131.21	204.51	1.21	1.36
88	77	None	1008	0.00	26.39	57.27	181.78	265.44	1.57	1.56
89	146	None	1099	0.00	18.88	51.77	117.44	188.09	1.11	1.32
90	132	None	912	0.00	18.54	42.64	136.38	196.98	1.16	1.14
91	99	None	1000	0.00	17.49	46.41	113.53	177.43	1.05	1.19
92	122	None	1000	0.00	14.72	45.36	114.68	174.76	1.03	1.12
93	95	None	892	0.00	15.57	49.56	108.19	173.31	1.02	1.21
94	-10	None	1024	0.00	39.29	77.25	152.22	268.76	1.59	2.17
95	149	None	996	0.00	18.27	41.90	131.77	191.94	1.13	1.12
96	118	None	999	0.00	18.63	43.79	124.55	186.97	1.10	1.16
97	67	None	1000	0.00	18.36	37.19	145.63	201.18	1.19	1.03
98	112	None	1025	0.00	4.15	27.63	127.53	159.31	0.94	0.59
99	-8	None	973	0.00	16.03	59.66	177.90	253.59	1.50	1.41
100	10	None	1004	0.00	18.85	51.11	145.98	215.94	1.28	1.30
101	66	None	1001	0.00	18.71	46.24	145.69	210.64	1.24	1.21
102	64	None	1016	0.00	13.15	39.22	141.66	194.03	1.15	0.98
103	21	None	975	0.00	8.43	37.98	123.62	170.03	1.00	0.86
104	48	None	993	0.00	10.53	30.19	123.03	163.75	0.97	0.76
105	157	None	999	0.00	2.97	20.07	73.65	96.69	0.57	0.43
106	152	None	531	0.00	9.78	27.15	143.81	180.74	1.07	0.69
107	139	None	471	0.00	8.40	25.58	99.57	133.55	0.79	0.63
108	178	None	533	0.01	6.26	23.58	83.81	113.65	0.67	0.56
109	130	None	460	0.00	10.85	27.34	86.73	124.92	0.74	0.71
110	171	None	721	0.00	18.21	32.37	91.37	141.95	0.84	0.94
111	280	None	0	0.00	24.25	44.66	96.82	165.73	0.98	1.28
			Averages	0.04	13.54	40.36	122.89	170.03	1.00	1.00
					sub to -4	53.89				

NOTES #4 & #6 Not Surveyed

#53 & #62 & #67 Frt Stk Lost - Not Recoverable

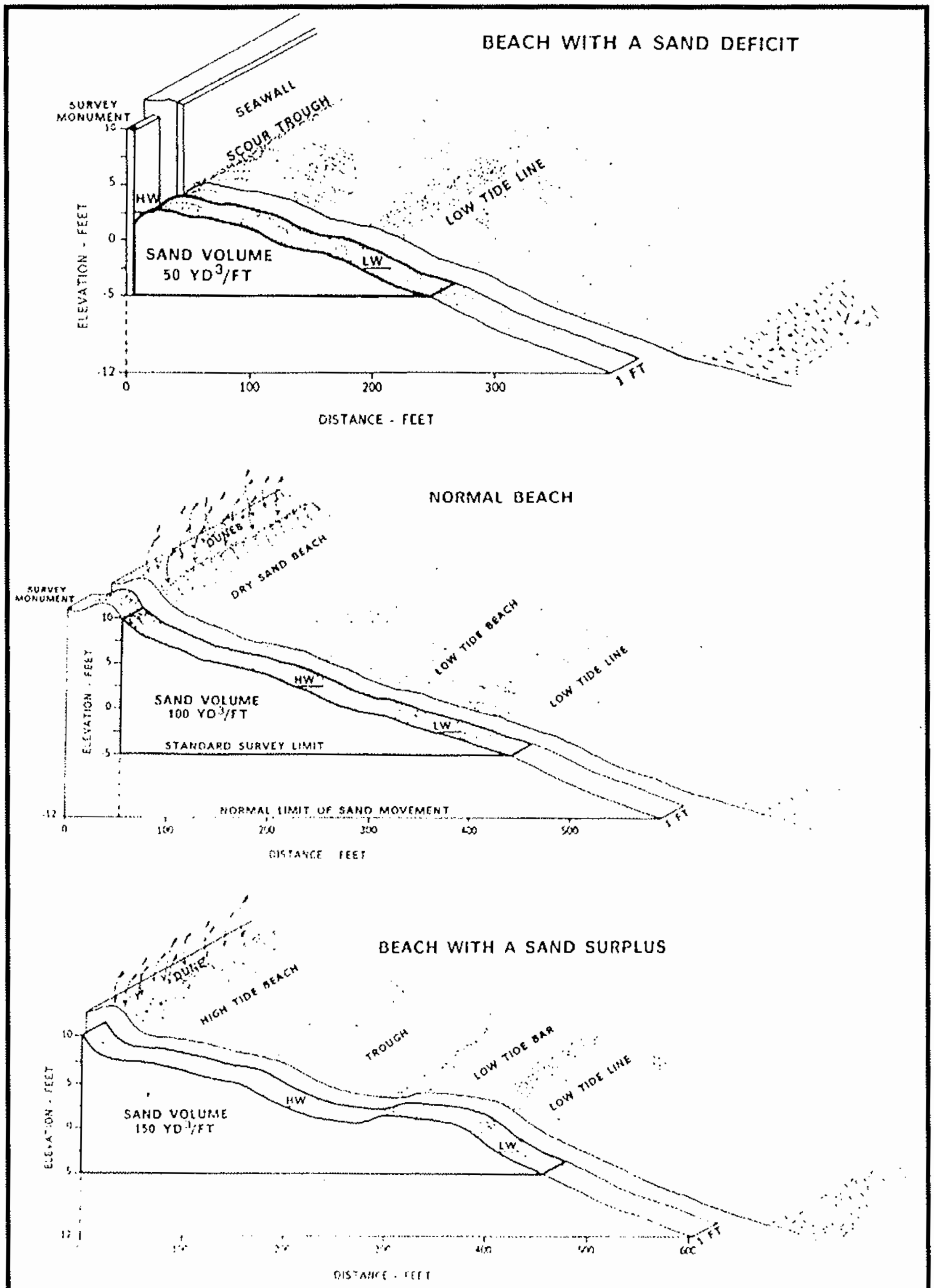


FIGURE G5-3. The concept of profile volumes (i.e., the sand volume contained in a unit length of shoreline between the dunes/seawall and representative underwater contours). In the absence of comparative data, profile volumes provide an objective measure of the beach condition from one place to another. [From Kana, 1990]

If profile volumes reflect the condition of the beach from place to place (assuming similar sediments and exposures to waves and currents), they can be used to quantify sand deficits with respect to some ideal beach condition. A number of analytical and numerical techniques are generally used to define a healthy beach/dune profile for a particular level of storm protection. Erosion models, such as S-BEACH used by the USACE, allow prediction of the expected sand volume losses or dune recession during storms of a particular size. While these models are important design tools and should be a part of any final analysis, they are limited by the availability of coastal process data which are needed to "drive" the models.

For this preliminary study, which was budget-limited, we used an empirical approach for estimating an ideal "minimum" profile volume. We located Bogue Banks profiles where there was more-than-average sand volume and reviewed the beach and backshore conditions for evidence of long-term stability, wide berms for recreation, and extra sand nearshore. We also obtained hurricane erosion data for *Bertha* (June 1996) and *Fran* (September 1996) which showed short-term sand losses to low-tide averaging ~8-15 cubic yards per foot (cy/ft). [Note: This range was also confirmed by re-surveys of 18 of our profile lines after Hurricane *Floyd* during the week of September 20, 1999.] Based on these criteria, we established a threshold minimum profile volume of 175 cy/ft (Fig. G5-5). While this is not a value based on determination of a particular level of storm protection, it is one that reflects the site-specific conditions of Boguo Banks. Based on experience elsewhere, it reflects a level which we believe will provide adequate protection for ~10-year return-period events.

Once a minimum profile volume is established, it is a straightforward procedure to compute the volume deficit at each point along the shoreline. Figure G5-5 shows that, on average, six reaches fall below the minimum volume--Emerald Isle-West, Emerald Isle-Central, Emerald Isle-East, Indian Beach/Salter Path, Pine Knoll Shores-West, and Pine Knoll Shores-East. Atlantic Beach, on average, presently contains nearly the minimum sand volume and can be used as a practical guide to what other reaches would look like if they were nourished as proposed in the present plan. By extrapolating the volume deficit over representative shore lengths, a measure of **initial** fill-volume requirement is obtained.

The actual amount of nourishment recommended consists of **three components**. It begins with the **volume deficit** and then takes into account the long-term **erosion** rate and the **quality of borrow area** sediment. For the present study, our team provided estimates of the additional sand needed over a 5-year, 10-year, and 20-year period to accommodate background erosion. These amounts were calculated by applying the site-specific erosion rates shown in Table G5-1 over the representative time periods. A final adjustment was made to account for variations in the quality of borrow material. For example, a borrow area with a fill ratio of 1.1 will require about 10 percent more nourishment than the volume requirement; a borrow area with a fill ratio of 2.0 will require twice as much nourishment. While these adjustments may seem confusing at first, they are important because of the wide differences in performance of various borrow areas. This last adjustment puts projects using alternate borrow areas on an equal basis and allows fairer comparisons of cost. For example, one million cubic yards of sand that have a fill ratio of 1.1 will perform much better than two million cubic yards that have a fill ratio of 4.0. Unfortunately, differences in borrow material quality are often ignored, leading to widely varying opinions regarding project performances.

In short, we developed a detailed beach condition survey, historical erosion rate data, and borrow area sediment quality data to establish:

- Initial profile volume deficit for six reaches.

- 5-year, 10-year, and 20-year volume requirements to accommodate the long-term background erosion.

APPENDIX G6. REFERENCES CITED

Birkemeier, W.A. 1985. Field data on seaward limit of profile change. Jour. Waterway Port, Coastal and Ocean Engineering, Vol. III(3), pp. 598-602.

CERC. 1984. *Shore Protection Manual.* 4th Edition, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Vir.; U.S. Government Printing Office, Washington, D.C., 2 vols.

Hallermeier, R.J. 1978. Uses for a calculated limit depth to beach erosion. In Proc. 16th Coastal Engineering Conf, ASCE, New York, NY, Vol. II, pp. 1493-1512.

Hine, A.C., and S.W. Snyder. 1985. Coastal lithosome preservation: evidence form the shoreface and inner continental shelf off Bogue Banks, North Carolina. *Marine Geology*, Vol. 63, pp. 307-330.

Kana, T.W. 1990. *Conserving South Carolina Beaches Through the 1990s: A Case for Beach Nourishment.* South Carolina Coastal Council, Charleston, SC, 33 pp.

NAS. 1995. *Beach Nourishment and Protection.* Committee on Beach Nourishment and Protection, Marine Board, Commission on Engineering and Technical Systems, National Research Council; National Academy Press, National Academy of Sciences, Washington, DC, 334 pp.

Reed, A. 1997. Sediment distribution patterns offshore of a replenished beach: Atlantic Beach and Fort Macon State Park, North Carolina. Unpubl. M.S. Thesis, Univ. North Carolina, Chapel Hill, 74 pp. + app.

Roessler, T.S. 1998. Effects of offshore geology and the Morehead City harbor project on eastern Bogue Banks, North Carolina. M.S. Thesis, Univ. North Carolina, Chapel Hill, 112 pp.

Thieler, R. 1997. Side scan sonar mosaics. Appendix 5 in A. Reed. 1997. Sediment distribution patterns offshore of a replenished beach: Atlantic Beach and Fort Macon State Park, North Carolina. Unpubl. M.S. Thesis, Univ. North Carolina, Chapel Hill, 74 pp. + app.

UNC. 1998. Bogue Banks historical beach profile data set. Digital files provided by T.S. Roessler, Univ. North Carolina, Chapel Hill. (See Roessler, 1998, in App. A)

USACE. 1976. General design memorandum: Morehead City Harbor, North Carolina. Wilmington District, USACE, 41 pp. + app.

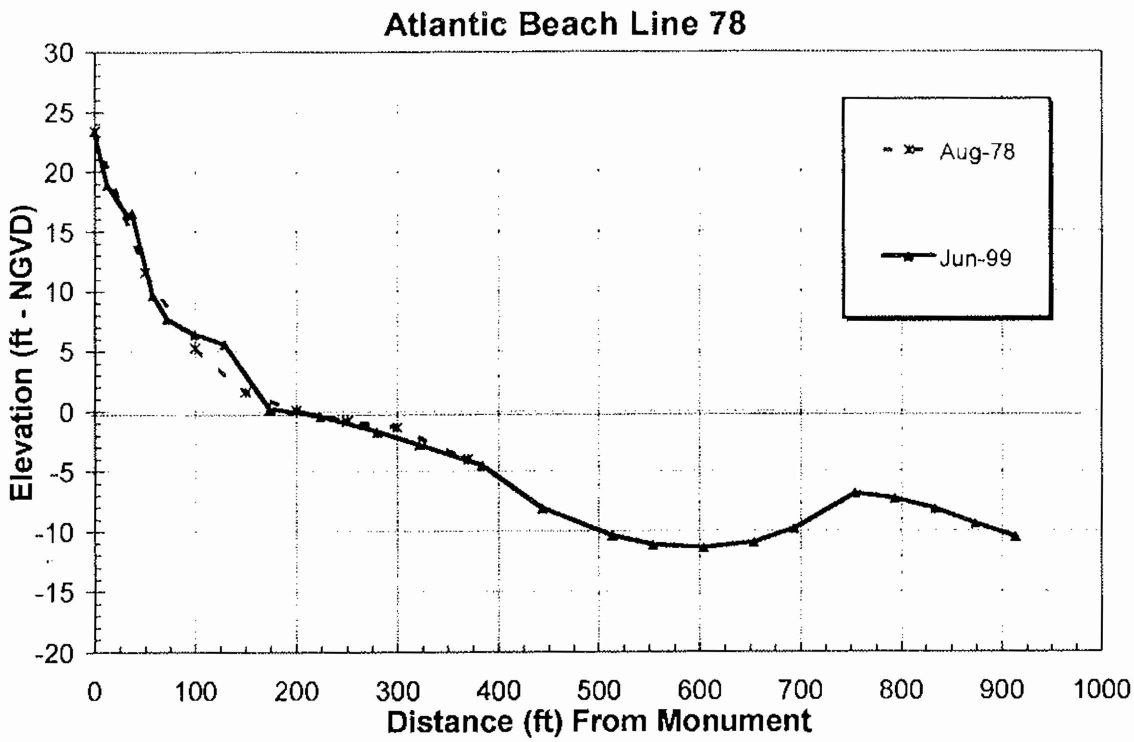
USACE. 1978. Bogue Banks historical beach profile data set. Digital files provided by Tom Jarrett, Wilmington District, U.S. Army Corps of Engineers.

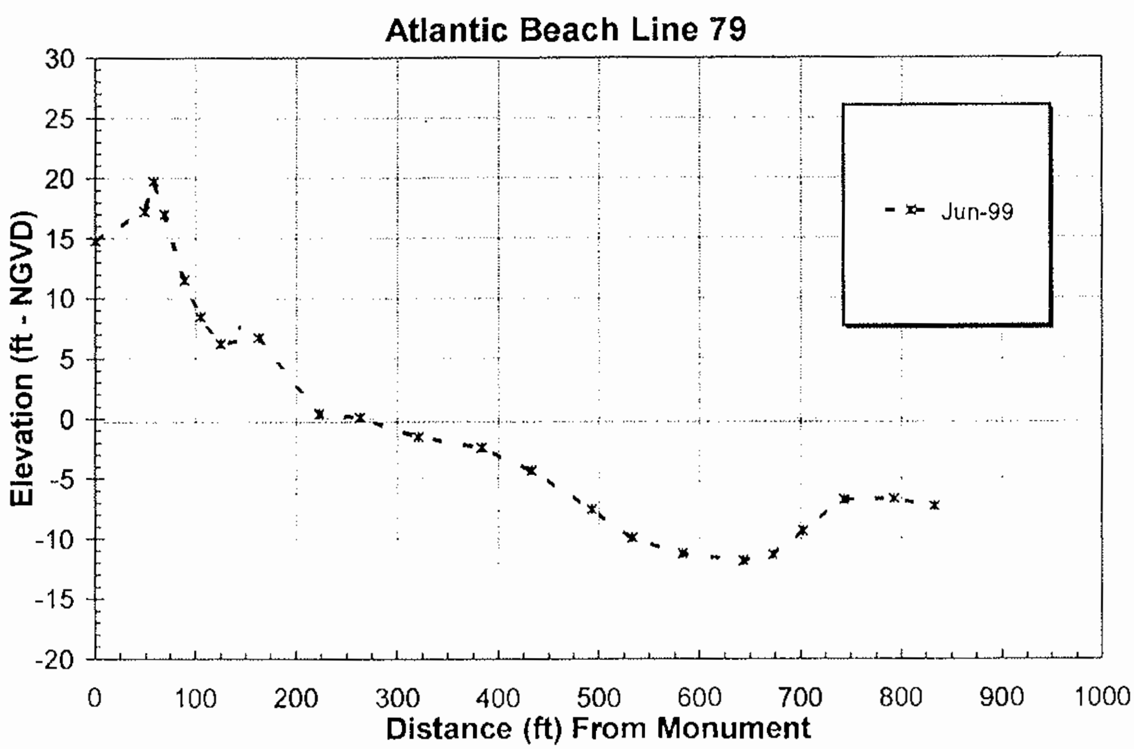
USACE. 1993. Beach erosion control and hurricane wave protection: Carolina Beach and vicinity area south project, New Hanover County, North Carolina. Final Environmental Impact Statement, U.S. Army Corps of Engineers, 55 pp. + attachment (June).

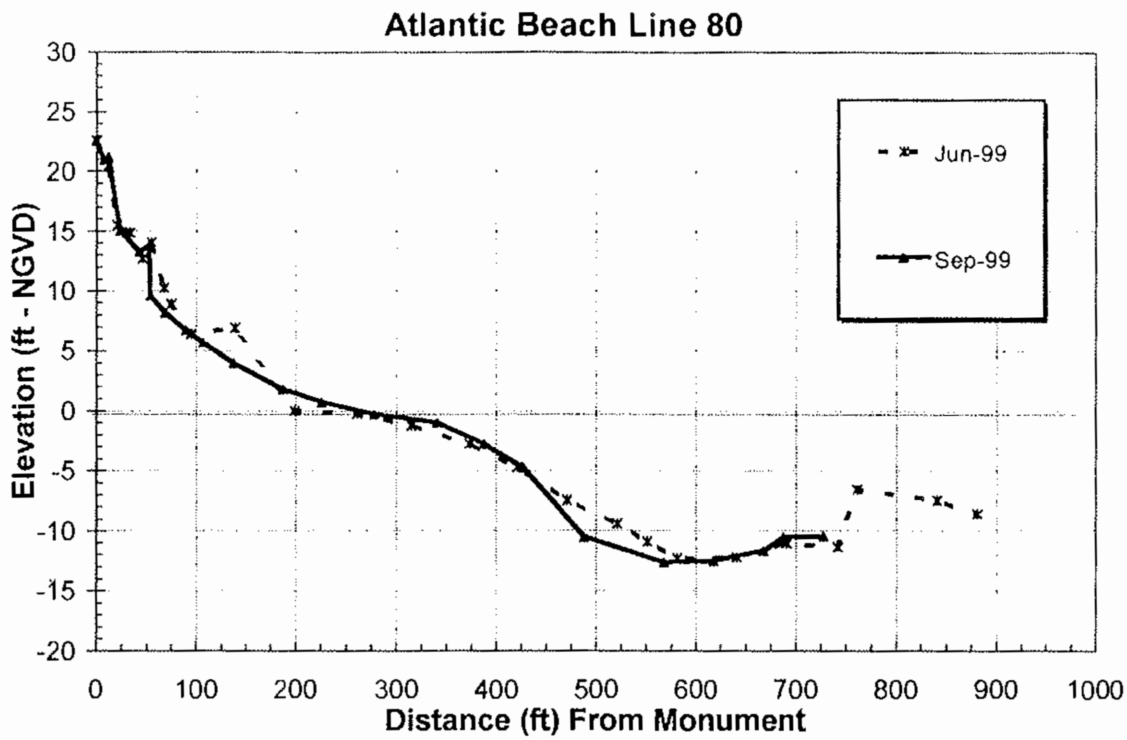
USACE. 1994. Environmental assessment — designation and use of a placement area for underwater nearshore berm: Morehead City harbor project, Morehead City, North Carolina. U.S. Army Corp of Engineers, Wilmington Dist., 18 pp. + figs. + app (August 1994).

ANNEX G-1

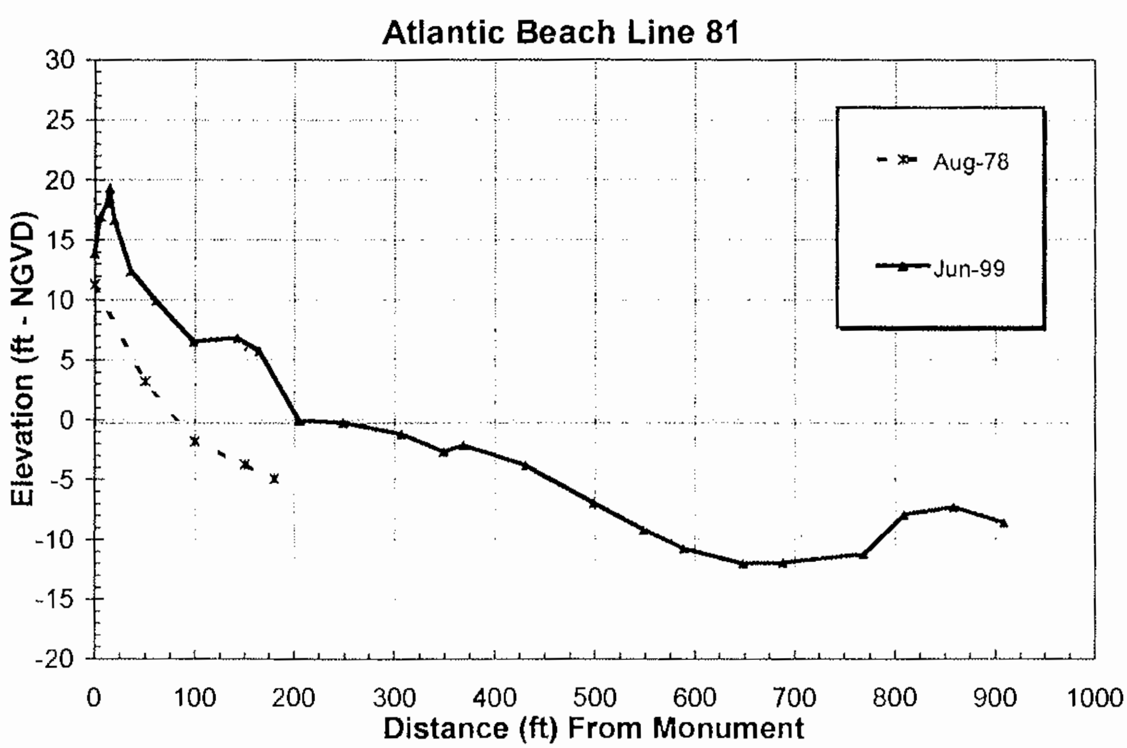
Beach Profile Plots


Atlantic Beach Line 78
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

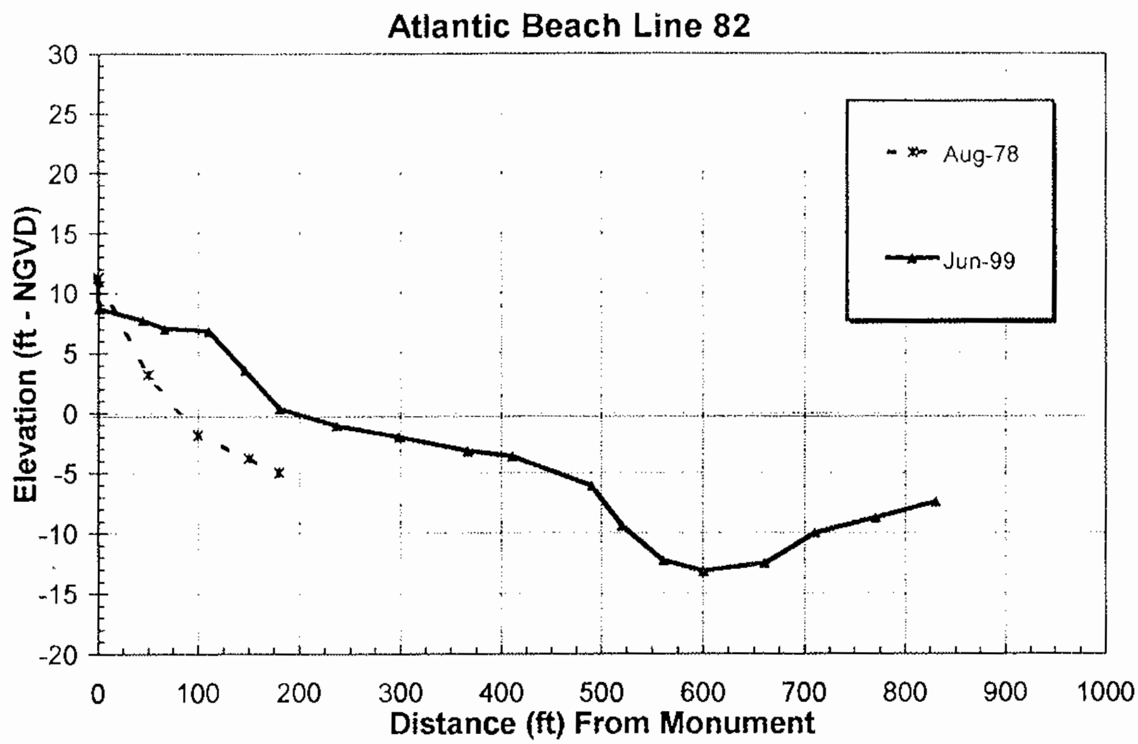

Atlantic Beach Line 79
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

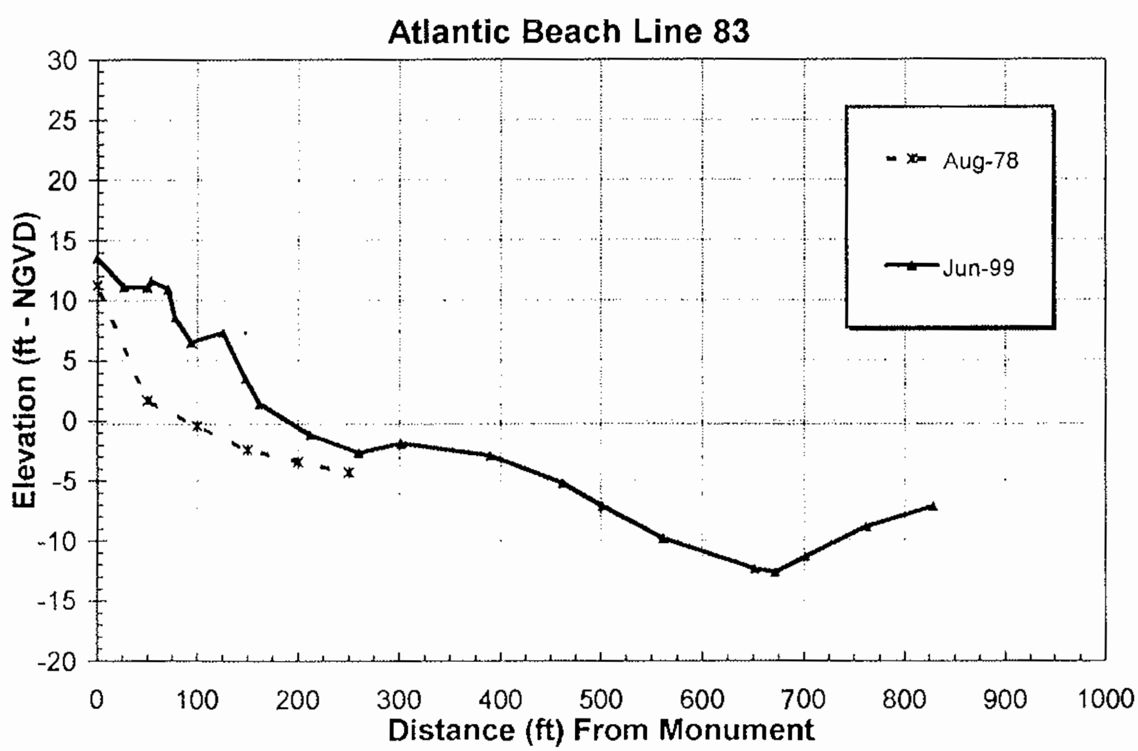


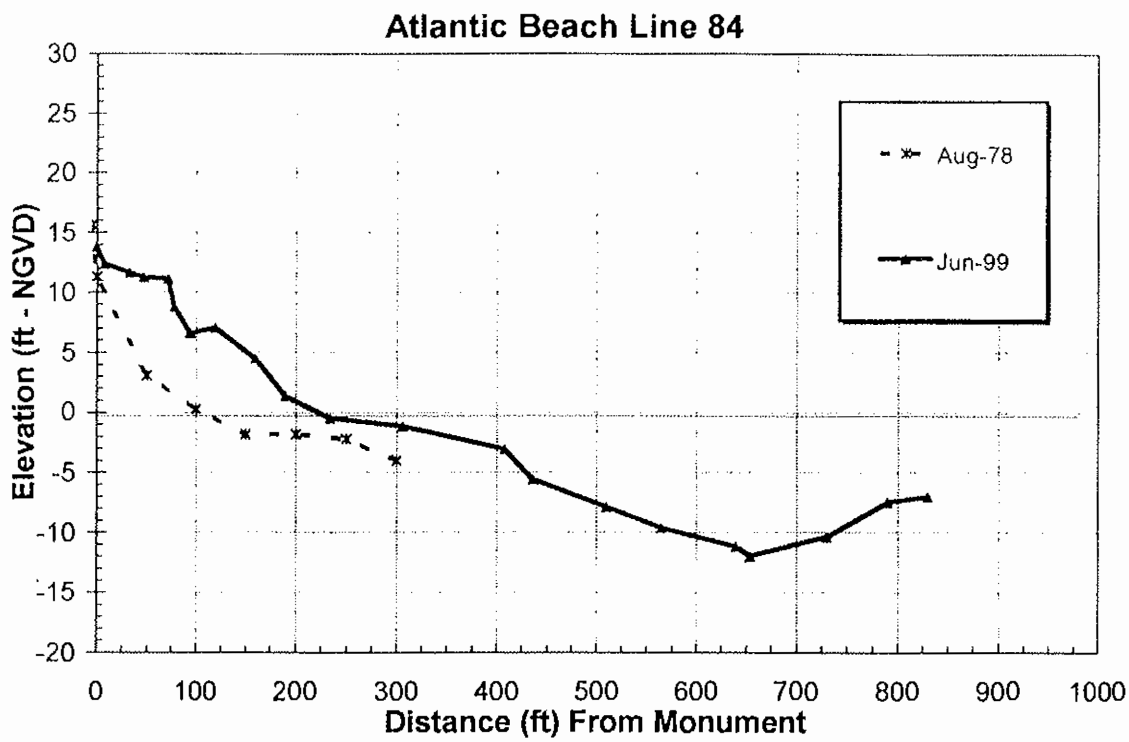
Atlantic Beach Line 80
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



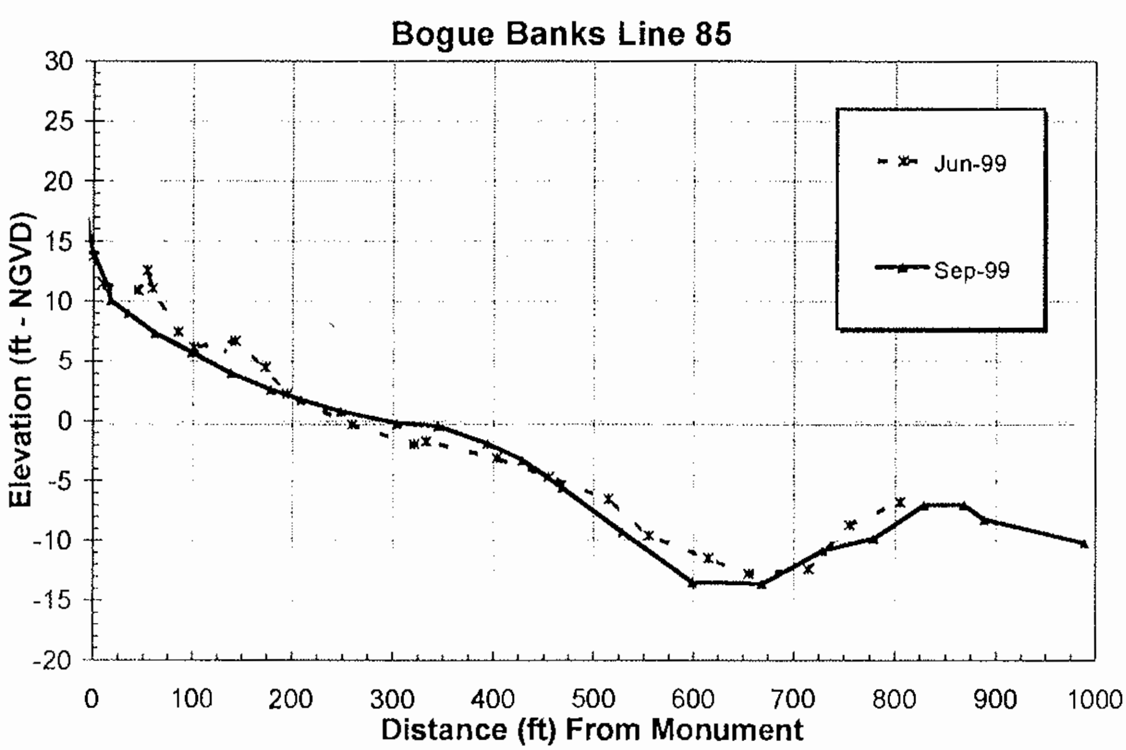
Atlantic Beach Line 81
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Atlantic Beach Line 82
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

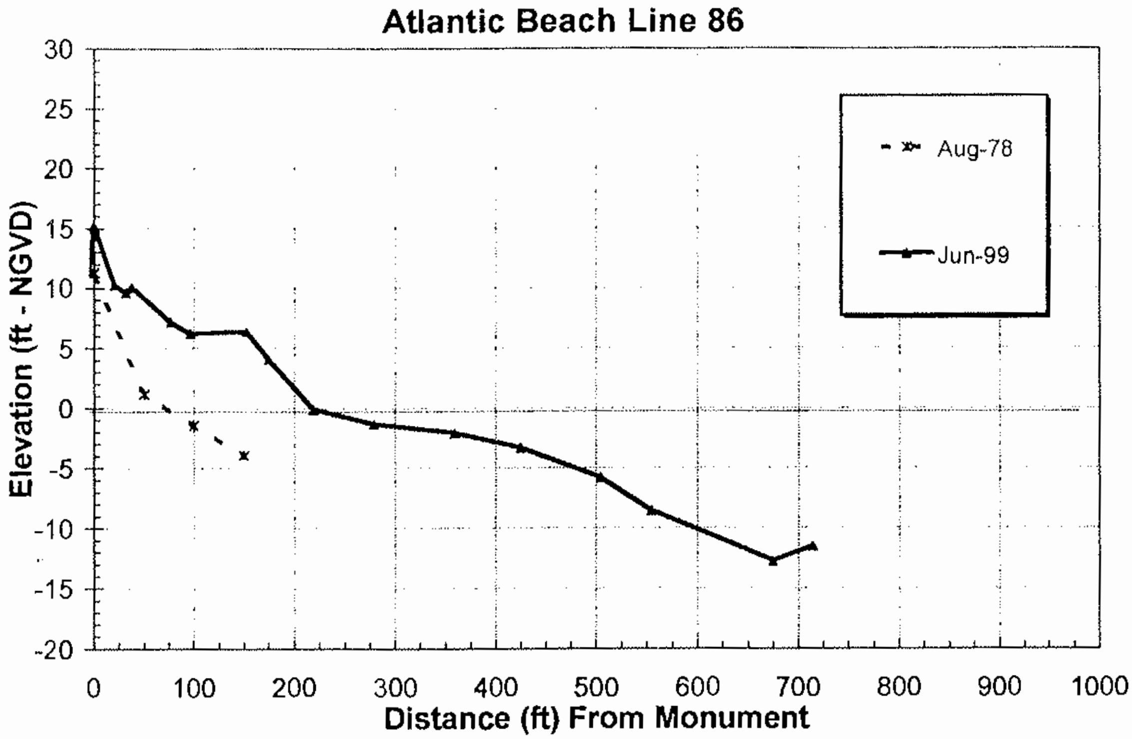

Atlantic Beach Line 83
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

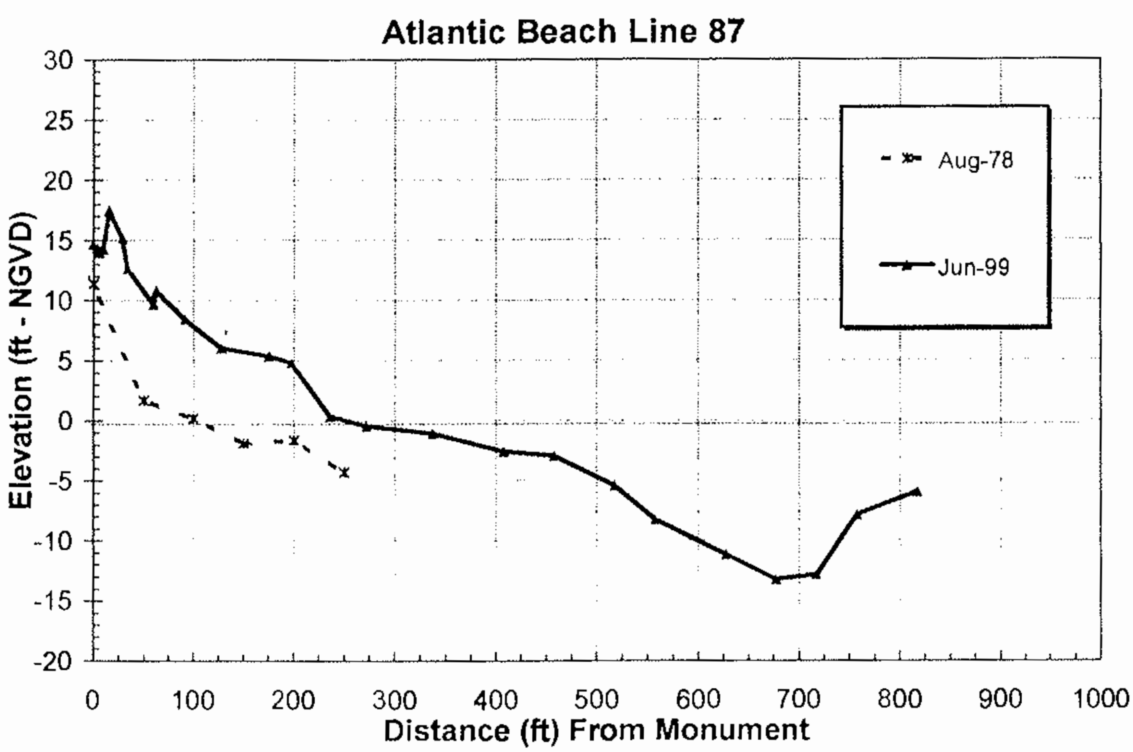


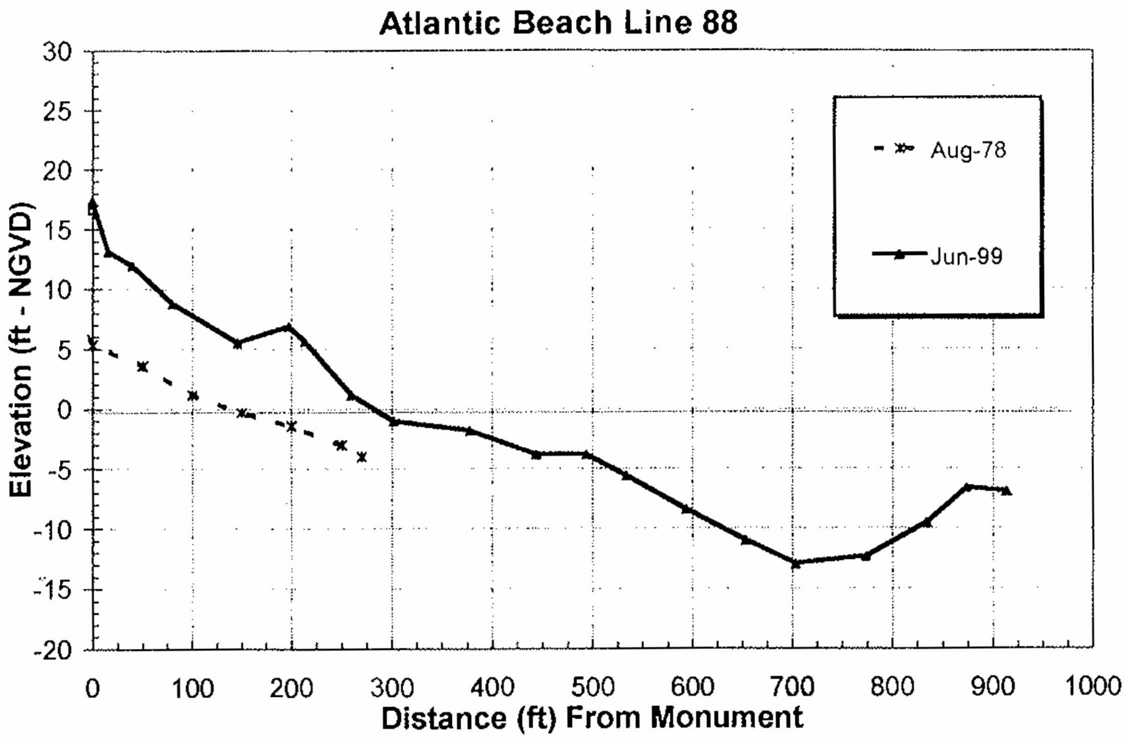
Atlantic Beach Line 84
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



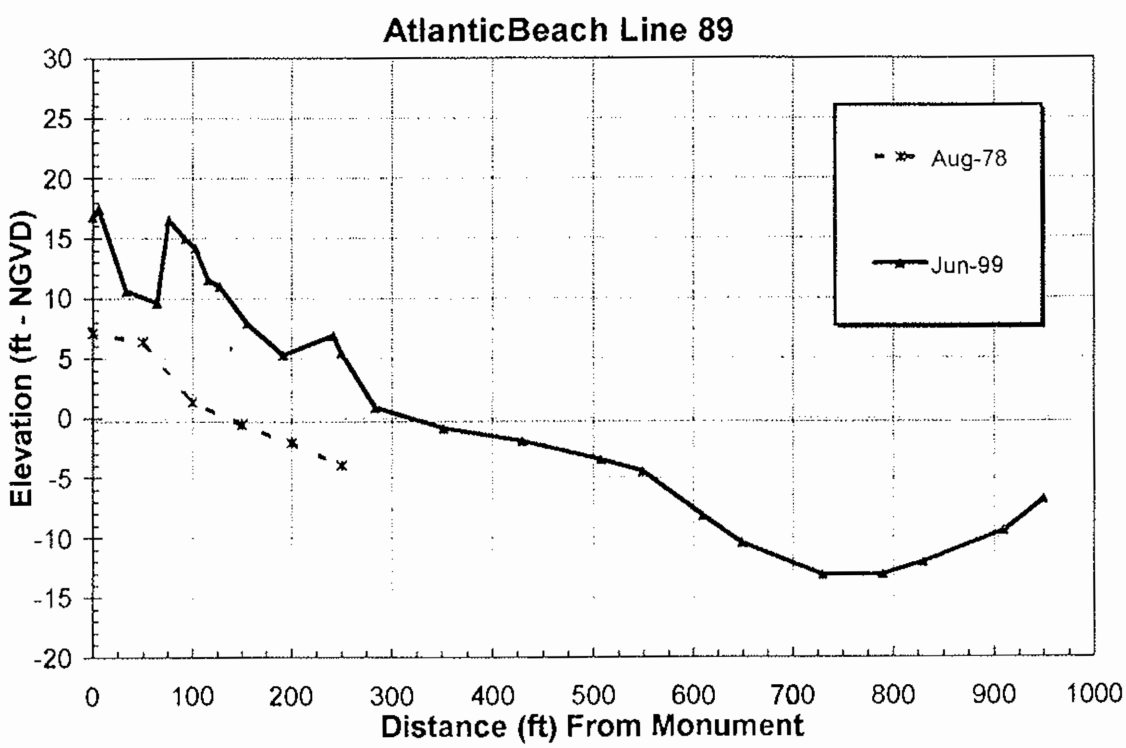
Bogue Banks Line 85
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Atlantic Beach Line 86
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

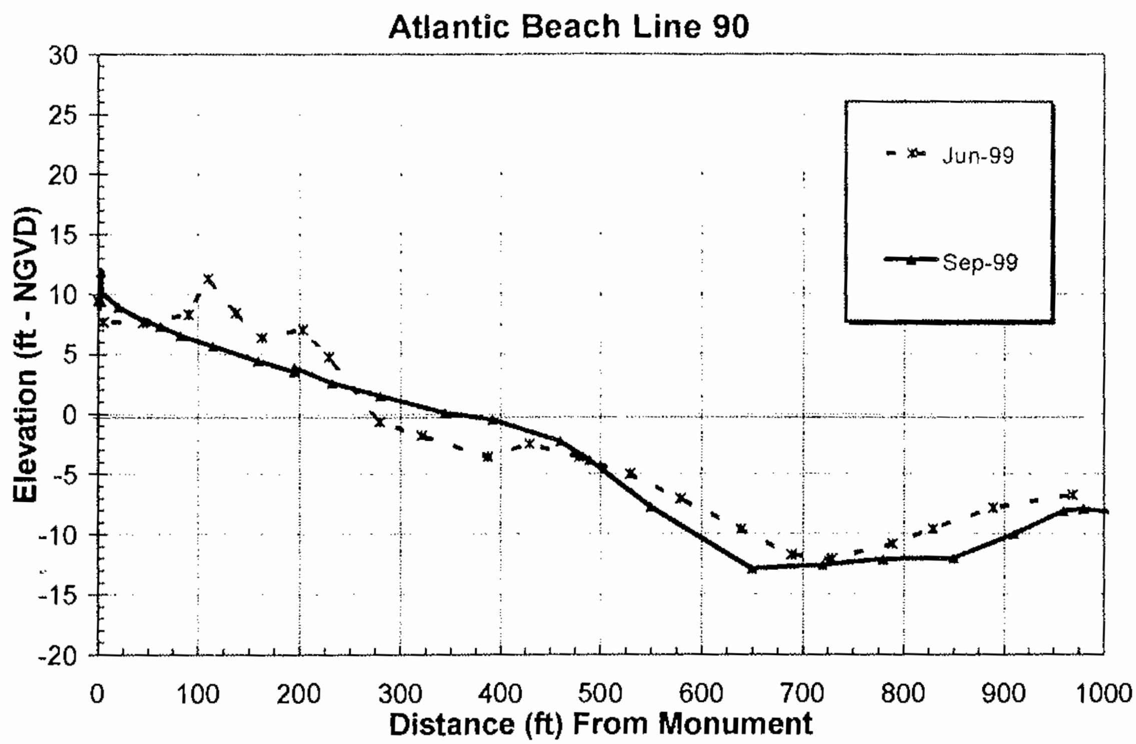

Atlantic Beach Line 87
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



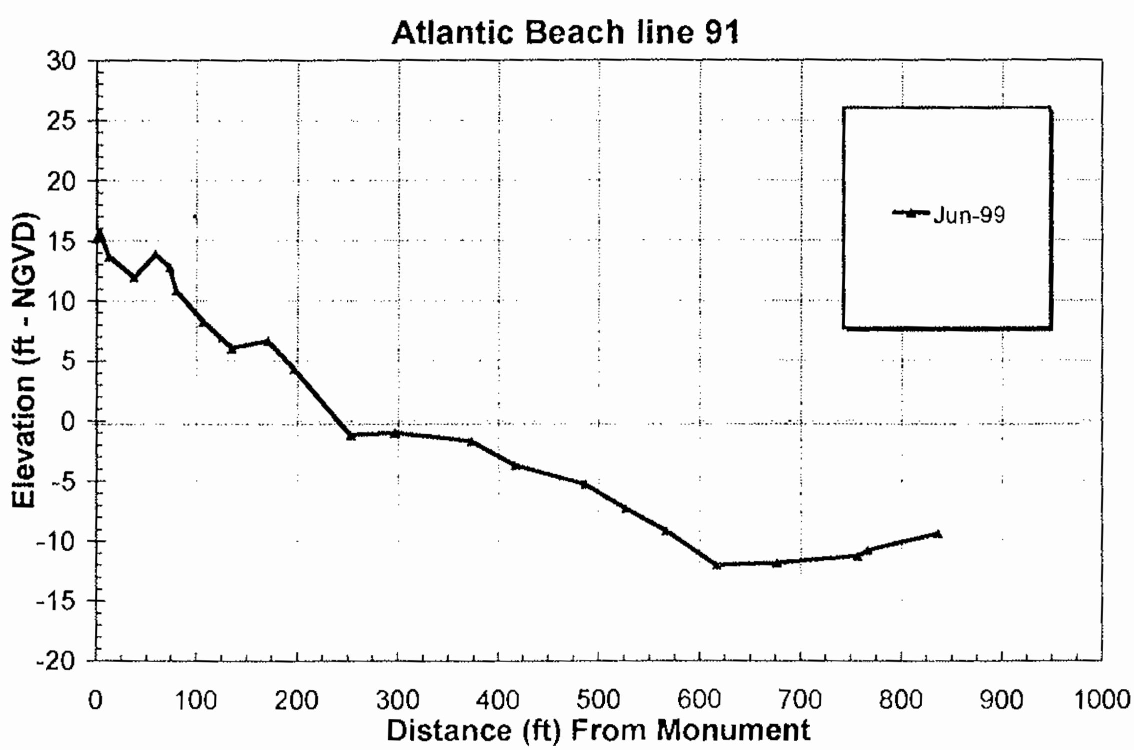
Atlantic Beach Line 88
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument



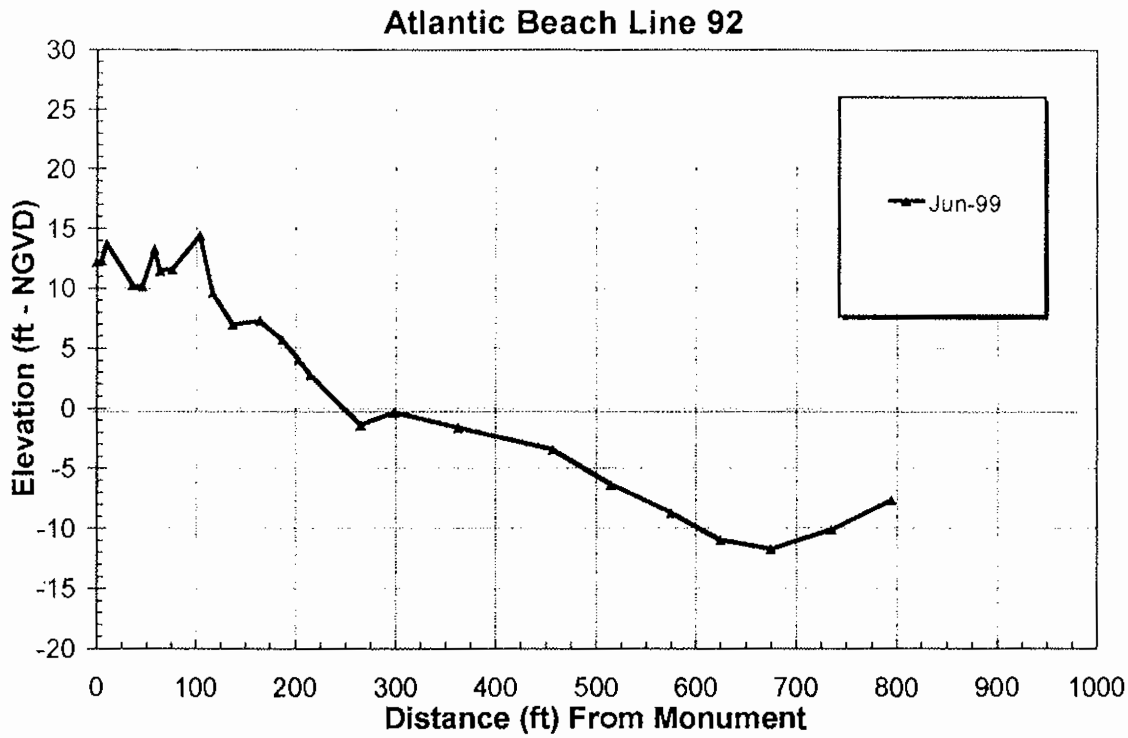
AtlanticBeach Line 89
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument



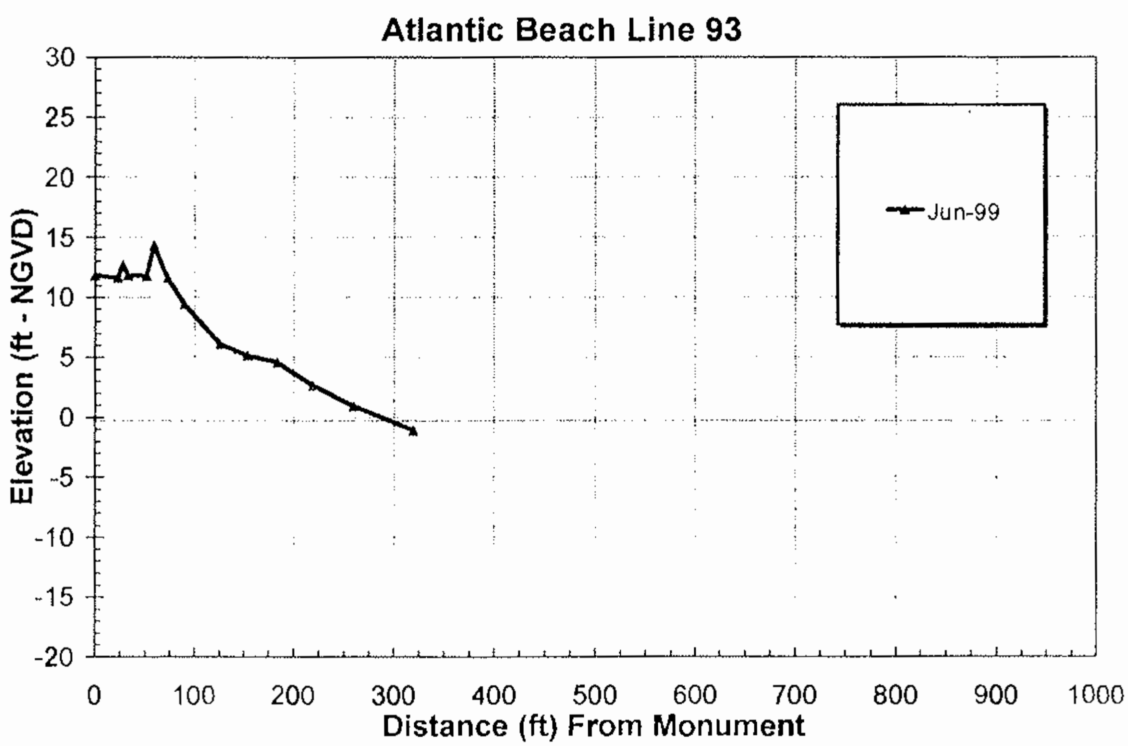
Atlantic Beach Line 90
Jun-99
Sep-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument



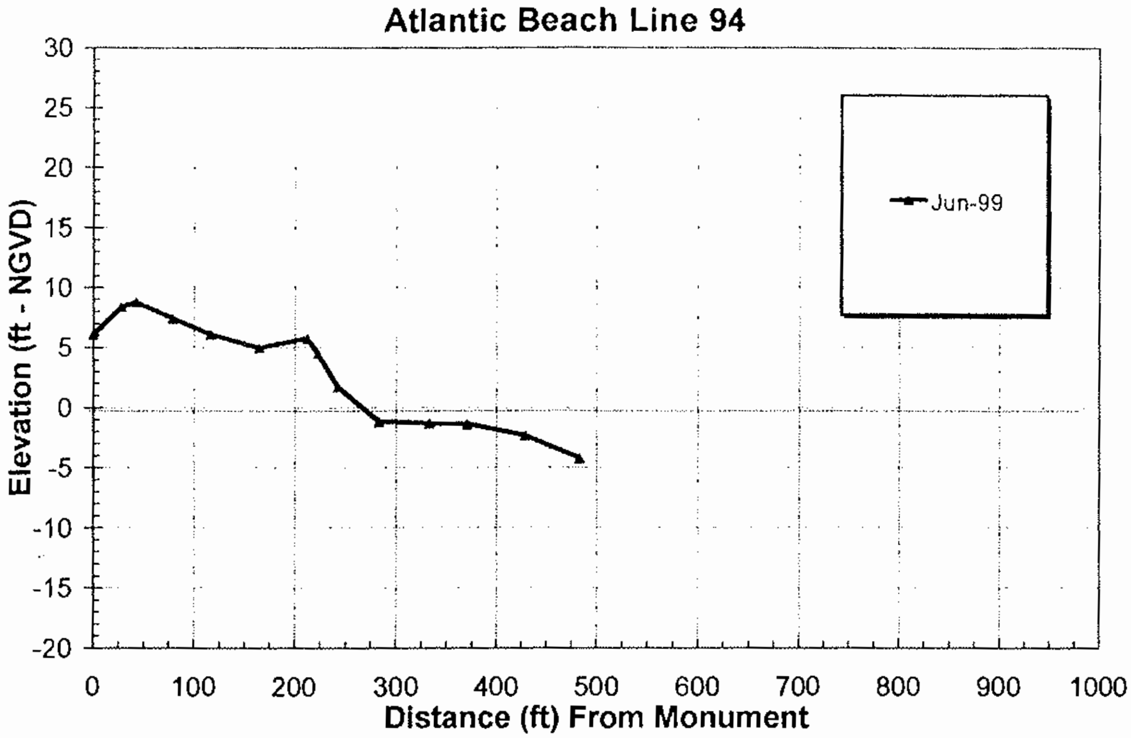
Atlantic Beach line 91
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

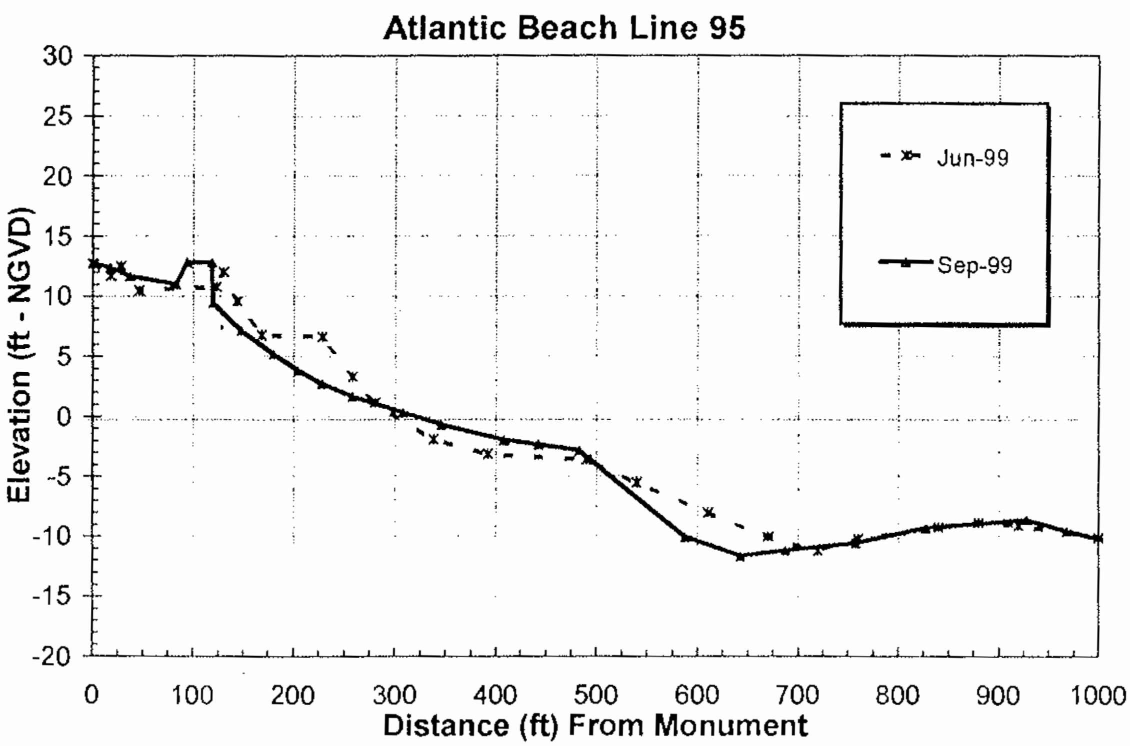


Atlantic Beach Line 92
30
25
20
15
10
5
0
-5
-10
-15
-20
Elevation (ft - NGVD)
Jun-99
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

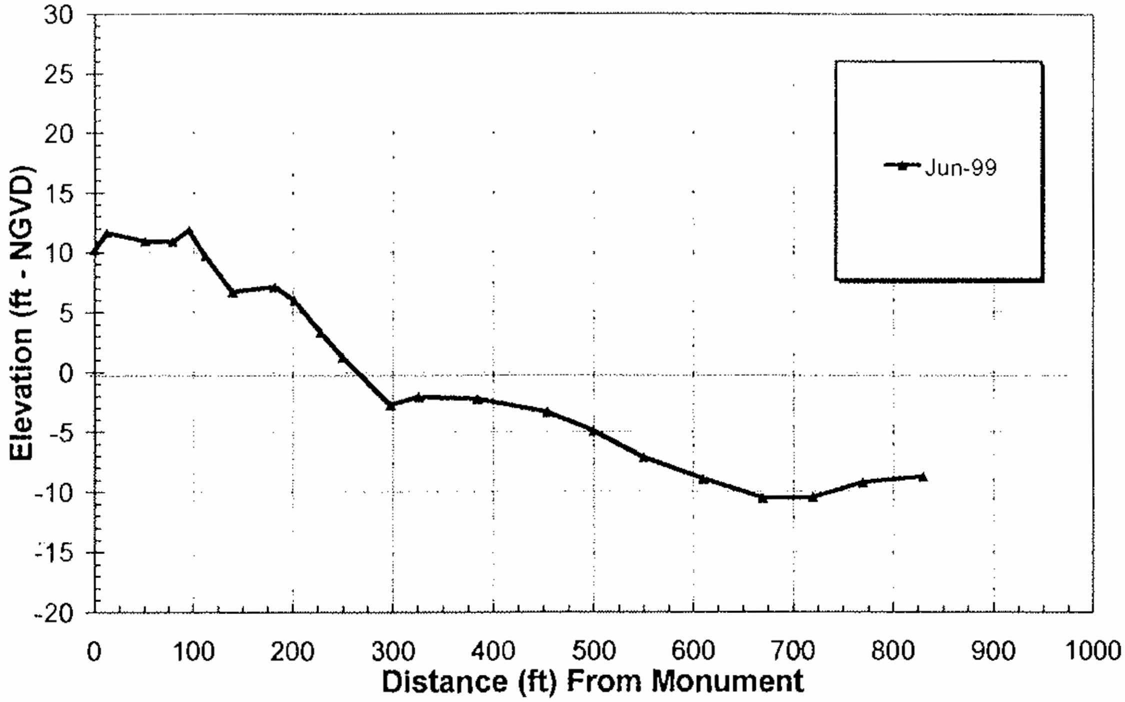


Atlantic Beach Line 93
30
25
20
15
10
5
0
-5
-10
-15
-20
Elevation (ft - NGVD)
Jun-99
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

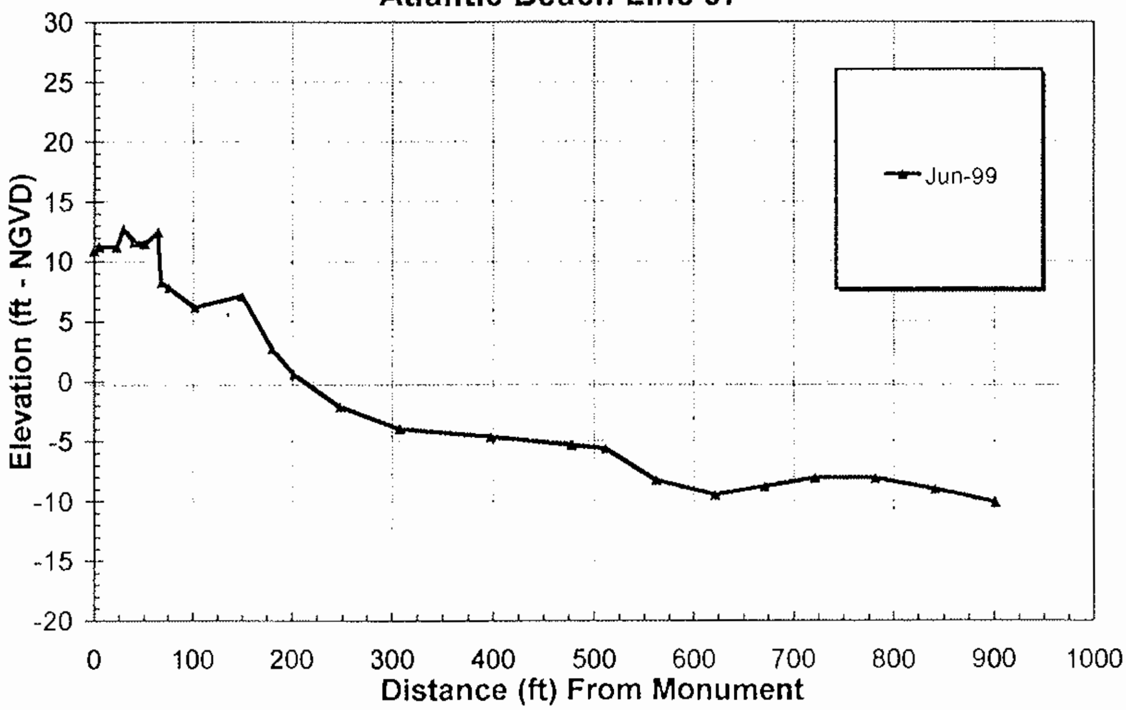

Atlantic Beach Line 94
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Jun-99

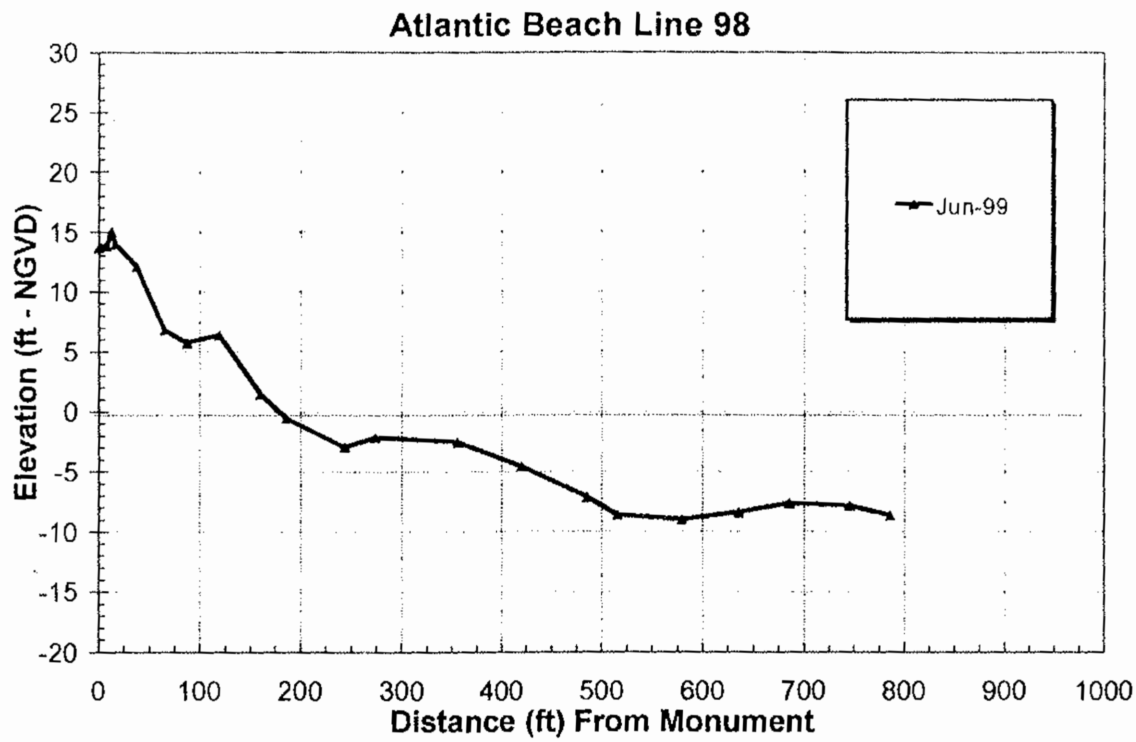

Atlantic Beach Line 95
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Jun-99
Sep-99

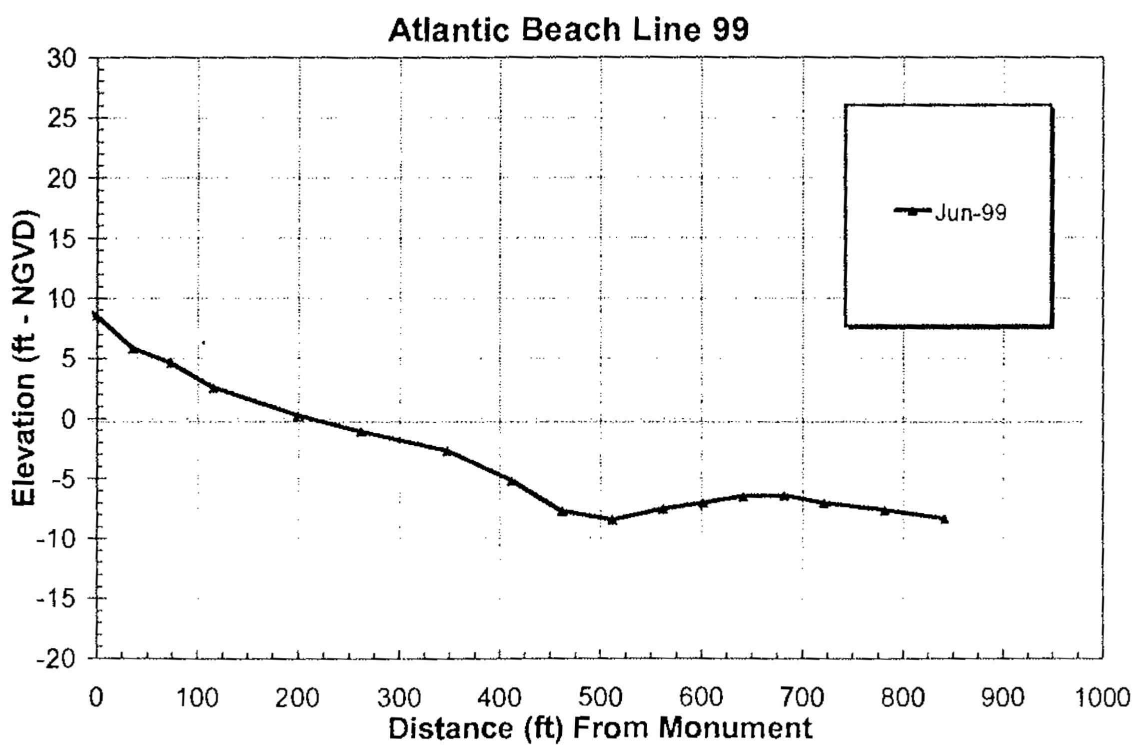
Atlantic Beach Line 96

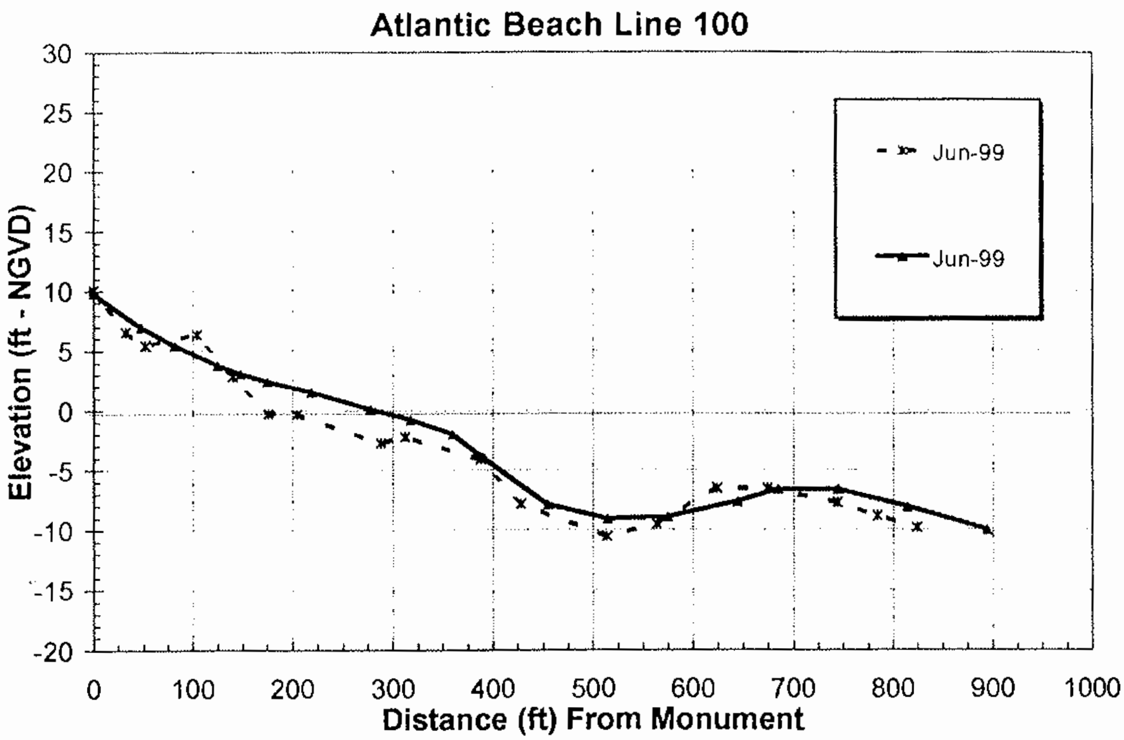


Atlantic Beach Line 97

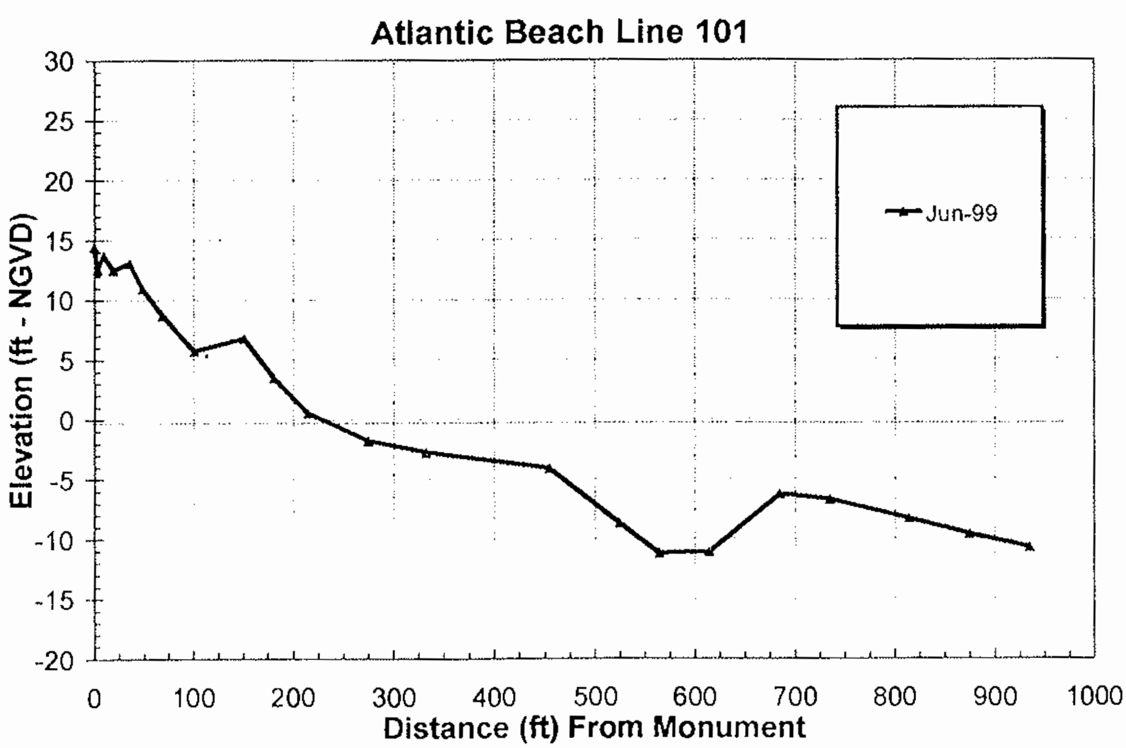



Atlantic Beach Line 98
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

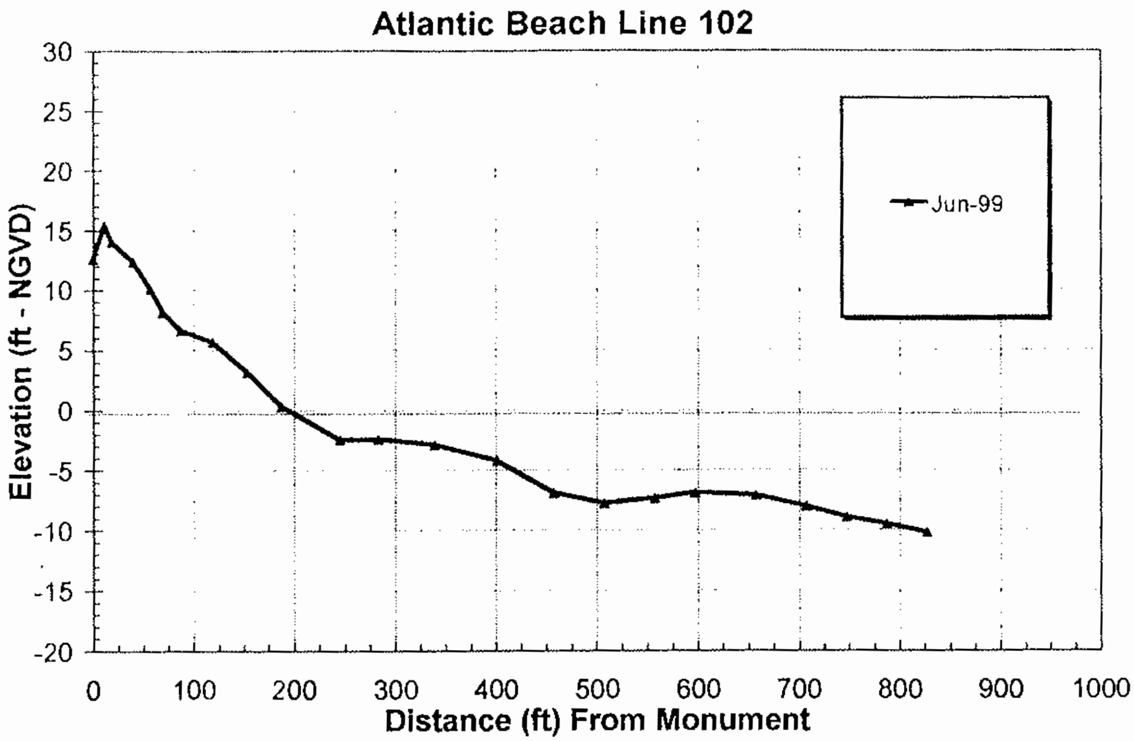

Atlantic Beach Line 99
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

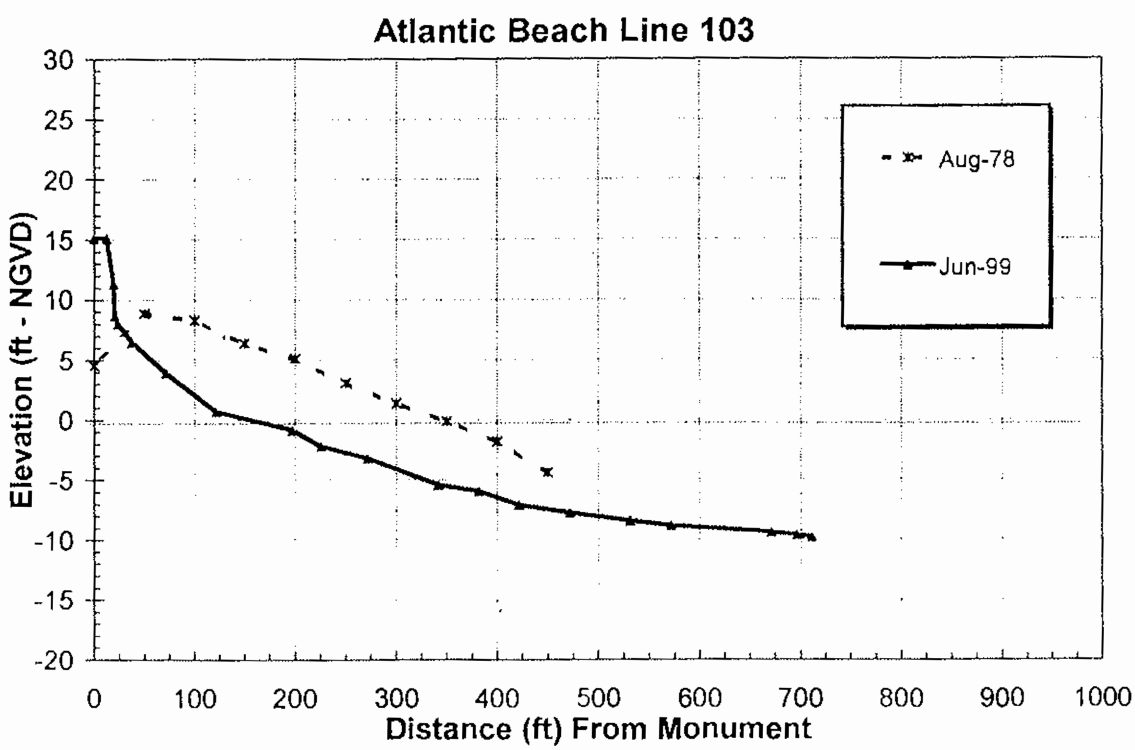


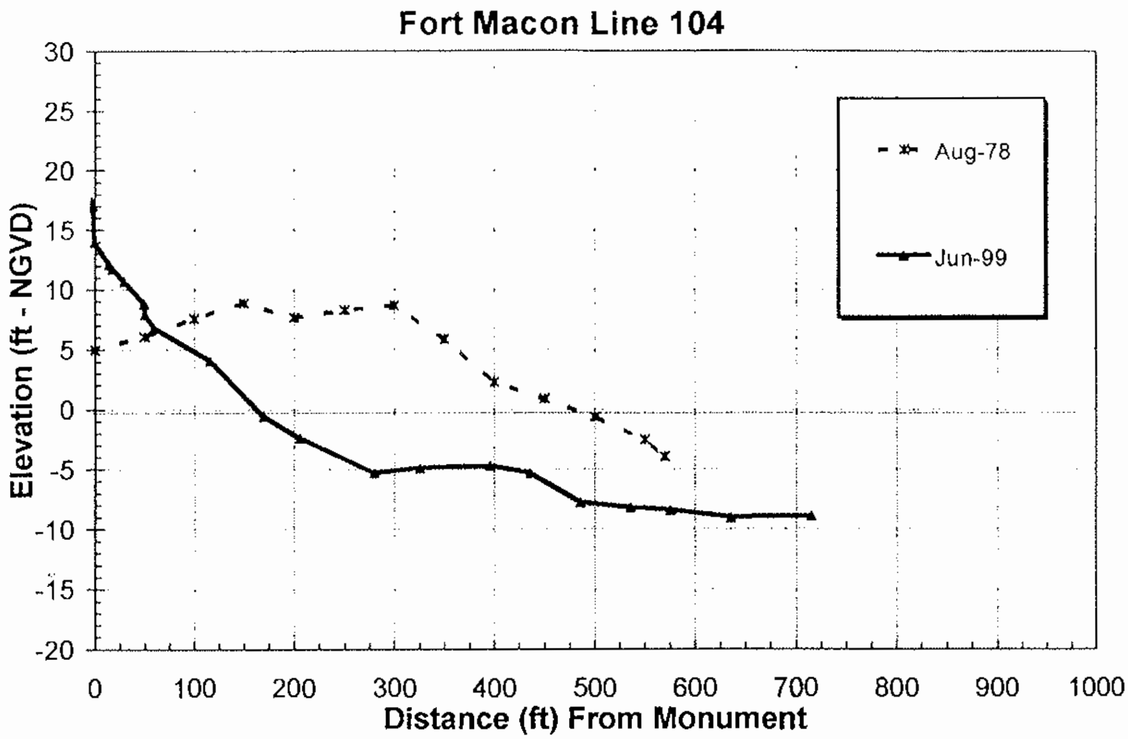
Atlantic Beach Line 100
Jun-99
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument



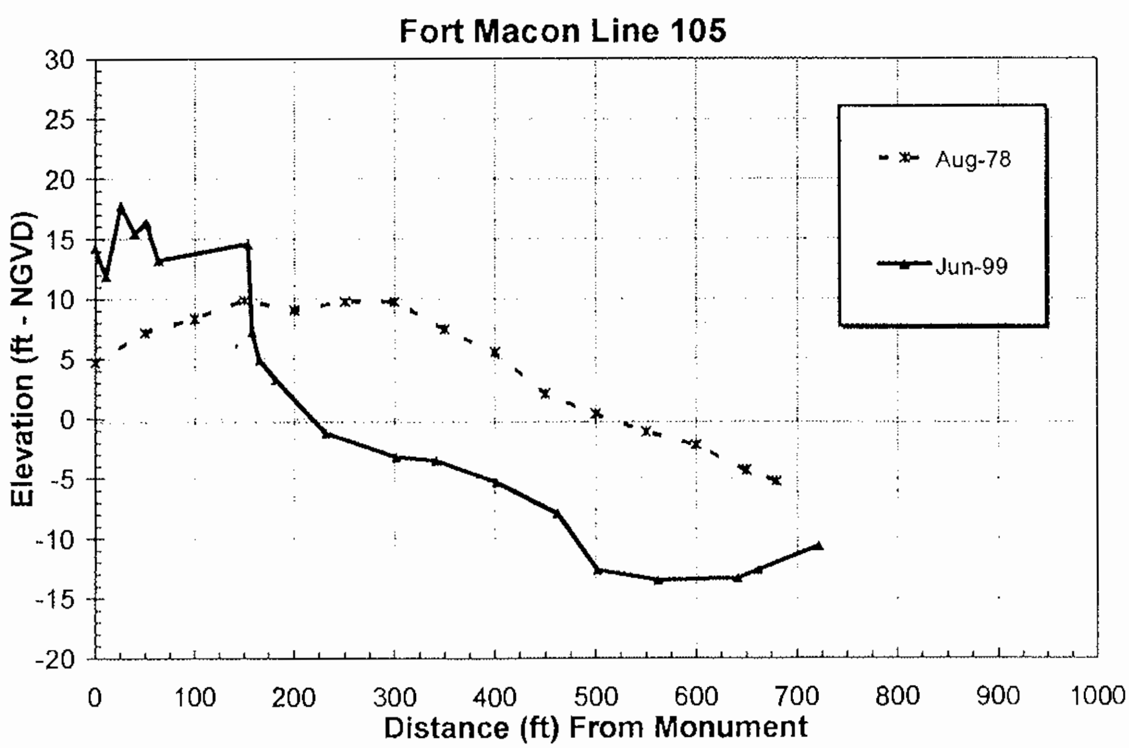
Atlantic Beach Line 101
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument


Atlantic Beach Line 102
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

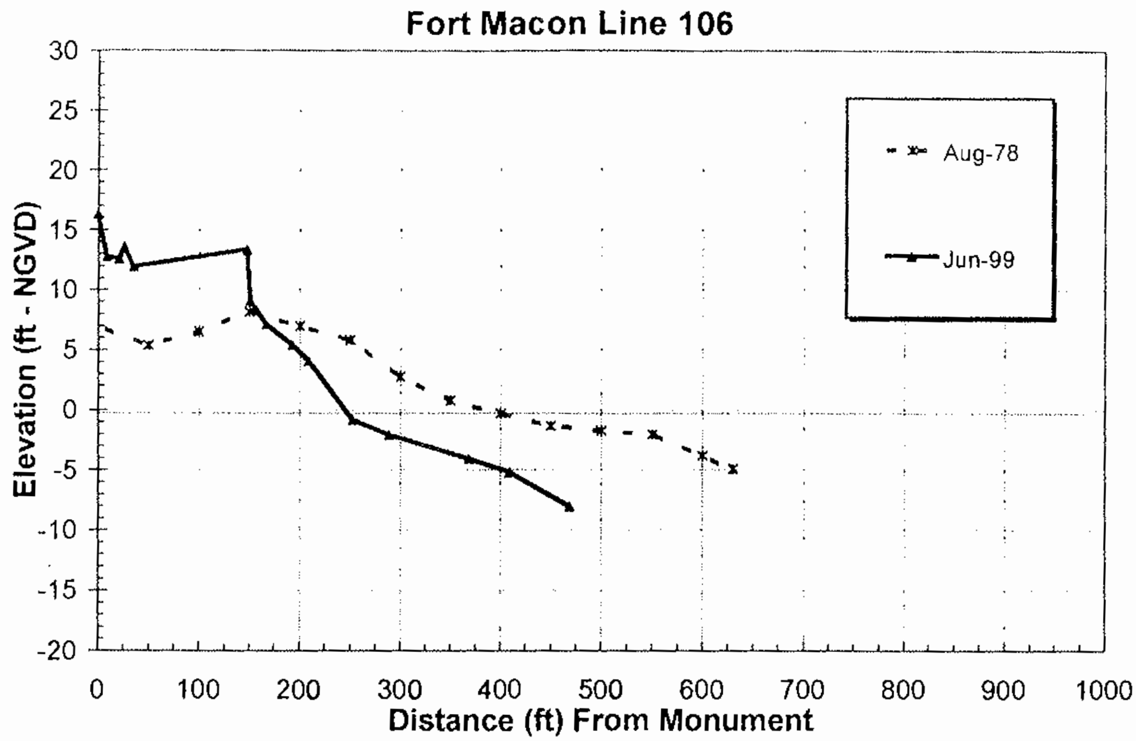

Atlantic Beach Line 103
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

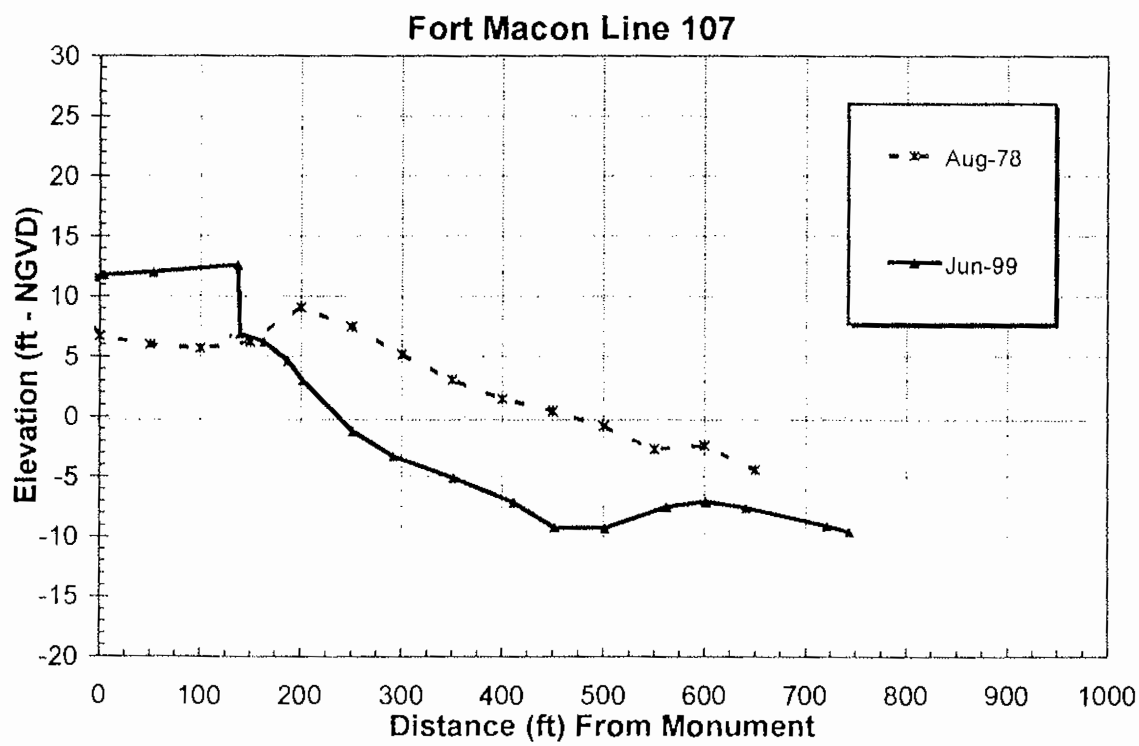


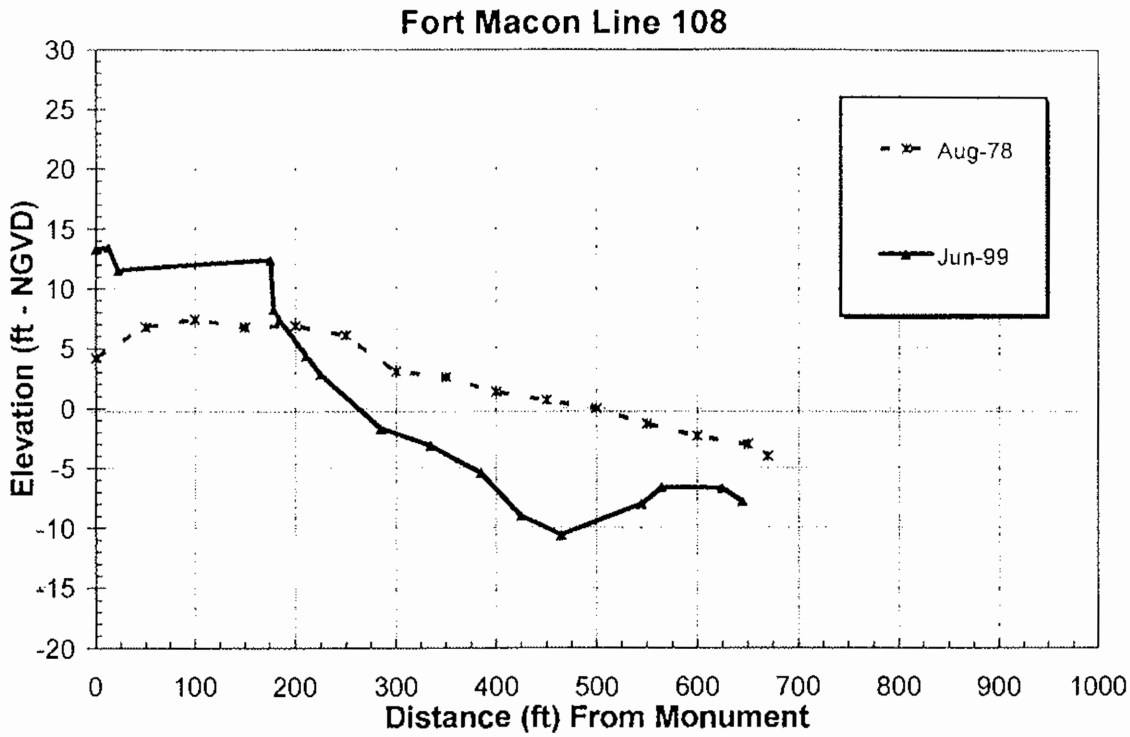
Fort Macon Line 104
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

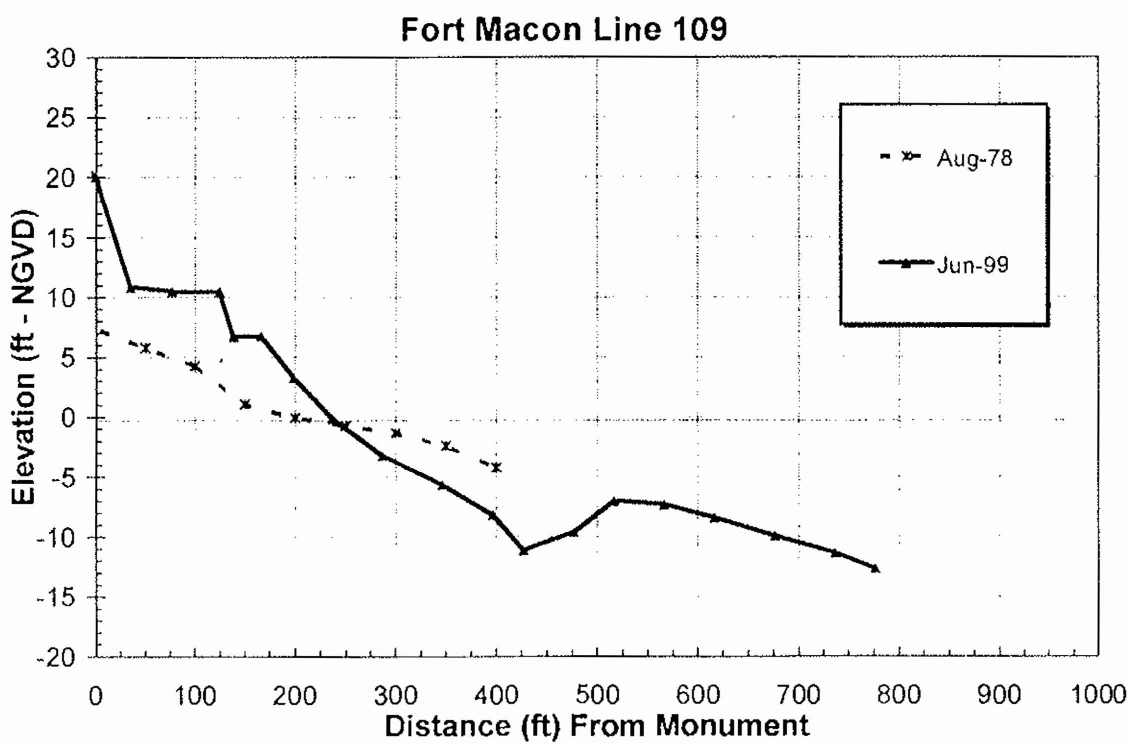


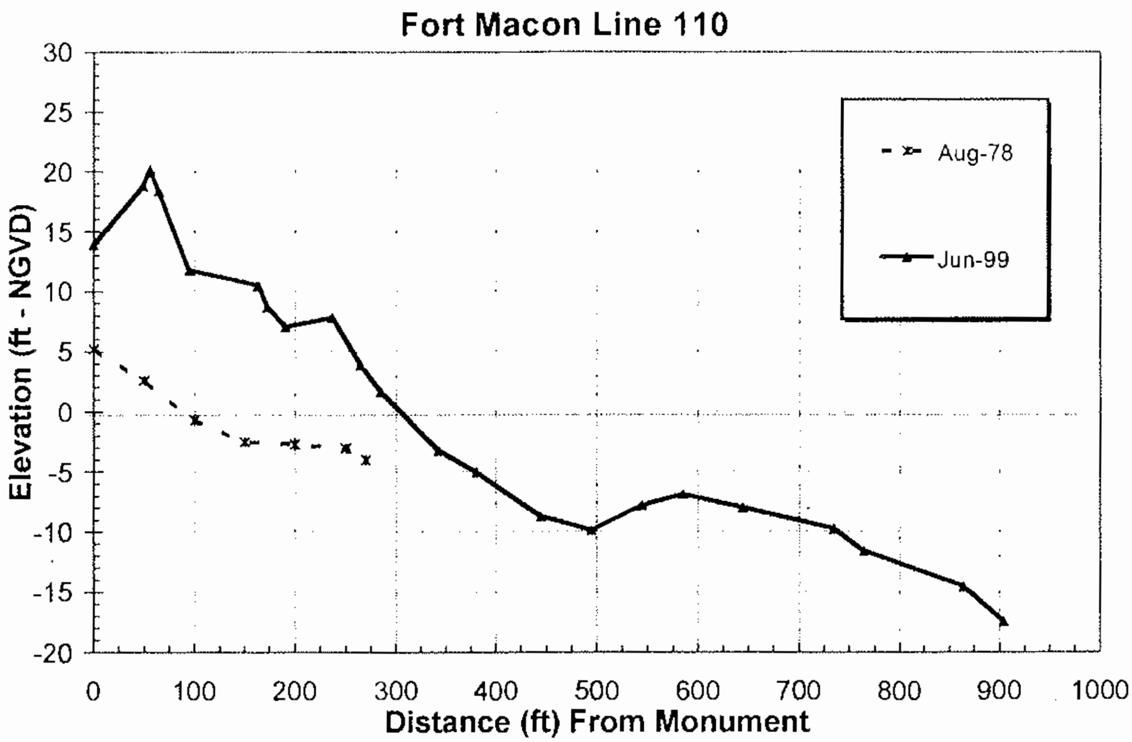
Fort Macon Line 105
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

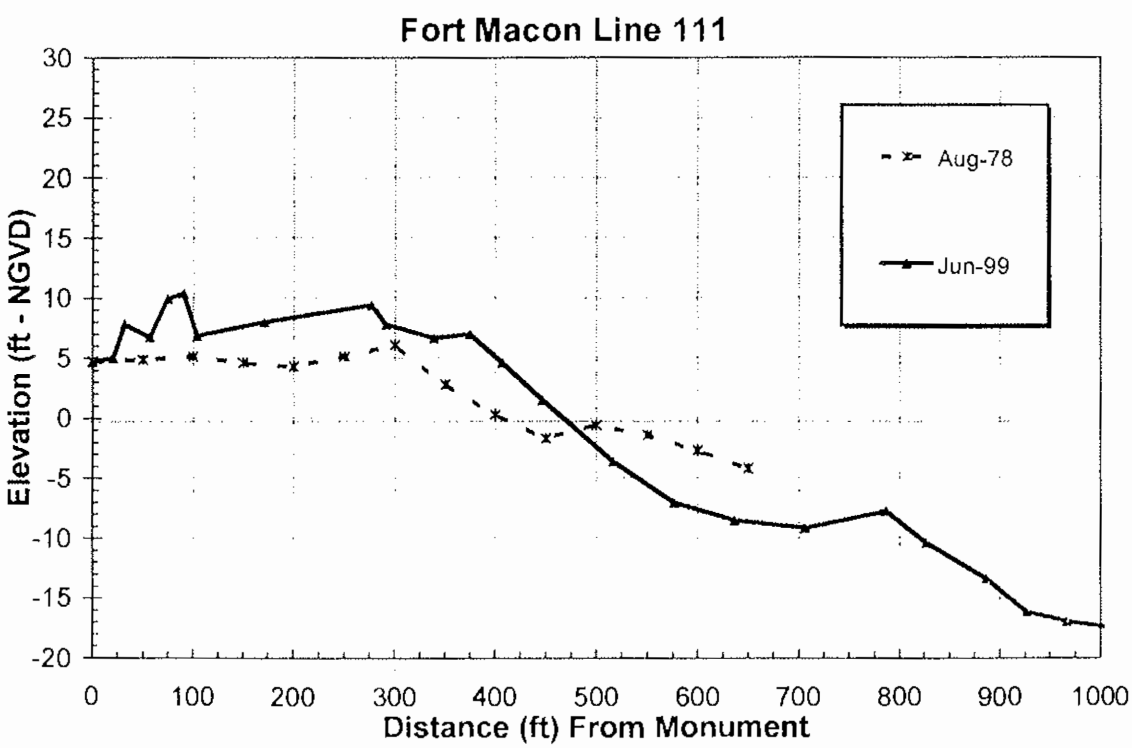

Fort Macon Line 106
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Aug-78
Jun-99

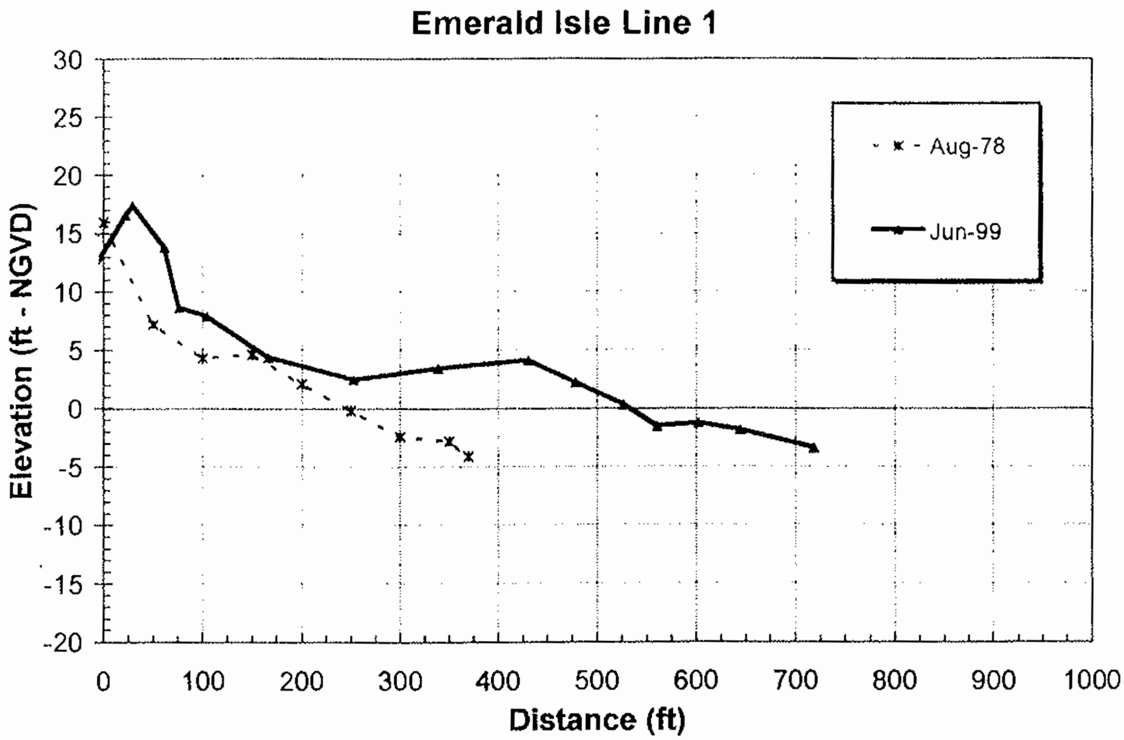

Fort Macon Line 107
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Aug-78
Jun-99


Fort Macon Line 108
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

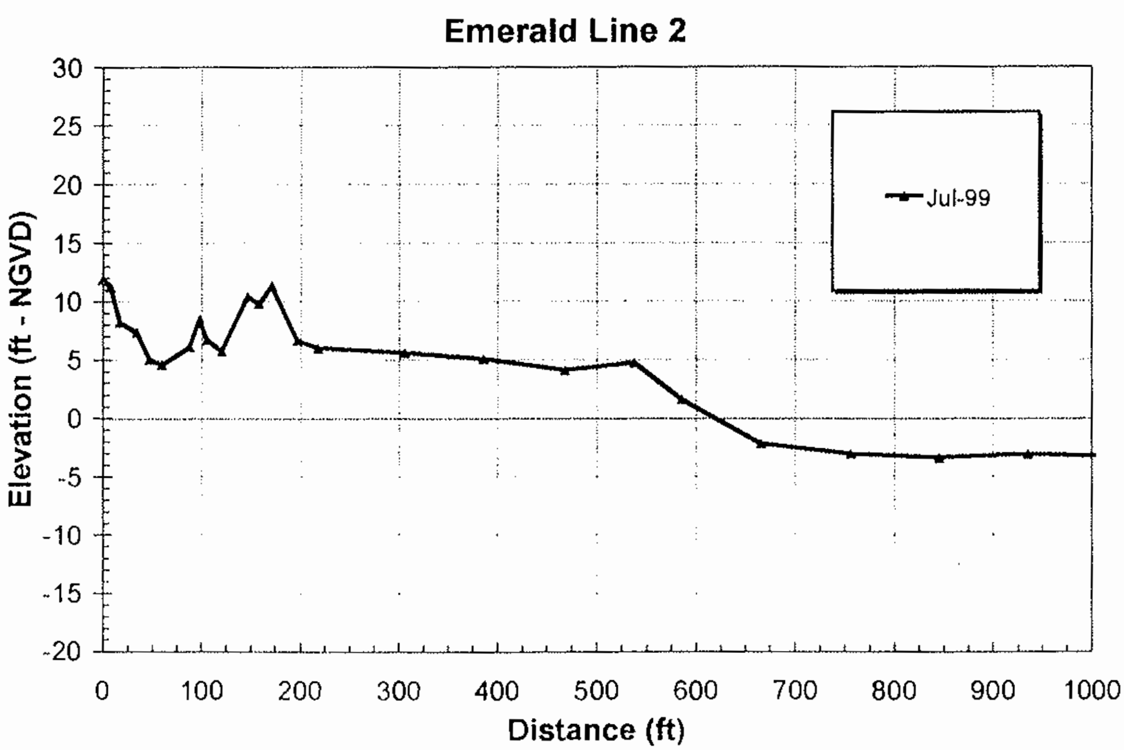

Fort Macon Line 109
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Fort Macon Line 110
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

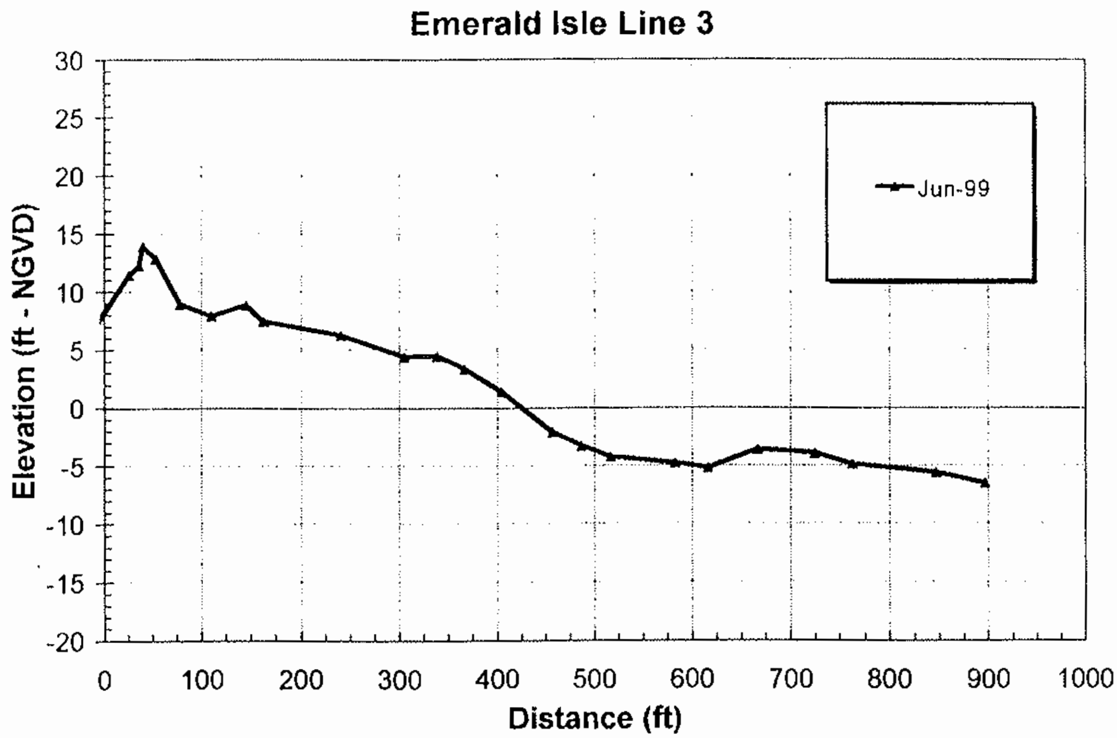

Fort Macon Line 111
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

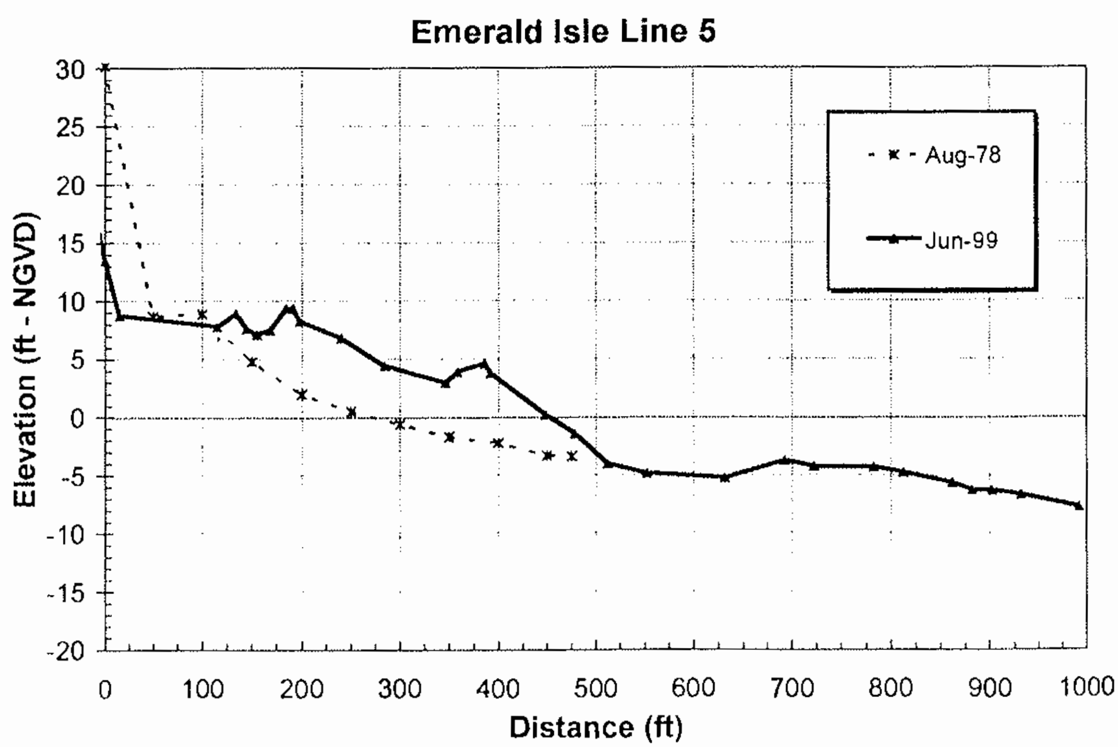


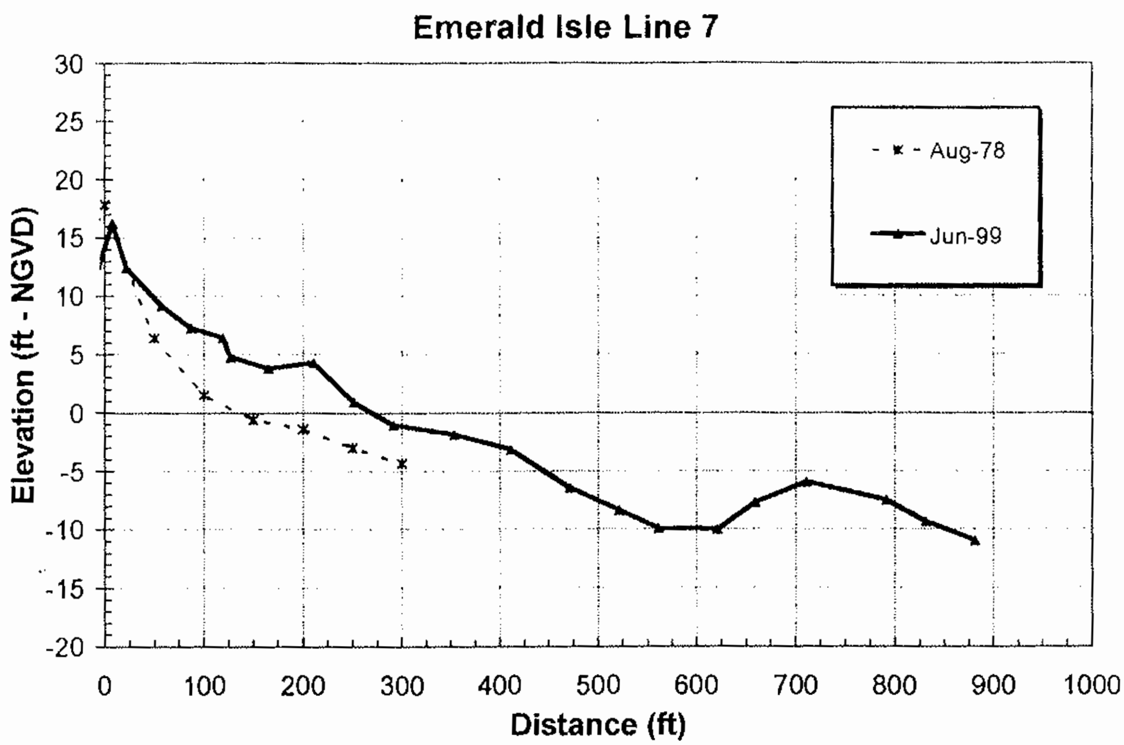
Emerald Isle Line 1
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)



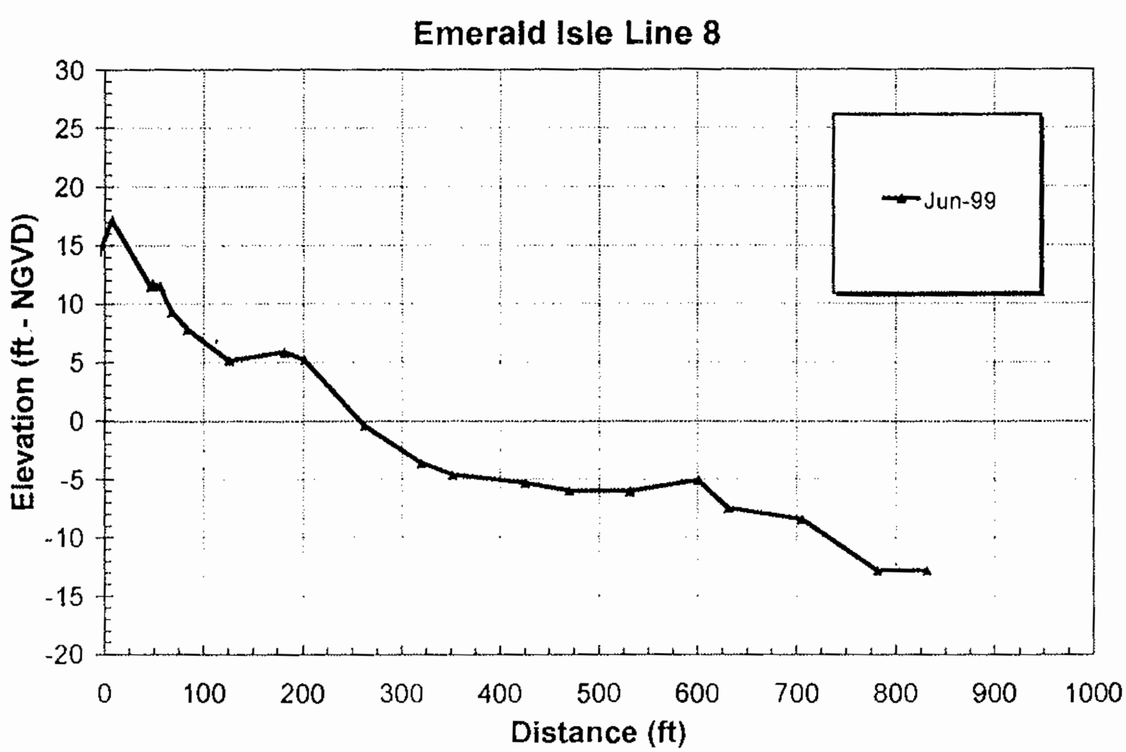
Emerald Line 2
Jul-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)


Emerald Isle Line 3
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

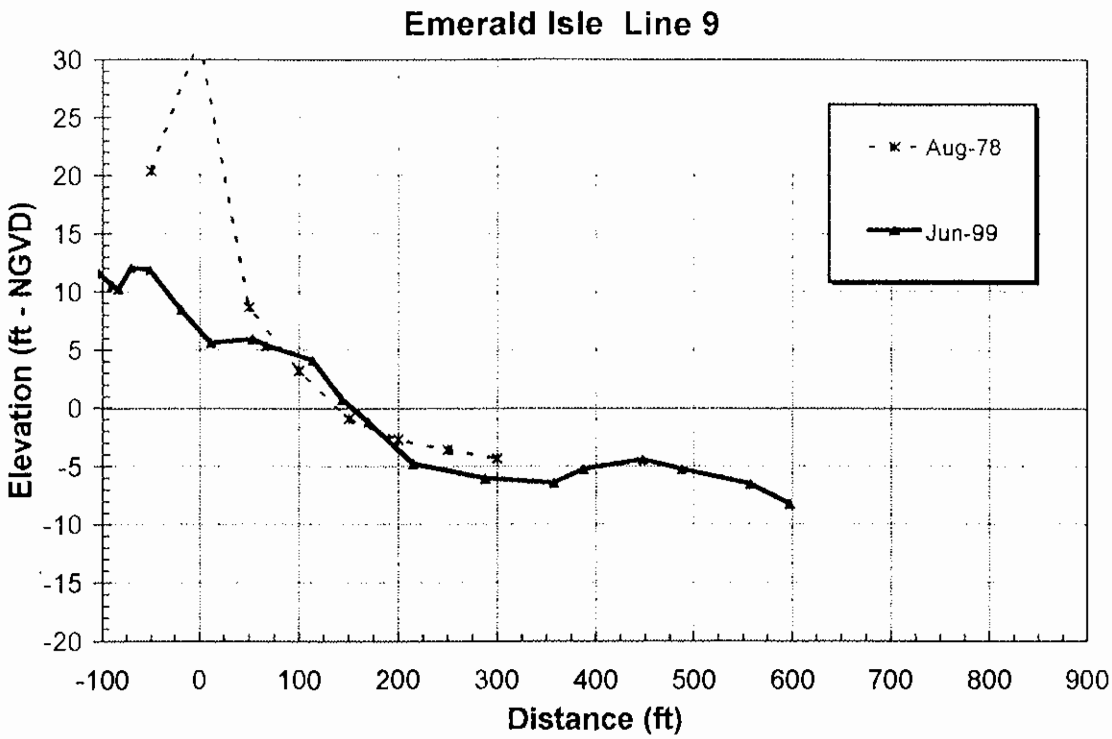

Emerald Isle Line 5
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

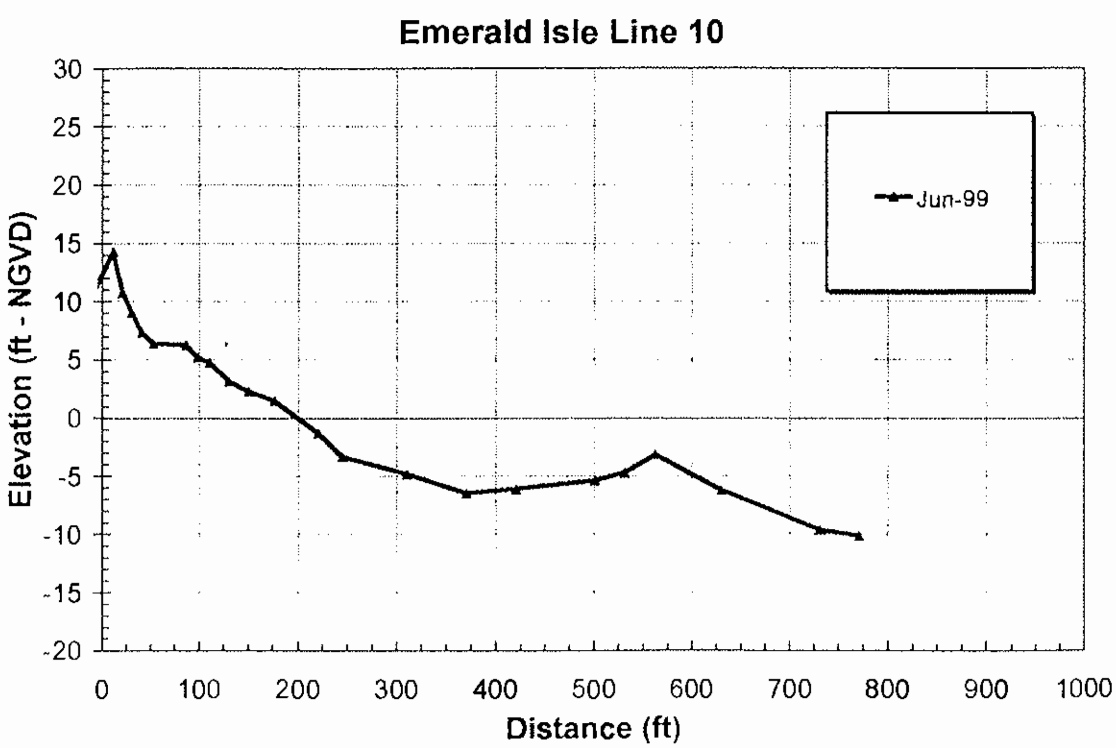


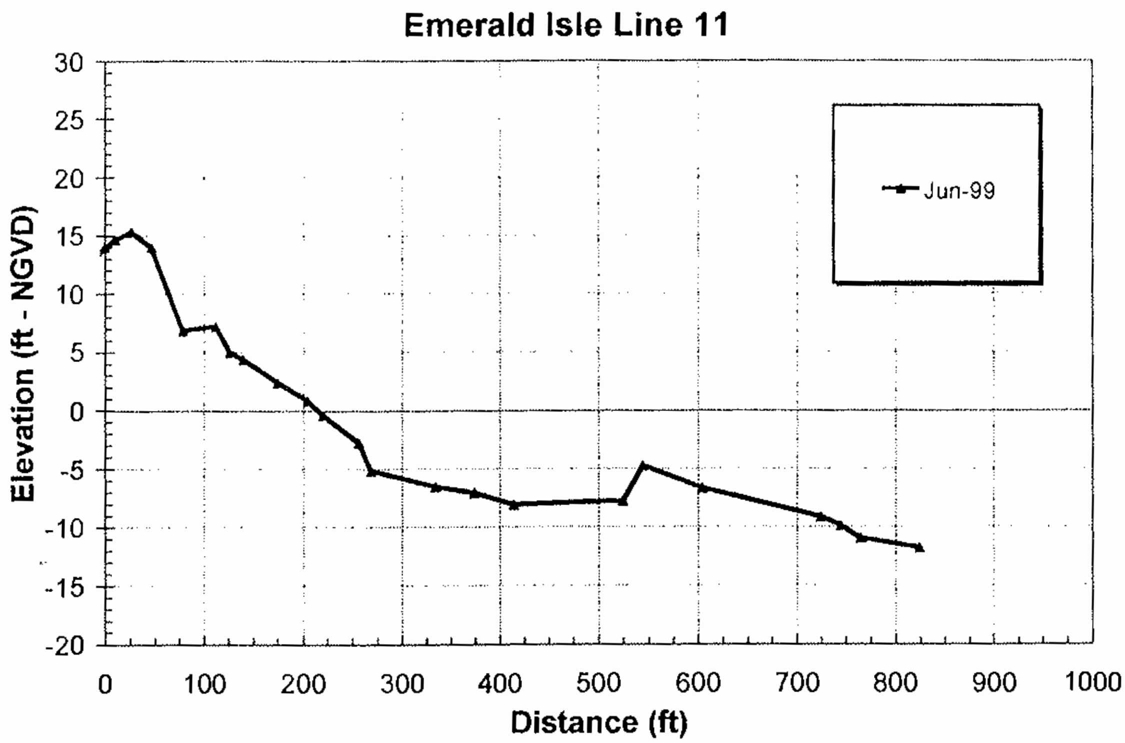
Emerald Isle Line 7
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



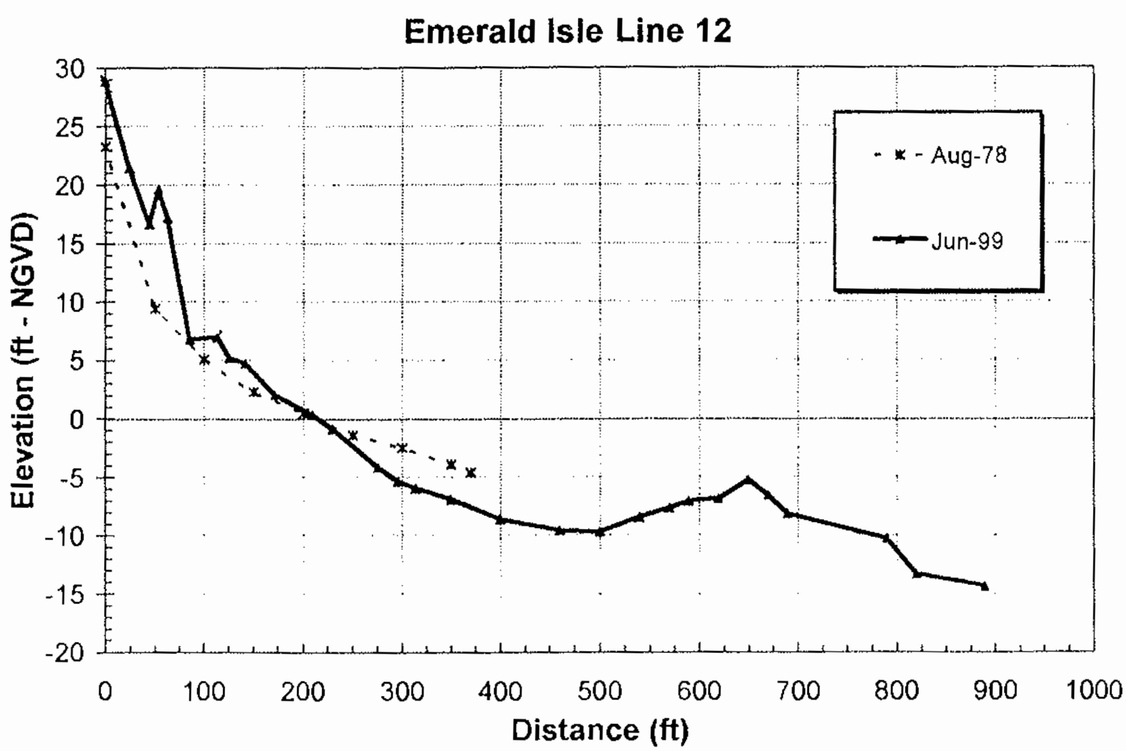
Emerald Isle Line 8
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle Line 9
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
-100
0
100
200
300
400
500
600
700
800
900
Aug-78
Jun-99

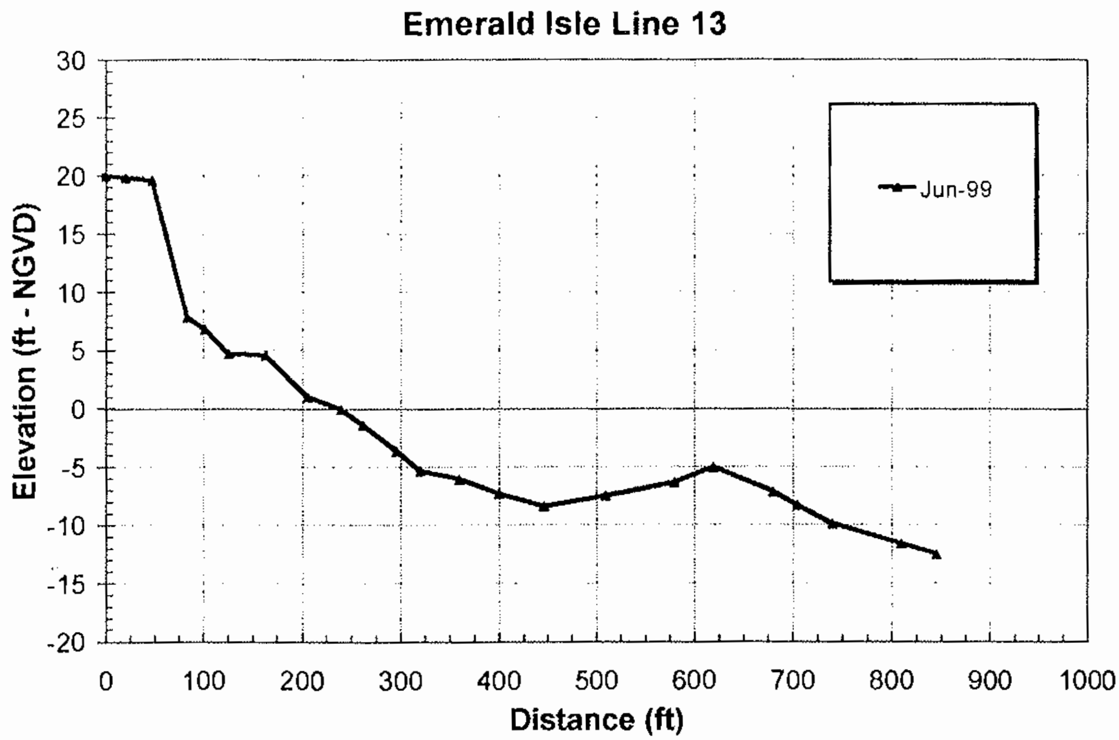

Emerald Isle Line 10
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Jun-99



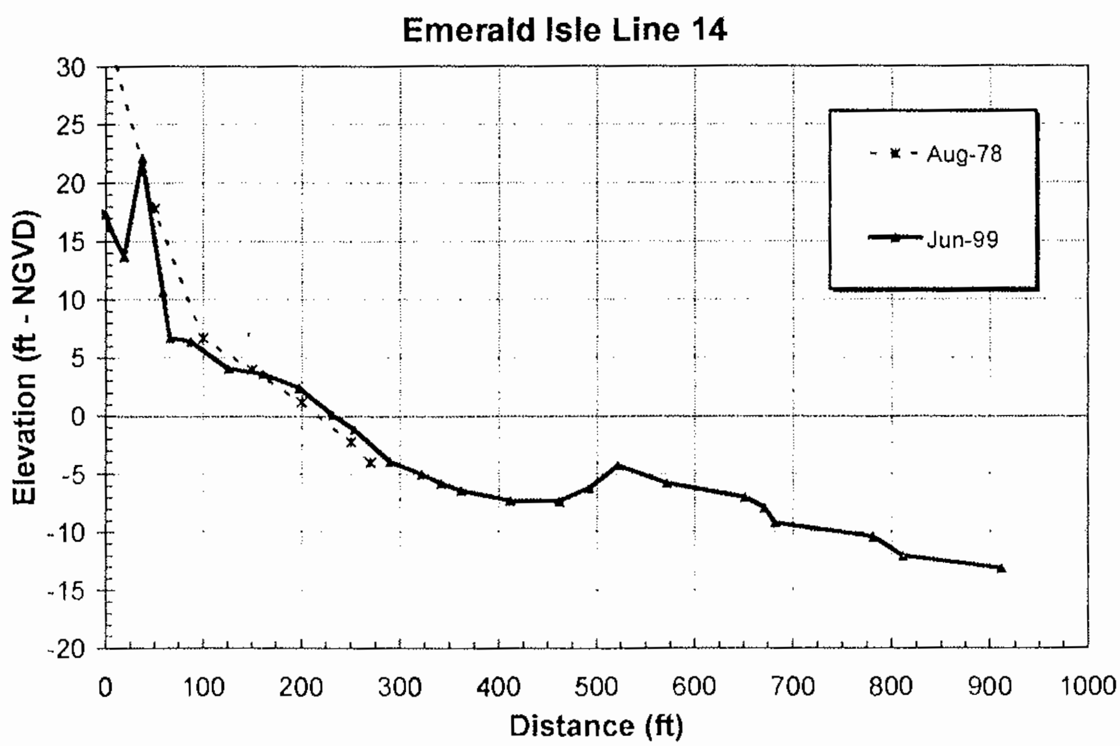
Emerald Isle Line 11
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



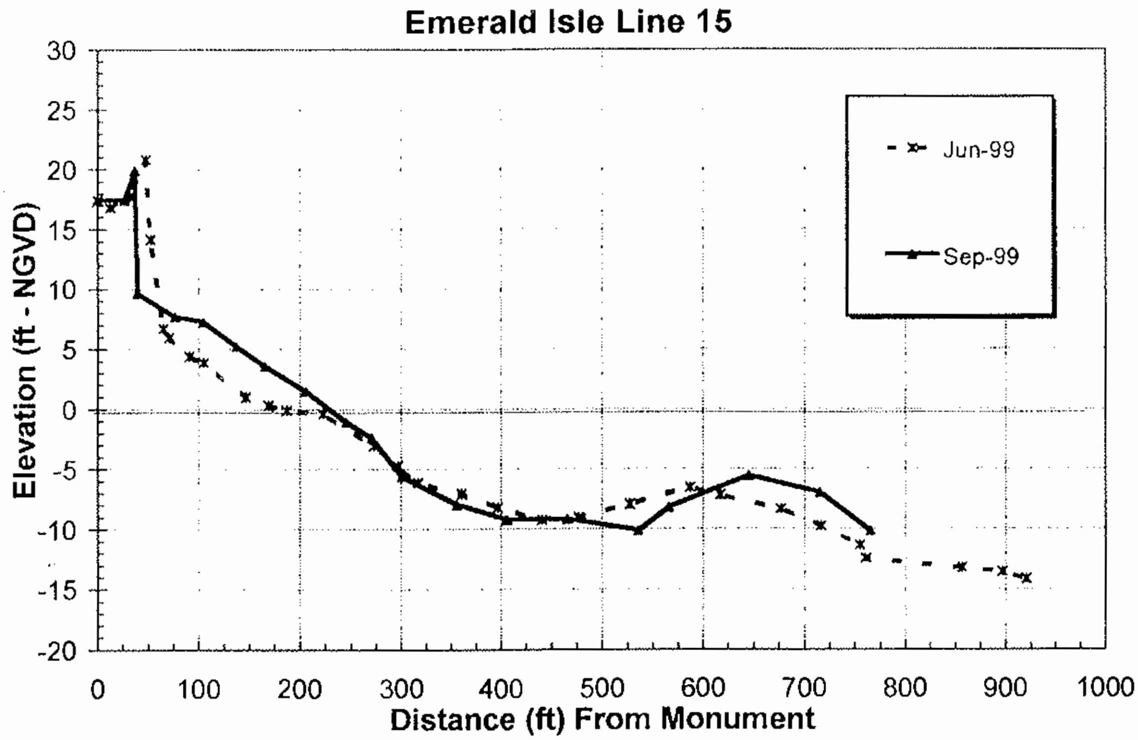
Emerald Isle Line 12
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

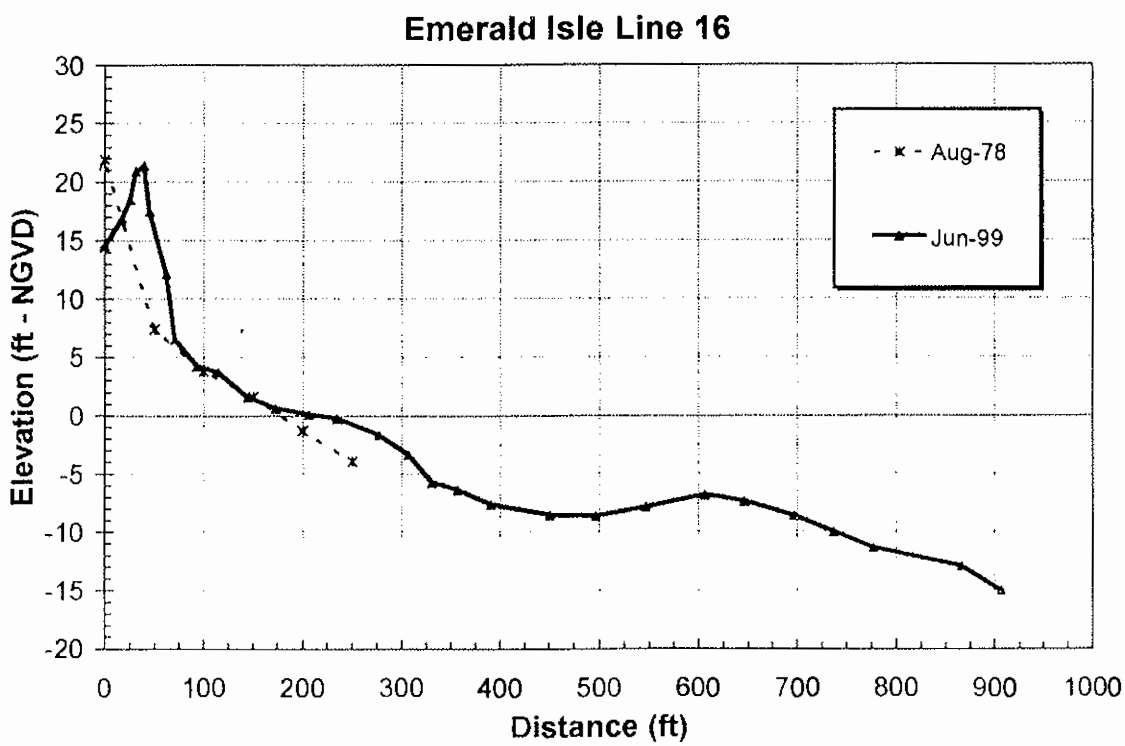


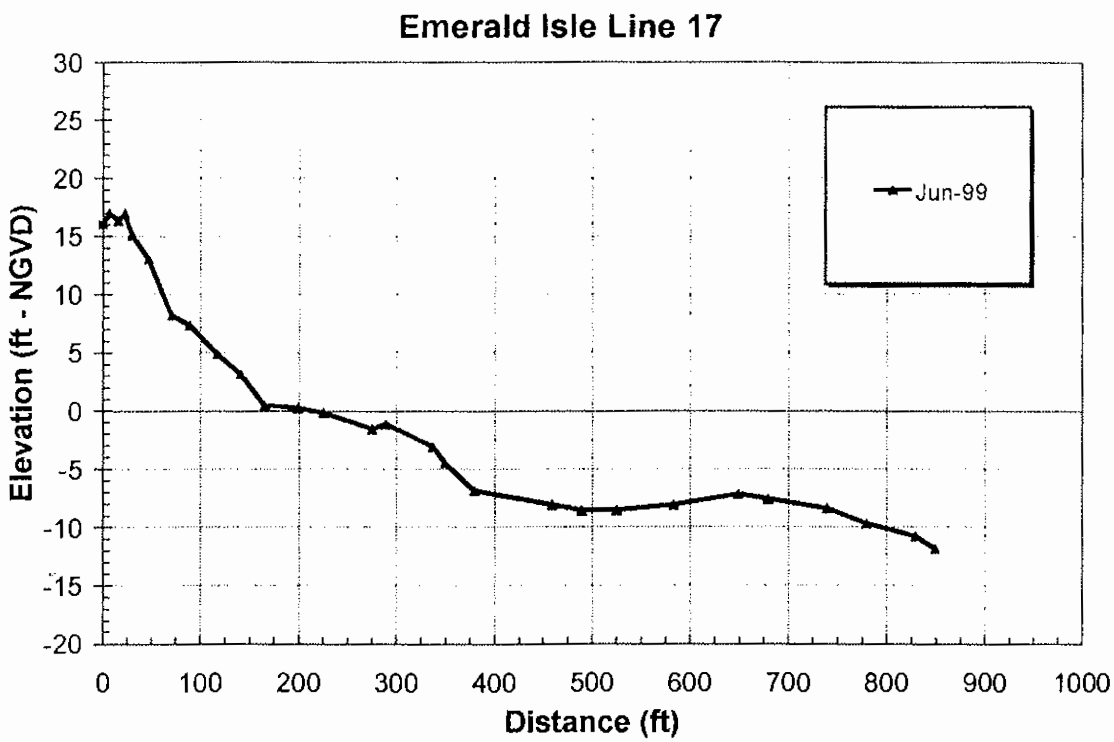
Emerald Isle Line 13
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



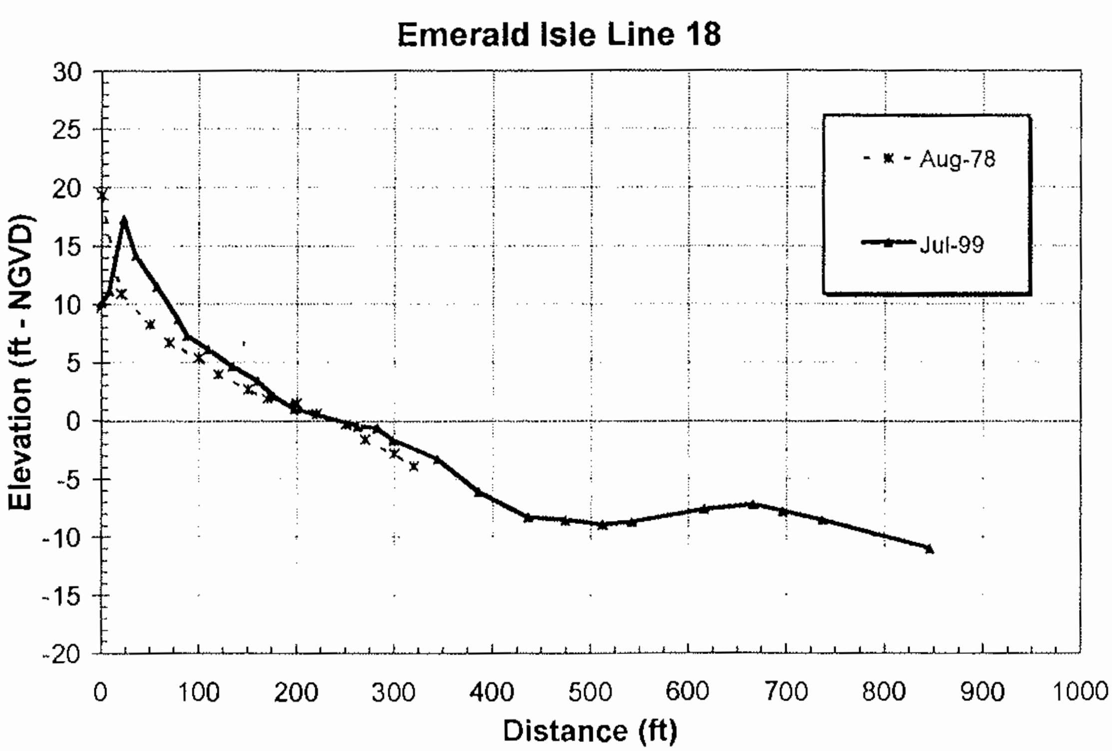
Emerald Isle Line 14
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle Line 15
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Jun-99
Sep-99

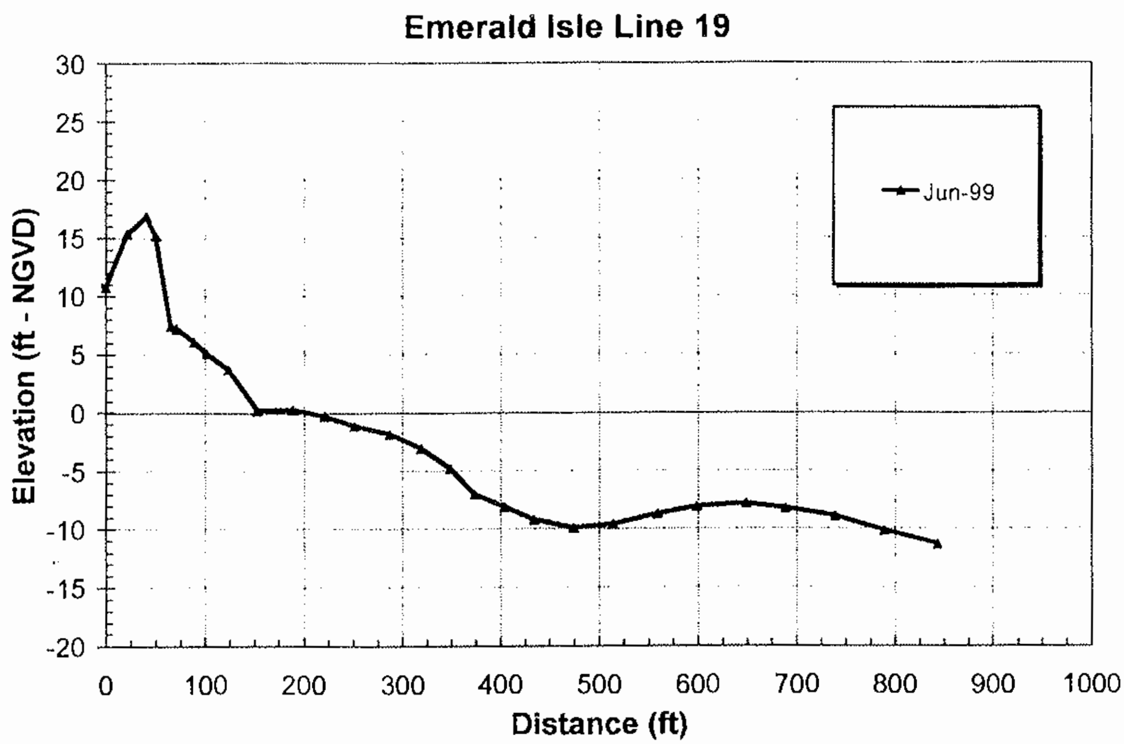

Emerald Isle Line 16
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)
Aug-78
Jun-99



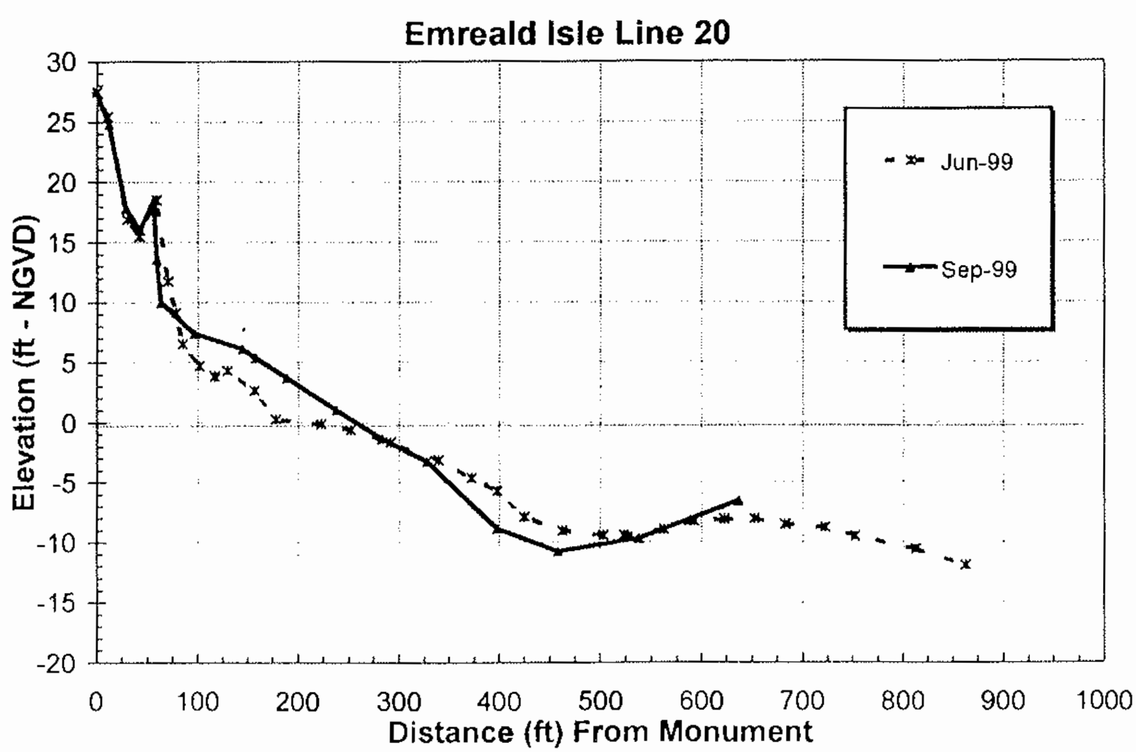
Emerald Isle Line 17
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



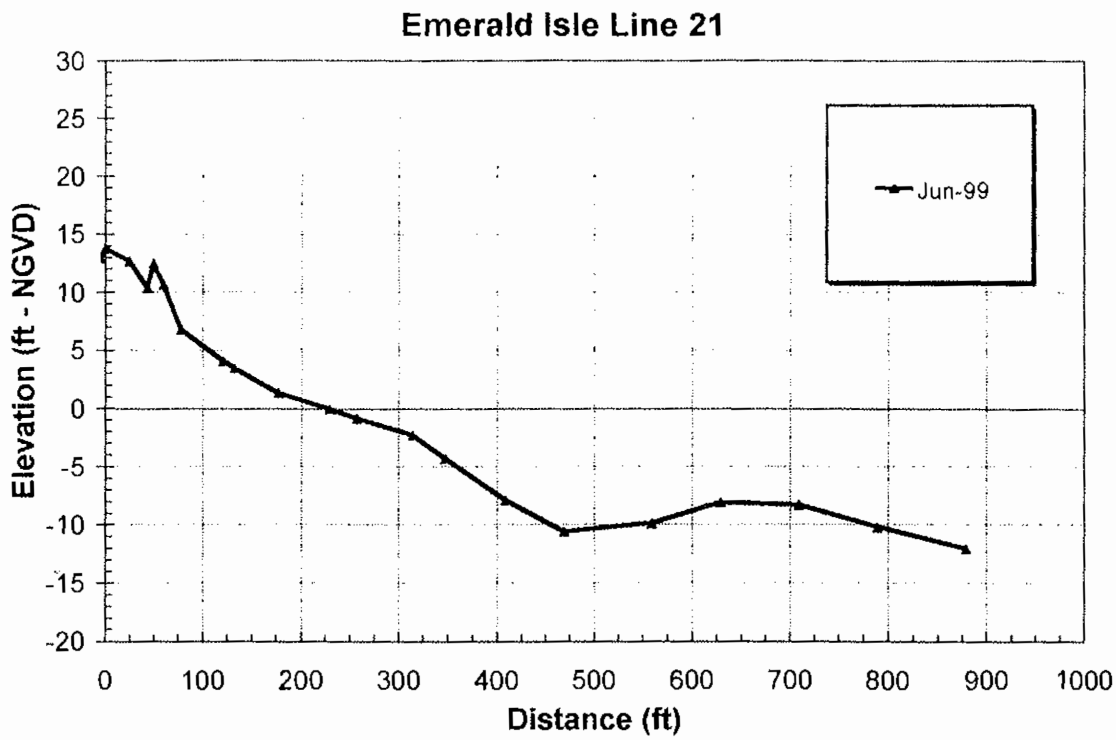
Emerald Isle Line 18
Aug-78
Jul-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



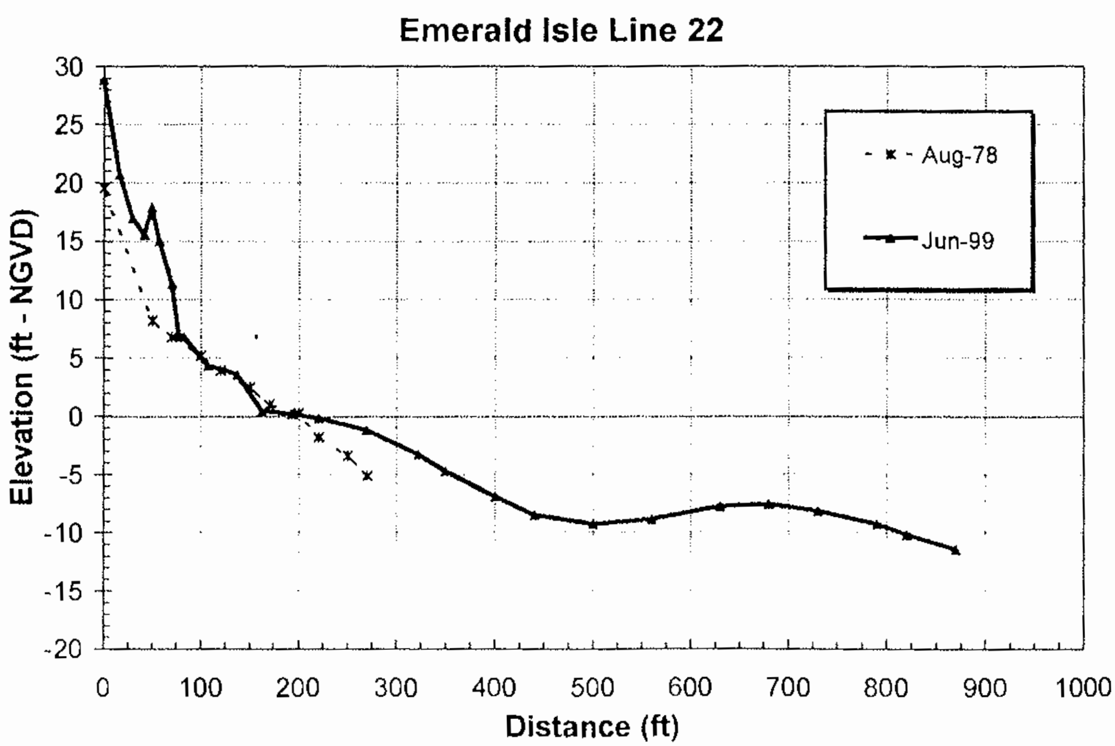
Emerald Isle Line 19
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)



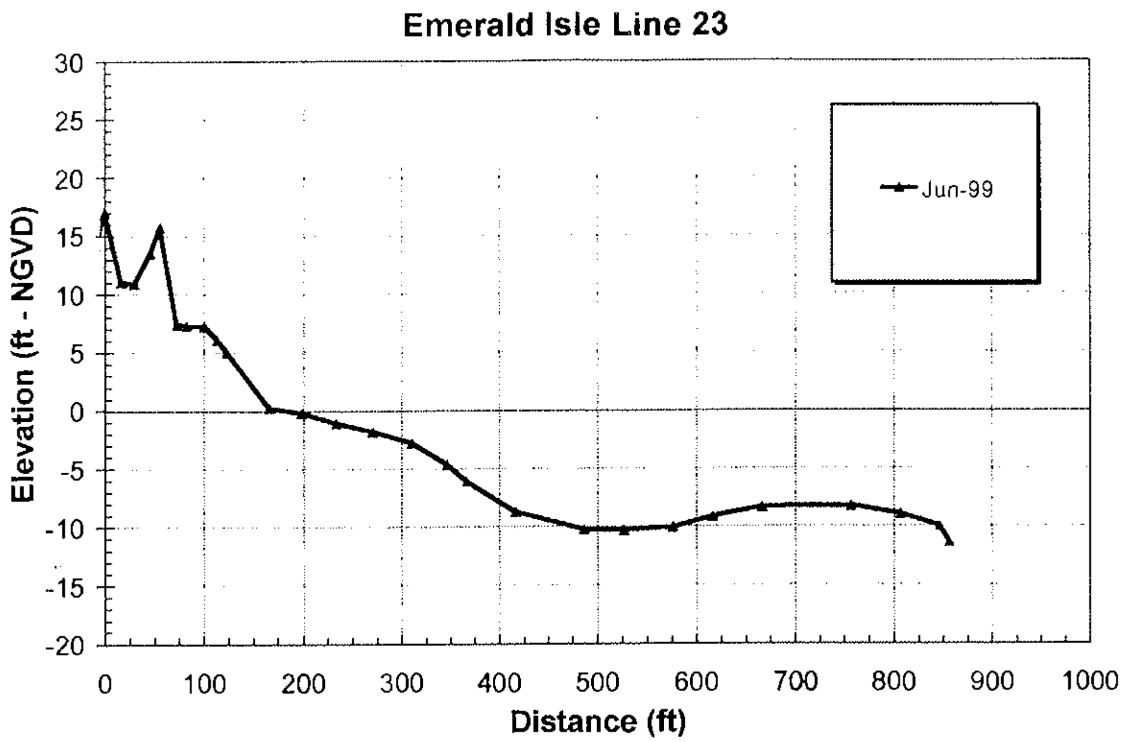
Emreald Isle Line 20
Jun-99
Sep-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument



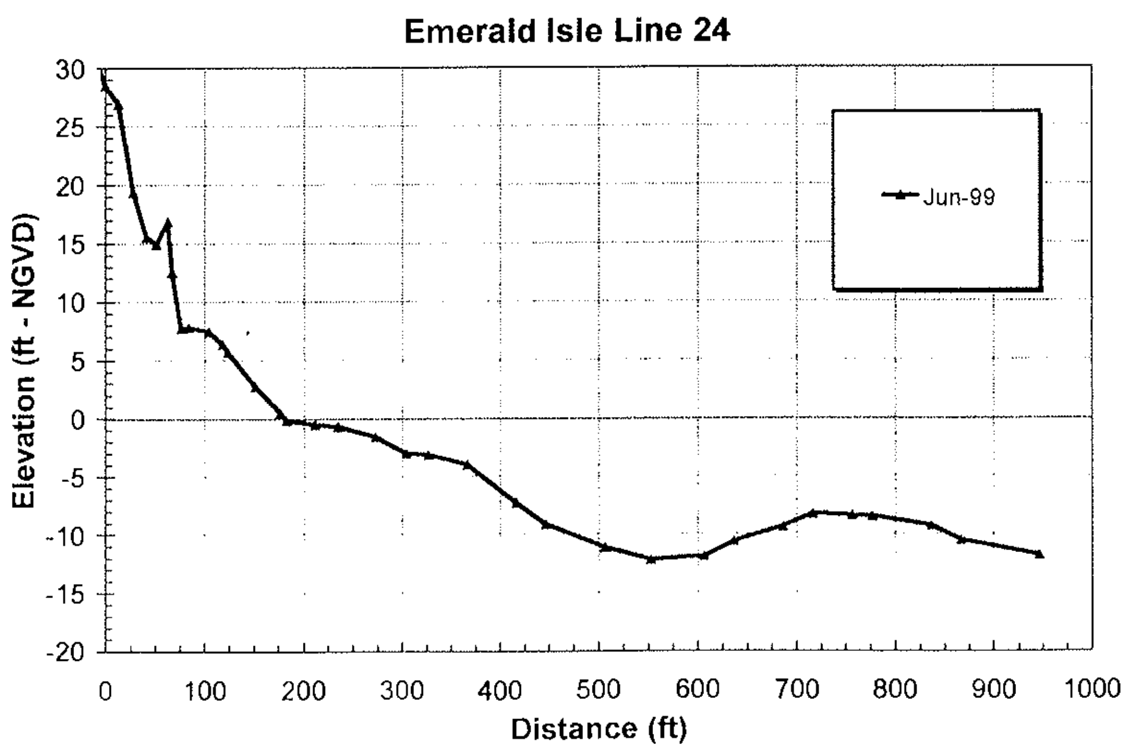
Emerald Isle Line 21
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



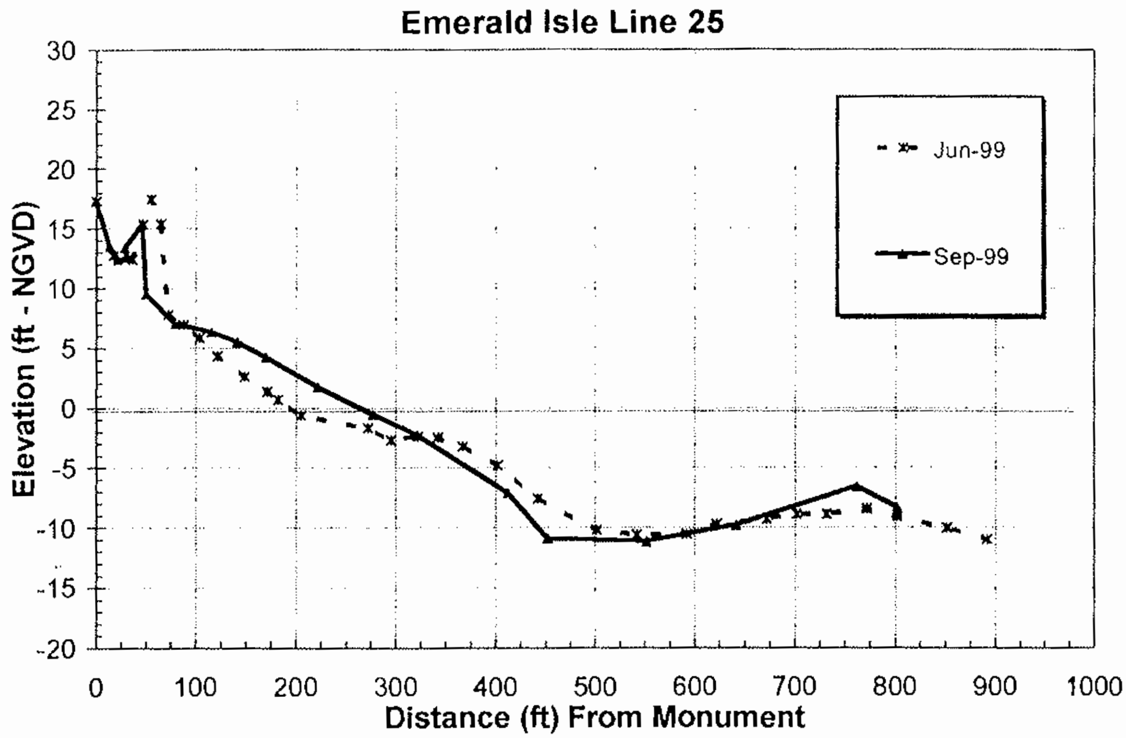
Emerald Isle Line 22
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

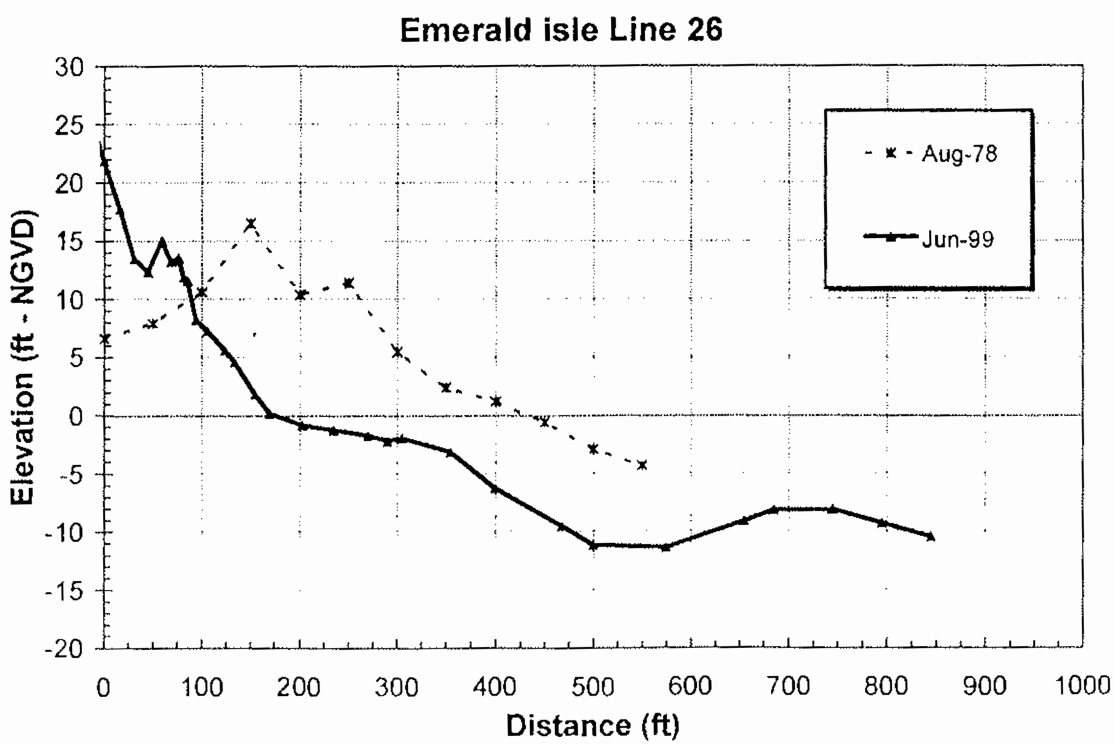


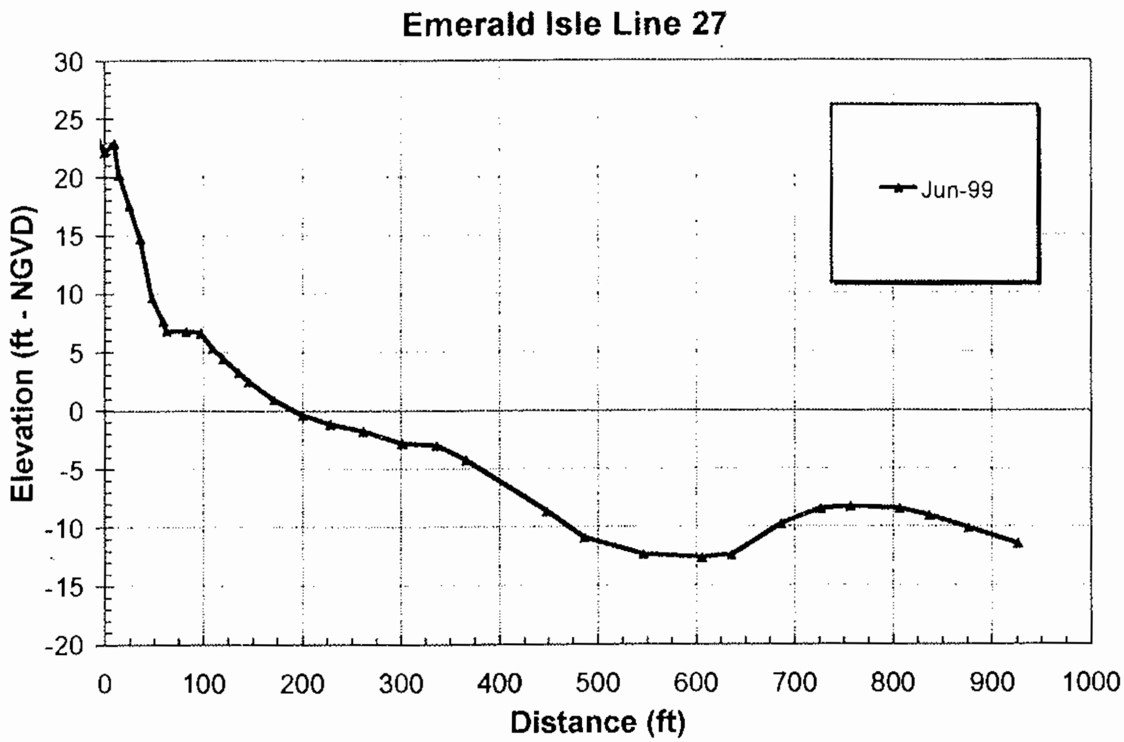
Emerald Isle Line 23
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

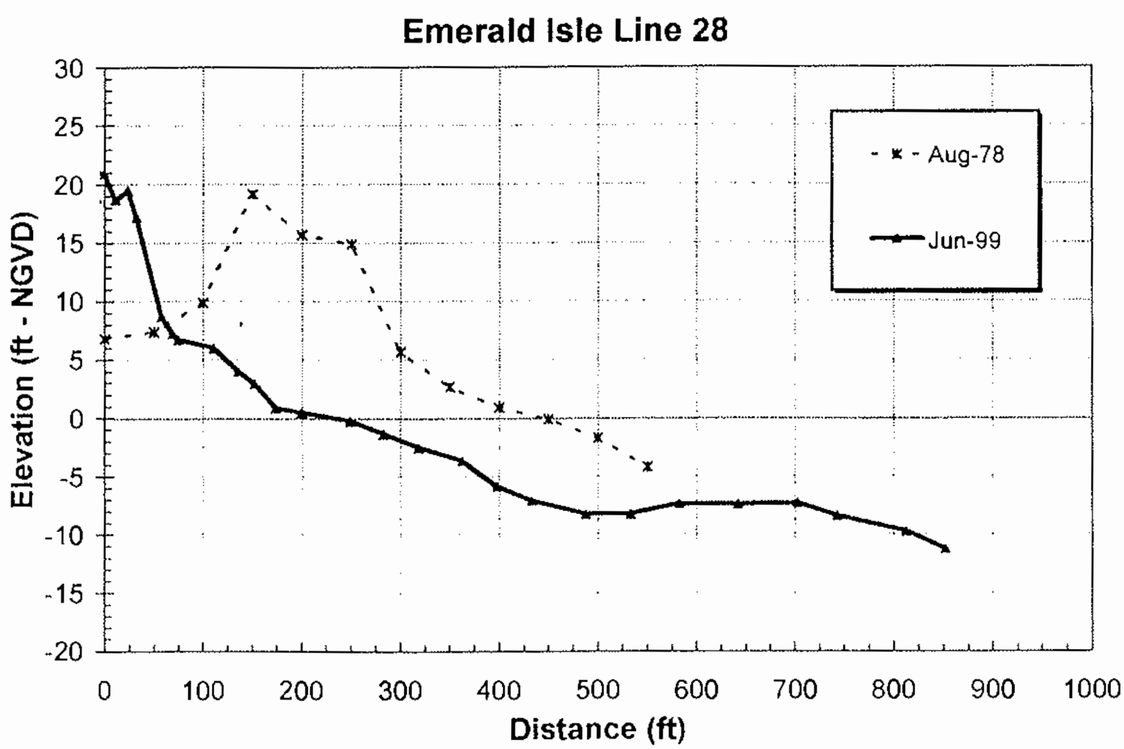


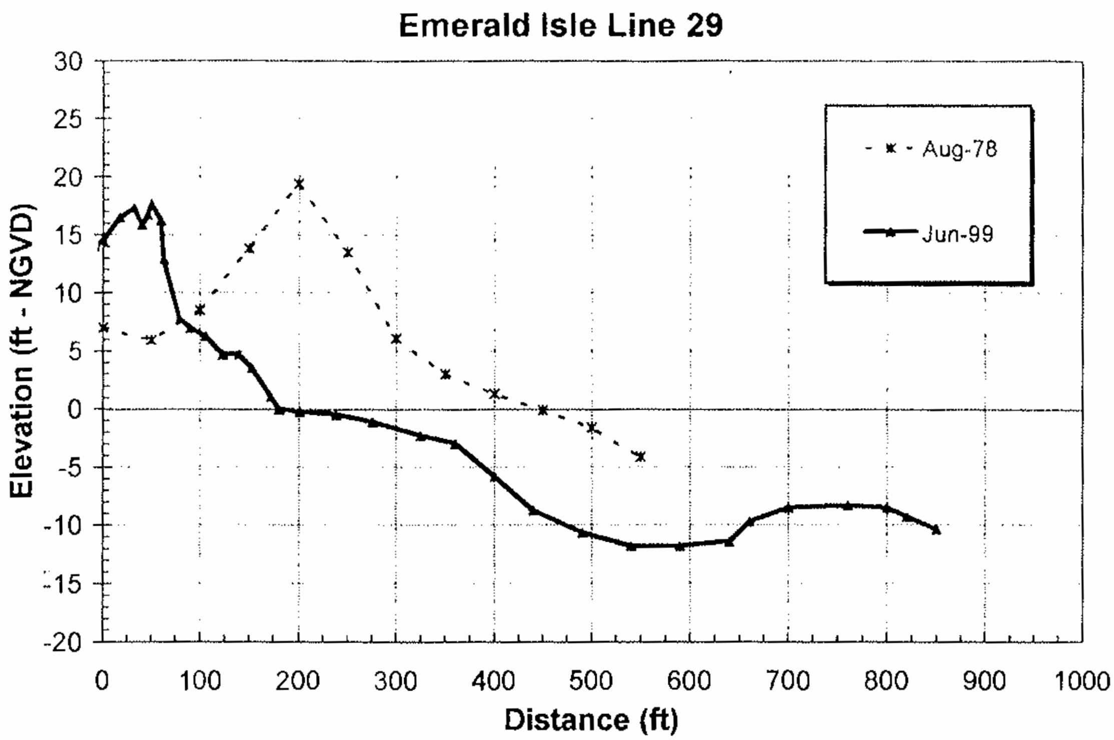
Emerald Isle Line 24
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)


Emerald Isle Line 25
Jun-99
Sep-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

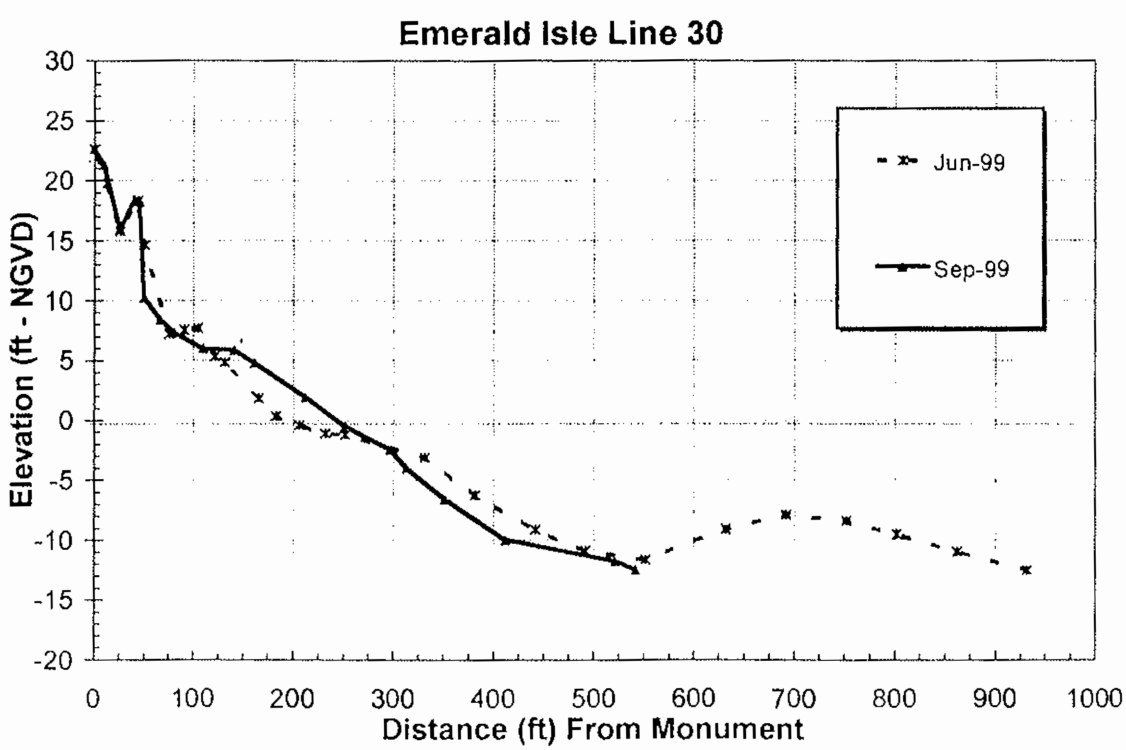

Emerald isle Line 26
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)


Emerald Isle Line 27
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

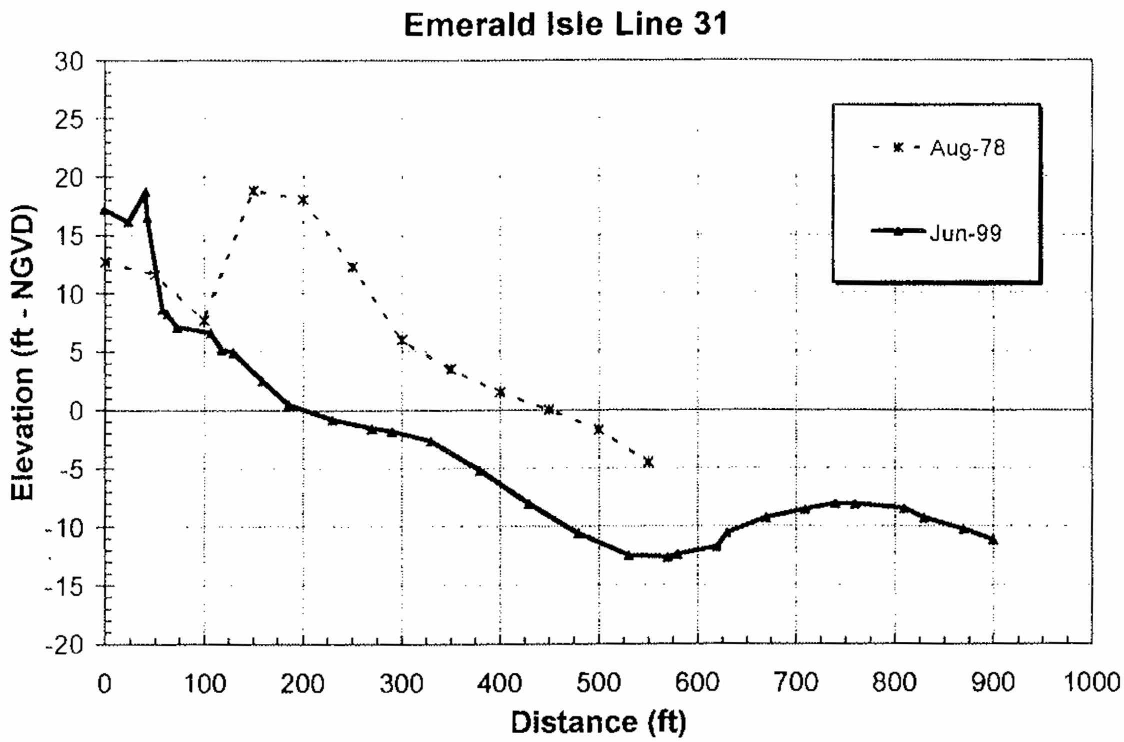

Emerald Isle Line 28
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

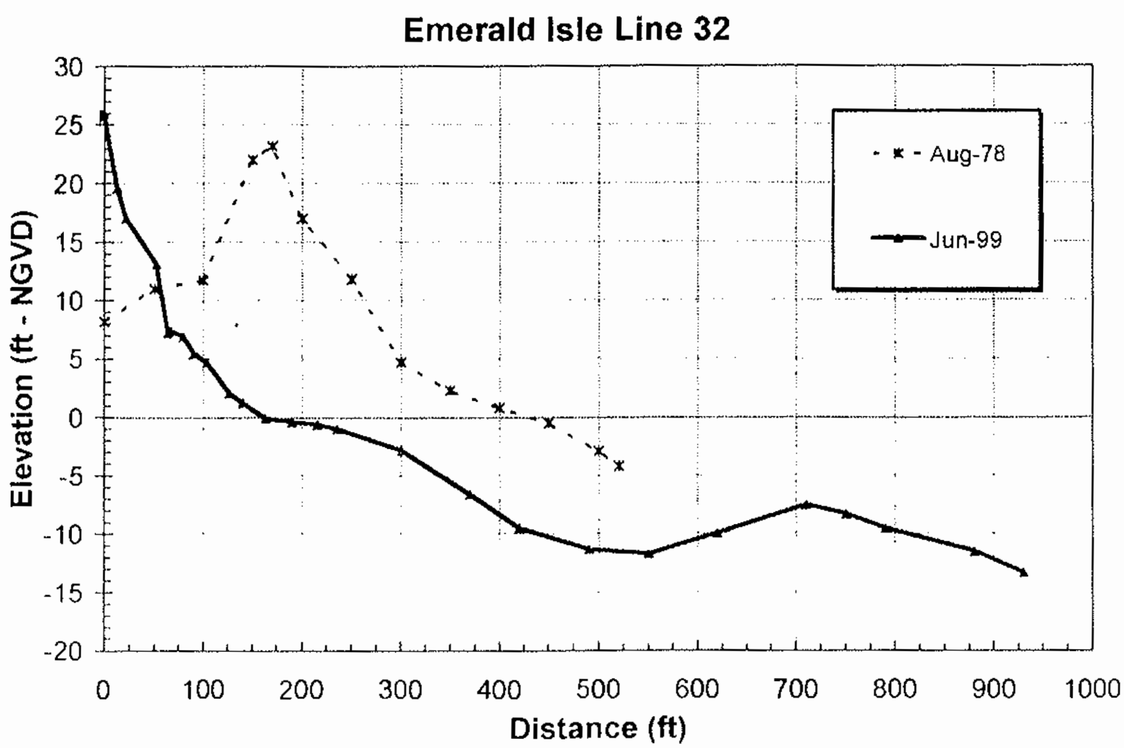


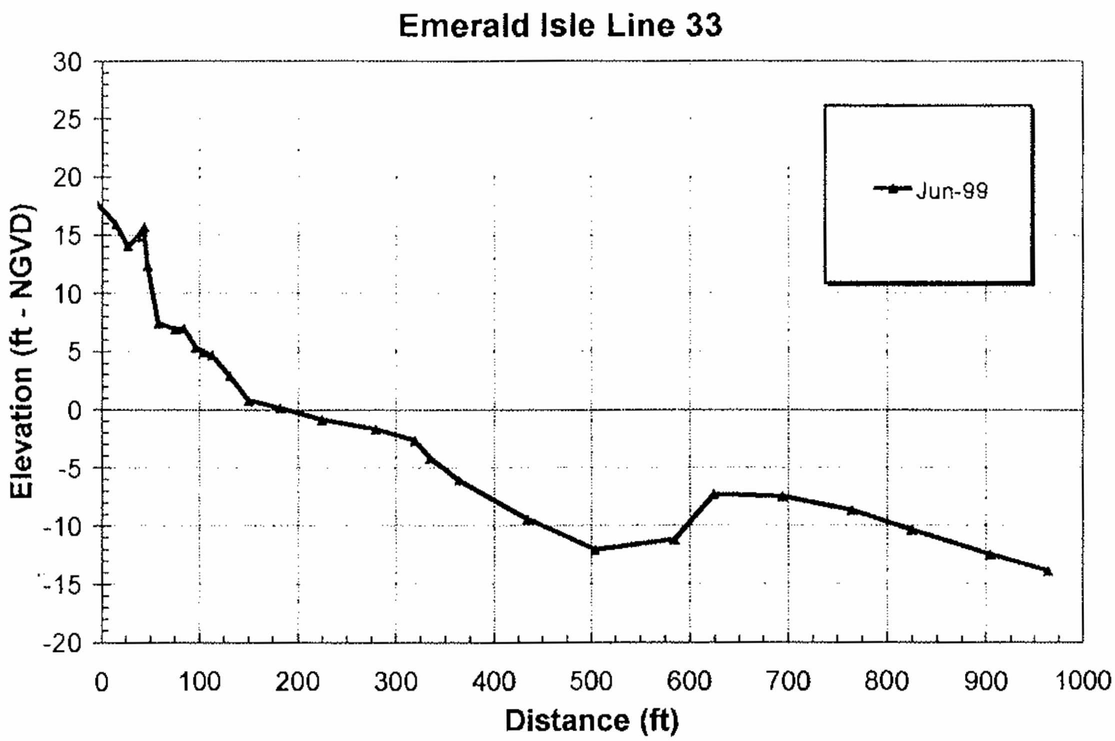
Emerald Isle Line 29
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

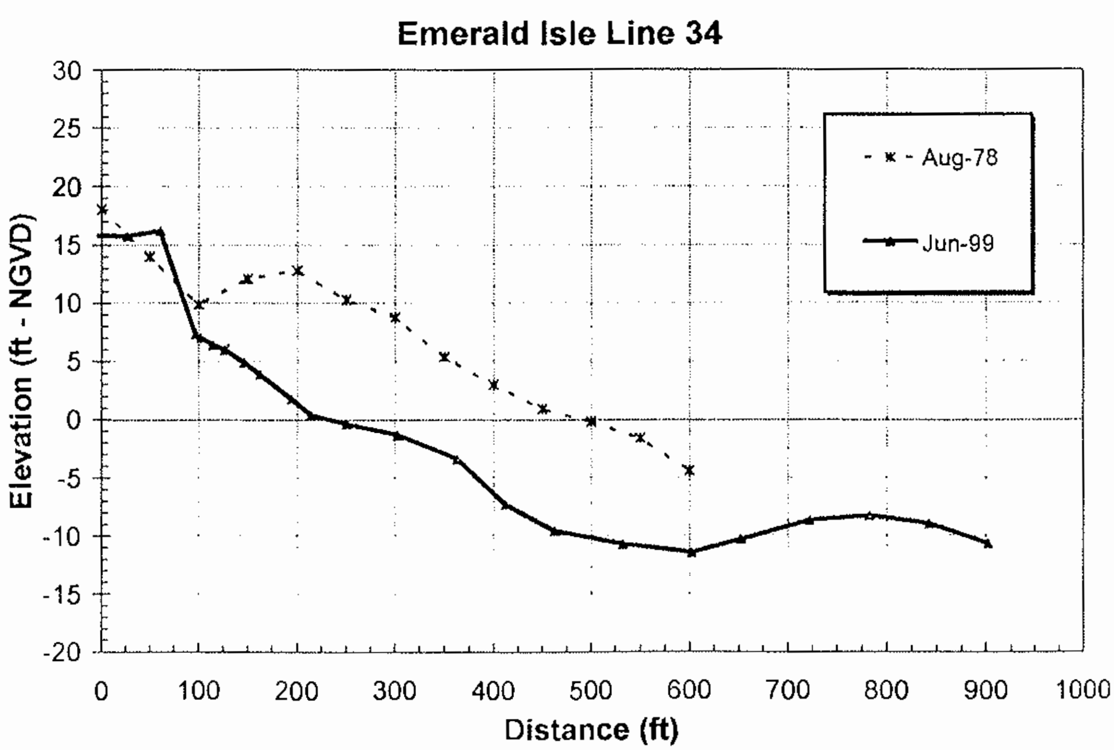


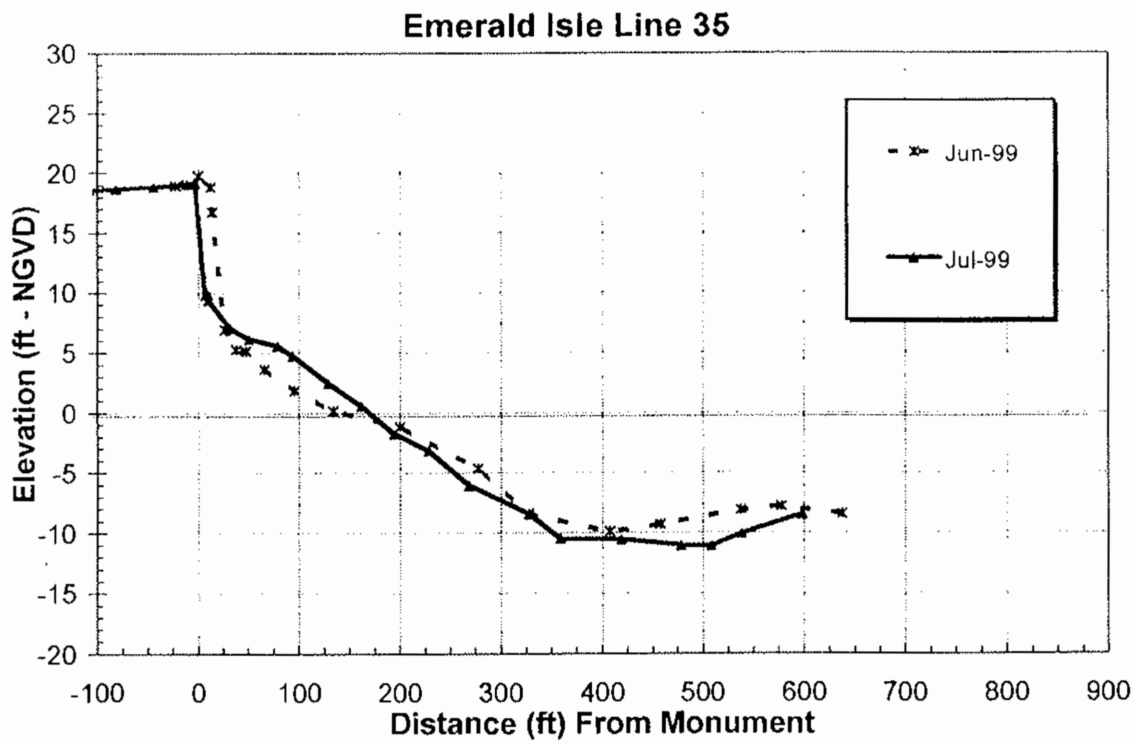
Emerald Isle Line 30
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Sep-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

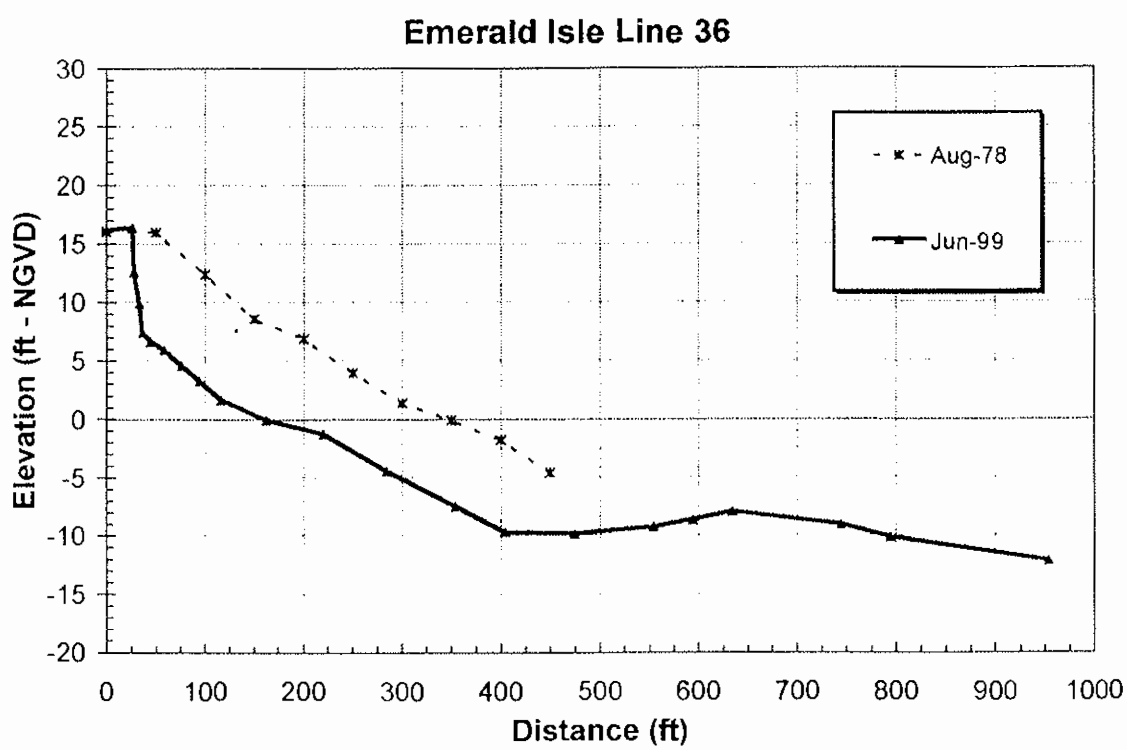

Emerald Isle Line 31
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

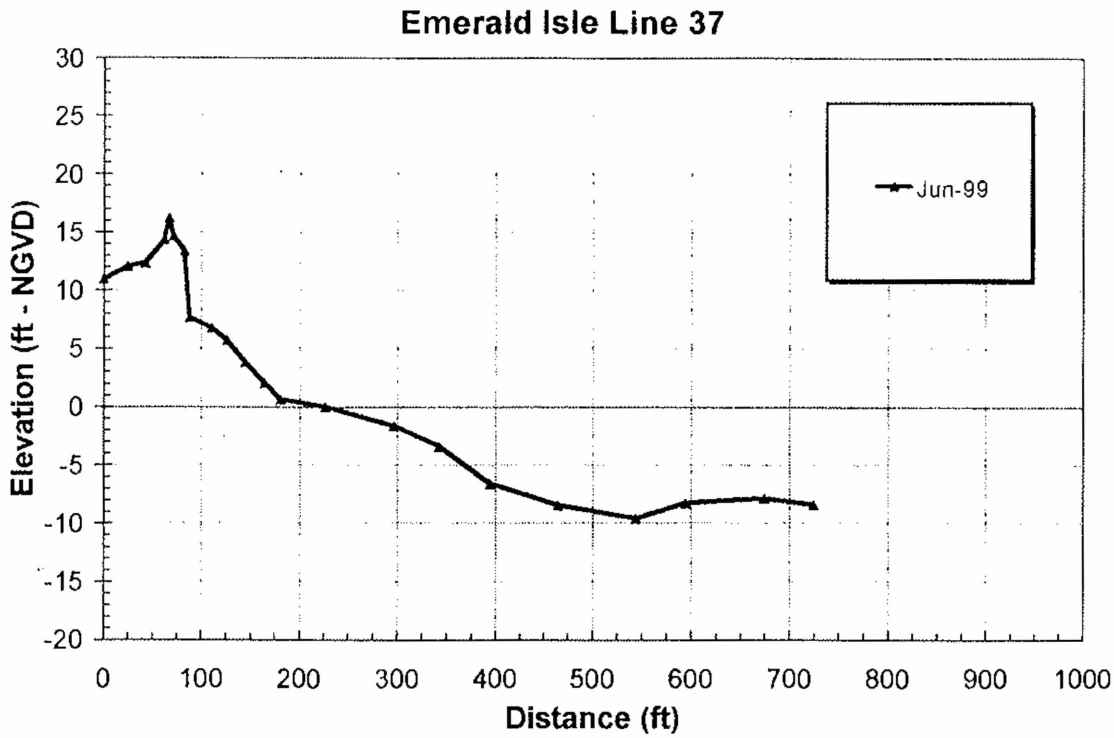

Emerald Isle Line 32
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

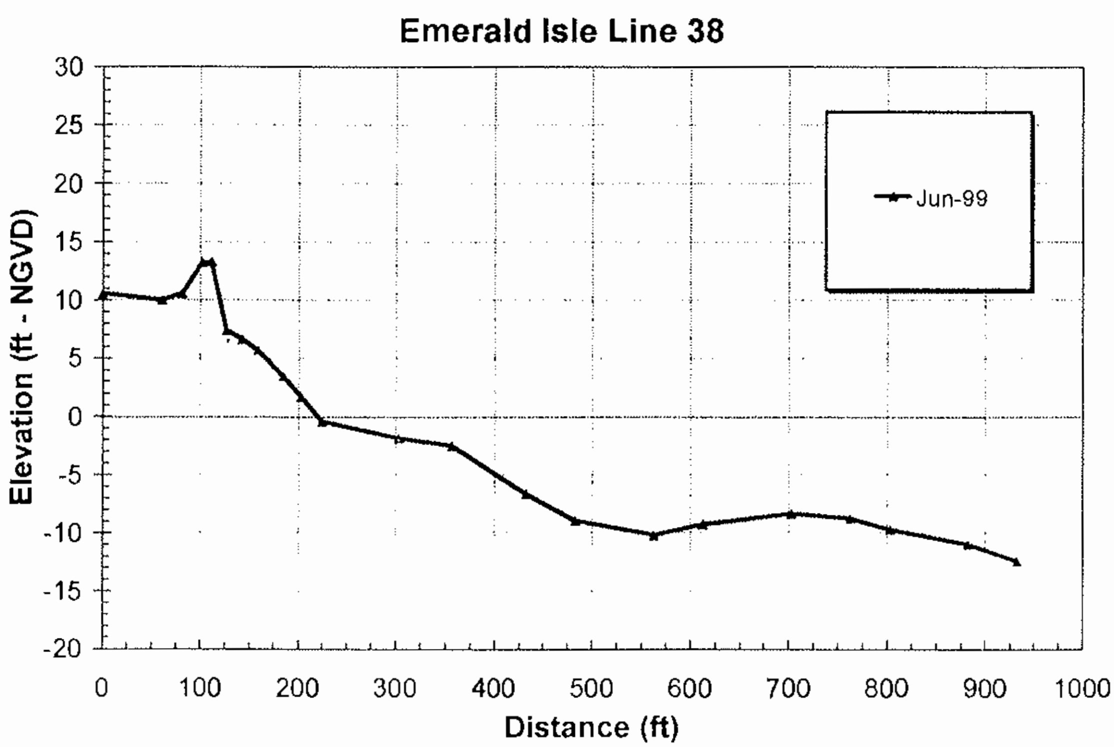

Emerald Isle Line 33
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

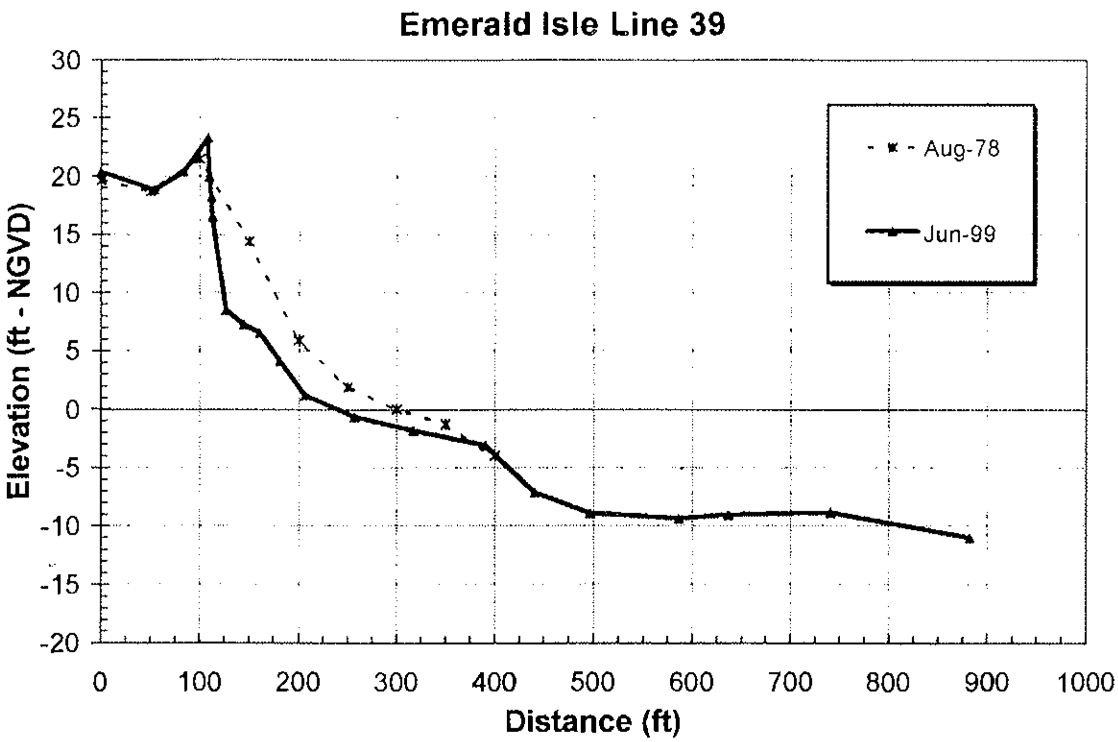

Emerald Isle Line 34
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

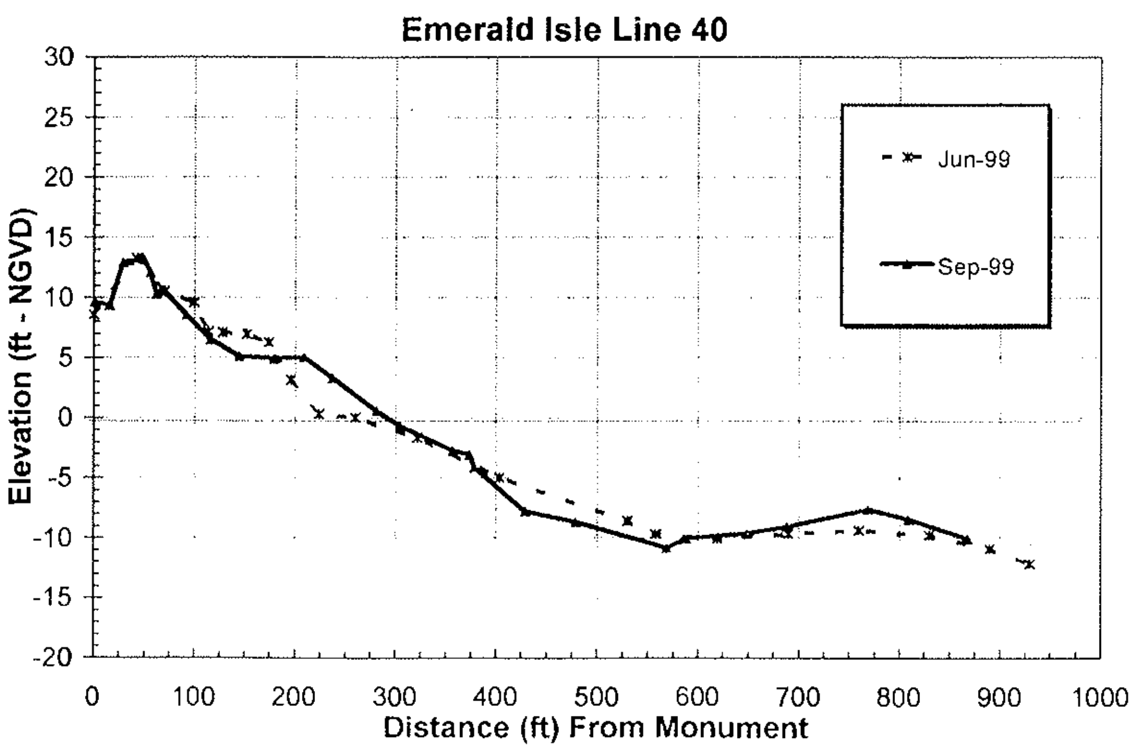

Emerald Isle Line 35
Jun-99
Jul-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
-100
0
100
200
300
400
500
600
700
800
900

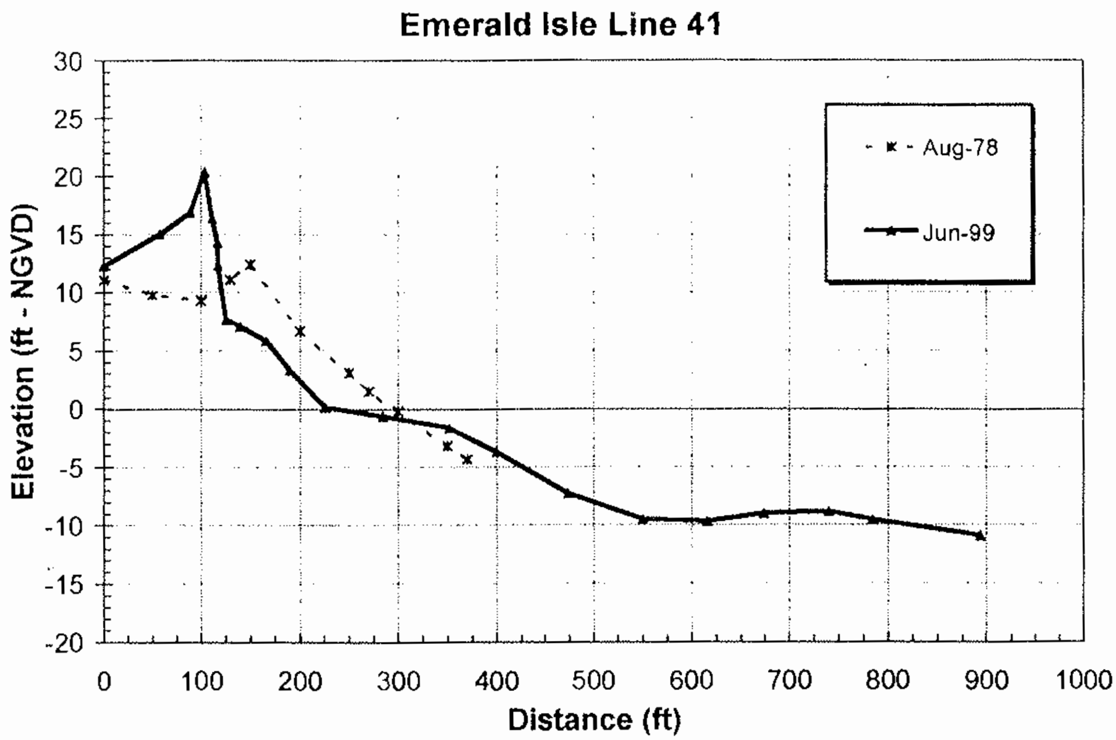

Emerald Isle Line 36
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

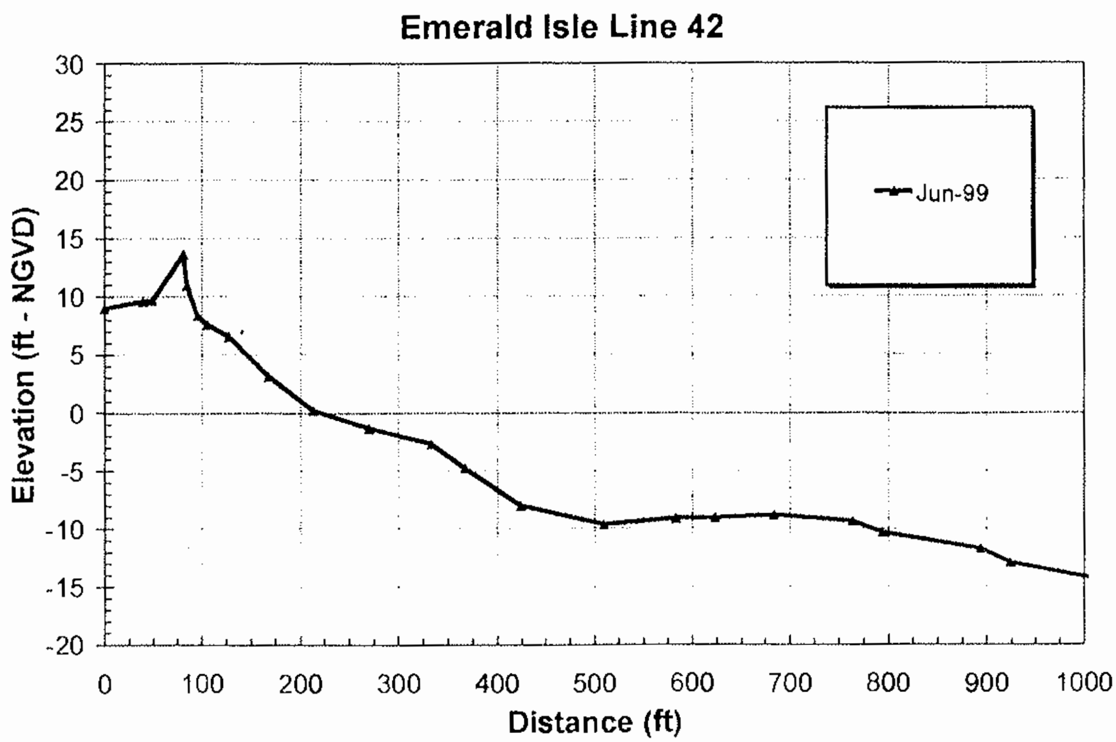

Emerald Isle Line 37
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)
Jun-99

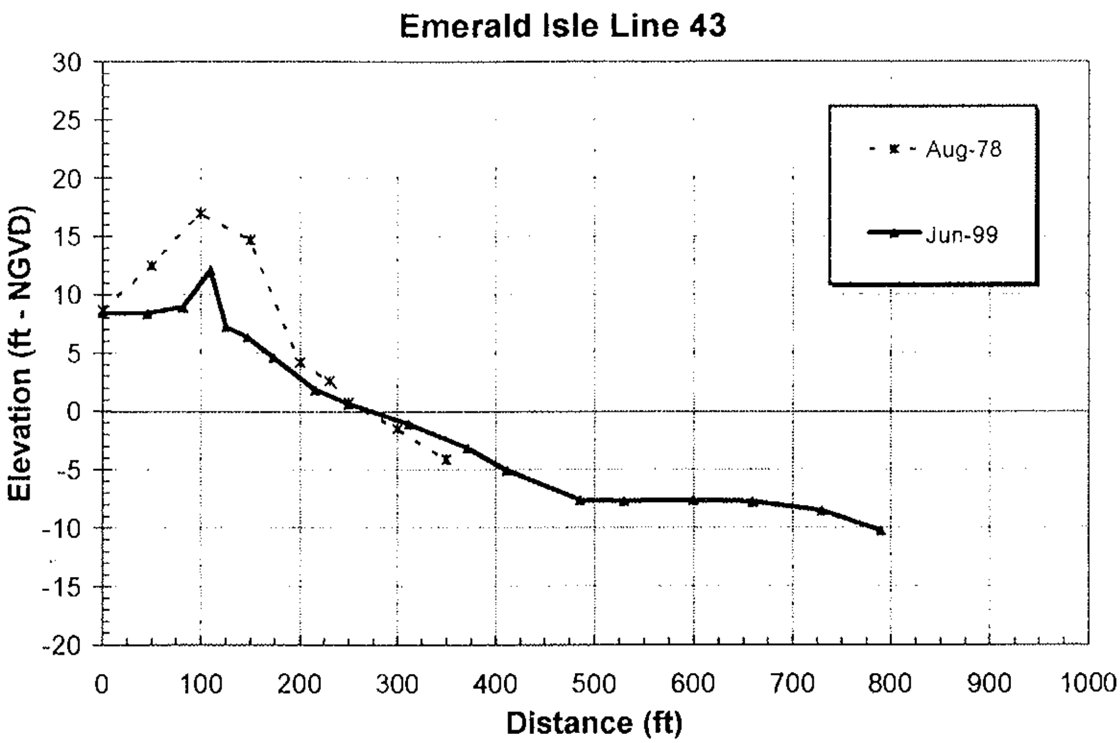

Emerald Isle Line 38
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)
Jun-99


Emerald Isle Line 39
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

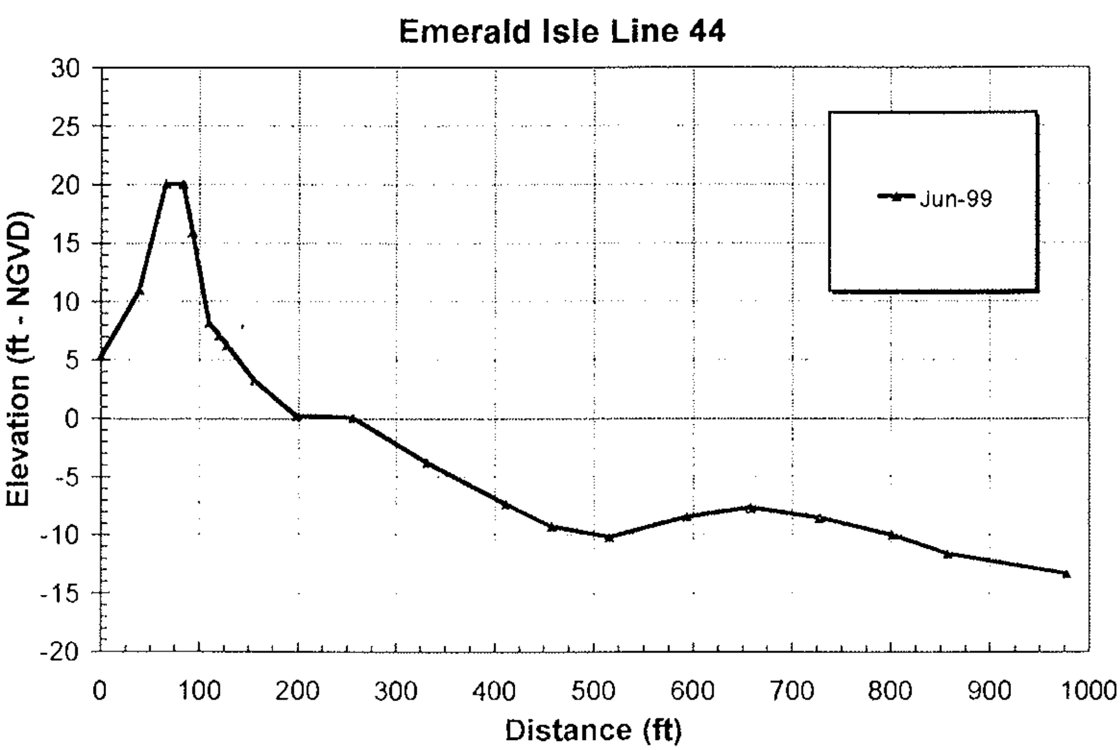

Emerald Isle Line 40
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle Line 41
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

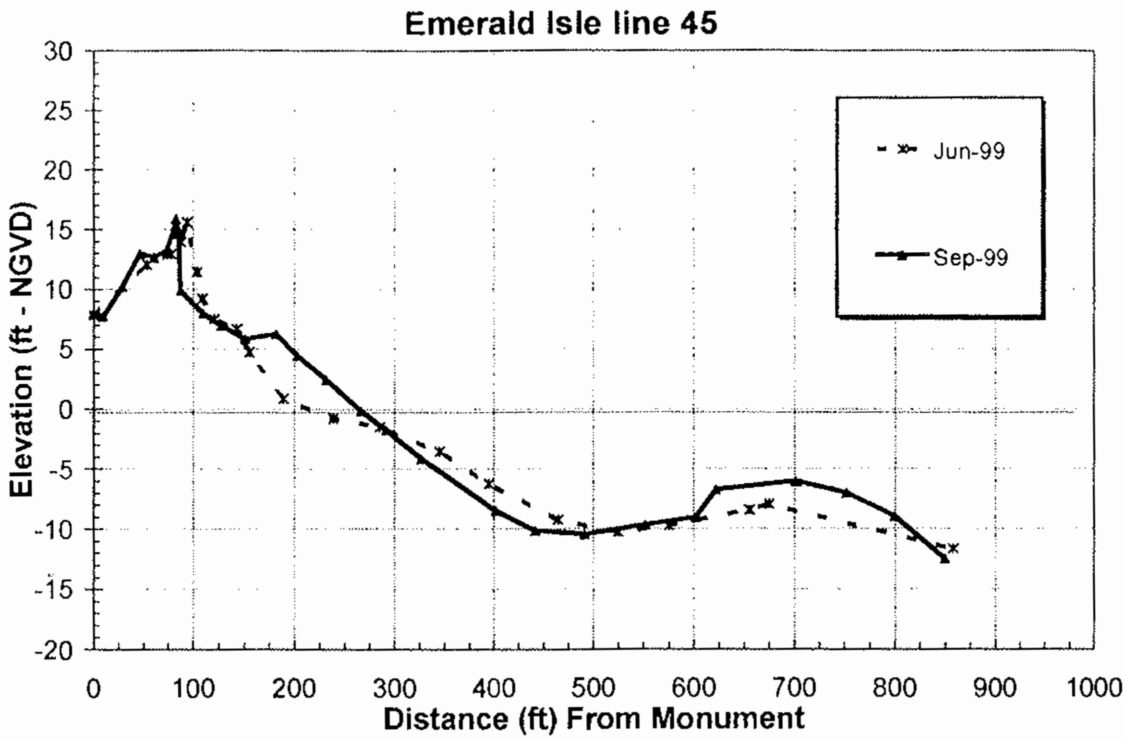

Emerald Isle Line 42
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

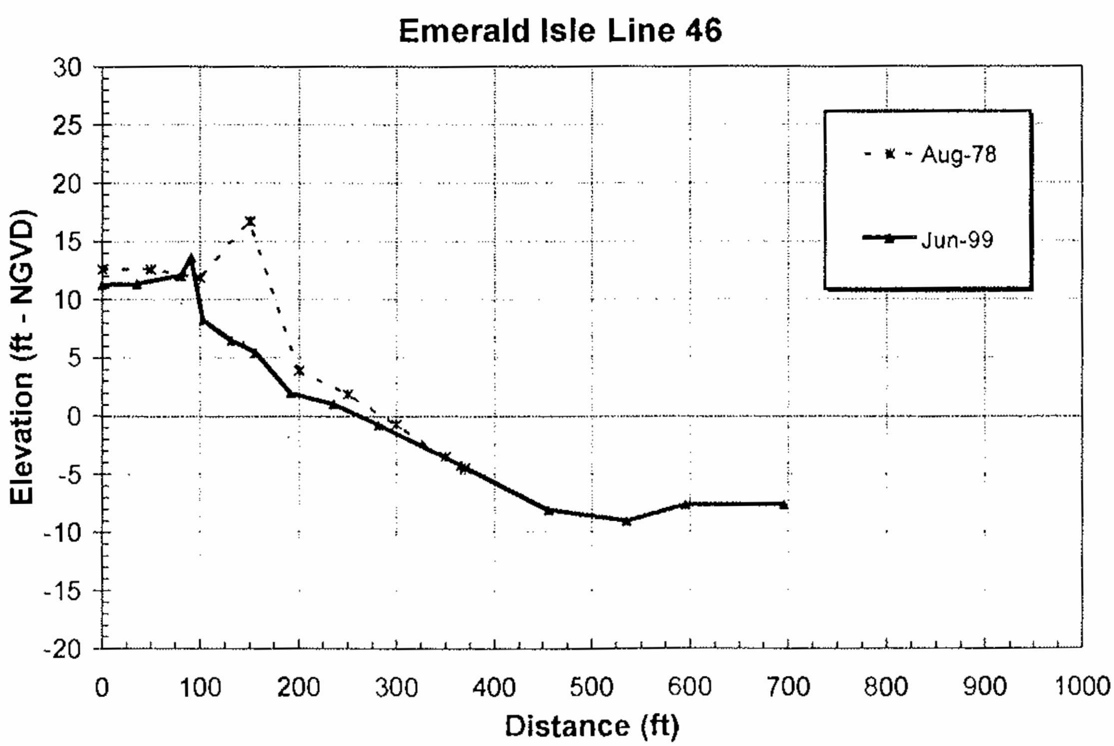


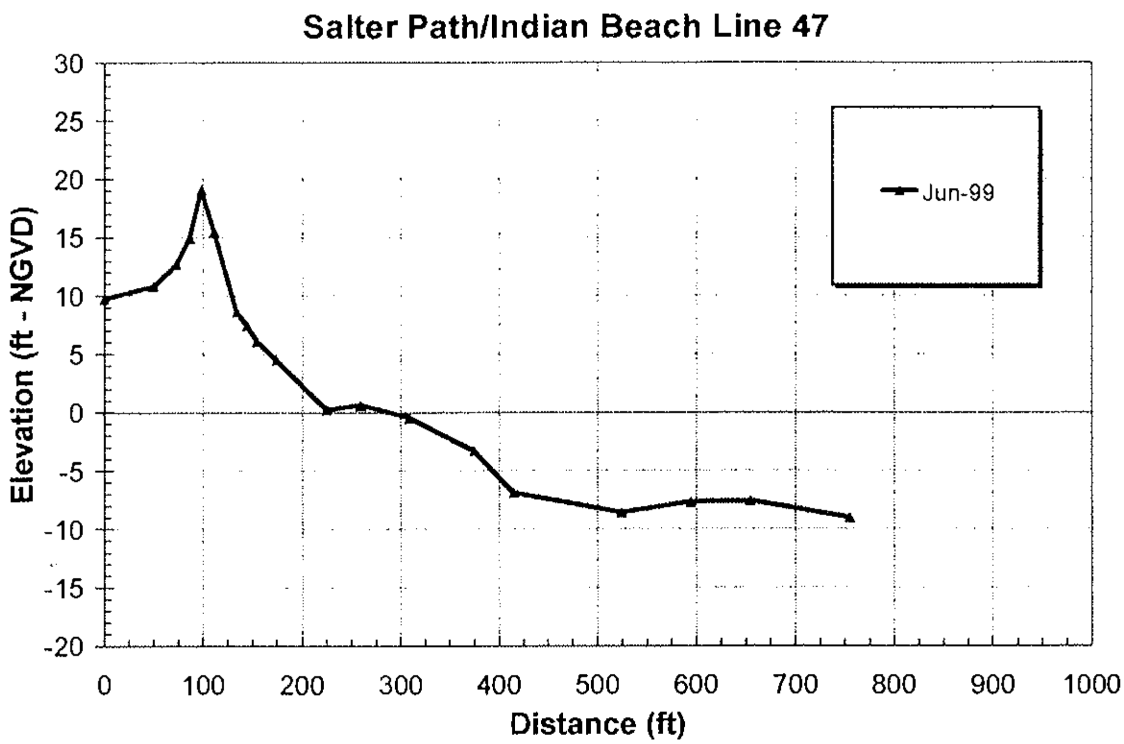
Emerald Isle Line 43
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



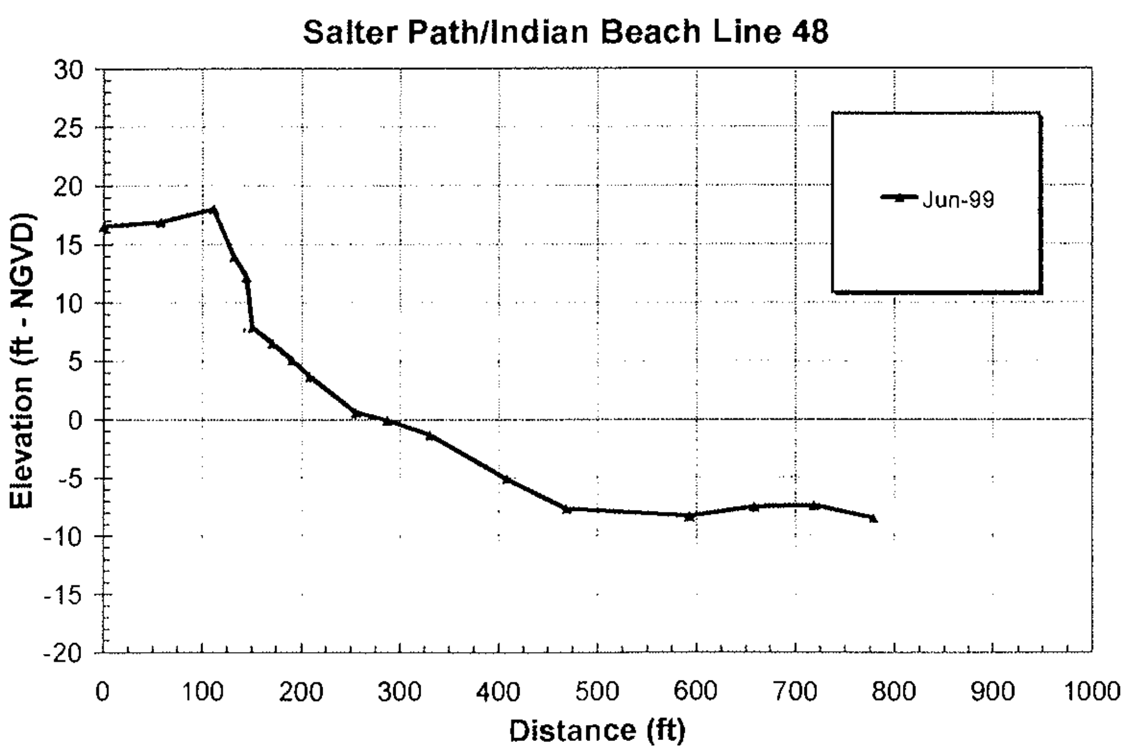
Emerald Isle Line 44
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle line 45
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

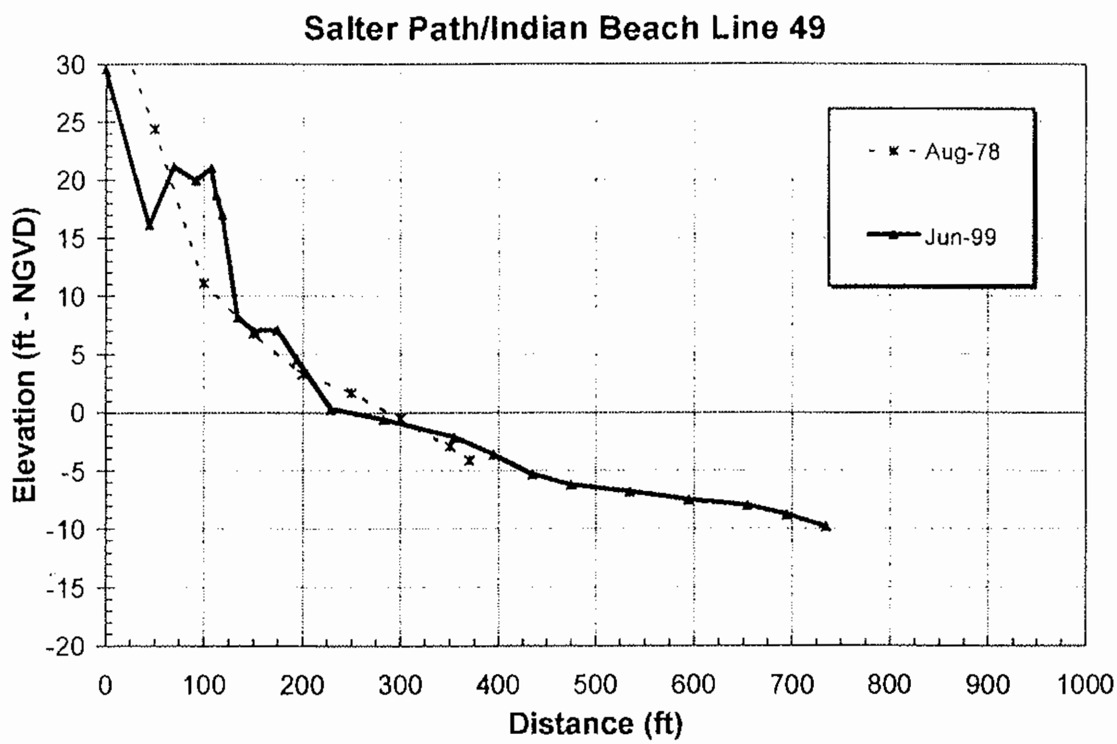

Emerald Isle Line 46
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

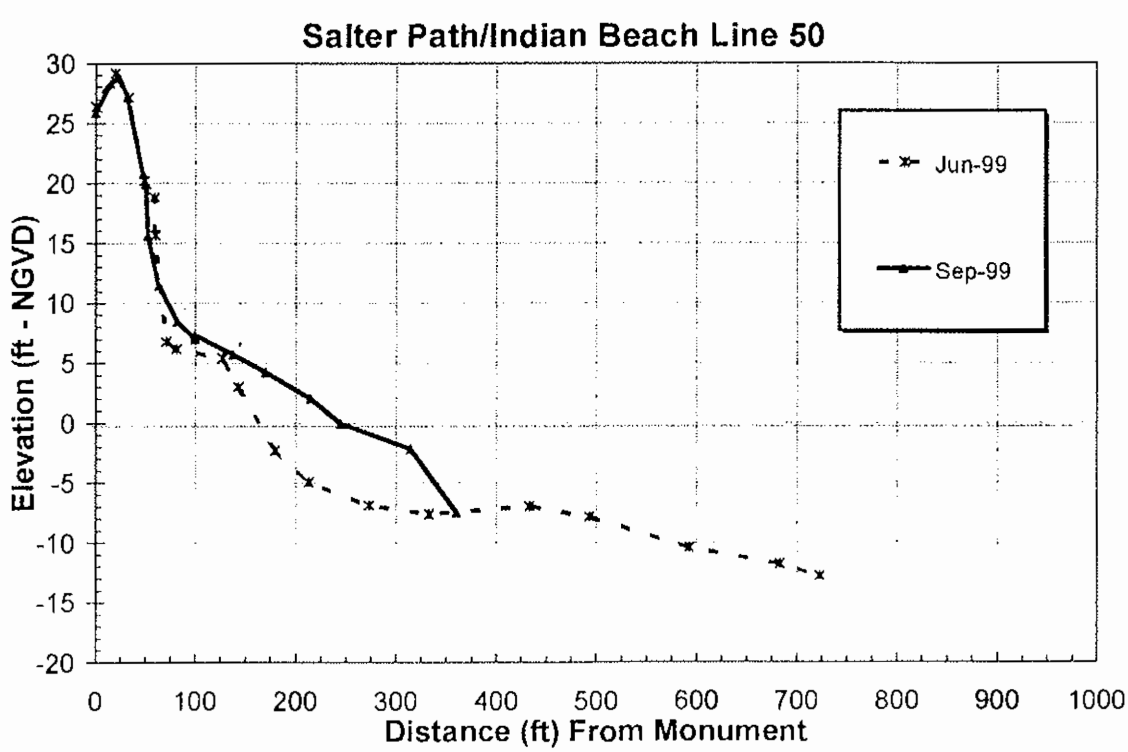


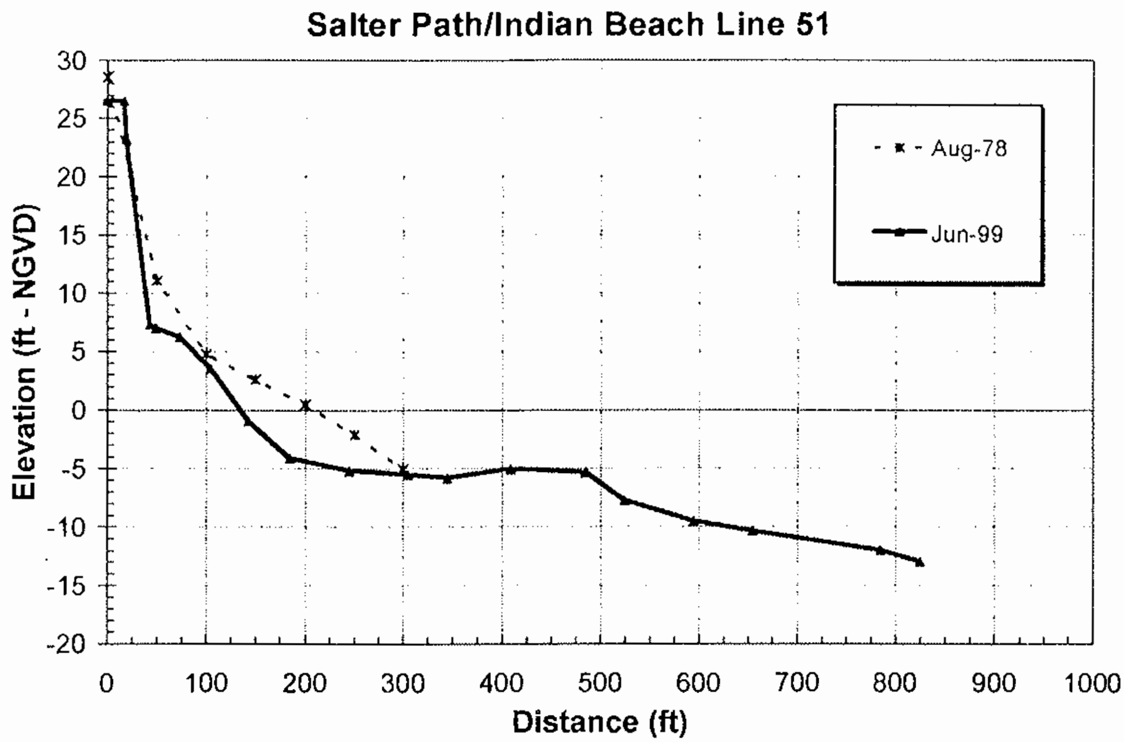
Salter Path/Indian Beach Line 47
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)
Jun-99

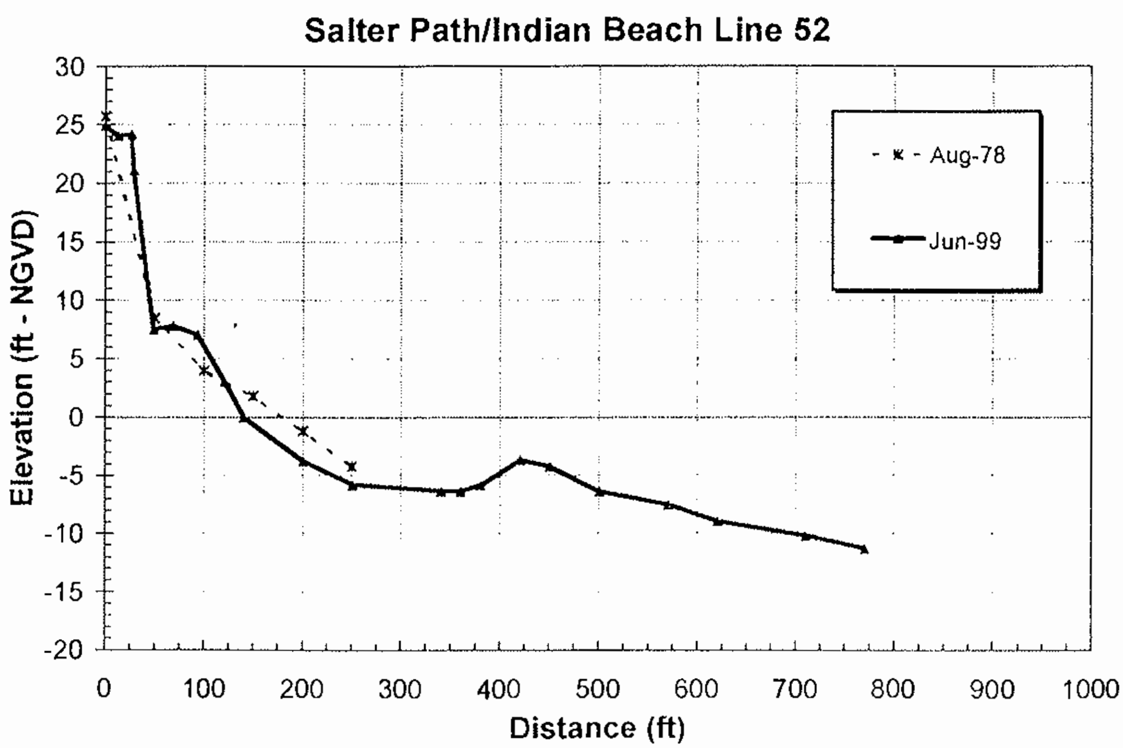


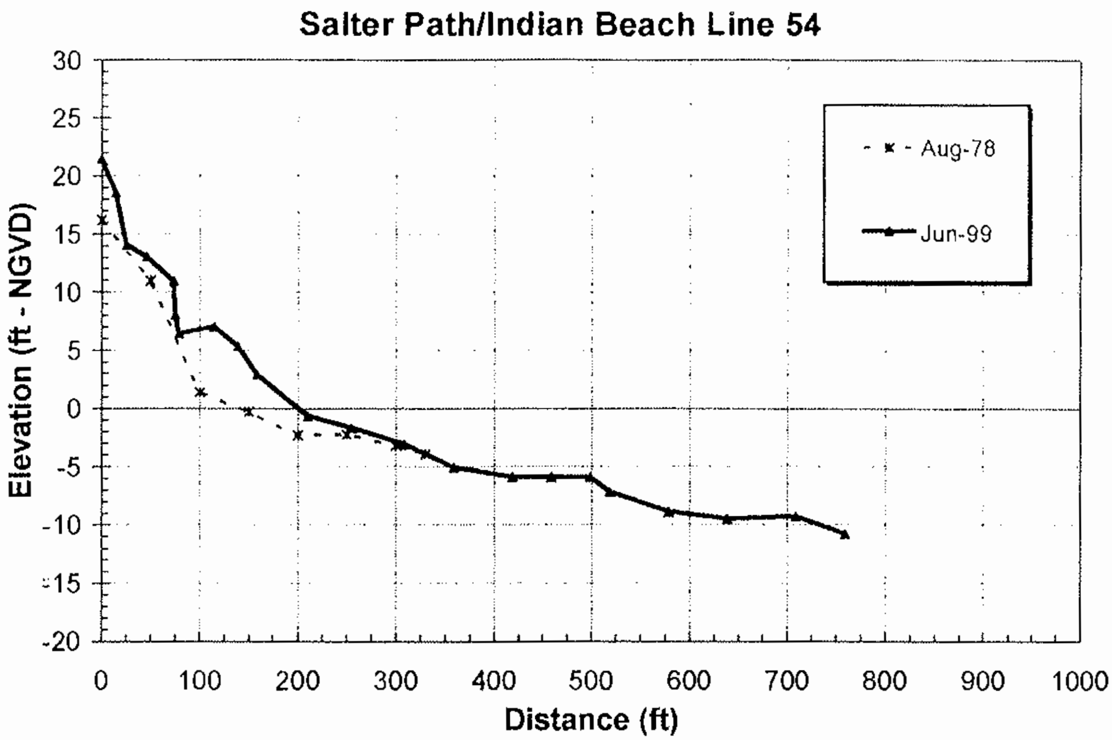
Salter Path/Indian Beach Line 48
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)
Jun-99

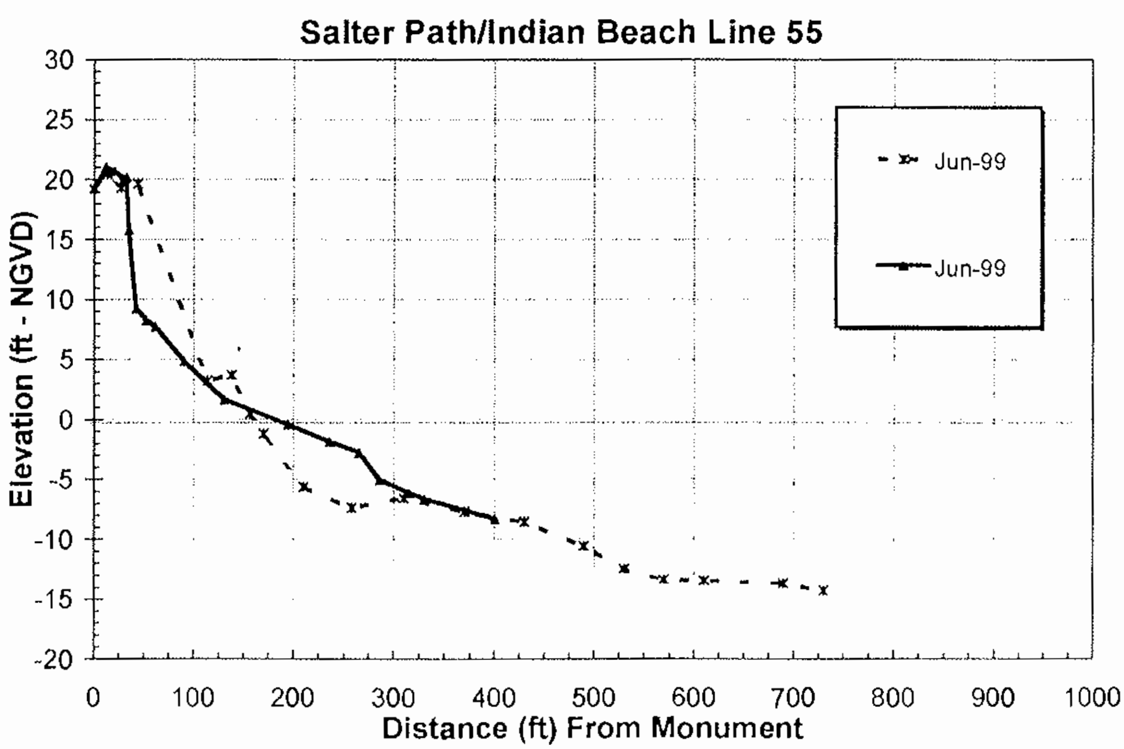

Salter Path/Indian Beach Line 49
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

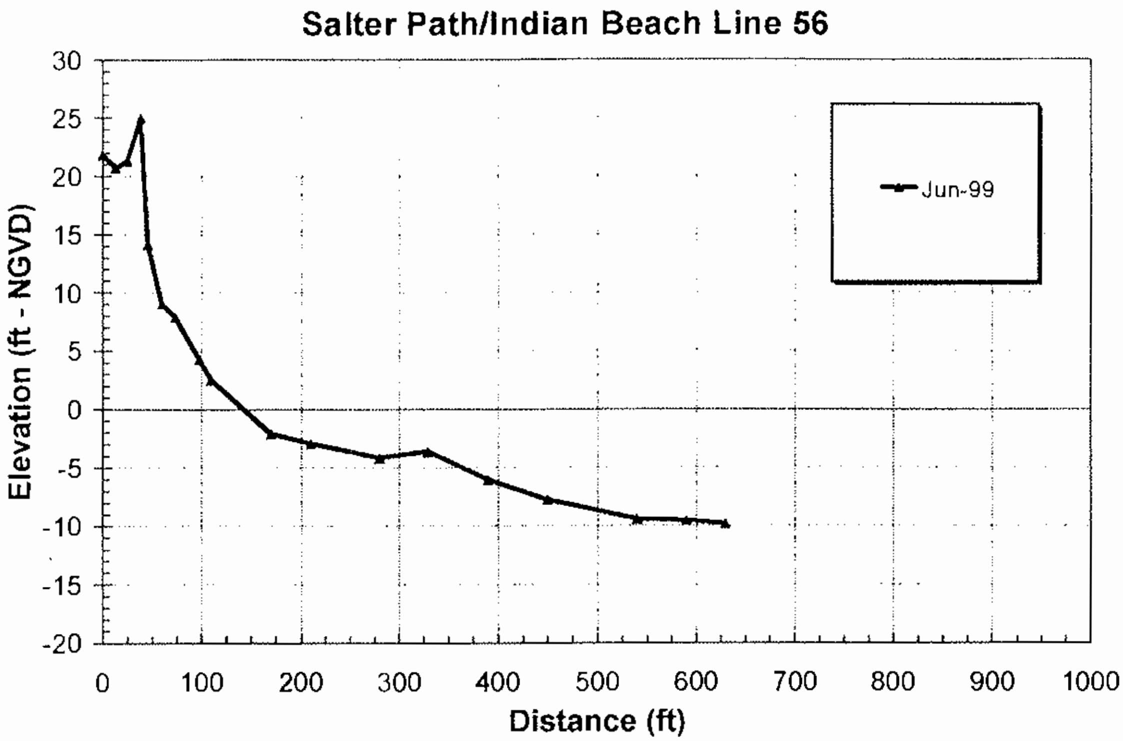

Salter Path/Indian Beach Line 50
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Salter Path/Indian Beach Line 51
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Aug-78
Jun-99

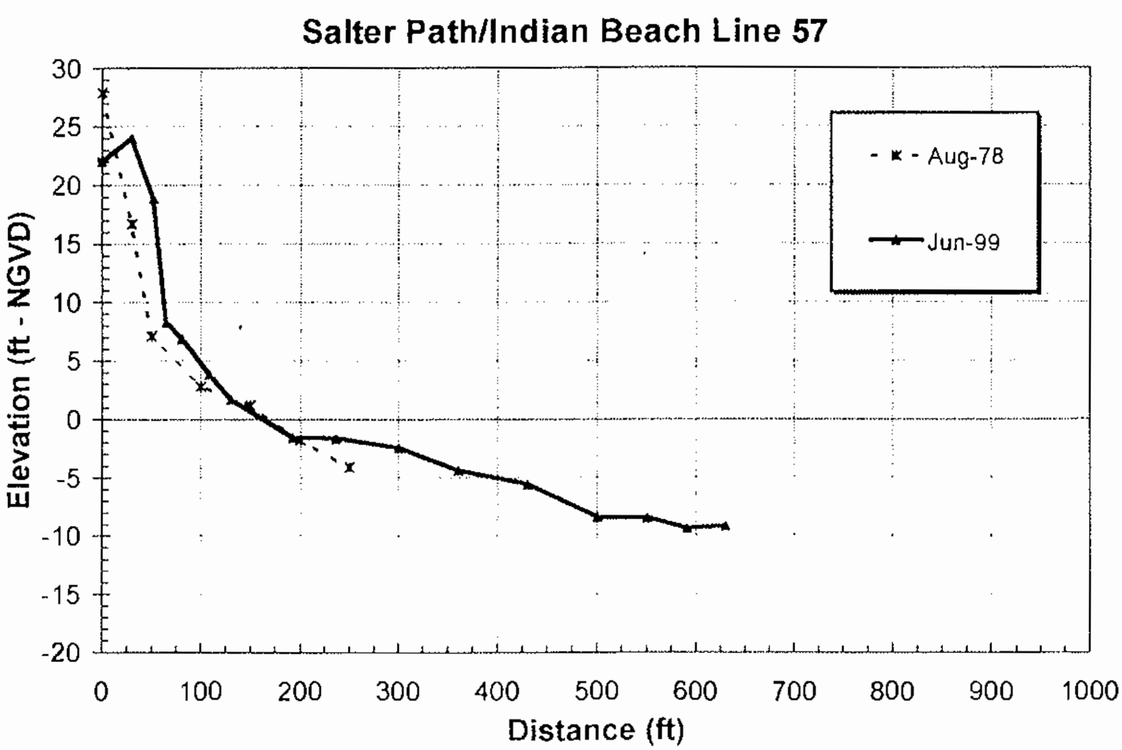

Salter Path/Indian Beach Line 52
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Aug-78
Jun-99


Salter Path/Indian Beach Line 54
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

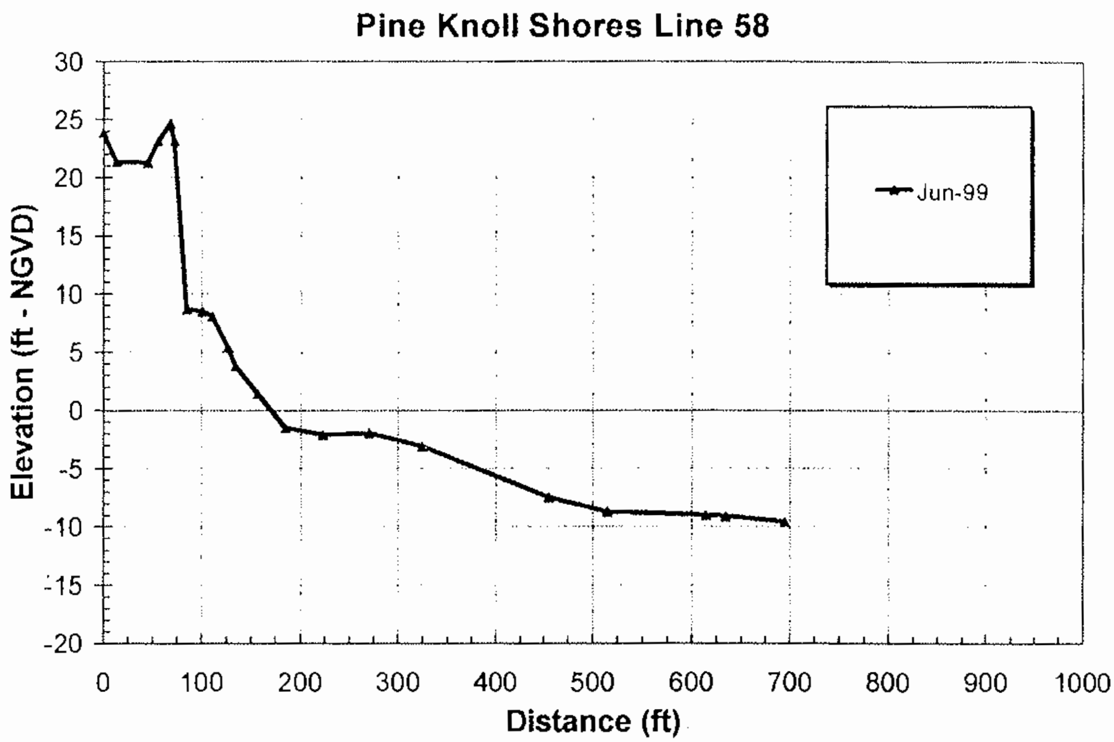

Salter Path/Indian Beach Line 55
Jun-99
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument



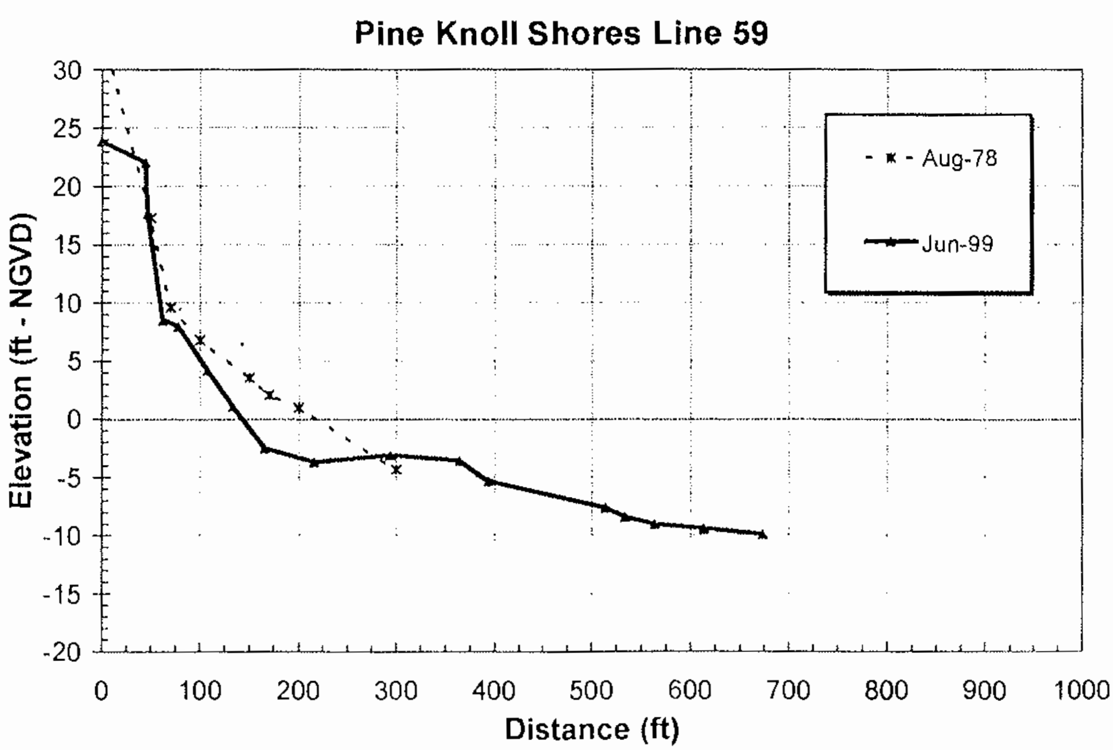
Salter Path/Indian Beach Line 56
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



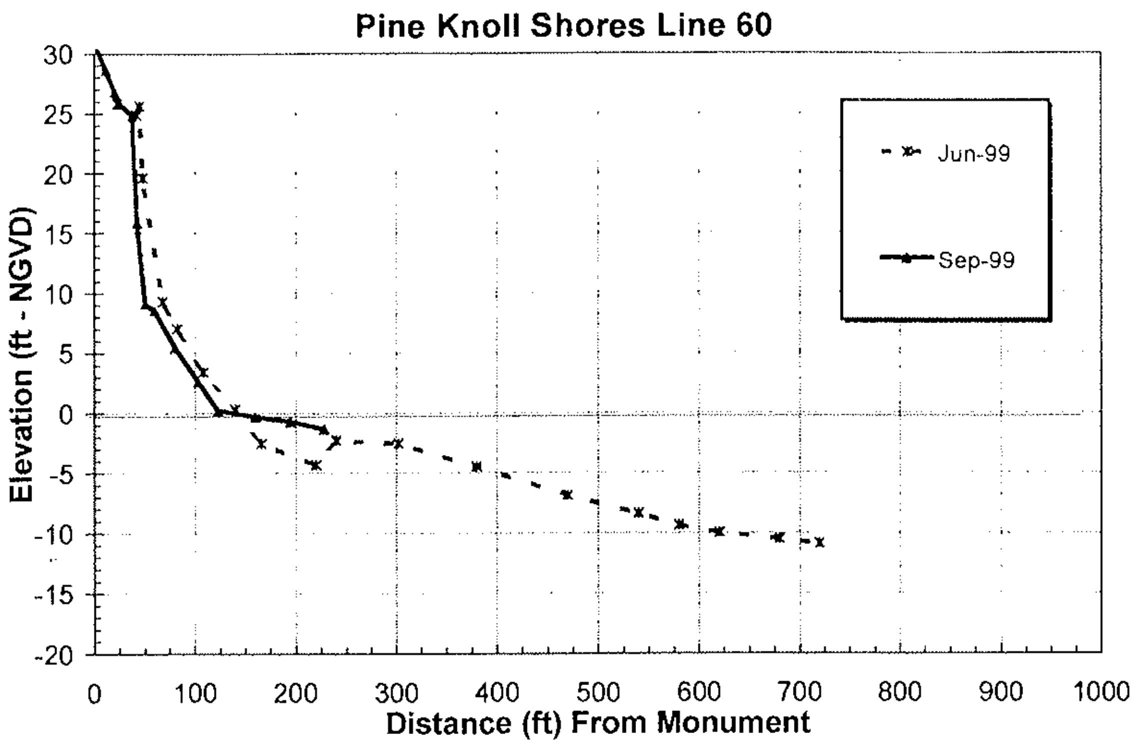
Salter Path/Indian Beach Line 57
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

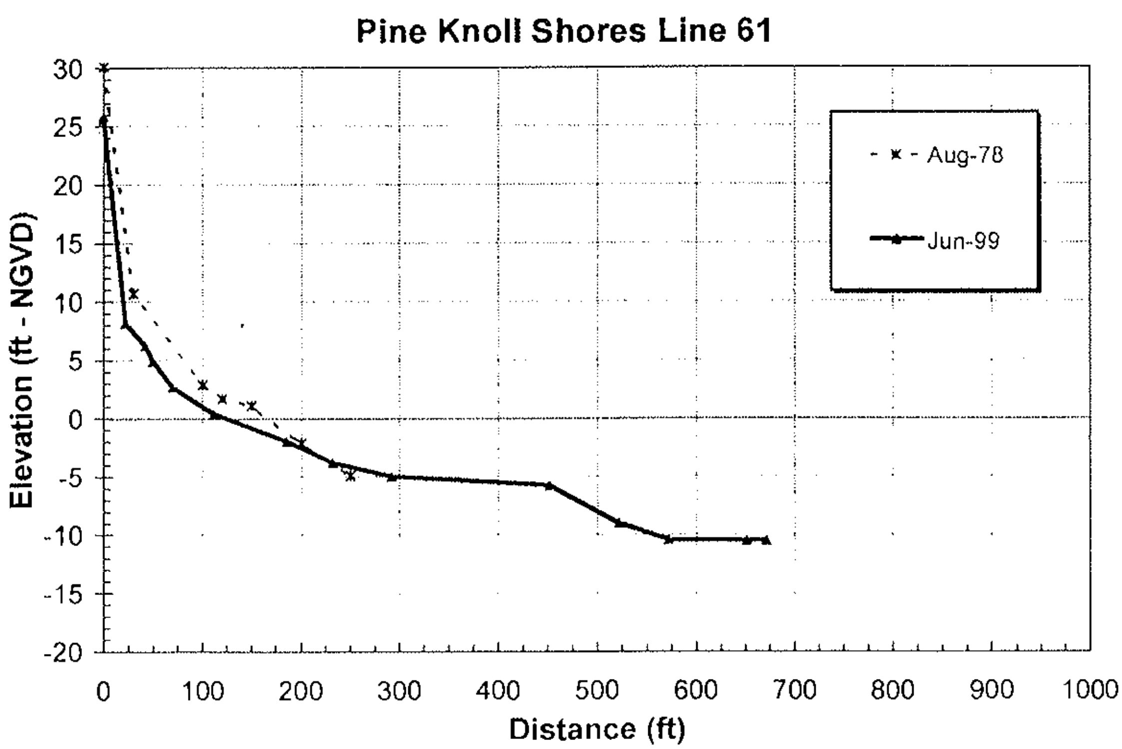


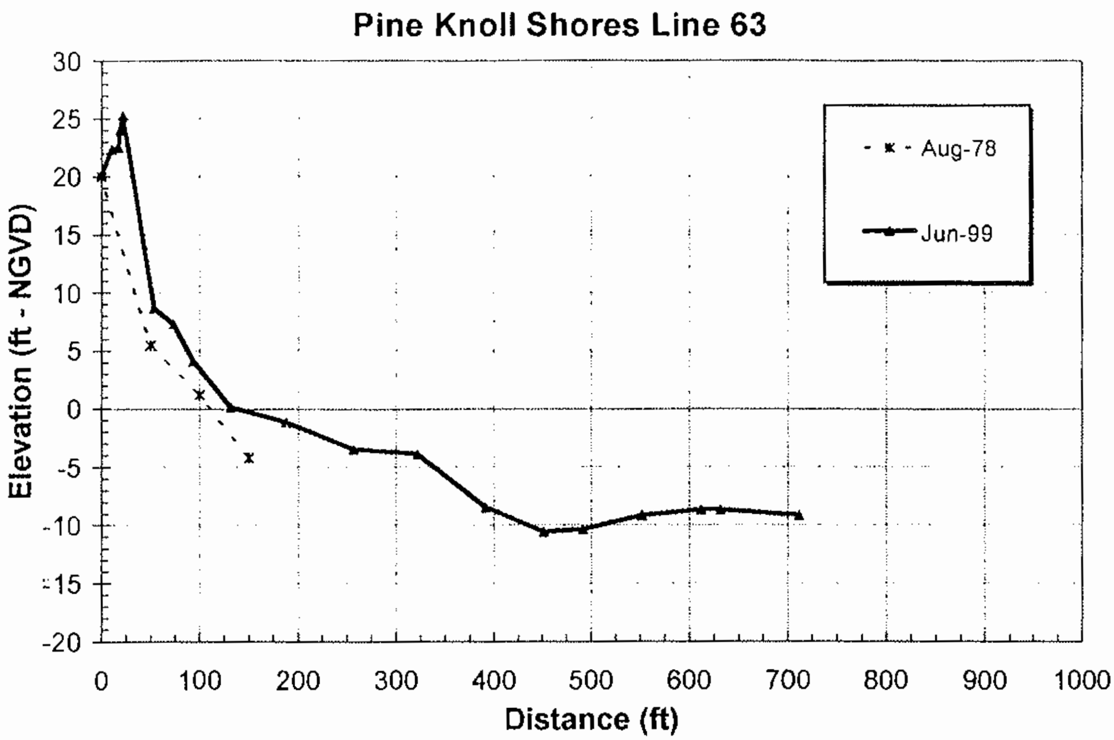
Pine Knoll Shores Line 58
Elevation (ft - NGVD)
Distance (ft)
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

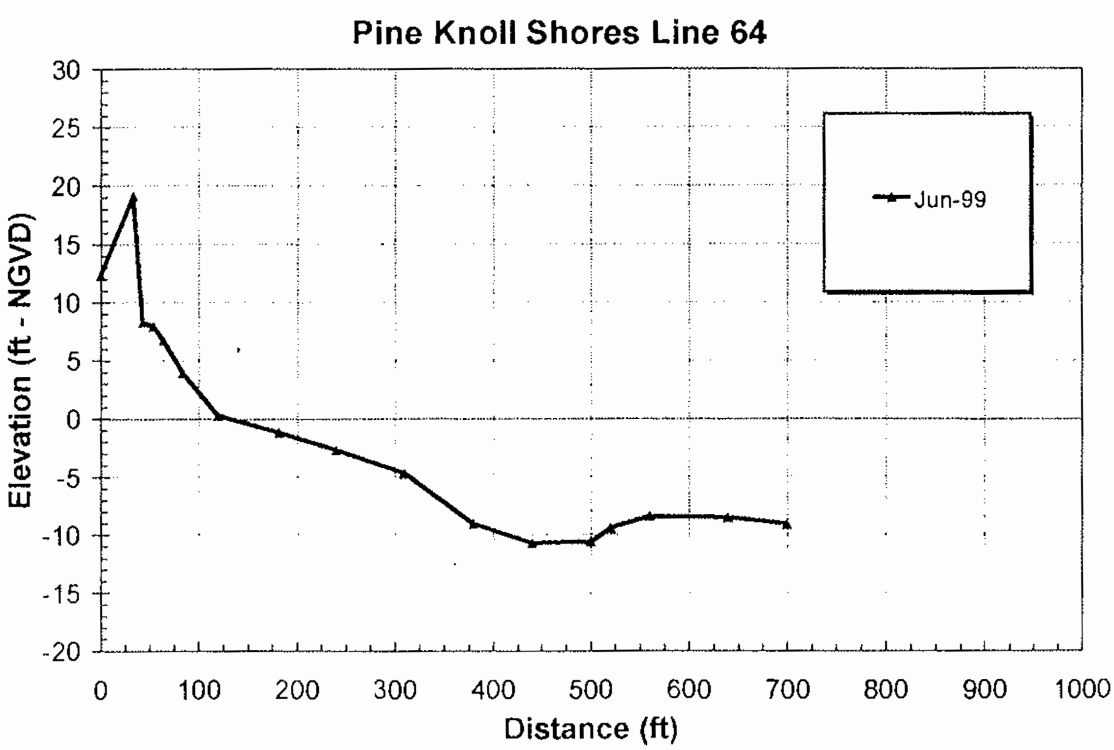


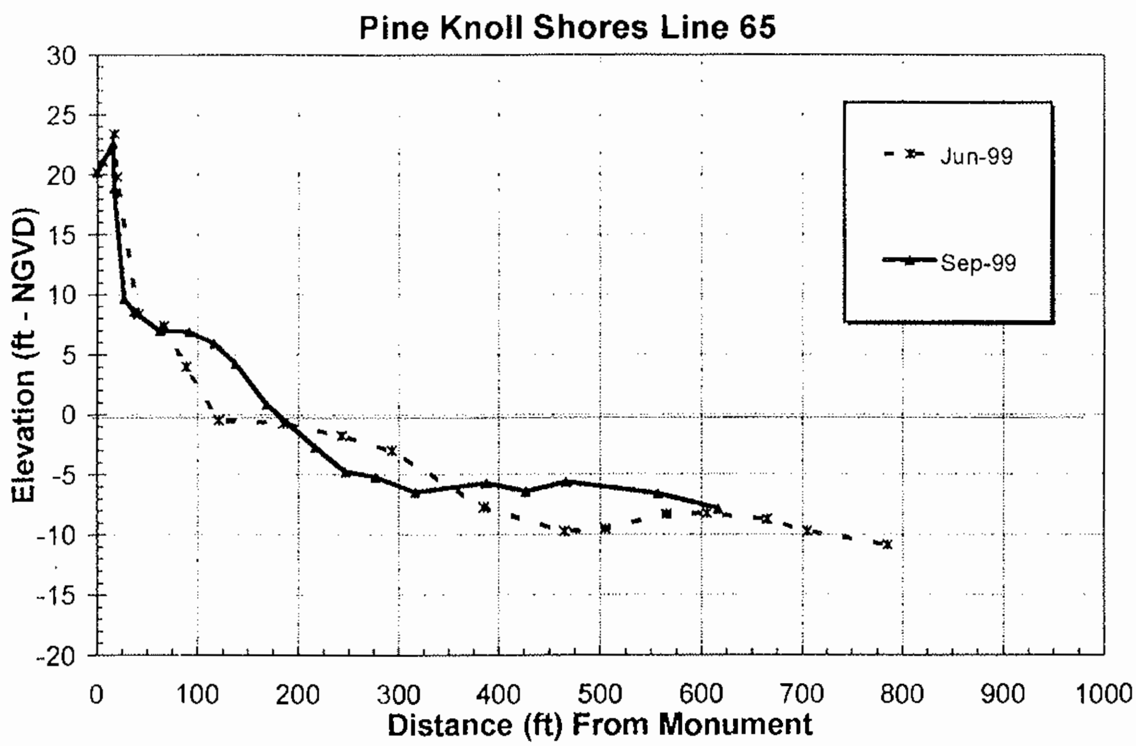
Pine Knoll Shores Line 59
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Pine Knoll Shores Line 60
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Sep-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

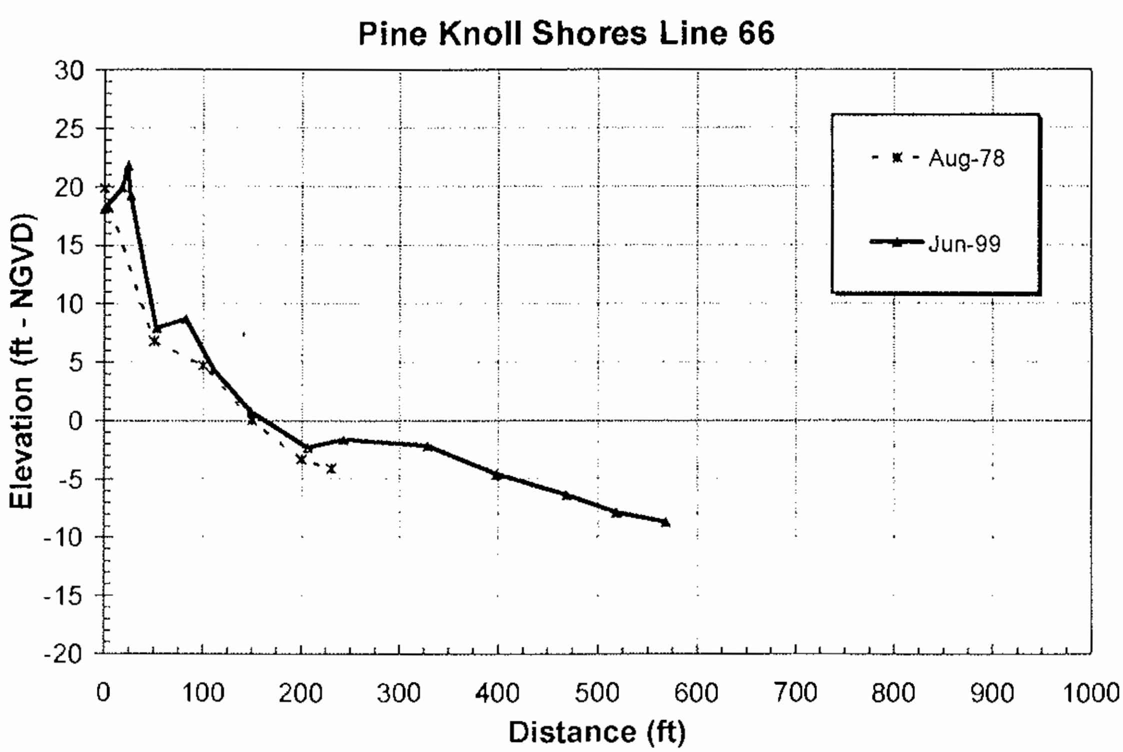

Pine Knoll Shores Line 61
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Pine Knoll Shores Line 63
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Pine Knoll Shores Line 64
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

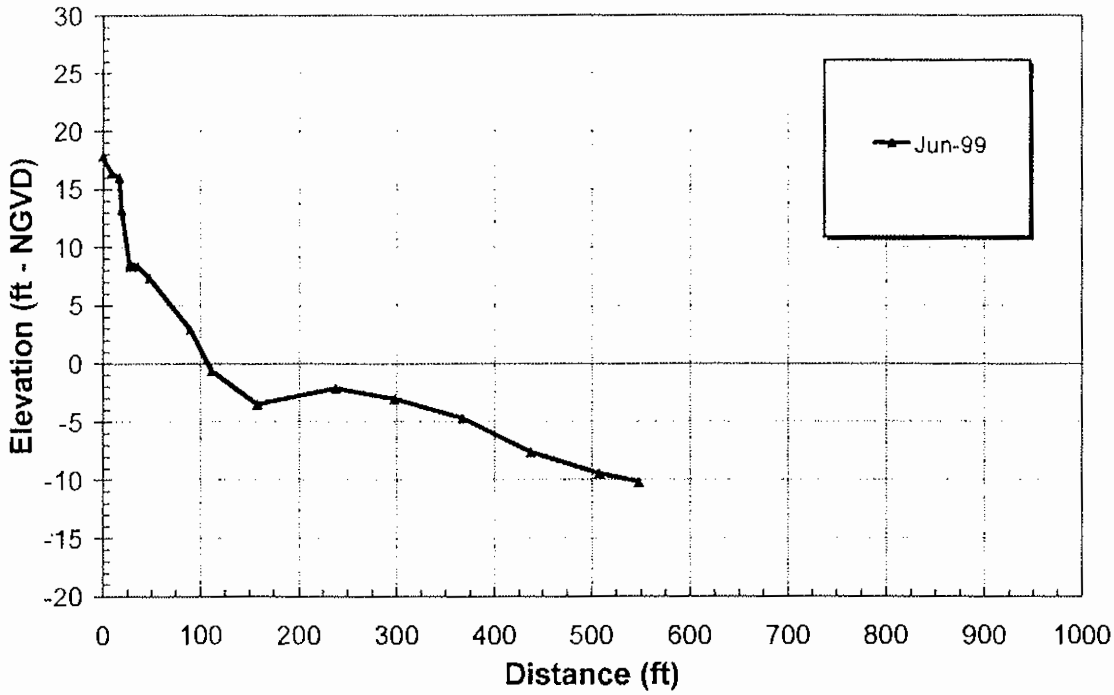


Pine Knoll Shores Line 65
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

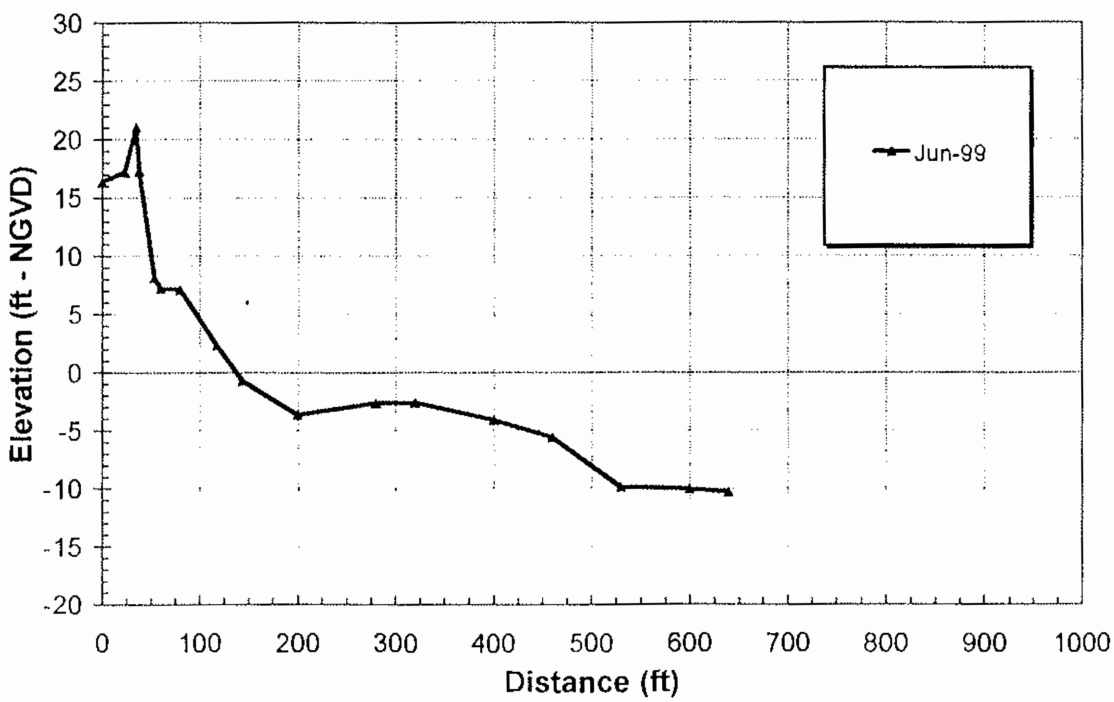


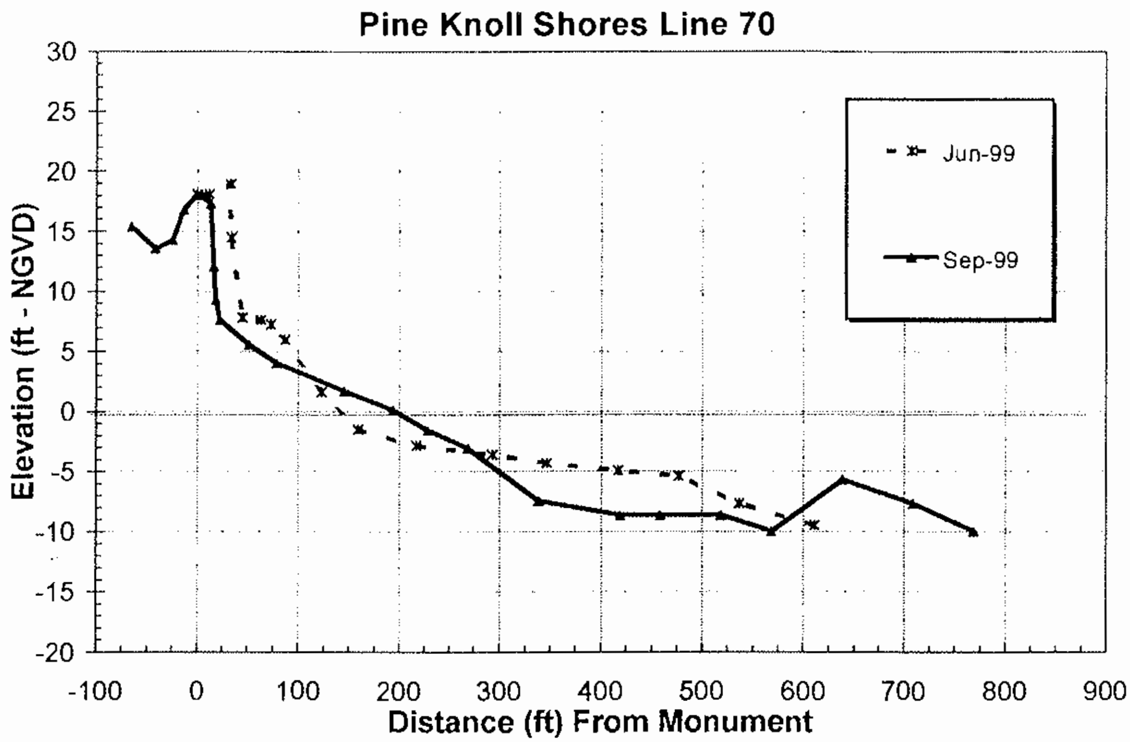
Pine Knoll Shores Line 66
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

Pine Knoll Shores Line 68

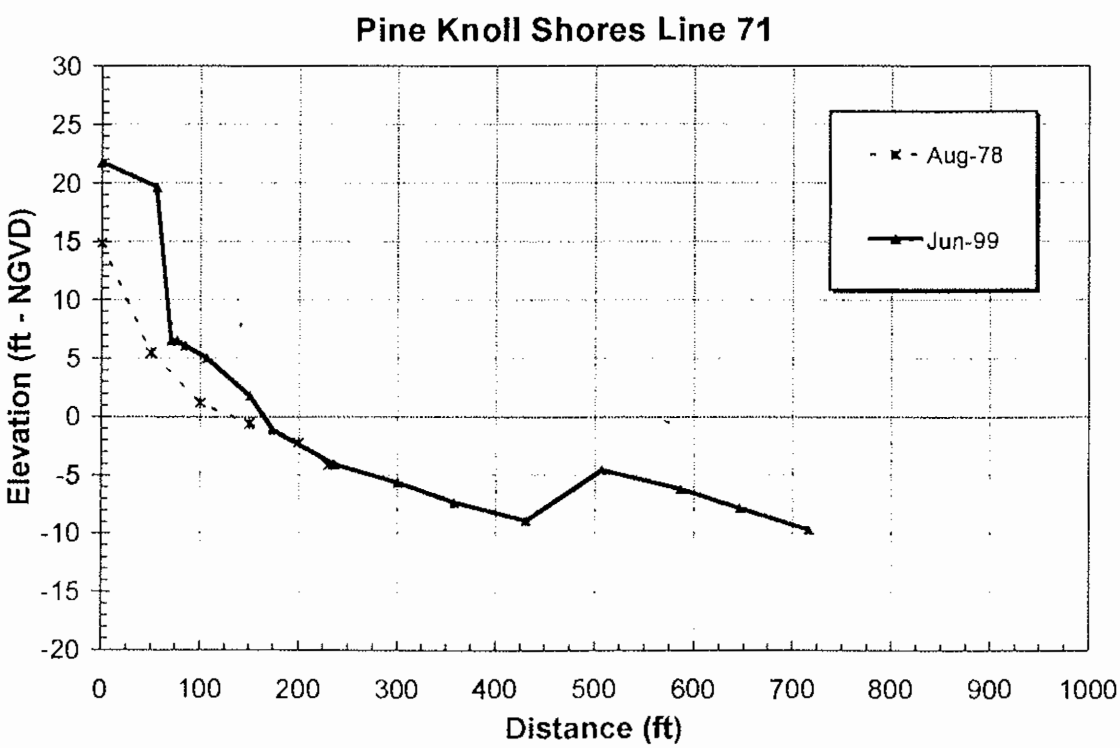


Pine Knoll Shores Line 69

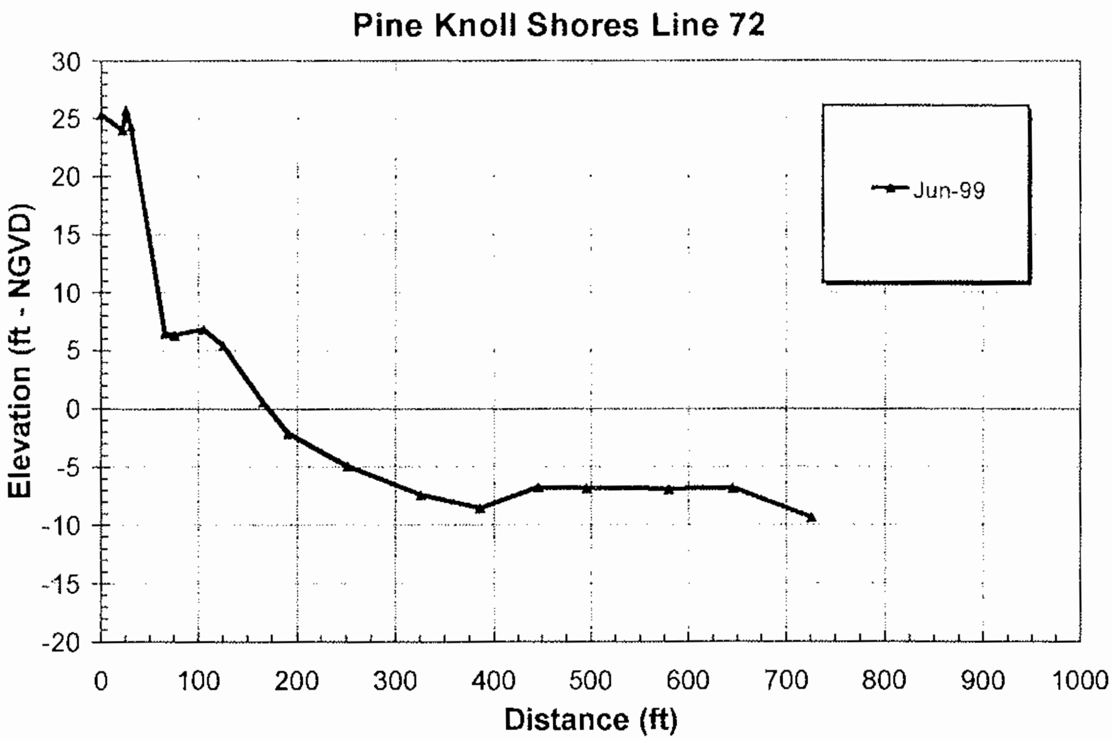


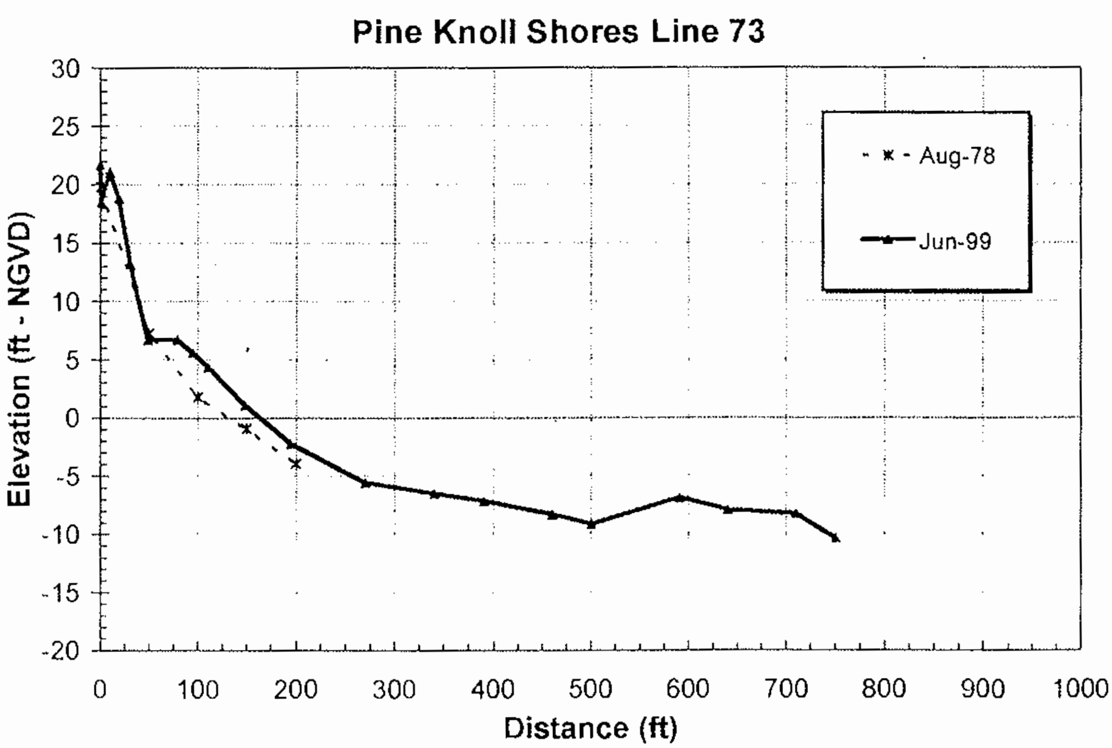


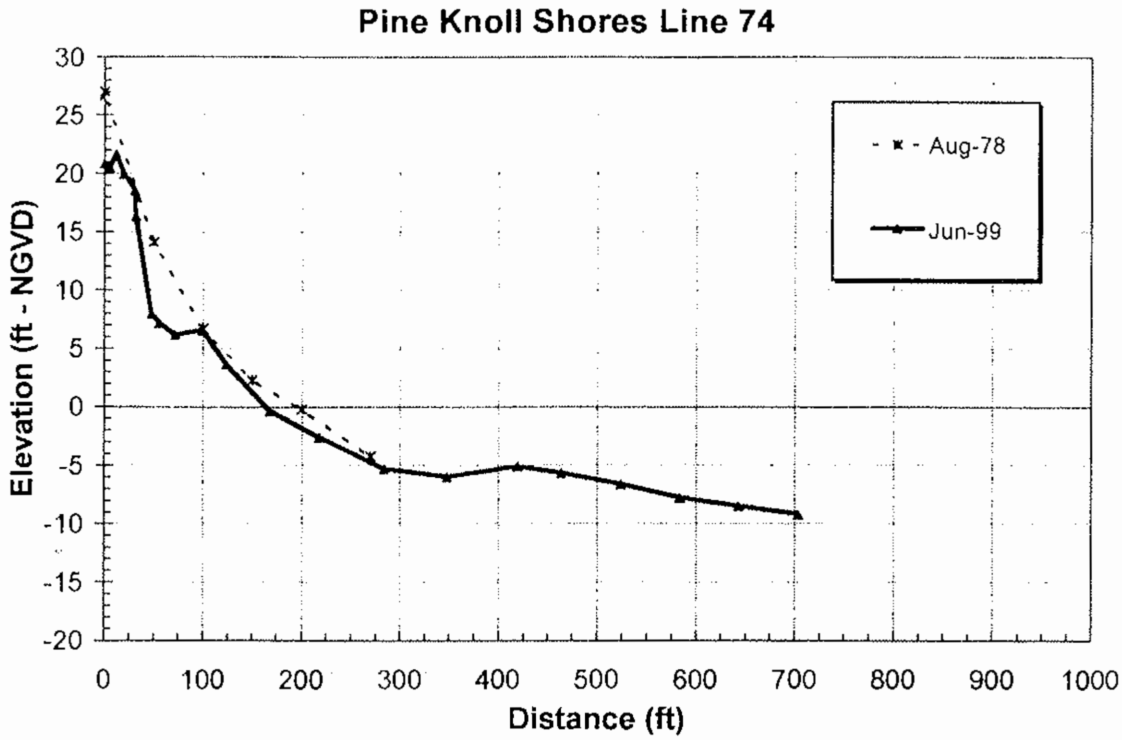
Pine Knoll Shores Line 70
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Sep-99
30
25
20
15
10
5
0
-5
-10
-15
-20
-100
0
100
200
300
400
500
600
700
800
900



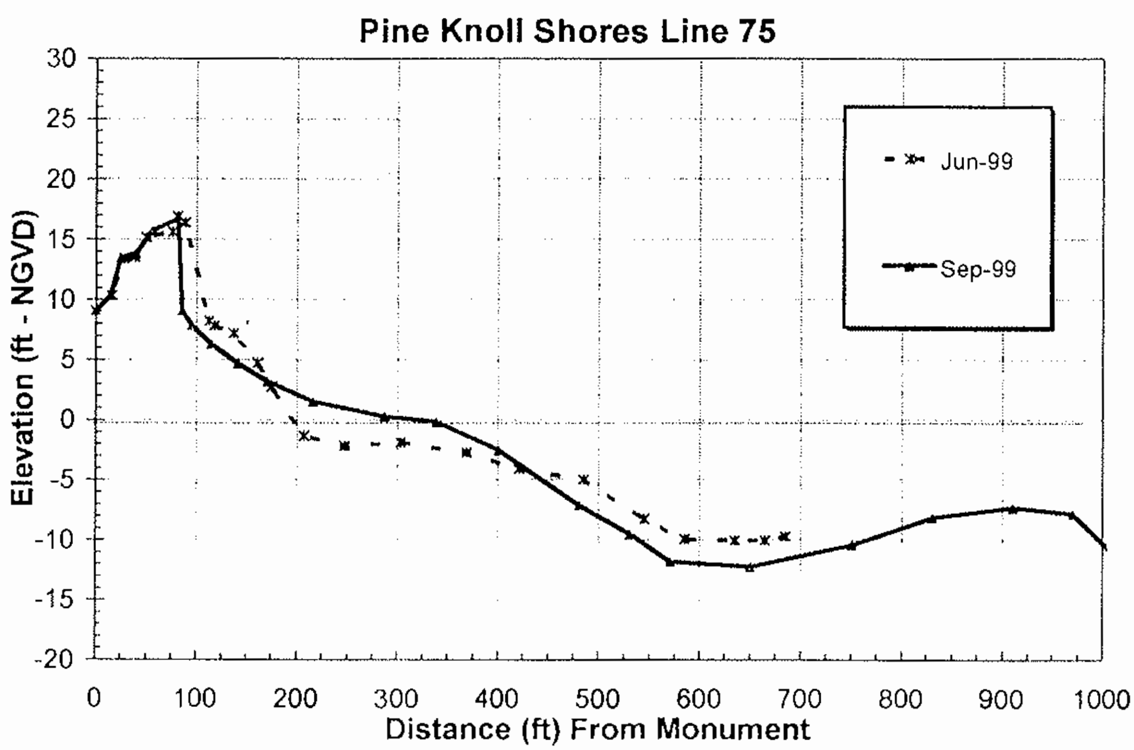
Pine Knoll Shores Line 71
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Pine Knoll Shores Line 72
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

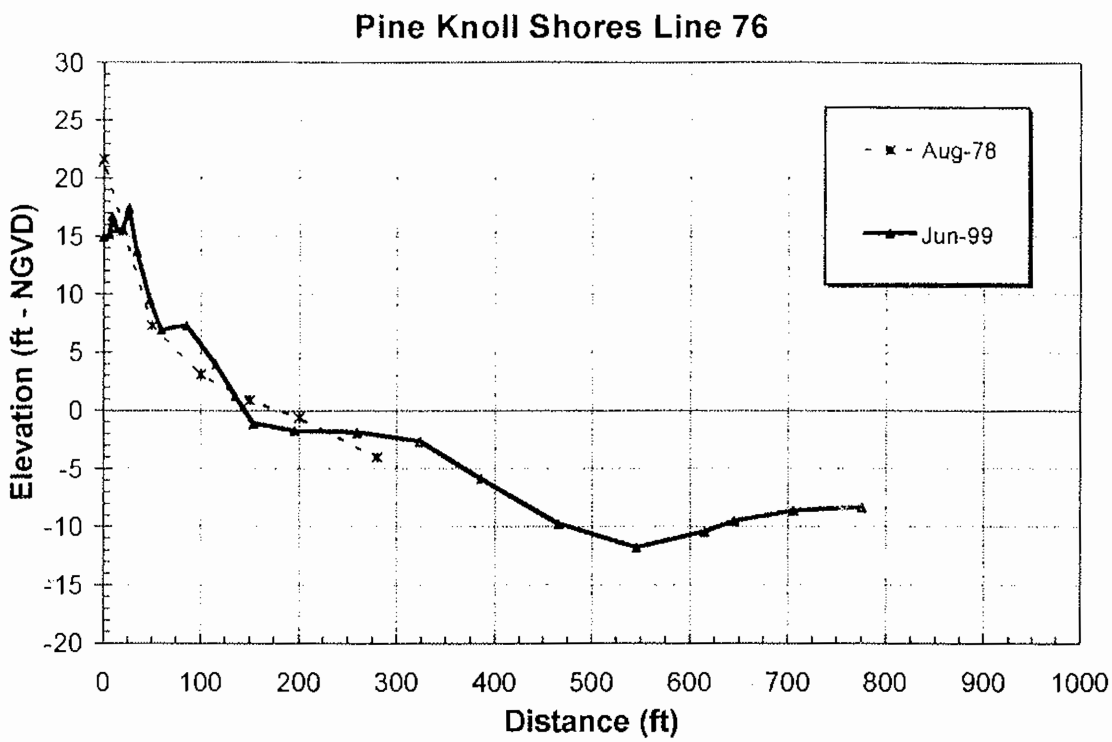

Pine Knoll Shores Line 73
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



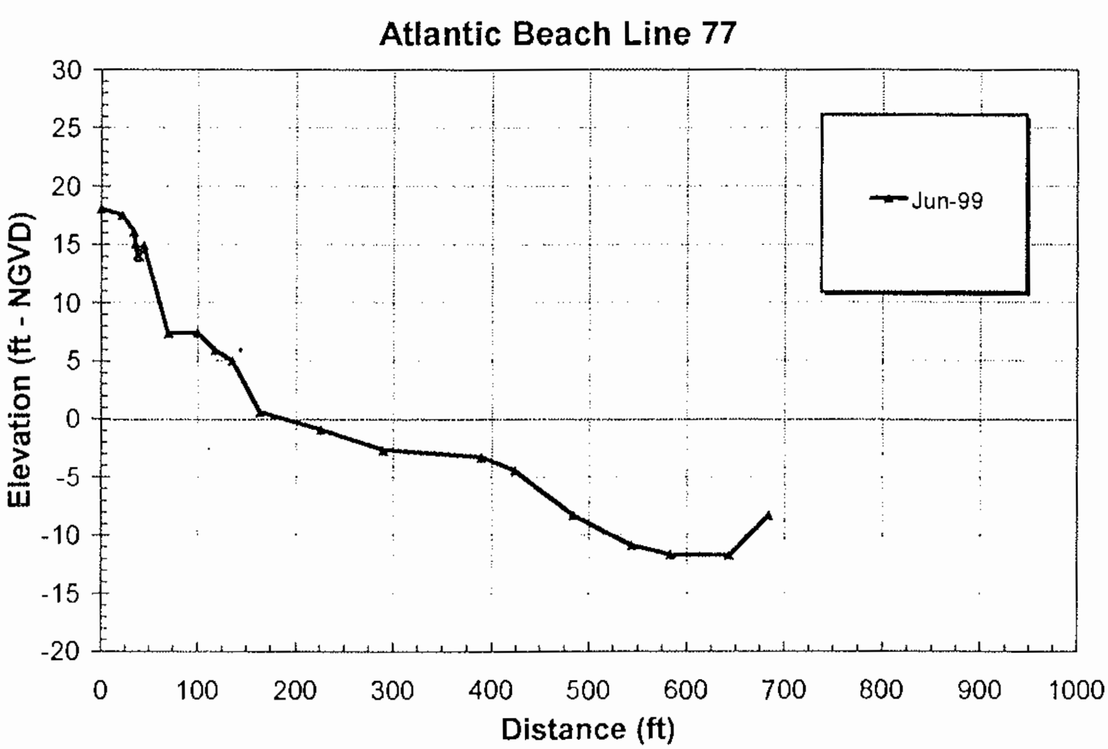
Pine Knoll Shores Line 74
30
25
20
15
10
5
0
-5
-10
-15
-20
Elevation (ft - NGVD)
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)
Aug-78
Jun-99



Pine Knoll Shores Line 75
30
25
20
15
10
5
0
-5
-10
-15
-20
Elevation (ft - NGVD)
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Jun-99
Sep-99



Pine Knoll Shores Line 76
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)



Atlantic Beach Line 77
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

Bogue Banks
Seabeach Amaranth Survey 9/12/01

moving east to west, starting at Atlantic Beach (approx. Raleigh Street) and ending at Shipwreck Ln.

	Latitude	Longitude	# of Plants
1	N 34 41.857	W 76 44.561	1
2	34 41.863	76 44.789	1
3	34 41.865	76 44.790	1
4	34 41.866	76 44.791	3
5	34 41.862	76 44.794	1
6	34 41.860	76 44.928	1
7	34 41.862	76 44.986	1
8	34 41.861	76 44.998	1
9	34 41.864	76 45.014	1
10	34 41.864	76 45.045	1
11	34 41.864	76 45.049	1
12	34 41.863	76 45.074	1
13	34 41.855	76 45.089	1
14	34 41.855	76 45.105	1
15	34 41.859	76 45.123	1
16	34 41.855	76 45.152	2
17	34 41.856	76 45.156	1
18	34 41.861	76.45.175	1
19	34 41.858	76 45.184	1
20	34 41.860	76 45.189	1
21	34 41.862	76 45.190	1
22	34 41.858	76 45.249	3
23	34 41.857	76 45.250	1
24	34 41.853	76 45.382	1
25	34 41.856	76 45.410	1
26	34 41.852	76 45.432	1
27	34 41.854	76 45.466	1
28	34 41.849	76 45.518	2
29	34 41.857	76 45.532	5
30	34 41.852	76 45.550	1
31	34 41.853	76 45.559	4
32	34 41.851	76 45.567	2
33	34 41.852	76 45.573	11
34	34 41.845	76 45.731	1
35	34 41.849	76 45.742	1
36	34 41.849	76 45.747	2
37	34 41.848	76 45.760	2
38	34 41.848	76 45.782	3
39	34 41.851	76 45.801	2
40	34 41.849	76 45.806	6
41	34 41.847	76 45.812	6
42	34 41.848	76 45.821	2
43	34 41.848	76 45.832	2
44	34 41.846	76 45.851	9

	Latitude	Longitude	# of Plants
45	34 41.845	76 45.889	2
46	34 41.848	76 45.899	1
47	34 41.847	76 45.930	1
48	34 41.846	76 45.954	1
49	34 41.846	76 45.984	1
50	34 41.848	76 45.994	1
51	34 41.846	76 46.050	3
52	34 41.846	76 46.060	2
53	34 41.846	76 46.069	3
54	34 41.845	76 46.095	1
55	34 41.837	76 46.195	1
56	34 41.832	76 46.301	1
57	34 41.831	76 46.424	1
58	34 41.832	76 46.429	1
59	34 41.832	76 46.440	1
60	34 41.832	76 46.474	2
61	34 41.830	76 46.491	1
62	34 41.831	76 46.520	1
63	34 41.828	76 46.527	1
64	34 41.826	76 46.661	1
65	34 41.821	76 46.691	1
66	34 41.804	76 46.936	2
67	34 41.804	76 46.989	3
68	34 41.801	76 46.906	6
69	34 41.801	76 47.119	3
70	34 41.800	76 47.131	4
71	34 41.797	76 47.172	5
72	34 41.794	76 47.245	1
73	34 41.753	76 47.878	1
74	34 41.753	76 47.891	1
75	34 41.751	76 47.903	1
76	34 41.737	76 48.047	1
77	34 41.735	76 48.076	1
78	34 41.735	76 48.089	1
79	34 41.731	76 48.119	1
80	34 41.727	76 48.203	1
81	34 41.727	76 48.212	2
82	34 41.709	76 48.438	2
83	34 41.693	76 48.637	1
84	34 41.668	76 48.913	1
85	34 41.668	76 48.927	1
86	34 41.665	76 48.965	1
87	34 41.663	76 48.968	2
88	34 41.659	76 49.010	1
89	34 41.544	76 50.106	1
90	34 41.540	76 50.148	2
91	34 41.535	76 50.194	1
92	34 41.522	76 50.330	1
93	34 41.510	76 50.449	1

	Latitude	Longitude	# of Plants
94	34 41.509	76 50.462	1
95	34 41.443	76 51.015	1
96	34 41.426	76 51.137	2
97	34 41.421	76 51.196	2
98	34 41.419	76 51.217	1
99	34 41.417	76 51.235	4
100	34 41.413	76 51.282	3
101	34 41.411	76 51.295	4
102	34 41.409	76 51.314	2
103	34 41.403	76 51.357	1
104	34 41.401	76 51.371	3
105	34 41.397	76 51.385	2
106	34 41.317	76 52.020	1
107	34 41.310	76 52.081	1
108	34 41.297	76 52.215	1
109	34 41.281	76 52.338	1
110	34 41.201	76 52.998	15
111	34 41.193	76 53.038	10
112	34 41.160	76 53.225	1
113	34 41.154	76 53.258	4
114	34 41.152	76 53.292	3
115	34 41.141	76 53.365	3
116	34 41.060	76 53.918	1
117	34 41.061	76 53.934	1
118	34 41.056	76 53.960	1
119	34 41.051	76 53.999	1
120	34 41.047	76 54.035	1
121	34 41.042	76 54.064	3
122	34 41.041	76 54.073	2
123	34 41.039	76 54.103	1
124	34 41.035	76 54.107	1
125	34 41.034	76 54.111	1
126	34 41.030	76 54.146	1
127	34 41.030	76 54.153	1
128	34 41.028	76 54.167	1
129	34 41.024	76 54.183	3
130	34 41.021	76 54.208	1
131	34 41.019	76 54.222	1
132	34 41.018	76 54.229	1
133	34 41.009	76 54.267	1
134	34 40.825	76 55.529	1
135	34 40.710	76 56.291	1
136	34 40.652	76 56.665	1
137	34 40.620	76 56.863	1
138	34 40.551	76 57.258	1
139	34 40.530	76 57.397	2
140	34 40.495	76 57.607	1
141	34 40.447	76 57.958	1
142	34 40.393	76 58.263	1

	Latitude	Longitude	# of Plants
143	34 40.353	76 58.472	3
144	34 40.321	34 58.686	1
145	34 40.305	76 58.791	1
146	34 40.275	76 58.900	1
147	34 40.209	76 59.272	2
148	34 40.196	76 59.353	1
149	34 40.183	76 59.426	2
150	34 40.170	76 59.507	1
151	34 40.163	76 59.541	1
152	34 40.159	76 59.574	1
153	34 40.140	76 59.676	1
154	34 40.134	76 59.716	1
155	34 40.129	76 59.732	1
156	34 40.078	77 00.002	1
157	34 39.919	77 00.780	1
158	34 39.814	77 01.252	1
159	34 39.794	77 01.324	1
160	34 39.509	77 02.588	1
161	34 39.456	77 02.823	3
162	34 39.449	77 02.851	9
163	34 39.445	77 02.867	1
164	34 39.443	77 02.879	1
165	34 39.438	77 02.892	1
166	34 39.356	77 03.235	1
167	34 39.169	77 03.929	1
168	34 39.054	77 04.359	1
169	34 38.921	77 04.804	2
170	34 38.923	77 04.808	1
171	34 38.921	77 04.810	1
		total # =	313

FINAL
ENVIRONMENTAL ASSESSMENT

Bogue Banks
Beach Nourishment Project
Carteret County North Carolina

Submitted in Conjunction with the
National Environmental Policy Act and
Federal Review of Permit Application ID 200000362

APPLICANTS:

Carteret County
Town of Pine Knoll Shores
Town of Indian Beach
Town of Emerald Isle

US Army Corps of Engineers
PO Box 1890 Wilmington NC 28402-1890

Prepared by:

Coastal Science & Engineering PLLC
804 Arendell Avenue (1) Morehead City NC 28557

19 OCTOBER 2001

FINAL ENVIRONMENTAL ASSESSMENT

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

PAGE

TABLE OF CONTENTS (CONTINUED)

PAGE

TABLE OF CONTENTS (CONTINUED)

PAGE

TABLE OF CONTENTS (CONTINUED)

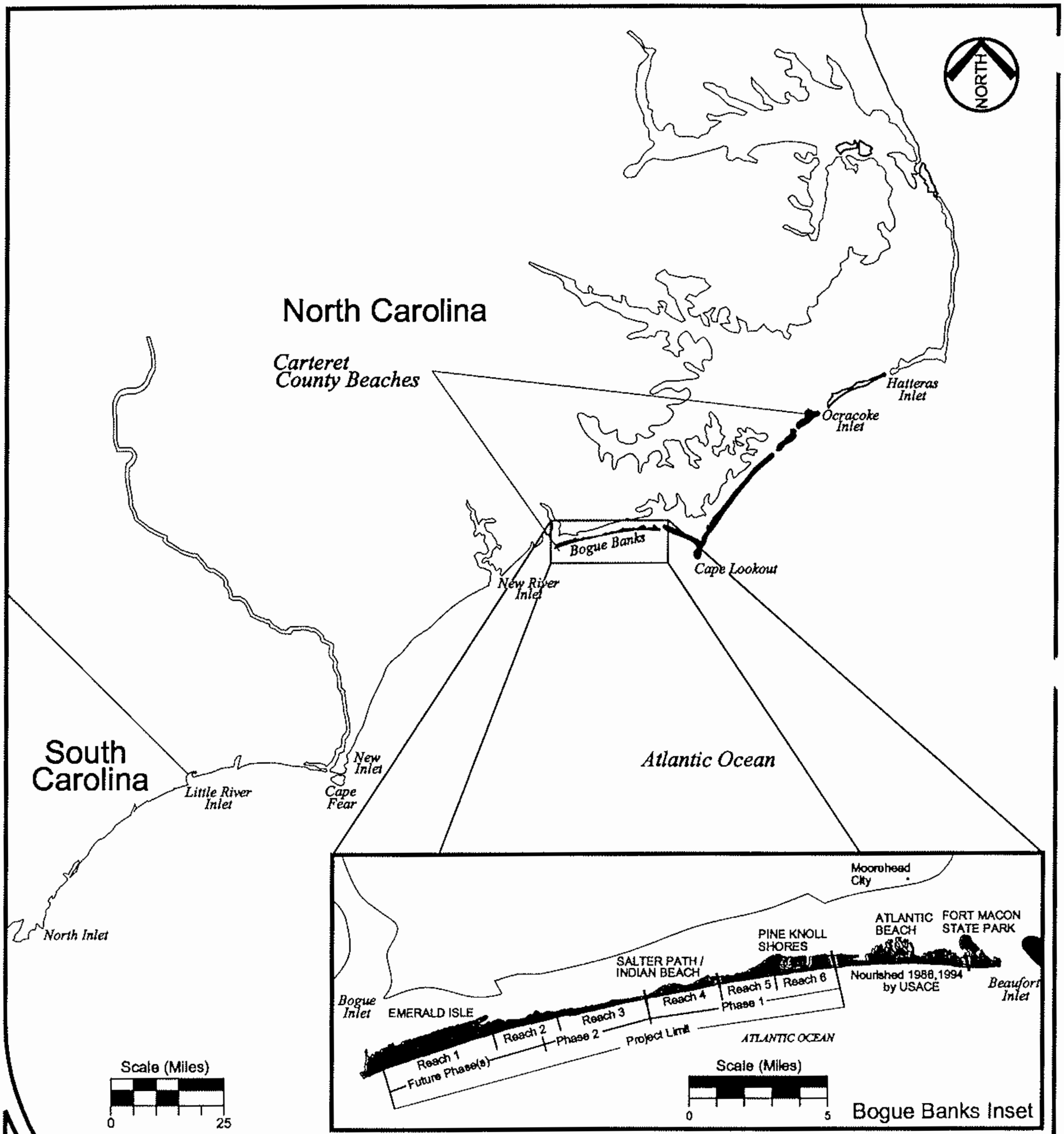
1.0 PURPOSE OF AND NEED FOR ACTION

This Environmental Assessment (EA) is prepared in accordance with the National Environmental Policy Act of 1969 (as amended) to address environmental concerns associated with a proposed beach nourishment project along Bogue Banks, North Carolina (Fig 1.1). The proposed beach nourishment project is being locally sponsored by Carteret County in conjunction with the Towns of Pine Knoll Shores, Indian Beach, and Emerald Isle. Funding is proposed by a combination of locally generated revenue sources.

Bogue Banks is one of the most stable barrier islands along the North Carolina coast (Pilkey et al 1998). However, it has sustained chronic erosion averaging about 2 feet per year (ft/yr) over the past 20-30 years (Benton et al, NCDEHNR 1992). Between 1996 and 1999, it was directly impacted by five hurricanes including *Fran* (1996) and *Floyd* (1999). The combination of chronic erosion and accelerated erosion associated with recent hurricanes has eliminated the dry beach along much of the island, caused erosion of the foredune, and damaged habitable structures.

During the past five years, an estimated 90 percent of the property owners in the proposed project area have scraped the beach and rebuilt their foredune at least twice. Many have scraped yearly including winter 2000 and winter 2001 when there were no major storms. A high percentage of property owners have rebuilt dune walkovers at least two or three times in the past five years.

The purpose of the proposed project is to restore the recreation beach and its associated habitats in the chronic erosion areas of Bogue Banks, eliminate the need for annual beach scraping, eliminate the need for frequent rebuilding of dune walkovers, allow foredunes to evolve naturally, and preserve property values and the tax base of Carteret County.



Site location map for Bogue Banks beach restoration project showing 16.8 mile project length, six (6) reaches defined in the SEPA EIS and Phases (for construction) as presently planned. Only Phase I is funded at this time (June 2001). There is no development or vehicular access to any other beach between Ocracoke Inlet and New River Inlet.

Figure 1.1

Coastal Science & Engineering, LLC

1.1 PROJECT SETTING

The project area includes the beaches reaching from the town limits of Pine Knoll Shores and Atlantic Beach to the western end of Emerald Isle, ~1 mile east of Bogue Inlet. Total project length is 16.8 miles of shoreline.

Bogue Banks is a barrier island with a southward facing ocean shoreline stretching some 25 miles between two large tidal inlets, Bogue Inlet to the west and Beaufort Inlet to the east. The Banks are surrounded by Bogue Sound on the north and Onslow Bay of the Atlantic Ocean on the south.

Of approximately 80 miles of barrier island shoreline located in Carteret County, Bogue Banks is the only developed area. The remainder, made up of Shackleford Banks and Core Banks to Ocracoke Inlet, will remain undeveloped in perpetuity as part of the Cape Lookout National Seashore. Bogue Banks is the only ocean shoreline in Carteret County with convenient vehicle access to all citizens.

1.1.1 Description of the Proposed Action

The proposed project consists of excavating by hydraulic dredge up to 6.7 million cubic yards of beach-quality sediment from ocean borrow areas situated 0.5 to 3.0 miles offshore of the project area. Sediment would be pumped onto the beach between the toe of the existing dune and the low water line and shaped by bulldozers into a profile that closely matches the contours and elevations of the natural beach. Approximately 50 percent of the excavations would be deposited by run-out from the discharge point between mean low water and the outer bar (~500 ft offshore). Typical fill sections would add ~44 to 113 cubic yards per linear foot (cy/ft) of beach and advance the shoreline 50 to 125 ft. The work would be performed in phases covering all or portions of each of six designated reaches according to the following schedule (subject to local funding availability).

- ***Phase I*** (funding approved) – Reaches 4, 5, and 6 – Towns of Pine Knoll Shores and Indian Beach – 7.2 miles – up to 3.1 million cubic yards* – November 2001 to April 2002.
- ***Phase II*** (subject to funding) – Reach 3 and eastern half of Reach 2 – Town of Emerald Isle – 3.0 miles – up to 1.7 million cubic yards* – November 2002 to April 2003.
- ***Phase III*** (subject to funding) – Reach 1 and western half of Reach 2 – Town of Emerald Isle – 6.7 miles – up to 1.9 million cubic yards* – November 2002 to April 2003 or November 2003 to April 2004 (or later environmental window).

[*Pro rata of base volume by reach given in permit application plus overfill volume up to 50 percent of base volume. Emergency nourishment is not planned but may be requested in lieu of or in addition to Phase III work in the event of major storm damage. Such work would be performed if it is associated with FEMA emergency recommendations and sponsorship under existing disaster assistance programs]

Three potential borrow areas (A, B1, and B2) have been sampled and delineated offshore of the project area, and have been tested for sediment compatibility (detailed results in later section of the EA). Sediments have been confirmed over an ~2.6 square-mile area to a section thickness averaging ~3 ft. This yields potentially ~9 million cubic yards of beach-quality sediment with overfill ratios (R_A's) averaging 1.2-1.3. Water depths in borrow areas are ~35-50 ft. The anticipated optimal equipment for excavations will be ocean-certified, self-contained hopper dredges. Such equipment typically excavates shallow trenches (~2-3 ft of section) in each pass (leaving narrow undisturbed areas at the margin of each cut), then travels to a buoyed pipeline anchored close to shore. Discharge to the beach is via submerged pipeline across the surf zone, then by way of shore-based pipe positioned along the dry beach.

The project will be built in ~1-2 mile sections, optimizing the disposition of pipeline. Sections will be pumped into place with the aid of temporary dikes pushed up by bulldozer in the surf zone. Daily operations will directly impact ~ 500-1000 ft of shoreline as work progresses in either direction from the submerged pipeline. Upon completion of a section, the submerged pipe and beach-building equipment will be shifted to the next section.

As construction progresses, sections will be graded to final contours, dressed to eliminate low areas, and opened for use by the community. Support equipment will be shifted out of completed sections as soon as practicable, such that construction activities in a given reach will disrupt normal beach use for only a month or so at any locality.

The finished sections will be allowed to adjust to natural processes for several months. Then in applicable areas, dune fencing and/or dune plantings will be installed.

1.1.2 Project History

The proposed project has been formulated over the past three years with input from state and federal resource agencies and concerned organizations and individuals. The plan results from:

- Coordination with the Carteret County Beach Preservation Task Force (1997-1999).
- A reconnaissance study of erosion prepared by CSE Baird-Stroud (September 1999 copy on file with USACE and federal resource agencies).
- A SEPA final EIS (first draft dated 6 March 2000 and final dated 6 April 2001).
- Permit application for the project (ID 200000362 dated 24 January 2001; public notice dated 16 March 2001).
- Interagency scoping meetings involving federal resource agencies on 12 October 1999 and 11 May 2001.

- Supplement to final SEPA EIS dated 8 May 2001 updating correspondence files, comments, and responses to the March 2001 public notice.

- Biological assessment report submitted to USACE and federal resource agencies on 5 July 2001.

- Community forums.

- Three funding referendums to date.

The applicants propose to perform the first phase of the work during the earliest environmental window for construction between 16 November 2001 and 15 April 2002. [These dates agreed upon 27 August in meetings with state and federal resource agency officials.] Work on subsequent phases would be performed 1-5 years later according to funding approvals within the applicant communities. The only previous nourishment in the project area was a March-24 May 1990 fill involving disposal of sediments dredged from the Atlantic Intracoastal Waterway by the USACE. An estimated 150,000 cy out of 278,000 cy were placed on the proposed project beach in the vicinity of the Ramada Inn in Pine Knoll Shores. The balance was placed along Atlantic Beach out of the proposed project area (USACE 1989, *Environmental Assessment and Finding of No Significant Impact, Maintenance Dredging of the Atlantic Intracoastal Waterway, Wilmington District*). Two other nourishment projects (in 1986 and 1994) have been completed by the USACE along Atlantic Beach involving disposal of >4 million cubic yards of sediment from various Beaufort Inlet navigation projects (USACE 1993).

1.2 SOCIAL AND ECONOMIC DEVELOPMENT

The oceanfront beaches and adjacent properties of Bogue Banks comprise a major social and economic resource for Carteret County. Tourism is the largest industry in Carteret County. The industry contributes ~$208 million annually to the economy of Carteret County, with a direct payroll of more than $38 million to over 3,400 workers. The majority of tourism in the county is centered on Bogue Banks, the only accessible barrier island along a 125-plus-mile length of the North Carolina coastline.

Bogue Banks represents less than 1 percent of Carteret County's land area but accounts for ~43 percent (over $2 billion of the county's $5.4 billion tax base) of Carteret County's ad valorem property tax base (1997). Approximately 61 percent of all locally generated revenues in the county derive from property taxes with the remainder from sales taxes, occupancy taxes, and fees. Nearly 80 percent of Carteret County's tax levy funds Carteret County schools. Out of 8,483 students in Carteret County schools, only 537 (6.3 percent) reside on Bogue Banks (1997-98). Thus, property owners on Bogue Banks provide almost half the funds for county schools but make up less than 10 percent of the school population. Any reduction of the effective subsidy derived from Bogue Banks property and economic activity would result in increased property taxes over the remainder of the county. Loss of the first row of oceanfront properties (which alone comprise nearly 10 percent of the county tax base) would result in a county-wide tax increase of ~$0.05/$100 (from $0.50/$100 to $0.55/$100) to make up for the reduced tax base.

Approximately 90 percent of Bogue Bank's oceanfront is developed, and an estimated 75 percent of remaining platted lots on the barrier island are developed. The island includes a mix of residential, commercial, and governmental development that supports a year-round population upward of 10,000 and a seasonal population exceeding 100,000. Much of the social fabric of the Carteret County and eastern North Carolina revolves around the tradition of renting houses and condominiums for a week or so every year and hosting family gatherings at the beach. This social tradition extends well beyond the county and draws visitors from many states and foreign countries. Generations of families living inland have been drawn to Bogue Banks for rest and relaxation. Tourism has grown exponentially along coastal North Carolina during the past century because of the coast's attraction, particularly along coastal counties such as Carteret which have and maintain the infrastructure, housing, and beaches to support the demand for access to the shore.

The beaches of Bogue Banks are a valuable ecological resource. Of nearly 80 miles of barrier island shoreline located in Carteret County, Bogue Banks is the only developed portion. The remainder, made up of Shackleford Banks and Core Banks to Ocracoke Inlet, will remain undeveloped in perpetuity as part of the Cape Lookout National Seashore. Bogue Banks serves to draw human activity away from the inaccessible beaches and ecosystems of Shackleford and Core Banks. Neighboring barrier islands to the west (such as Bear Island) include another 25 miles of inaccessible wilderness preserves, giving the Cape Lookout region the highest ratio (3:1) of preserved to developed barrier islands in North Carolina for any 100-mile reach. The health of the beach environment is essential to a positive experience for the beach visitor. The damage associated with severe storms results in the loss of high oceanfront dunes, scrub and maritime forests.

The sportfishing industry in Carteret County is second in size only to Dare County. The health of those activities (including fishing, boat building, and outfitting and supply) is dependent on the health of the marine environment.

Project Planning Objectives – In undertaking the beach nourishment project, Carteret County has several objectives that the project must meet. Those objectives are summarized as follows:

- Preservation of the environmental, cultural and aquatic resources of the county.
- Provide an easily accessible recreational beach available to all citizens of the county.
- Provide protection of oceanfront property as a resource of tax revenues to the municipalities of Bogue Banks and the county.
- Maintain the economic viability of tourism, the county's largest industry.

1.3 SUMMARY OF PROJECT NEED

Bogue Banks is the only developed, accessible beach in Carteret County, representing ~35 percent of the county shoreline and 1 percent of the county land area. Residential and business properties on Bogue Banks account for ~43 percent of the county tax base but receive a much lower percentage of county services and investments. Chronic erosion, while occurring at low rates compared to many shorelines, has accelerated recently as a result of five landfall hurricanes in quick succession since 1995. Loss of beach area and a general sand deficit have left nearly 17 miles of oceanfront vulnerable to damage during even minor storms. The most recent hurricane (*Floyd* 1999) caused upward of $30,000,000 damage in the county, largely concentrated along Bogue Banks' oceanfront, where the beach is narrowest. Little or no property damage occurred along Atlantic Beach, which had a much wider beach as a result of nourishment in 1986 and 1994.

Erosion poses an immediate threat to property, infrastructure, and the county tax base. Loss of oceanfront properties to erosion would result in tax increases ranging from $0.05 to $100 for all mainland residents to $0.31 to $100 for Indian Beach residents, with Pine Knoll Shores properties in between these amounts.

Tourism, the county's primary industry, will decline if the beach continues to erode. Presently, there is less recreational beach area for the public than five years ago. Property owners have increased the frequency of beach scraping to rebuild foredunes and protect imminently threatened homes. Associated with erosion and dune scraping has been a decline in beach habitats for nesting sea turtles and other organisms.

A citizens' Beach Preservation Task Force (meeting frequently between 1997 and 2000) determined that the only viable alternative is to rebuild the beach via nourishment. Over a ten-year period, nourishment results in lower costs compared to the "no-action" alternative or "property abandonment and retreat" alternative.

A ten-year nourishment project is estimated to require approximately 6.7 million cubic yards to restore the sand deficit and provide for average yearly losses over a decade or so and for differences in sediment quality between the existing beach and the borrow area. This level of effort would add 44-113 cubic yards per foot (cy/ft) along 16.8 miles of beach from Pine Knoll Shores to western Emerald Isle and widen the recreational beach 50-125 ft. The project would restore eroded areas to a similar condition as that of Atlantic Beach.

Viable beach-quality sand with composite overfill ratios around 1.15 to 1.50 exists in several strategic offshore areas close to the shoreline. Preliminary estimates indicate that these deposits can be excavated and placed on the beach via hydraulic dredge at a cost of approximately $25 million. Other potential borrow sources (including shoals in Bogue Inlet, Bogue Sound, and Beaufort Inlet, or existing spoil areas controlled by the USACE) are considered less cost effective because of their distance to the project area or their poorer quality material.

The proposed project (in total) will require ~14-15 months to construct if only one dredge is available. The applicants desire to complete the project at the earliest time and in the shortest time practicable, and will seek ways to complete construction during cold weather months when environmental impacts are expected to be lowest. The earliest period of construction for Phase I (Reaches 4, 5, and 6) is now estimated to be 16 November 2001 through 30 April 2002. Construction activities will directly impact a particular property for only a few days as nourishment proceeds section by section at an average rate of about 500-1,000 feet per day. The project will be monitored carefully after construction to quantify its longevity and document environmental change. As the first nourishment along most of Bogue Banks, it will necessarily serve as a prototype for future beach maintenance efforts.

1.4 AREAS OF CONTROVERSY

Beach nourishment, in general, involves three primary areas of controversy: (1) funding, (2) physical impacts, and (3) environmental impacts.

1.4.1 Funding

Funding for the proposed project will involve a combination of locally generated funds, derived primarily from increases in property taxes in the affected areas (ie, special tax districts on Bogue Banks). Local sales taxes will contribute a portion of the funds. For Reach 4 (Indian Beach-Salter Path), the State of North Carolina may contribute up to $950,000 to nourish an ~2,200-ft state-owned tract in Salter Path, such that the beach fill will be contiguous. These are the only state funds that are being considered for application to the project.

The Town of Pine Knoll Shores (Reaches 5 and 6) and the Town of Indian Beach (Reach 4, excluding the state property) have applied for and received approval for a US Department of Agriculture (USDA) loan under the Rural Development Act to finance local bonds for their reaches. The USDA has prepared a Class II

Environmental Assessment for Reaches 4, 5, and 6 of the project dated 6 June 2001 (Appendix A3). These funds plus interest will be repaid in their entirety by property owners within the affected communities. No federal grants will be used for the project.

1.4.2 Physical Impacts

Nourishment is the "only engineered shore-protection alternative that directly addresses the problem of a sand budget deficit . . . improves natural protection while also providing additional recreational area." (NAS, 1995, Beach Nourishment & Protection, pp. 1-2). While it has grown in acceptance in recent years, nourishment engenders polarization between proponents who consider it the preferred solution to erosion and opponents who consider it to be a temporary stop-gap measure against an advancing sea (NAS, 1995). Its success depends on the frequency of storms, but more importantly, on the background erosion rate and long-term processes controlling shoreline change at the particular site. Nourishment adds to the littoral budget a measure of sediment which will become subject to onshore/offshore as well as longshore transport. Just as a natural beach waxes and wanes between storms, a nourished beach will adjust to daily and seasonal variations in waves and tides.

Most of the controversy and debate regarding the success of nourishment relates to:

- Insufficient postproject documentation of physical changes.
- Wide disparities in background erosion rates and nourishment sediment quality, making extrapolations from one site to another misleading.
- Use of different criteria for evaluating success.

These controversies are anticipated to persist within the community until such time as there is physical proof of the effect of nourishment along Bogue Banks. Presently, 70 percent of Bogue Banks has little or no experience with nourishment and has little quantitative data on which to define the background erosion rate or project erosion rates after nourishment. Yet, certain factors suggest that Bogue Banks is a better candidate site for nourishment than many other East Coast beaches:

- Nourishment experience at Atlantic Beach (25 percent of Bogue Banks) provides physical evidence of a wider dry beach and reduced storm damage throughout the 1990s compared to similarly exposed beaches in the proposed project area.
- Several independent erosion estimates confirm that 20-year volumetric losses have averaged 1-3 cubic yards per foot per year (cy/ft/yr), a rate that is relatively low. This is comparable to Myrtle Beach (SC) (1.6 cy/ft/yr) but only a fraction of Hunting Island (SC) (~25 cy/ft/yr).

- Linear erosion estimates quoted by Pilkey et al. (1998) and most likely based on NC Division of Coastal Management erosion maps are <2 ft/yr for all Bogue Banks localities except Pine Knoll Shores and Indian Beach, which are estimated at 2-3 ft/yr.

- Bogue Banks is a south-facing beach, partially in the lee of Cape Lookout and less exposed to damaging waves which tend to be more frequent from the northeast.

- Rates of net longshore transport are relatively low along Bogue Banks because of its orientation and placement with respect to Cape Lookout and the prevailing direction of ocean waves.

- The proposed project length of 16.8 contiguous miles would make it one of the longest nourishments on the East Coast. Numerous studies have proven that nourishment longevity is proportional to the square of the length of the project (NAS, 1995).

- The proposed borrow areas (A, B1, B2) contain sediments that are a similar mixture and quality of sand and shell material found on the native beach and much coarser than the spoil sediments placed by the Corps along Atlantic Beach. Sediment containing coarser material tends to hold a wider dry beach and require less volume for the underwater portion of the profile (Dean, 1991; NAS, 1995).

- The proposed quantity of nourishment (44-113 cy/ft) incorporates (a) initial volume to replace the sand deficit and (b) advance nourishment equivalent to approximately ten years of background erosion. In addition, plans call for increasing the nourishment volume in proportion to the overfill ratio (R_A) of the borrow area sediments because a certain fraction will be unstable on the beach (~15-30 percent using the combination of borrow areas A, B1, and B2 specified later in this report).

- The proposed project will be surveyed yearly from the dune line to beyond the outer bar and compared against the prenourishment conditions using volumetric calculations. Performance will also be evaluated based on persistence of a dry beach. Success will be defined in relation to how closely the postnourishment volume erosion rate compares with the estimated prenourishment volume erosion rate.

Not all physical impacts are predictable prior to construction. It is widely recognized that isolated erosion "hot spots" sometimes develop after nourishment as "packages" of sediment accumulate in one area, leaving deficits nearby. Nearshore bars also evolve, form runnels and outlets, and create related nearshore cell circulation which may locally cause scour of the berm. Such features occur on unnourished as well as nourished beaches. Regardless of the cause of physical changes, the proposed project area is expected to undergo the same transformations as a natural beach, but to do so with the ocean displaced about 100 ft seaward. By artificially increasing the average separation distance between development and the ocean, private property damage will be reduced for any return-period storm, and the tax base of the county will be preserved for another decade or so. After a decade of monitoring, the community will reevaluate the cost and benefits of nourishment and determine at that time based on experience whether continued nourishment is preferable to doing nothing or abandoning property.

1.4.3 Environmental Impacts

The primary environmental impacts of nourishment relate to mortality of in-situ organisms, changes in habitat, mobilization of fine-grained sediments, and pollution due to accidental spills during construction.

1.4.3.1 ***Mortality of In-Situ Organisms*** – The project will result in the excavation of sediments and organisms in the upper 2-3 ft an approximate 2.58-square-mile area offshore of Bogue Banks. This area represents about 3 percent of the ocean bottom between Bogue Banks and the three-mile state jurisdiction limit. Most of the sessile organisms (predominantly polychaete worms) excavated will die. As fill is placed on the beach, some in-situ organisms (eg, amphipods, *Donax* clams, and *emerita* mole crabs) will be smothered. These are unavoidable impacts. Studies have shown that borrow areas and nourished beaches recolonize eventually. Natural recovery appears to be most rapid under the following conditions (all of which are applicable for the proposed project):

- Excavations by hopper dredge which tends to make shallow cuts and leaves undisturbed furrows from which rapid recruitment of organisms takes place.
- Use of beach-quality sediment comparable to the native beach.
- Construction during cold-weather months when biological populations are a small fraction of their summer densities.
- Minimization of fines in the borrow area and nourishment area, which elevate turbidity levels.

In a recently published study in New Jersey, considered the most intensive analysis of environmental impacts of nourishment to date, beach habitats recovered to prenourished conditions in 2-6.5 months. Offshore borrow areas recovered in 2-2.5 years based on the results of a seven-year Corps-sponsored study costing over $8 million (ref: Burlas, Ray and Clark 2001).

1.4.3.2 ***Changes in Habitat*** – The project will leave shallow cuts over the borrow area, exposing older sediments to the water column. These sediments will have been less reworked by organisms but contain similar sediment textures and nutrients as the removed sediments. As such, they will leave an unoccupied niche habitat that is expected to become recolonized at time frames comparable to the life cycles of various species. Some studies have demonstrated that recolonization of borrow areas occurs in a few months or less (eg, Jutte et al 1999b), while other studies show recolonization occurring over 1-2 year periods. The proposed borrow area and construction method will be similar to sites where recovery occurred rapidly (a few months). However, because the only way of confirming recovery is by systematic monitoring, the applicants have initiated benthic sampling before construction and plan to continue benthic sampling after construction to document the degree and rate of recovery at this particular site.

The beach fill will displace the shoreline and inshore topography about 100 ft seaward. This will create more beach habitat (expanded turtle nesting sites), reduce the frequency of dune scarping and associated vegetation loss, and eliminate many chronic escarpments in the foredune. It will also lessen demand by property owners for beach scraping and dune restoration. Frequent beach scraping is believed by some researchers to cause mortalities and population reductions in some surf-zone species (eg, Peterson et al 2000). It also introduces coarser sediments in the foredune and inhibits revegetation because of the poorer water retention compared to natural dune sands. Existing littoral habitats will be displaced seaward but will be maintained in similar proportion as the native beach. Nutrients introduced with the nourishment sediments will provide a food source to attract benthic organisms to the new foreshore. Recent studies have found that recolonization of the beach in similar settings as Bogue Banks may occur within one month or less (Jutte et al 1999a). Because it is uncertain to what degree or how rapidly recolonization will occur, the applicants plan to monitor benthic recovery along the beach after construction.

A prenourishment beach and borrow area sampling was completed in June 2001. A second prenourishment sampling is scheduled fo November 2001 (see Appendix A-4). In addition, the applicants sponsored a biological survey of offshore borrow areas by UNC's Institute of Marine Sciences in 1999-2000 which provides additional baseline information for the project (Appendix C).

1.4.3.3 ***Mobilization of Fine-Grained Sediments*** – The proposed project will mobilize silts and clays in the borrow area, raising turbidity in the immediate area of construction. Use of hopper dredges will return some of the silt and clay immediately to the borrow area by on-board drainage as the hoppers are loaded. Fine-grained sediments transported to the beach will be unstable and, during placement, will winnow by normal surf-zone mixing. These fines will raise turbidity levels around the point of discharge, then settle seaward of the longshore bar (lower foreshore). The increase in turbidity due to the project is unavoidable. However, turbidity during similar construction at other sites has been shown to be short-lived (hours to days) and below the natural variations in turbidity observed between storms and calm days. The proposed borrow area contains an average of ~4 percent fines (silts and clays) which is well below the state and USACE guidelines of 10 percent.

1.4.3.4 ***Pollution Due to Accidental Spills*** – Federal and state regulations place a high burden on contractors to prevent accidental spillage of fuel, grease, and related substances used in the operation of hydraulic or mechanical equipment. Zero releases are unattainable, but detectable discharges are rare. The applicants will monitor construction and insure that all federal and state requirements for discharge of contaminants are met by the contractors.

2.0 ALTERNATIVES

Under existing federal and state laws, there are only three alternatives for dealing with erosion along Bogue Banks: (1) no action; (2) abandon property, retreat, and relocate; (3) nourish the beach.

Structural shore protection involving seawalls, revetments, and bulkheads is not allowed under present North Carolina Coastal Area Management Act (CAMA) regulations. Semi-hard solutions involving sand-retaining structures, such as groins and detached break-waters, plus nourishment are not recommended in areas of low erosion rates away from inlets (NAS 1995).

Of the three primary alternatives, all have large costs associated with them as described below, and whether nourishment is the lowest cost alternative depends on a combination of four main factors:

- Existing sand deficit with respect to the desired scale of the beach.
- Average, long-term erosion rate at the site.
- Density and value of developed property at risk.
- Proximity of beach-quality borrow sediments and their cost of transportation to the project area.

> *Beach nourishment can provide protection from storm and flooding damage when viewed within human time scales (decades not centuries) in those situations where its use is technically feasible, provided that:*
>
> - *erosion rates are effectively incorporated into project design . . .*
> - *. . . engineering standards are used for planning design and construction, and*
> - *projects are maintained . . .*
>
> *. . . Beach nourishment may not be technically or economically feasible or justified for some sites, particularly those with high rates of erosion. Government authorities with responsibility for coastal protection should view beach nourishment as a valid alternative for providing natural shore protection and recreational opportunities, restoring dry beach area that has been lost to erosion. (NAS 1995, p. 3)*
>
> [NOTE: Signatories to this statement include Dr. R.J. Seymour, chair, Scripps; Dr. Robert G. Dean, University of Florida; Dr. Paul Komar, Oregon State University; Dr. Orrin H. Pilkey, Duke University; and Dr. Robert L. Wiegel, University of California Berkeley; among others.]

2.1 NO-ACTION ALTERNATIVE

The no-action alternative is evaluated based on whether the alternative considered meets the project planning objectives. In terms of those objectives, the no-action alternative is not a viable plan of action for Carteret County and the municipalities of Bogue Banks. Discussions of each objective are provided below.

Planning Objective: *preservation of the environmental, cultural and aquatic resources of the county*

The no-action alternative would not meet this objective given the current state of the beach. Continued erosion will increase the frequency of dune scraping. Forty acres of vegetation and its associated habitat will be lost. Turtle nesting habitat will be eliminated because of steep escarpments and unstable back beach areas subject to wave uprush.

Planning Objective: *provide an easily accessible recreational beach available to all citizens of the county*

The no-action alternative would not meet this objective. Significant recreational beach has been lost due to erosion of the shoreline. In many locations recreational use is limited to low tide periods. When structures are permitted to fail due to erosion of the beach, the costs of demolition and removal are often borne by the municipality. It is estimated, based on expenditures by municipalities and the county over the past four years, that without a substantial berm, costs for cleanup of debris on the beach will be $400,000 per year. Accounting for escalation and normalized to present worth, debris cleanup costs are $3,509,000. The costs associated with rebuilding beach access structures borne by homeowners, municipalities, the county and by homeowners associations is estimated at $2.1 million per year. A survey of the beach indicated that in excess of 80 percent of access structures either had been repaired or were in need of repair. It was observed that, in areas of Atlantic Beach and west Emerald Isle where a wide berm exists, few access structures were repaired. It is estimated that the average repair cost is $3000 per property. Escalating the costs and normalizing to present value results in costs for access structure repair of $19,161,950.

Planning Objective: *provide protection of oceanfront property as a resource for tax revenues to the municipalities of Bogue Banks and to the county*

The no-action alternative would not achieve this objective. Based on the number of oceanfront properties that it is estimated will be lost over the ten-year analysis period, the net present value of property tax revenues lost for the municipalities and the county is $6,332,889. This is present worth for a ten-year project period.

In addition to loss of revenue to municipalities and the county, there would be a negative economic impact caused by the retarded appreciation of all property on Bogue Banks. The precedent for this trend is Topsail Island in Onslow County. Property on North Topsail Island showed zero appreciation between the last revaluation conducted by Onslow County. It is unlikely that Bogue Banks would experience a zero increase over an assessment period. According to assessments conducted in 1989 and 1997, Bogue Banks property appreciated at approximately 4.8 percent annually. Real estate brokers contacted indicate an appreciation over the last five years of 10-15 percent annually. Just a lag of only 2.0 percent in the rate of appreciation would result in an economic loss of some $ 9 to 106 million with escalation over a 10 year period. With escalation and normalized to present worth, that represents over 1.25 billion dollars over a ten-year period. This value manifests itself in lost value to owners, lost revenues to real estate brokers and in reduced appreciation for purposes of tax revenues (estimated ~$8.6 million at the going rate over ten years).

These revenue losses would have to made up by each municipality (including those on the mainland) and the county by increasing ad valorem taxes on non-oceanfront properties and, in the case of the county by additional taxes levied on properties not located on Bogue Banks.

Planning Objective: *maintain the economic viability of tourism, the county's largest industry*
The no-action alternative would not meet this objective. Healthy beaches providing suitable recreational beach are the main attraction of the tourism industry. Loss or degradation of that attraction would have a significant impact on the tourism industry. Loss of oceanfront properties would eliminate indefinitely the rental income and associated economic activity generated by the income. Bogue Banks is the only accessible island for large-scale tourism over a reach of 100 miles of coastline in central North Carolina. All adjacent beaches are inaccessible nature preserves with no vehicle access.

In the past five years, there has been an increase in storm frequency, increase in dune scraping frequency, apparent decline in the rate of property value appreciation compared to other beach communities, and increased public perception of erosion. All of these factors contribute to economic impacts which can not be quantified precisely. However, it is possible to estimate a range of potential costs based on recent experience in Bogue Banks. Following are potential costs that will accrue over a *ten-year period* to the entire community and property owners on Bogue Banks if no action is taken in response to continued erosion.

A) Impacts to community (Carteret County) economy – government losses:	
- Reduced property tax revenues (see above)	$6.3 million
- Loss in occupancy tax due to lower beach use	$1.1 - $2.8 million
- Loss in sales tax due to lower beach use	$13.1 - $32.8 million
- Debris removal after storms (walkovers, decks, etc.)	$3.5 million
- Reduced property tax revenues (due to lower Bogue Banks property value appreciation)	$8.6 million
Subtotal	$32.5 to $55.9 million
B) Environmental Impacts to Carteret County:	
- Loss of 40 acres of vegetated dunes	not quantifiable
- Reduced turtle nesting area	not quantifiable
- Chronic impacts to beach fauna	not quantifiable
- Loss of recreational beach (computations given in Appendix F–Economic Studies)	$0.8 - $2.1 million
C) Impacts to Owners in Special Tax Districts on Bogue Banks	
- Beach scraping after storms	$2.2 million
- Reconstruction of walkovers and beach access	$19.1 million
Subtotal	$21.3 million
Poststorm repairs (foundations, sheathing, windows, etc.)	not calculated

D) Other Potential Private Losses:

- Reduction in payroll in tourism industry due to lower beach use	$32.1 - $80.2 million
- Reduction in other (nontax, nonpayroll) tourist expenditures	$90 - $226 million

Total Economic Costs for No-Action Alternative (10 Years)

Community/Governmental (A & B above)	**~$53.8 million – $77.2 million**
Private [C & D above]	**~$143 million – $327 million**

Estimates are present worth of escalated annual costs. Details of determination of costs are presented in Appendix F.

The above-listed estimates have been determined for the ten-year project life. Given the marginal condition of the beach today, it is likely that the cost of repairs will increase faster than the rate of inflation and faster than the above estimates because shoreline damage increases geometrically with decreasing distance to the waterline. Additionally, escalation rates for real estate used in the analyses is 4.8 percent annually compared to a historic appreciation in market value of 10 to 15 percent annually. Therefore estimates are considered conservative.

2.2 RETREAT/RELOCATION ALTERNATIVE

The relocation/retreat alternative involves moving oceanfront structures that are threatened by erosion of the shoreline. As of March 2000, the town building inspectors of Emerald Isle and Pine Knoll Shores had identified 173 oceanfront properties in Emerald Isle and 36 properties in Pine Knoll Shores that are threatened or, in many cases, condemned due to beach erosion.

Study of the retreat/relocation alternative involved identification of oceanfront properties that would be threatened over the ten-year study period. A survey was conducted to locate the toe of the naturally occurring dune along the project area. Using the long-term erosion rates developed in the Shoreline Assessment and Preliminary Beach Restoration Plan Report, a ten-year setback zone was determined for reaches of the beach that fall into one of the six erosion rate zones. Beach erosion rates for each of the six areas are shown in Table 2.1. [Note: These erosion rates are considered conservative with respect to the property relocation alternative. Higher erosion rates would impact more properties and result in substantially higher costs.]

A visual survey was made of the oceanfront properties to identify structures that fall into the ten-year setback zones for each reach. This included single family residential structures and condominium units.

TABLE 2.1. Erosion rates and 10 year retreat distances for project areas.

Location	Long-Term Erosion Rate (ft/yr)	10-Year Retreat Distance (ft)
West Emerald Isle	2.0	20
Central Emerald Isle	2.0	20
East Emerald Isle	2.0	20
Indian Beach/Salter Path	2.0	20
West Pine Knoll Shores	3.0	30
Central Pine Knoll Shores	2.0	20
East Pine Knoll Shores	3.0	30

Using tax maps, a count of properties was determined in each of two categories: (1) the properties with sufficient land area to allow relocation of the structure on site, and (2) those properties where erosion of the property and street setback requirements will require that the structure be relocated to another lot. Estimates of moving costs are based on discussions with house movers, on costs from R.S. Means Cost database, and on the project cost experience of Stroud Engineering in Carteret County. Detailed breakdowns of the costs for relocation on site, relocation to new lot, and total present day costs for each municipality are provided in Appendix F.

The retreat/relocation alternative is evaluated based on whether the alternative plan meets the project planning objectives. In terms of those objectives, the retreat/ relocation alternative is not a viable plan of action for the County. Discussions of each objective are provided below.

Planning Objective: *preservation of the environmental, cultural and aquatic resources of the county*
The retreat/relocation alternative would not meet this objective given the current condition of the beach. Continued erosion will increase the frequency of scarping. Forty acres of vegetation and its associated habitat will be lost. Turtle nesting will be eliminated because of steep escarpment and unstable back-beach areas subject to wave uprush.

Planning Objective: *provide an easily accessible recreational beach available to all citizens of the county*
The retreat/relocation alternative would not meet this objective. Significant recreational beach has been lost due to erosion of the shoreline. In many locations recreational use is limited to low-tide periods. Additionally, with the loss of oceanfront properties, there is loss of beach access areas. In Emerald Isle and Indian Beach, beach access is provided at locations where public street rights-of-way dead end at the back of the dunes. Loss of the oceanfront property will include loss of these beach access areas.

Planning Objective: *provide protection of oceanfront property as a resource for tax revenues to the municipalities of Bogue Banks and to the county*
The retreat/relocation alternative would not achieve this objective. The total economic loss associated with this alternative is evaluated. The total losses are evaluated and expressed here in terms of the net

present worth in year 2000. The evaluation includes annual escalation of construction costs and land values. The losses include the costs of property lost, costs of property that must be purchased to relocate a structure, and the costs of relocation. It is assumed in the analysis the condominiums located in the setback zone will have to demolished and reconstructed at another location on the development site. Costs are distributed equally over the 20-year study period with escalations included for real estate value and construction costs.

The present worth of retreat/relocation is shown in Table 2.2. The present worth of the retreat/ relocation alternative is $110,940,556 compared to the project costs for beach nourishment of $30,000,000. Both represent year 2000 costs. [Note: This does not count the costs associated with the no-action alternative, many of which will also apply under the retreat/relocation alternative.]

Planning Objective: *maintain the economic viability of tourism, the county's largest industry*
The retreat/relocation alternative will not meet this objective. Healthy beaches providing suitable recreational beach are the main attraction of the tourism industry. Loss or degradation of that attraction would have a significant impact on the tourism industry. As with the no-action alternative, loss of vacation rental revenues is not quantified. Loss of oceanfront properties would eliminate indefinitely some rental properties and reduce the remaining number of viable the rental properties thereby reducing rental incomes and associated economic activity generated in Carteret County and its municipalities.

TABLE 2.2. Net present worth of retreat/relocation alternative.
[Discount rate = 6.125%. Discount rate is yield on 30-yr treasury bond, latest auction reported in Wall Street Journal, 02/24/2000.]

	ANNUAL COSTS OF RELOCATION / RECONSTRUCTION				
Cash Flow Year	**Single Family Relocate On Site**	**Relocate Off Site**	**Condominiums Rebuild On Site**	**Rebuild MH Sites**	
1	$1,076,400	$ 8,991,000	$2,180,250	$156,000	
2	$1,108,692	$ 9,393,930	$2,245,658	$160,680	
3	$1,141,953	$ 9,796,860	$2,313,027	$165,500	
4	$1,176,211	$10,199,790	$2,382,418	$170,465	
5	$1,211,498	$10,602,720	$2,453,891	$175,579	
6	$1,247,843	$11,005,650	$2,527,507	$180,847	
7	$1,285,278	$11,408,580	$2,603,333	$186,272	
8	$1,323,836	$11,811,510	$2,681,432	$191,860	
9	$1,363,551	$12,214,440	$2,761,875	$197,616	
10	$1,404,458	$12,617,370	$2,844,732	$203,545	
Present Value	**$9,444,103**	**$82,357,407**	**$19,129,046**	**$1,368,711**	
				TOTAL NPV	**$110,940,556**

The applicants' economic analysis was evaluated by the USACE Planning Department on 18 May 2001and determined to be "adequate and thorough". USACE provided a list of differences between beach nourishment economic analyses prepared by the applicants for the proposed privately funded project and those required for federally funded projects. USACE stated that the differences "should not be considered deficiencies".

2.3 NOURISHMENT ALTERNATIVE

Beach nourishment may be performed at a continuum of levels but to be viable should fully restore the profile deficit with respect to a "healthy" beach and provide advance nourishment for approximately ten years to accommodate the background erosion rate. Nourishment is the only practicable solution that will offset the sand deficit, maintain the recreational beach, and protect developed property and community infrastructure. There are many ways beach nourishment can be accomplished. This section outlines the main implementation alternatives with respect to sand sources, beach fill design, methods of construction, construction schedule, and maintenance.

2.3.1 Alternate Borrow Areas

Based on previous practice along the US East Coast, the following classes of borrow sources have been used for beach nourishment (CERC 1984):

- Lagoon sediments
- Inlet shoals (inshore)
- Inlet shoals (offshore)
- Nearshore bars
- Offshore deposits
- Recycled spoil sediments
- Accreting spits/beach deposits
- Attached bar deposits
- Inland deposits
- Freshwater pond deposits
- Fillets at jetties
- Imported material

In general, economics favor the borrow source(s) that matches the native beach quality, involves the shortest transportation distance, and minimizes environmental impacts. Large-scale projects such as the present Bogue Banks restoration plan require large volumes of material which may not be available in only one deposit.

2.3.1.1 ***Unacceptable Sources*** – The following sediment sources are considered unacceptable for the project.

- *Lagoon deposits in Bogue Sound* – generally much too fine compared to native beach sand and would not provide sufficient quantities of beach-compatible sediment.

- *Nearshore bar(s) along the project area* – part of the active profile and important for wave energy dissipation, therefore inappropriate as a borrow source; sediments too fine for the dry beach in this setting.

- *Accreting spits/beach deposits* – Bogue Banks has insufficient quantities of sand in accreting spits or accreting beach zones (eg, western Emerald Isle) for the project. At least 20 times more sand is required than resides onshore as "surplus" near the ends of the island.

- *Attached bar deposits* – only very limited reaches near the inlets have any "surplus" sands in attached bars. This would provide only a tiny fraction (of the order 1-2 percent) of the material required for the project.

- *Inland deposits* – Most of Bogue Banks is developed or privately owned. Even if a large tract were available and suitable for sand mining, costs of land acquisition in this setting would increase the cost of the project well beyond other alternatives. Other inland deposits on the mainland may be beach quality, but transportation distances make them much more expensive than other alternatives.

- *Freshwater pond deposits* – There are no known freshwater ponds nearby that require maintenance excavations or could provide the quantities of beach compatible sediment required for the project.

- *Fillets at jetties* – There is insufficient excess littoral sand trapped in fillets along the jetties/ groins at the inlets adjacent to Bogue Banks.

- *Imported material* – Imported beach-quality sediment from sources more than 15 miles from Bogue Banks will be significantly more expensive because of transportation costs than the acceptable sources (listed below).

2.3.1.2 ***Acceptable Sources*** – The following sediment sources were evaluated in more detail because of their likelihood of providing acceptable material (see also Appendix E).

- *Offshore deposits* – A sand search over a 50-square-mile area off Bogue Banks revealed about six square miles of beach-quality sand in close proximity to the project area in the areas designated borrow areas A, B1, and B2 as detailed herein.

- *Inlet shoals (inshore)* – Review of aerial photos and ground-truth sampling confirmed the presence of extensive inlet shoals at Bogue Inlet which contain beach-quality sediment. Studies by the USACE confirm that beach-quality material exists in some inshore areas of Beaufort Inlet. Because of unresolved issues regarding certain conservation habitats, Bogue Inlet shoals are not considered feasible for the present project. Beaufort Inlet shoals are not as economic as the proposed borrow areas and, therefore, are also not considered viable at this time.

- *Inlet shoals (offshore)* – Studies by the USACE confirm that beach-quality material exists in offshore shoals of Beaufort and Bogue Inlets. Because of the above reasons, they are not considered economic for the proposed project.

- *Recycled spoil sediments* – Studies by the USACE confirm that beach-quality material resides in certain spoil areas, such as Brandt Island, which can be "recycled" to the beach. Upon further review (see EIS), these sediments were rejected as being too fine for the project beach.

The results of sediment sampling and review of published reports (see Section 3 and Appendix E) yield the following ranking of acceptable borrow areas with respect to quality (as measured by composite overfill factors, R_A):

1) Offshore area borrow areas B1 and A at 65:35 ratio.
2) Offshore area borrow areas B2 and A at 65:35 ratio.
3) All other potential sources.

With respect to transportation distances, the above-listed resources are ranked as follows (best to worst):

1) Offshore, areas B1 and B2, average distance <2 miles
2) Offshore area A, average distance ~5 miles
3) Bogue Inlet shoals, average distance ~10 miles
4) Brandt Island, average distance ~12 miles
5) Beaufort Inlet, average distance ~14 miles

The preferred borrow areas are A, B1, and B2 based on sediment quality and transportation distance (detailed in Section 3 and Appendix E).

2.3.2 Alternate Fill Profile

Beach nourishment may be performed at a continuum of scales, depending on the goals of the project, availability of borrow sediment, method of construction, and budget. Since the proposed project area has not been nourished to any extent, there are no site-specific data to use as a guide other than the existing natural profile and available erosion rate estimates. Nearby Atlantic Beach has been nourished twice, but its sediment characteristics (after nourishment) differ somewhat from those in the proposed project area.

As detailed later in the present report, CSE Baird-Stroud (1999) evaluated the condition of the beach and inshore zone along Bogue Banks, using the profile volume method (Kana 1993; Kana and Mohan 1996). This method establishes site-specific criteria by which volume deficits can be determined against an ideal or desirable profile volume (ie, one which contains sufficient dimensions to sustain daily, seasonal, and storm fluctuations of the beach without significant damage to the backshore). The profile volume method, if performed to the estimated depth of closure, integrates all cross-shore variations in profile geometry and is therefore insensitive to the timing of surveys.

The analyses (CSE Baird-Stroud 1999) demonstrated that there is a profile deficit averaging ~40 cy/ft along the 16.8-mile reach from western Emerald Isle to Pine Knoll Shores (profiles 8-76), compared to the existing profile volume along Atlantic Beach. Considering the fact that Atlantic Beach sustained Hurricanes *Dennis* and *Floyd* (1999) as well as *Fran* (1996) with only minor damage compared to other sections of Bogue Banks, its profile volume yields a rational minimum value for decadal planning.

The desired fill volume is one that restores the deficit (with respect to the criteria and goals of the project) plus adds "advance nourishment" to increase longevity. Advance nourishment is generally related to the anticipated average annual losses from the project area (ie, the background erosion rate). The Bogue Banks Beach Preservation Task Force evaluated projects which factored in 5-year, 10-year, and 20-year advance nourishment requirements based on best-available background erosion rates. It was the decision of the task force to formulate the project around the ten-year nourishment project (ie, initial deficit averaging ~40 cy/ft plus ten-year advance nourishment averaging 10 cy/ft). This provides a reasonable time period over which the first project can be evaluated and provides a project scale that is practical for dredging. Small-scale projects do not afford economies of scale during construction and result in more frequent nourishments and the associated disruption to normal beach use by people and animals.

The proposed fill will be placed by hydraulic dredge between the base of the foredune and the outer bar. Only the profile above high water is controllable in nourishment construction. Intertidal and underwater portions of the profile will be subject to natural adjustment by waves. Given the relatively high back-beach elevations along most of Bogue Banks and the issue of easements for construction, the majority of the fill will be placed no higher than +7 ft NGVD (the natural elevation of the berm) and seaward of the existing toe of the foredune and all development. Along portions of eastern Emerald Isle, a low dune (elevations <+12 ft NGVD) will be constructed as part of the project to prevent the dredge slurry from flowing landward across developed property (only in the event the predredge profiles show an absence of a foredune exceeding +9 ft NGVD at the time of construction — not a factor at present because all such properties have been scraped and contain a foredune as of June 2001).

Other fill profiles considered included:

- *Nourishment entirely below low water* – not the applicants' preferred alternative because it is more difficult to control sand placement, does not provide a safe working platform during construction, and does not provide immediate restoration of the dry beach and associated back-beach habitats.

- *Nourishment largely contained in a protective foredune* – not the applicants' preferred alternative because (1) a dry beach and healthy underwater profile are necessary prerequisites for a stable foredune; (2) nourishment sediments should be subject to wave action so material will sort naturally, bleach to a natural color, and winnow out fines; and (3) the project's primary goal is to restore a viable recreational beach for broad benefit to the community.

- *Smaller fill sections* – not the applicants' preferred alternative because they become more expensive per unit volume to construct due to economies of scale, they will not restore the minimum profile deficit, and they will leave more reaches vulnerable to storm damage.

2.3.3 Alternate Methods of Construction

There are two basic methods for nourishing beaches — via mechanical placement using land-based equipment and via hydraulic placement using dredges. In either method, mechanical equipment such as dozers, graders, etc., are used to spread the material in a controlled manner. Some projects involve combinations of hydraulic and mechanical transfer. The preferred method depends on the scale of the project, proximity of the borrow area, and type of borrow area. Hydraulic dredges involve high initial costs to cover the setup of discharge pipeline, etc. Land-based equipment such as trucks or scraper pans can be mobilized at low cost. After mobilization, the unit costs of sand placement depend on transportation distance. In general, unit costs of hydraulic fills are lower because of efficiencies in production and placement. Therefore, large-scale nourishments such as the proposed project tend to be more cost effective if constructed by hydraulic dredge.

2.3.3.1 *Methods Considered Unsuitable* – The following excavation and sand transfer methods are considered unsuitable for the present project.

- *Over-road trucks* – None of the designated borrow areas are situated inland, and none are directly accessible by road.
- *Mechanical conveyor belt* – None of the designated borrow areas are situated close enough to the project area for this technique to be economic.
- *Drag line* – None of the designated borrow areas are situated close enough to the project area for this technique to be economic.
- *SeadozerÔ* (c/o Cape Fear International, Beaufort, NC) – None of the designated borrow areas are situated close enough to the project area for this technique to be economic. The method would result in more ocean bottom being impacted because it involves "pushing" material by jets/prop wash from borrow areas to the beach, a minimum distance of 0.5 miles. Portions of the project area are situated >0.5 miles from the nearest borrow source. It is uncertain whether the SeadozerÔ is certified by the U.S. Coast Guard to work seaward of the open-ocean jurisdiction (COLREGS) line, a primary requirement for excavations in the offshore borrow areas (A, B1, and B2).
- *Traditional cutterhead suction dredges* – ocean-certified dredges are required by the U.S. Coast Guard for any excavations seaward of the COLREGS line. Generally, ocean-certified cutterhead suction dredges are the largest of their kind due to the certification requirements. Curtterheads are of the order 5-10 ft in diameter. Such dredges require a minimum operational depth of ~20 ft and work most efficiently if excavations remove at least 4-6 ft of section. Because the designated offshore borrow areas will be limited to excavations of ~2-3 ft for environmental reasons, cutterhead suction dredges will not be practical or efficient. They would result in deeper cuts and produce more variation in offshore substrate depth after construction.

- *Miscellaneous methods* – bucket dredging and transfer by barge are not cost effective for areas A, B1, or B2 and are generally not allowed seaward of the COLREGS line. Split-hull barges are not considered feasible because they require a minimum water depth of the order 20 ft for discharge. This depth would place the material too far seaward to achieve the project goals.

2.3.3.2 *Methods Considered Suitable*

- *Ocean-certified hopper dredge* – Self-propelled hopper dredges with built-in pump-out capability are feasible for borrow areas A, B1, and B2. Ocean-certified equipment typically requires ~25 ft minimum operational depth and is efficient for excavating shallow cuts of the order 1-3 ft. During excavation and loading, the slurry drains via scuppers discharging some fines in situ and leaving coarser material in the hopper compared to the excavated material. For example, contractors have noted 60-80 percent reduction of "fines" on the beach as a result of washing in situ. By fines, we mean sediments in the very fine sand, silt, and clay range (D. Hussin, Great Lakes Dredge & Dock Co, May 2001, pers. comm.). When loaded, the dredge travels to a temporary mooring and submerged pipeline near the project site. It hooks up to the pipeline and pumps the material from the hopper to the beach where it is spread mechanically by dozers.

- *Ocean-certified suction dredge equipped for shallow cuts* – one such dredge exists among U.S. companies which has been specially designed for shallow cuts. This "dustpan" dredge (so nicknamed) is presently owned by Weeks Marine, Inc. (NJ) and is used primarily for beach nourishment involving thin borrow areas offshore (P. Lamourie, Aug'99, pers. comm.). The dredge works most efficiently if the borrow area is close to the project area (e.g., excavations paralleling the beach less than one mile offshore). The slurry is pumped directly to the beach via submerged pipeline and distributed with the aid of dozers and other land-based equipment. In contrast to self-contained hopper dredges, the excavations are pumped only once and therefore transfer more fines to the beach according to the quality of the sediment in the borrow area. Unit costs may be substantially lower than all other methods if the pumping distances are short. This method is considered most feasible for borrow areas B1 and B2.

2.3.4 Alternate Construction Schedule

The proposed project involves a substantial volume of sand (up to 6.7 million cubic yards). Based on project experience elsewhere, one ocean-certified dredge can excavate and place on the order of 15,000-40,000 cy in a 24-hour period. The average production per day varies widely according to transportation distance and specifications of the project. In any case, a substantial period of time will be required to complete the project. For example, if production averages 15,000 cy/day, 400 calendar days (~13 months) will be required to excavate and place ~6 million cubic yards (4.5 million x 1.33 to account for overfill).

Preliminary discussions with environmental agencies indicate construction during colder months is favored because biological productivity tends to be lowest then. Construction during winter also avoids disruption of the peak tourism season.

The following general construction schedules were considered (including advantages and disadvantages).

2.3.4.1 *Construction Anytime Based on Dredge Availability and Lowest Bid*

- *Advantages* – Likely results in lowest construction cost and substantial financial savings to the community because the contractor controls the schedule around other workload and weather and only mobilizes once. Yields the earliest project completion and initiation of improved storm protection and recreational benefits.

- *Disadvantages* – Likely encroaches on high biological productivity periods, nesting seasons, and tourist season.

2.3.4.2 *Construction During Limited "Environmental" Windows Between ~November and ~April*

- *Advantages* – Direct environmental impacts occur during periods of lowest biological productivity. Avoids prime tourist season. Yields early benefits if the project can be initiated in fall 2001.

- *Disadvantages* – A five-to-six month construction window is insufficient to complete the entire project unless more than one dredge is used. Each dredge introduces large mobilization costs, increasing the total cost of the project. The narrower the dredging window, the fewer contractors will be willing to bid the project, further raising the cost of construction. Down time for weather is more likely during winter than summer. Delays project benefits for at least one year if the winter 2001-2002 construction window is missed and leaves properties and beach-dune habitats vulnerable to further erosion damage.

2.3.4.3 *Construction During Two or More Seasons Within Limited "Environmental" Windows*

- *Advantages* – The only viable schedule in the event only one dredge is available for the project. Generally similar environmental advantages but produces direct impacts over two seasons rather than one (not along the same project reaches).

- *Disadvantages* – Will require at least two mobilizations, increasing the project costs. Postpones project benefits (wider beach, improved storm protection, etc.) for the areas uncompleted during the first window. Causes disruption to habitats over two seasons instead of one.

Other schedules considered but found not acceptable were:

- *Yearly fills for limited reaches* – result in much higher construction costs because of multiple mobilizations and repeated environmental impacts and disruption to normal beach use; delays project benefits along reaches constructed last.

- *Multiple, smaller scale fills* – result in much higher construction costs because of multiple mobilizations and the additional labor required to place "thin" nourishment sections; produce repeated environmental impacts and delay natural recovery of biological populations; do not fully restore the deficit, leaving property and backshore habitats insufficiently protected during storms.

- *Medium-scale fills* – essentially the same disadvantages as multiple, smaller scale fills.

Nourishment at the scale proposed (base volume ~4.5 million cubic yards or ~50 cy/ft, and volume with advance/overfill nourishment ~6.7 million cubic yards or ~75 cy/ft) over a 16.8-mile reach will restore the sand deficit. Addition of 50-75 cy/ft compares favorably with the estimated maximum volumetric erosion during Hurricane *Floyd* (<15 cy/ft). This means that the profile will generally have sufficient volume to allow cross-shore adjustment during storms. The proposed project will not eliminate all dune recession during major storms whenever the surge overtops the berm. However, the need for and frequency of beach scraping after the project due to major storms is expected to decline to a fraction of what it was during the 1990s. This has been proven for the site by the experience of Atlantic Beach over the past five years. Dune fencing and revegetation will be used to promote gradual improvement of the foredune after the project and after storms.

Requested Construction Schedule – From the above list of options, we propose 2.3.4.2 and 2.3.4.3 – namely, construction during environmental windows which may extend into the fall and spring. Specifically, the applicants seek authorization to commence construction as early as 16 November and continue construction as late as 30 April during multiple years. The applicants anticipate performing biological monitoring and environmental sampling as required in permits before and after construction.

2.3.5 Alternative Plans and Costs by Reach

Six reaches and multiple alternatives are outlined in Tables 2.3.1-2.3.7 (preliminary project alternative sheets) for the reaches as listed below:

- Pine Knoll Shores – East
- Pine Knoll Shores – West
- Indian Beach/Salter Path
- Emerald Isle – East
- Emerald Isle – Central
- Emerald Isle – West

The upper half of each sheet gives dimensions and fill volume requirements (no adjustment for borrow fill ratios) and nourishment requirements (adjusting for specific borrow fill ratios). This is why different nourishment volumes are indicated for each alternative.

Unit costs are given as the estimated pumping cost (excluding dredge mobilization) for a particular borrow area, distance, and equipment type. The applicable unit costs range from \$2.75/cy to \$7.00/cy based on current market conditions. The low range applies to pipeline dredges equipped to excavate thin borrow layers of fine sand and pump over distances of about 0.5 mile (typically \$2-\$3/cy; E. Elefson, Weeks Marine, August 1999, pers. comm.). The higher range applies to self-propelled hopper dredges equipped to excavate thin layers, then travel to and pump out via short, buoyed pipelines close to shore in water depths of 20 ft or more (typically \$3-\$7/cy). The inshore water depths off Bogue Banks are favorable for ocean-going hopper dredges. The anticipated equipment assumes that excavations will be restricted to shallow cuts (~2-3 ft thick) for environmental reasons.

Unit costs per foot of shoreline and per foot per year are given along with a probable range of pumping costs (exclusive of engineering and dredge mobilization). The indicated cost range applies to each "10-year" alternative ±15 percent. The bottom of each project plan sheet gives a range of expected "soft costs" including dredge mobilization, engineering, permitting, and surveys. In each case, the low-range soft-cost estimate assumes at least four reaches are executed around the same time under a single design service and a single dredge mobilization procurement. Without these economies of scale, the soft costs for individual reaches will be close to the high range.

NOTE: Tables 2.3.1-2.3.7 were prepared in September 1999 prior to additional surveys of borrow area sediment quality. They reflect early estimates of overfill ratios and include alternate borrow areas such as Bogue Inlet (area C) and the Corps' Beaufort Inlet maintenance projects which are not being considered for the present project under permit 200000362.

The *Preliminary Project Alternative – Summary-Bogue Banks* (Table 2.3.7) summarizes the lowest cost alternative for each reach and provides totals for the six reaches (ten-year alternatives only).

The estimated total cost for six reaches (ten-year projects) is approximately $24.25 million to $26.75 million. This averages $273-$302 per linear foot of shoreline in the nourishment areas, or ~$27-$30/ft/yr if considered over 10 years (without interest). Because of variations in sediment quality in each borrow area, the nourishment volume requirement is higher than the profile volume requirement. For the assumptions made in unit cost estimates and borrow areas, the nourishment volume for the 10-year plan (six reaches) would be ~6.7 million cubic yards (~75 cy/ft). A fill of this magnitude will initially widen the dry beach by ~100 ft.

As can be seen in the preliminary project alternatives (Tables 2.3.1-2.3.7), the "20-year" plan is incrementally more costly than the "10-year" plan, based on the anticipated cost of replacing erosion losses during the period. The Emerald Isle-East reach was found to have the highest average annual erosion rate at ~3.2 cy/ft/yr. This yields a "20-year" nourishment cost of ~$6.9 million versus a "10-year" cost of ~$4.8 million (ie, 44 percent higher). The difference was substantially less for other reaches with the average around 25 percent higher. Based on this, a 20-year project using today's prices has a total cost of ~$31 million, which suggests average annual costs of longer duration projects will decline over time. However, given the limited database of historical surveys for the project area, the Beach Preservation Task Force recommended planning around a "10-year" project. Detailed monitoring over the life of the project will confirm the fill losses and allow calculation of the average annual cost of nourishment. The task force considers the cost of the "10-year nourishment" alternative substantially below the cost of the "no-action" alternative or the "abandonment/relocation" alternative, even if the costs are extrapolated out several decades and include periodic renourishment to restore erosion losses.

TABLE 2.3.1

Pine Knoll Shores - East	**Preliminary Project Alternatives**		September-99
	From Maritime Road to Atlantic Beach Town Line		
Beach Condition	Fair		
Reach Length (ft)	**15,437**	Applicable Profiles	65 - 76
Longterm Vol Erosion Rate cy/ft	-1.88	*Moderate Erosion*	
Profile Volumes (cy/ft)		*Dry Beach to +2.5 ft:*	*9.46*
(Base Dunes to -10' NGVD)	**135.18**	*Wet Beach to -5.0 ft:*	*43.12*
Estimated Sand Deficit	39.82	*Underwater to Bar (-10 ft):*	*82.61*

Fill Volume Reqmt - No Overfill	Unit Volume (cy/ft)	Net Volume (cy)
Initial Deficit	39.82	614,701
Deficit Plus 5 yr Advance	49.22	759,809
Deficit Plus 10 yr Advance	*58.62*	*904,917*
Deficit Plus 20 yr Advance	77.42	1,195,133

** Federal officials have indicated that Pine Knoll Shores does not presently qualify for matching federal funds because of the lack of public beach accesses in the reach. Soft costs not included.*

Borrow Area Alternatives	**Alternative 1**	**Alternative 2**	**Alternative 3**
	A *(RA=1.10)*	**B1** *(RA=1.62)*	**Corps Inlet** *(RA=1.5)*
Distance to Borrow Area (miles)	*3 - 4*	*0.5*	*6.5 - 9.5*
Feasible Equipment	*Hopper Dredge*	*Pipeline Dredge*	*Pipeline or Hopper*
Nourishment with Overfill			
(10 yr Reqmt Only)	**995,409**	**1,465,965**	**1,357,375**
Estimated Pumping Costs			
Unit Pumping Cost Est ($/cy)	$4.75	$2.75	$3.35
5-yr Project	$3,970,003	$3,384,950	$3,818,041
10-yr Project	**4,728,191**	4,031,405	**4,547,208**
20-yr Project	6,244,568	5,324,315	6,005,541
For The 10-yr Project			
Net Pumping Costs (per ft)	$306.29	**$261.15**	**$294.57**
Annual Unit Costs (per ft/yr)	$30.63	**$26.12**	**$29.46**

Probable Pumping Cost Range - 10-yr Project

Plus 15%	5,437,420	4,636,116	5,229,289
Estimated Reach Cost	**4,728,191**	**4,031,405**	**4,547,207***
Minus 15 %	4,018,962	3,426,694	3,865,126

Note: Preliminary Plan
The above cost estimates do not include final engineering, additional geotechnical surveys to confirm borrow areas, environmental surveys and assessment, permitting, preparation of plans & specifications, construction observations, post construction monitoring and construction mobilization which will vary depending on the number of projects completed.

Estimated Soft Costs	*Low Range*	*High Range*
Dredge Mobilization	$250,000	$1,000,000
Engineering, Permitting and Surveys	250,000	500,000
Totals	**$500,000**	**$1,500,000**

Note: The low range cost estimate assumes at least four projects are designed, permitted and constructed under a single procurement and dredge mobilization so that costs may be shared. The high range estimate assumes design and construction are performed independently of any other projects. **These soft costs are included on the summary project plans illustrated in Figure H, rounding each total.**

TABLE 2.3.2

Pine Knoll Shores - West	**Preliminary Project Alternatives**		September-99
	From Town Line @ Salter Path to Maritime Road		
Beach Condition	Poor		
Reach Length (ft)	**8,760**	Applicable Profiles	59-65
Longterm Vol Erosion Rate cy/ft	-0.36	*Slow Erosion*	
Profile Volumes (cy/ft)		*Dry Beach to +2.5 ft:*	*6.83*
(Base Dunes to -10' NGVD)	**123.78**	*Wet Beach to -5.0 ft:*	*40.55*
Estimated Sand Deficit	51.22	*Underwater to Bar (-10 ft):*	*76.40*

Fill Volume Reqmt - No Overfill	Unit Volume (cy/ft)	Net Volume (cy)	* *Federal officials have indicated that Pine Knoll Shores does not presently qualify for matching federal funds because of the lack of public beach accesses in the reach. Soft costs not included.*
Initial Deficit	51.22	448,687	
Deficit Plus 5 yr Advance	53.02	464,455	
Deficit Plus 10 yr Advance	*54.82*	*480,223*	
Deficit Plus 20 yr Advance	58.42	511,759	
Borrow Area Alternatives	**Alternative 1**	**Alternative 2**	**Alternative 3**
	A *(RA=1.10)*	**B1** *(RA=1.62)*	**Corps Inlet** *(RA=1.5)*
Distance to Borrow Area (miles)	*2 - 2.5*	*0.5*	*9.5 - 11*
Feasible Equipment	*Hopper Dredge*	*Pipeline Dredge*	*Hopper*
Nourishment with Overfill			
(10 yr Reqmt Only)	**528,246**	**777,962**	**720,335**
Estimated Pumping Costs			
Unit Pumping Cost Est ($/cy)	$4.75	$2.75	$4.00
5-yr Project	$2,426,778	$2,069,148	$2,786,731
10-yr Project	**2,509,166**	**2,139,394**	**2,881,339**
20-yr Project	2,673,942	2,279,887	3,070,555

For The 10-yr Project			
Net Costs (per ft)	$286.43	**$244.22**	**$328.92**
Annual Unit Costs (per ft/yr)	$28.64	**$24.42**	**$32.89**
Probable Cost Range - 10-yr Project			
Plus 15%	2,885,541	2,460,304	3,313,540
Estimated Reach Cost	**2,509,166**	**2,139,394**	**2,881,339***
Minus 15 %	2,132,791	1,818,485	2,449,138

Note: Preliminary Plan
The above cost estimates do not include final engineering, additional geotechnical surveys to confirm borrow areas, environmental surveys and assessment, permitting, preparation of plans & specifications, construction observations, post construction monitoring and construction mobilization which will vary depending on the number of projects completed.

Estimated Soft Costs	*Low Range*	*High Range*
Dredge Mobilization	$250,000	$1,000,000
Engineering, Permitting and Surveys	250,000	500,000
Totals	**$500,000**	**$1,500,000**

Note: The low range cost estimate assumes at least four projects are designed, permitted and constructed under a single procurement and dredge mobilization so that costs may be shared. The high range estimate assumes design and construction are performed independently of any other projects. **These soft costs are included on the summary project plans illustrated in Figure H, rounding each total.**

TABLE 2.3.3

Indian Beach - Salter Path — **Preliminary Project Alternatives** — September-99

From Town Line near 1st St to Pine Knoll Shores Town Line

Beach Condition	Fair		
Reach Length (ft)	**13,417**	Applicable Profiles	48-58
Longterm Vol Erosion Rate cy/ft	0	*Stable*	
Profile Volumes (cy/ft)		*Dry Beach to +2.5 ft:*	*9.92*
(Base Dunes to -10' NGVD)	**134.01**	*Wet Beach to -5.0 ft:*	*42.18*
Estimated Sand Deficit	40.99	*Underwater to Bar (-10 ft):*	*81.91*

Fill Volume Reqmt - No Overfill	Unit Volume (cy/ft)	Net Volume (cy)
Initial Deficit	40.99	549,963
Deficit Plus 5 yr Advance	40.99	549,963
Deficit Plus 10 yr Advance	*40.99*	*549,963*
Deficit Plus 20 yr Advance	40.99	549,963

* Possibility for federal/local cost sharing @ 50/50. Borrow material quality will affect performance of the project and may result in lower longevity. Estimate based on the additional pumping/transportation cost to project area. Soft costs and mobilization not included.

Borrow Area Alternatives	**Alternative 1**	**Alternative 2**	**Alternative 3**
	A *(RA=1.10)*	**B2** *(RA=1.80)*	**Corps Inlet** *(RA=1.5)*
Distance to Borrow Area (miles)	*1 - 2*	*0.25 - 0.5*	*11 - 13.5*
Feasible Equipment	*Hopper Dredge*	*Pipeline Dredge*	*Hopper*
Nourishment with Overfill			
(10 yr Reqmt Only)	**604,959**	**989,933**	**824,944**
Estimated Pumping Costs			
Unit Pumping Cost Est ($/cy)	$4.75	$2.75	$5.00
5-yr Project	$2,873,556	$2,722,316	$4,124,721
10-yr Project	**2,873,556**	**2,722,316**	**4,124,721**
20-yr Project	2,873,556	2,722,316	4,124,721
For The 10-yr Project			
Net Costs (per ft)	$214.17	**$202.90**	**$307.43**
Annual Unit Costs (per ft/yr)	$21.42	**$20.29**	**$30.74**
			($154. If 50% matching funds)
Probable Cost Range - 10-yr Project			*($15. If 50% matching funds)*
Plus 15%	3,304,589	3,130,663	4,743,429
Estimated Reach Cost	**2,873,556**	**2,722,316**	**4,124,721***
Minus 15 %	2,442,522	2,313,969	3,506,013

Note: Possibility of matching federal funds at 50/50%.

Note: Preliminary Plan
The above cost estimates do not include final engineering, additional geotechnical surveys to confirm borrow areas, environmental surveys and assessment, permitting, preparation of plans & specifications, construction observations, post construction monitoring and construction mobilization which will vary depending on the number of projects completed.

Estimated Soft Costs	*Low Range*	*High Range*
Dredge Mobilization	$250,000	$1,000,000
Engineering, Permitting and Surveys	250,000	500,000
Totals	**$500,000**	**$1,500,000**

Note: The low range cost estimate assumes at least four projects are designed, permitted and constructed under a single procurement and dredge mobilization so that costs may be shared. The high range estimate assumes design and construction are performed independently of any other projects. **These soft costs are included on the summary project plans illustrated in Figure H, rounding each total.**

TABLE 2.3.4

Emerald Isle - East	**Preliminary Project Plan**			September-99
	From 24th Street to 1st Street (Town Line)			
Beach Condition	Poor			
Reach Length (ft)	**12,900**	Applicable Profiles	36-48	
Longterm Vol Erosion Rate cy/ft	-3.24	*Moderate Erosion*		
Profile Volumes (cy/ft)		*Dry Beach to +2.5 ft:*	*8.62*	
(Base Dunes to -10' NGVD)	**132.25**	*Wet Beach to -5.0 ft:*	*48.73*	
Estimated Sand Deficit	42.75	*Underwater to Bar (-10 ft):*	*74.90*	

* Possibility for Federal/Local cost sharing @ 50/50. Borrow material quality will affect performance of the project and may result in lower longevity. Estimate based on the additional pumping/transportation cost to project area. Soft costs and mobilization not included.

Fill Volume Reqmt - No Overfill	Unit Volume (cy/ft)	Net Volume (cy)
Initial Deficit	42.75	551,475
Deficit Plus 5 yr Advance	58.95	760,455
Deficit Plus 10 yr Advance	*75.15*	*969,435*
Deficit Plus 20 yr Advance	107.55	1,387,395

Borrow Area Alternatives	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
	A *(RA=1.10)*	**B2** *(RA=1.80)*	**C** *(RA=1.15)*	**Corps Inlet** *(RA=1.50)*
Distance to Borrow Area (miles)	*<1 - 2*	*~0.25*	8 - 10.5	13.5 - 16
Feasible Equipment	*Hopper Dredge*	*Pipeline Dredge*	*Hopper Dredge*	*Hopper*
Nourishment with Overfill				
(10 yr Reqmt Only)	**1,066,379**	**1,744,983**	**1,114,850**	**1,454,153**
Estimated Pumping Costs				
Unit Pumping Cost Est ($/cy)	$4.75	$2.75	$6.00	$6.00
5-yr Project	$3,973,377	$3,764,252	$5,247,140	$6,844,095
10-yr Project	**5,065,298**	**4,798,703**	**6,689,102**	**8,724,915**
20-yr Project	7,249,139	6,867,605	9,573,026	12,486,555

Note: Possibility of matching federal funds at 50/50%.

For The 10-yr Project				
Net Costs (per ft)	$392.66	**$371.99**	**$518.54**	**$676.35**
Annual Unit Costs (per ft/yr)	$39.27	**$37.20**	**$51.85**	**$67.64**
				($338. If 50% matching funds)
Probable Cost Range - 10-yr Project				*($34. If 50% matching funds)*
Plus 15%	5,825,093	5,518,509	7,692,467	10,033,652
Estimated Reach Cost	**5,065,298**	**4,798,703**	6,689,102	**8,724,915***
Minus 15 %	4,305,503	4,078,898	5,685,736	7,416,178

Note: Preliminary Plan The above cost estimates do not include final engineering, additional geotechnical surveys to confirm borrow areas, environmental surveys and assessment, permitting, preparation of plans & specifications, construction observations, post construction monitoring and construction mobilization which will vary depending on the number of projects completed.

Estimated Soft Costs	*Low Range*	*High Range*
Dredge Mobilization	$250,000	$1,000,000
Engineering, Permitting and Surveys	250,000	500,000
Totals	**$500,000**	**$1,500,000**

Note: The low range cost estimate assumes at least four projects are designed, permitted and constructed under a single procurement and dredge mobilization so that costs maybe shared. The high range estimate assumes design and construction are performed independently of any other projects. **These soft costs are included on the summary project plans illustrated in Figure H, rounding each total.**

TABLE 2.3.5

Emerald Isle - Central	Preliminary Project Alternatives			September-99
	From Ebb Tide Drive to 24th Street			
Beach Condition	Fair			
Reach Length (ft)	**14,545**	Applicable Profiles	25-36	
Longterm Vol Erosion Rate cy/ft	-1.56	*Slow Erosion*		
Profile Volumes (cy/ft)		*Dry Beach to +2.5 ft:*	*9.55*	
(Base Dunes to -10' NGVD)	**137.87**	*Wet Beach to -5.0 ft:*	*52.42*	
Estimated Sand Deficit	37.13	*Underwater to Bar (-10 ft):*	*75.90*	

Fill Volume Reqmt - No Overfill	Unit Volume (cy/ft)	Net Volume (cy)	
Initial Deficit	37.13	540,056	
Deficit Plus 5 yr Advance	44.93	653,507	
Deficit Plus 10 yr Advance	*52.73*	*766,958*	
Deficit Plus 20 yr Advance	68.33	993,860	
Borrow Area Alternatives	**Alternative 1**	**Alternative 2**	**Alternative 3**
	A *(RA=1.10)*	**C** *(RA=1.15)*	**Corps Inlet** *(RA=1.50)*
Distance to Borrow Area (miles)	*2 - 4*	*6 - 8*	16 - 19
Feasible Equipment	*Hopper Dredge*	*Hopper Dredge*	*Hopper*
Nourishment with Overfill			
(10 yr Reqmt Only)	**843,654**	**882,002**	**1,150,437**
Estimated Pumping Costs			
Unit Pumping Cost Est ($/cy)	$5.00	$5.50	$7.00
5-yr Project	$3,594,288	$4,133,431	$6,861,822
10-yr Project	**4,218,268**	**4,851,008**	**8,053,057**
20-yr Project	5,466,229	6,286,164	10,435,528

* Possibility for federal/local cost sharing @ 50/50. Borrow material quality will affect performance of the project and may result in lower longevity. Estimate based on the additional pumping/transportation cost to project area. Soft costs and mobilization not included.

For The 10-yr Project			
Net Costs (per ft)	$290.02	**$333.52**	**$553.67**
Annual Unit Costs (per ft/yr)	$29.00	**$33.35**	**$55.37**

Probable Cost Range - 10-yr Project			
Plus 15%	4,851,008	5,578,660	9,261,016
Estimated Reach Cost	**4,218,268**	**4,851,008**	**8,053,057***
Minus 15 %	3,585,528	4,123,357	6,845,099

Note: Preliminary Plan - The above cost estimates do <u>not</u> include final engineering, additional geotechnical surveys to confirm borrow areas, environmental surveys and assessment, permitting, preparation of plans & specifications, construction observations, post construction monitoring and construction mobilization which will vary depending on the number of projects completed.

Estimated Soft Costs	*Low Range*	*High Range*
Dredge Mobilization	$250,000	$1,000,000
Engineering, Permitting and Surveys	250,000	500,000
Totals	**$500,000**	**$1,500,000**

Note: The low range cost estimate assumes at least four projects are designed, permitted and constructed under a single procurement and dredge mobilization so that costs may be shared. The high range estimate assumes design and construction are performed independently of any other projects. **These soft costs are included on the summary project plans illustrated in Figure H, rounding each total.**

TABLE 2.3.6

Emerald Isle - West	**Preliminary Project Alternatives**		September-99
	From ~Shipwreck Lane to Ebb Tide Drive		
Beach Condition	Fair		
Reach Length (ft)	**23,702**	Applicable Profiles	8-25
Longterm Vol Erosion Rate cy/ft	-0.22	*Very Slow Erosion*	
Profile Volumes (cy/ft)		*Dry Beach to +2.5 ft:*	*9.48*
(Base Dunes to -10' NGVD)	**145.43**	*Wet Beach to -5.0 ft:*	*51.48*
Estimated Sand Deficit	29.57	*Underwater to Bar (-10 ft):*	*84.47*
Fill Volume Reqmt - No Overfill	Unit Volume (cy/ft)	Net Volume (cy)	
Initial Deficit	29.57	700,868	
Deficit Plus 5 yr Advance	30.67	726,940	
Deficit Plus 10 yr Advance	*31.77*	*753,013*	
Deficit Plus 20 yr Advance	33.97	805,157	
Borrow Area Alternatives	**Alternative 1**	**Alternative 2**	Alternative 3
	A *(RA=1.10)*	**C** *(RA=1.15)*	N/A
Distance to Borrow Area (miles)	*5 - 8*	*2 - 5*	
Feasible Equipment	*Hopper Dredge*	*Hopper Dredge*	
Nourishment with Overfill			
(10 yr Reqmt Only)	**828,314**	**865,964**	N/A
Estimated Pumping Costs			
Unit Pumping Cost Est ($/cy)	$5.50	$5.00	
5-yr Project	$4,397,989	$4,179,907	
10-yr Project	**4,555,726**	**4,329,822**	
20-yr Project	4,871,199	4,629,652	
For The 10-yr Project			
Net Costs (per ft)	$192.21	**$182.68**	
Annual Unit Costs (per ft/yr)	$19.22	**$18.27**	
Probable Cost Range - 10-yr Project			
Plus 15%	5,239,085	4,979,295	
Estimated Reach Cost	**4,555,726**	**4,329,822***	
Minus 15 %	3,872,367	3,680,349	

Note: Preliminary Plan -The above cost estimates do not include final engineering, additional geotechnical surveys to confirm borrow areas, environmental surveys and assessment, permitting, preparation of plans & specifications, construction observations, post construction monitoring and construction mobilization which will vary depending on the number of projects

Estimated Soft Costs	*Low Range*	*High Range*
Dredge Mobilization	$250,000	$1,000,000
Engineering, Permitting and Surveys	250,000	500,000
Totals	**$500,000**	**$1,500,000**

Note: The low range cost estimate assumes at least four projects are designed, permitted and constructed under a single procurement and dredge mobilization so that costs may be shared. The high range estimate assumes design and construction are performed independently of any other projects. **These soft costs are included on the summary project plans illustrated in Figure H, rounding each total.**

TABLE 2.3.7

Summary - Bogue Banks	Preliminary Project Plan	September-99
	Emerald Isle-West to Pine Knoll Shores East	
Beach Condition	Fair to Poor	
Reach Length (ft)	**88,761**	Applicable Profiles: **8 - 76**
Longterm Vol Erosion Rate cy/ft	-1.15	*Slow to Moderate Erosion*
Profile Volumes (cy/ft)		*Dry Beach to +2.5 ft: 9.17 cy/ft*
(Base Dunes to -10 ft NGVD):	**136.63**	*Wet Beach to -5.0 ft: 47.30 cy/ft*
Estimated Average Sand Deficit:	38.37	*Underwater to Bar (-10 ft): 80.17 cy/ft*

Note: Averages are weighted for the applicable shoreline length

Fill Volume Reqmt - No Overfill	Unit Volume (cy/ft)	Net Volume (cy)
Initial Deficit	38.37	3,405,750
Deficit Plus 5 yr Advance	44.11	3,915,129
Deficit Plus 10 yr Advance	*49.85*	***4,424,508***
Deficit Plus 20 yr Advance	61.32	5,443,266

Note: The fill volume requirement is less than the nourishment volume for a particular borrow area because of differences in sediment quality. Borrow Area A will require ~10% greater nourishment volumes; Borrow Area B1 will require ~62% greater volumes; Borrow Area B2 will require ~80% greater volumes; and Borrow Area C will require ~ 15% greater volumes to provide equivalent project performance and longevity. Unit dredging costs vary with distance between the Borrow area and the beach, type of equipment used, and quality of the sediments.

Lowest Cost Alternative (Borrow Area)	**Nourishment Volume (cy)**	**Pumping Costs**
	10-yr Project	*10-yr Project*
*1 Pine Knoll Shore - East (**B1**)*	1,465,965	**$4,031,405**
*2 Pine Knoll Shore - West (**B1**)*	777,962	**2,139,394**
*3 Indian Beach/Salter Path (**B2** or A)*	989,933	**2,722,316**
*4 Emerald Isle - East (**B2** or A)*	1,744,983	**4,798,703**
*5 Emerald Isle - Central (**A**)*	843,654	**4,218,268**
6 Emerald Isle - West (C or A)	865,964	**4,329,822**
Totals	6,688,461 cy	**$22,239,908**

Note: Similar costs are likely for Projects 3,4 & 5 using alternate borrow areas. The indicated nourishment volume requirement and unit pumping costs will vary according to which Borrow Area is chosen. See individual project sheets for details.

For The 10-yr Project	*Rounded*
Net Costs (per ft)	**$250**
Annual Unit Costs (per ft/yr)	**$25**

Probable Cost Range - 10-yr Project	
Plus 15%	25,500,000
Estimated Pumping Cost	**$22,250,000***
Minus 15 %	19,000,000

* Possibility for federal/local cost sharing @ 50/50 for some of the projects using Corps borrow areas in Beaufort Inlet and Bogue Inlet. See individual project sheets for details.

Estimated Soft Costs	*Low Range*	*High Range*
Dredge Mobilization	$800,000	$2,000,000
Engineering, Permitting and Surveys	1,200,000	2,500,000
Estimated Total Soft Costs	**$2,000,000**	**$4,500,000**

Note: The low range cost estimate assumes at least four projects are designed, permitted and constructed under a single procurement and a single dredge mobilization so that costs may be shared. The high range assumes two dredge mobilizations will be required because of different equipment requirments for each borrow area.

2.4 APPLICANTS' PREFERRED ALTERNATIVE

The applicants' preferred alternative is beach nourishment using offshore borrow areas A, B1, and B2 in close proximity to the six project reaches (Fig 2.1).

Following development of the preliminary plan (CSE Baird-Stroud 1999) (Section 2.3.5 of this report), additional surveys were performed and reported in CSE (2000) and CSE Stroud (2001). The project has also been revised based on comments from state resource agencies under the SEPA EIS review (final environmental impact statement published 6 April 2001) and from federal resource agencies through the public notice and subsequent meetings.

Based on the involvement of three municipalities and the present timelines for funding, the proposed project will be constructed in two or three phases over at least three years (ie, three environmental windows). Three borrow areas (A, B1, and B2) will be used, but excavations will be limited to specific areas within A, B1, and B2 (described in Section 3). Fill sections will involve up to the indicated volumes given in the permit application and in this report but may be less depending on final construction bids because the project funding will be fixed. Representative fill sections are given in the permit application (Appendix A-2). The fill sections shown in the permit application indicate a base fill volume (based on the ~4.5 million cubic yard volume deficit) and an additional "overfill" volume representing the additional quantity needed to match the performance of the native beach. The final project volume and section volumes cannot be known with certainty until bids are received and compared with the budget available for each phase. Based on best-available information, the proposed project will now be executed as follows.

2.4.1 Phase I

Reaches 4, 5, and 6 – Towns of Pine Knoll Shores and Indian Beach (transects 48-77). See sheets 3d, 3e, 3f, 7, 8, and 9 of the permit application (Appendix A-2).

Requested dates for construction: 1 November 2001 through 30 April 2002

Negotiated dates for construction (27 August 2001): *16 November through 15 April 2002*

Borrow areas: B1, B2, and A within the revised areas and sections (described in Section 3). Approximately 65 percent of the fill will be obtained from B1 and B2, and 35 percent will be obtained from A.

Estimated Phase I volumes:	Initial Base Volume (cy)	Advance Nourishment Plus Overfill Volume (cy)	Total Volume (cy)
Reach 4	550,000	440,000	990,000
Reach 5	480,000	240,000	720,000
Reach 6	905,000	445,000	1,350,000
Phase I Total			3,060,000

Phase I dimensions:

	Depth of Cut (ft)	Volume Cubic Yards (%)	Areas (acres / mile²)
Borrow area A	~2	1,071,000 (35)	332 / 0.52
Borrow areas B1 and B2	~3	1,989,000 (65)	411 / 0.64
Phase I Total		3,060,000 (100)	743 / 1.16

Beach Area	Length (ft)	Avg Unit Volume (cy/ft)	Estimated Added Dry Beach Width (ft)	Estimated Added Dry Beach (acres)
Reach 4	13,400	73.9	82	25.2
Reach 5	8,800	81.8	91	18.4
Reach 6	15,400	87.7	97	34.3
Phase I Total	35,600 (~7.1 miles)			77.9

Inshore (Surf Zone) Areas	Average Width Impacted by Direct Filling (ft)	Area (acres)
Reach 4	525	161
Reach 5	510	103
Reach 6	525	186
Phase I Total		450

Time required for construction: ~153 days (at 20,000 cubic yards per day average)

Average production per day: ~250 ft

Fill sequence (anticipated):

Begin Phase I in Reach 5 – Pine Knoll Shores West to avoid November surf fishery in Atlantic Beach
Fill Reach 5 @ ~1,800 ft per week (impacted areas)
Fill Reach 6 – Pine Knoll Shores East
Fill Reach 4 – Indian Beach
End Phase I

Type of equipment and construction sequence: Hydraulic dredge

There are an estimated 20 self-propelled hopper dredges and one shallow-cut suction dredge certified to perform work of this type in the U.S. Therefore, there is a 95 percent probability that the type of equipment used will by a self-propelled hopper dredge. (Such dredges are described in Section 2.3). Hopper dredges excavate borrow areas, then travel to an inshore site about 1,000 ft offshore where they connect to a temporary pipeline. From there, a slurry of sediment and water is pumped to shore and distributed in sections along the beach. Sediment is discharged parallel to the shore and semi-contained by low berms. The slurry runs alongshore and down-profile, carrying finer grained sediments into the surf where it is mixed and sorted by waves. Clay-sized particles dissipate beyond the surf zone and silts and very fine sands tend to settle beyond the outer bar. The balance settles in the trough or in the new berm. After completion of ~1-2 miles, the landing pipe from offshore is moved to a new locality. The area just filled is graded to the final slopes (matching the natural beach elevation and slopes above high water) and then left to adjust naturally. Typically, a given 1-2 mile reach is only impacted by construction activities for approximately one month, and then the operation moves to another reach.

Phase I (Reaches 4, 5, and 6) represents ~42.4 percent of the total project length and ~45.7 percent of the total project volume. Phase I has been approved by the municipal sponsors, and a funding plan is in place for construction at the earliest time.

2.4.2 Phase II

Reach 3 and portions of Reach 2 – Emerald Isle East and Emerald Isle Central (ie, Indian Beach/Emerald Isle town line at transect 48 to ~30th Street at transect 34). See sheets 3b, 3c, 5, and 6 of the permit application (Appendix A-2).

Anticipated dates for construction: 16 November 2002 through 15 April 2003.

Borrow areas: B1, B2, and A within the revised areas and sections (described in Section 3). Approximately 65 percent of the fill will be obtained from B1 and B2, and 35 percent will be obtained from A.

Estimated Phase II volumes:

	Initial Base Volume (cy)	Advance Nourishment Plus Overfill Volume (cy)	Total Volume (cy)
Reach 3	970,000	485,000	1,455,000
Reach 2 (east part)	150,000	75,000	225,000
Phase II Total	1,120,000	560,0000	1,680,000

Phase II dimensions:

	Depth of Cut (ft)	Volume Cubic Yards (%)	Acres (acres / mile²)
Borrow area A	~2	588,000 (35)	182 / 0.285
Borrow areas B2 and B1	~3	1,092,000 (65)	226 / 0.353
Phase II Total		1,680,000 (100)	408 / 0.638

Beach Area	Length (ft)	Avg Unit Volume (cy/ft)	Estimated Added Dry Beach Width (ft)	Estimated Added Dry Beach (acres)
Reach 3	12,900	112.8	125	37.0
Reach 2 (east part)	2,800	80.4	89	5.7
Phase II Total	15,700 (3.0 miles)			42.7

Inshore (Surf Zone) Areas	Average Width Impacted by Direct Filling (ft)	Area (acres)
Reach 3	575	~170
Reach 2 (east part)	475	~30
Phase II Total		200

Time required for construction: ~112 days (at 15,000 cubic yards per day average)

Average production per day: ~140 ft

Fill sequence (anticipated):

Begin Phase II at east end of Reach 3 (Indian Beach/Emerald Isle town line at transect 48)
Fill Reach 3
Fill eastern 2,800 ft of Reach 2 ending at 30th Street (~transect 34)
End Phase II

Type of equipment: Hydraulic dredge (see Section 2.4.1 for information on construction sequencing)

Note: Phase II is not presently approved and funded by the applicants. However, the indicated reaches have been designated by community leaders as the priority areas (Mayor B. Harris, March 2001, pers. comm.).

Phase II (Reach 3 and part of Reach 2) represents 17.9 percent of the total project length and 25.1 percent of the total project volume.

2.4.3 Phase III

Remainder of Reach 2 from 30th Street (transect 34) to Ebb Tide Drive (transect 25) and all or portions of Reach 1 (Ebb Tide Drive to Shipwreck Lane, transect 8) – Central and Western Emerald Isle.

Anticipated dates for construction: 16 November 2002 through 15 April 2003 **or** 16 November 2003 through 15 April 2004

Borrow areas: B1, B2, and A within the revised areas and sections (described in Section 3). Approximately 65 percent of the fill will be obtained from B1 and B2, and 35 percent will be obtained from A.

Estimated Phase III volumes:

	Initial Base Volume (cy)	Advance Nourishment Plus Overfill Volume (cy)	Total Volume (cy)
Reach 2 (west part)	617,000	308,000	925,000
Reach 1	753,000	282,000	1,035,000
Phase III Total	1,370,000	590,000	1,960,000

Phase III dimensions:

	Depth of Cut (ft)	Volume Cubic Yards (%)	Acres (acres / mile²)
Borrow area A	~2	686,000 (35)	212 / 0.33
Borrow areas B2 and B1	~3	1,274,000 (65)	263 / 0.41
Phase III Total		1,960,000 (100)	475 / 0.74

Beach Area	Length (ft)	Avg Unit Volume (cy/ft)	Estimated Added Dry Beach Width (ft)	Estimated Added Dry Beach (acres)
Reach 2 (west part)	11,700	79.1	88	23.6
Reach 1	23,700	43.7	49	26.7
Phase III Total	35,400 (6.7 miles)			50.3

Inshore (Surf Zone) Areas	Average Width Impacted by Direct Filling (ft)	Area (acres)
Reach 2 (west part)	425	114
Reach 1	425	231
Phase III Total		345

Time required for construction: ~130 days

Average production per day: 270 ft

Fill sequence: To be determined upon review of conditions around time of construction

Type of equipment: Hydraulic dredge

Note: Phase III is not presently approved and funded by the applicants. However, the indicated reaches have been designated by community leaders as the remaining priority areas for restoration.

Phase III may be further subdivided or reduced in scope if future conditions show favorable trends in sand volume gains. Phase III (Reach 1 and the west part of Reach 2) represents 39.9 percent of the total project length and 29.3 percent of the total project volume.

2.4.4 Summary

2.4.4.1 Phase I: Reaches 4, 5, and 6 — 3,060,000 cy — Nov 2001 – Apr 2002
Transects 48 to 77 (Pine Knoll Shores and Indian Beach town limits)
37,600 linear feet (7.1 miles)

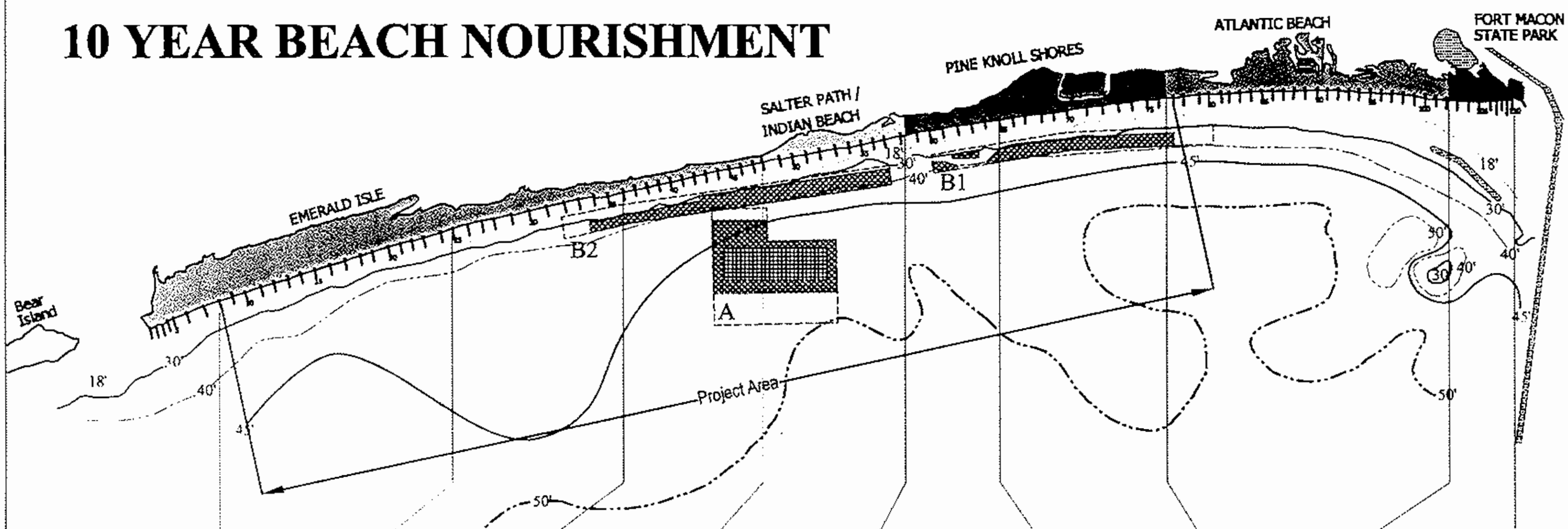
2.4.4.2 Phase II: Reach 3 and 2,800 ft of Reach 2 — 1,680,000 cy — Nov 2002 – Apr 2003
Transects 34 to 48 (eastern Emerald Isle, 1st Street to 30th Street)
15,700 linear feet (3.0 miles)

2.4.4.3 Phase III: Reach 1 and remainder of Reach 2 — 1,960,000 cy — Future
Transects 8 to 34 (western and central Emerald Isle, Shipwreck Lane to 30th Street)
35,400 linear feet (6.7 miles)

2.4.4.4 Totals: Reaches 1 through 6 — 6,700,000 cy
Transects 8 to 77 [Shipwreck Lane (Emerald Isle) to Atlantic Beach town line)
88,700 linear feet (16.8 miles)

See Appendix A-2 for detailed maps and cross-sections of the proposed project.

PREFERRED ALTERNATIVE
10 YEAR BEACH NOURISHMENT



REACH 1 Emerald Isle West 1	REACH 2 Emerald Isle Central 2	REACH 3 Emerald Isle East 3	REACH 4 Indian Beach Salter Path 4	REACH 5 Pine Knoll Shores West 5	REACH 6 Pine Knoll Shores East 6	Atlantic Beach	Fort Macon State Park
						Nourished by USACE 1986-1994	
Recommended Project: 10 Year	Recommended Project: 10 Year	Recommended Project: 10 Year	Recommended Project: 10 Year	Recommended Project: 10 Year	Recommended Project: 10 Year		
Nourishment Volume: 1,035,000 cy	Nourishment Volume: 1,150,000 cy	Nourishment Volume: 1,455,000 cy	Nourishment Volume: 990,000cy	Nourishment Volume: 720,000 cy	Nourishment Volume: 1,350,000 cy		
Length: 23,700 ft	Length: 14,545 ft	Length: 12,900 ft	Length: 13,417 ft	Length: 8,760 ft	Length: 15,437 ft		
Borrow Area A & B2: Bogue Inlet Shores via hopper dredge	Borrow Area A,B1, & B2: Salter Path Offshore Deposits	Borrow Area A,B1, & B2: Salter Path Offshore Deposits	Borrow Area A & B2: Salter Path Offshore Deposits	Borrow Area A & B1: Inshore Deposits	Borrow Area A & B1: Inshore Deposits		

Summary:

Length: ~88,760 ft - 16.8 miles

10-Yr Nourished Volume Required: ~6,700,000 cy

Incorporates first cost volume, 10 year advance nourishment plus overfill (Ra).

NOTE: Nourishment volumes are based on a computed profile volume deficit to the outer bar, background volume erosion rate, and overfill ratio for the indicated borrow area. Use of alternative areas will result in revised nourishment volumes and unit construction costs. The low-end cost estimate assumes shared engineering, permitting, and construction mobilization costs. The high-end cost estimate assumes independently formulated and executed projects. Details are given in CSE Baird/Stroud (1999); CSE - Stroud 2000 and present report.

Borrow area key

- CSE Borrow Areas
- Corps Borrow Areas

R_a values for borrow areas:

Borrow Area A - ~1.15
Borrow Area B1 - ~1.58
Borrow Area B2 - ~1.50

Native beach composite

Mean grain size ~0.30mm.

Depth contours (ft below MLW)

18'
30'
40'
45'
50'

CSE
Coastal Science & Engineering PLLC

PROJECT NORTH
0 5000 10000

Bogue Banks
Beach Nourishment
North Carolina

Prepared For:
Carteret County
North Carolina

Drawing Title:

Fig 2.1

3.0 AFFECTED ENVIRONMENT

3.1 LAND USE

3.1.1 Character of Bogue Banks

Bogue Banks is a barrier island with a southward facing ocean shoreline stretching some 25 miles between two large tidal inlets, Bogue Inlet to the west and Beaufort Inlet to the east. The area of Bogue Banks is surrounded by Bogue Sound on the north and Onslow Bay of the Atlantic Ocean on the south. The island is made up of the Fort Macon State Park; the Towns of Atlantic Beach, Pine Knoll Shores, Indian Beach, and Emerald Isle; and the unincorporated area of Salter Path.

Of almost 80 miles of barrier island shoreline located in Carteret County, Bogue Banks is the only developed area. The remainder, made up of Shackleford Banks and Core Banks to Ocracoke Inlet, will remain undeveloped in perpetuity as part of the Cape Lookout National Seashore. Bogue Banks is the only ocean shoreline in the county with direct vehicle access.

Topography on Bogue Banks varies from the salt marsh flats and flood prone drainage areas along the island's northern shoreline on Bogue Sound to dune ridges on the island interior and along the ocean shoreline. Dune ridge elevations reach 40 feet (ft) above sea level at some locations.

Bogue Banks' soils vary with Newhan sandy soils in the nearshore, beach and dune zones; Duckston, Corrolla and Newhan soils in the scrub zones; Duckston, Corrolla, and Fripp soils in the maritime forest zones; and Carteret soils in the salt marsh zones. Corrolla soils are fine sands, moderately to poorly drained that occur behind the frontal dune line. Fripp sands are excessively well drained and make up the interior dune ridge areas. Duckston fine sands are poorly drained and are in the troughs between dune ridges and on flats between dunes and marshes. Newhan fine sands are excessively well drained and make up the dune ridges that parallel the ocean shoreline. Carteret soils are the fine organic muck found in the salt marsh environment.

Vegetation on Bogue Banks reflects elevation and the amount of exposure to salt spray. As distance from the shoreline increases, sparse beach grasses merge with dense scrub vegetation. Maritime forests thrive in areas where the island is wide enough to provide sufficient protection from salt spray for forest growth. Maritime forests generally occur on lands that have been stable for at least 50 years. Vegetation typical of freshwater wetlands and tidal flats populate flood prone areas and natural and manmade drainage ways.

3.1.2 Typical Development

Development of Bogue Banks ranges from the densely developed portions of Atlantic Beach to the Theodore Roosevelt Natural Area in Pine Knoll Shores. Oceanfront development is, for the most part, residential with pockets of commercial hotels and campgrounds, multi-family condominium developments, and high-density mobile home parks. It is estimated that development of oceanfront lots has reached 90 percent build out.

Setbacks for oceanfront construction are established by regulations of the NC Division of Coastal Management (DCM). Residential construction setbacks are 30 times the long- term erosion rate as established by maps prepared by DCM. Maps currently in use were updated in 1992. The setback for large commercial or permanent structures in excess of 5000 square feet is 60 times the long-term erosion rate. The minimum setback is 60 ft in areas with long-term erosion rates less than 2 ft. The line for measurement of setbacks is the first line of stable vegetation. In locations where vegetation is sparse, the line is interpolated from adjacent areas where vegetation exist. The measurement line is typically established in the field by DCM personnel as part of the CAMA permitting process.

3.2 WETLANDS

There are no areas of 404 wetlands or coastal wetlands identified in the project area.

3.3 AGRICULTURAL LANDS

No agricultural land is in or adjacent to the project area. Low water retention capacity of the sandy barrier island soils preclude establishment of agricultural crops.

3.4 LITTORAL PROCESSES AND EROSION

Existing data on the littoral processes and erosion on the oceanfront side of Bogue Banks include:

- Historical, but not recent tidal statistics.
- Several versions of wave conditions as outputs from wind/wave models, but no wave measurements.
- Estimates of wave and current energy fluxes along the beach as outputs from different wave-shoaling models, but only brief visual measurements of waves and currents.
- Estimates of longshore sediment transport, especially at Atlantic Beach, from (1) wave-shoaling model studies performed by the Corps of Engineers (USACE) and the University of North Carolina (UNC), and (2) qualitative measures of diffusion/advection of the Atlantic Beach nourishment sand from UNC studies.
- Extensive sets of topographic surveys (beach profiles) for Atlantic Beach (only) from both USACE and UNC, with profile sets for the entire island available from 1978 (USACE) and 1999 (CSE Baird-Stroud).

3.4.1 Tides

Tides have been measured at Duke Marine Lab in Beaufort on the **sound** side of the islands continuously since 1973. Tidal measurements at other locations were made only during brief studies in 1960 and 1973 and show (USACE 1999):

Tide Gauge Location	Mean	Tide Range in 1960 (ft) Spring	Tide Range in 1973 (ft) Mean
Atlantic Beach (ocean side)	3.6	4.3	3.6
Morehead City	2.8	3.4	2.9
Duke Marine Lab (Beaufort)	2.5	3.0	2.9
Shell Point (Harkers Island)	1.3	1.6	1.6

The more recent 1973-1989 data set at Duke Marine Lab shows a tide range of 3.0 ft and a spring tide range of 3.5 ft. (http://www.opsd.nos/noaa.gov/cgi-bin/websql/ftp/staqry.pl)

3.4.2 Hurricanes

Tidal surges from storms add to the astronomically produced tides for a total stillwater superelevation. Frequency of occurrence of hurricanes is highly variable (Barnes 1998). One estimate of hurricane frequency made in the 1970s was 1.6 hurricanes per year for Bogue Banks (Sarle 1977). North Carolina hurricanes increased in frequency in the 1990s. With respect to beaches, the most important effect of hurricanes is the surge. Surge levels do not necessarily correlate with hurricane strength or "category," since categories are determined by wind and pressure, not surge. For example, surge levels at Atlantic Beach were estimated for *Hazel* (1954, Category 4) at 7.0 ft mean sea level (MSL), for *Ione* (1955, Category 3) at 7.2 ft MSL, and *Donna* (1960, Category 3) at 10.6 ft MSL (USACE 1966). *Donna* may be an appropriate "design" hurricane for Bogue Banks, since it is the only recent hurricane to have breached the island (near the location of a relict inlet in eastern Emerald Isle).

NCSU (Knowles et al 1973) estimated surge levels for different return periods of storms, along each section of the North Carolina coast. For the section that includes Bogue, stillwater surge levels in feet above MSL are 7.63 ft for a 25-year storm, 9.33 ft for 50-year, and 10.95 ft for 100-year. These surges were then translated into estimates of resulting dune retreat, using empirical data from several storms. Dune retreat is a function of surge, height and massiveness of the dune, and distance between the dune and the mean waterline. In the 70s Bogue's average dune reached 16 ft above MSL and had a toe 8.9 ft above MSL that was 158 ft from mean high water. Estimates of dune retreat were 21 ft for a 25-year storm, 162 ft for 50-year, and 220 ft for 100-year. Bogue's beaches are currently much narrower than in this study (the dunes are closer to the water). However, site-specific measurements after *Floyd* (1999) showed that dune retreat averages somewhat less than these model predictions--about 15 ft.

3.4.3 Waves

Wave heights, frequencies, and directions have been estimated for this area by various sources over the years. However, all such studies are based on observations or estimates of offshore winds, which models then convert into the resulting waves. In some studies these waves are then shoaled into breaking-wave depths using wave-refraction models. Estimating waves in this manner results in large errors compared to wave measurements. Early estimates of wave heights include Nummedal et al (1977) who used Navy shipboard wind observations to determine offshore wave heights for the area of 5.5 ft, with a 7 ft height exceeded 27 percent of the time. The Corps of Engineers Wave Information Study's 1956-75 data set of waves (Jensen 1983) modeled from winds shows mean wave height for the area in 10 meters (m) of water (Phase III dataset) of 4.3 ft (USACE 1992). Summary wave statistics (from USACE CERC's website) for the deeper (20-27m) Phase II stations are:

Station	Dates	Depth (m)	Mean Height (ft)	Mean Period (sec)	Mean Direction (azimuth degrees)
#45 (25 nm south ofEmerald Isle)	1956-75	27	3.9	6.2	112.5
	1976-95	27	3.9	7.4	112.5
#46 (7 nm southeast of Cape Lookout)	1956-75	20	3.6	6.4	112.5
	1976-95	20	3.9	8.2	90.0

Using a 1976-93 version of the Station #46 WIS data set, a University of North Carolina study (Roessler 1998, Fig 25) found wave heights shoaled all the way into the breakpoint varied considerably depending on the direction of approach, but averaged about 3.9 ft, except at the easternmost end of the island where Bogue is sheltered somewhat by Beaufort Inlet's ebb-tidal delta and the Corps' offshore dredging disposal areas.

The applicants have installed an offshore wave gauge about 8 miles off Pine Knoll Shores and an inshore wave gauge adjacent to the Iron Steamer pier for purposes of obtaining a site-specific record of incident waves between November and May.

3.4.4 Dimensions of Littoral Zone (Depth of Closure)

The depth offshore to which there is active interchange of sediment with the beach is of consequence to beach nourishment projects. The goal is to avoid taking sediment from within the active system, since that sediment is already, to some extent, helping to maintain the beach. The depth of closure is defined in standard texts, such as the Shore Protection Manual (CERC 1984), as the depth beyond which there is active motion of the seabed for an average of only 12 hours per year. Six different methods and sources of information were utilized in determining this depth for Bogue Banks, and the results are detailed in Appendix G2. Those calculations produce the following conclusions:

1) Hindcast data of extreme (12 hr/yr) conditions produce depths of closure between 13 ft and 18 ft MLW.

2) Measured storm conditions produce closure depths between 16 ft and 22 ft.

3) During the few hours that hurricanes are present in the immediate vicinity, closure depth has been computed as 36 ft.

4) The limit of sediment activity was measured at a nearby but more open-coast site at between 3.9 and 6.4 m (13-21 ft).

5) Mapping sediment types by color, texture, and size result in a boundary between beach and shelf sands between 32 and 33 ft depths.

6) The Corps of Engineers' nearshore berm off of Atlantic Beach in 25-30 ft depths has not exhibited significant motion and has not contributed sediment to the beach.

3.4.5 Littoral Transport

Studies of the potential for longshore sediment transport are detailed in Appendix G4. All of the quantitative studies used waves that are part of the USACE Wave Information Study, which is a compilation of wave predictions as modeled from the offshore winds that generate waves. Various versions of these databases have been produced over the years, but no measurements have been made of the directional wave field.

Hindcast studies of waves predict different magnitudes and opposite directions of sediment transport along Bogue Banks, depending on which database is used. Early studies (USACE 1976) predicted net transport eastward. Updated versions of the winds for the same time period (1956-75) produced significantly greater transports, but still to the east. Recent studies (USACE 1999) show westward transport, using winds from a different time (1976-95). Other studies (Roessler 1998) also show westward transport. However, our studies detailed in Appendix G4 show that the magnitudes and direction of transport are solely a function of which wave database is used. When we used the same databases as the above studies, we confirmed their results, even though our wave-shoaling methods were different. Thus, the qualitative results (net direction and rough magnitude) do not depend on the different wave-shoaling methods and topographic data used by different investigators.

More reliable than computation of transport from waves modeled from winds are geological indicators of net sediment accumulation. These indicators allow some qualitative conclusions to be reached regarding longshore sediment transport along Bogue.

Net longshore transport rates are low along Bogue Banks. Evidence includes:

1) Erosion rates measured from aerial photos and beach profiles do not vary dramatically along the island. The change (divergence) of transport rates along the beach is what causes net erosion/accretion.

2) There are no large accumulations of sand at the end of the cell (western end of Emerald Isle). Although that area is currently accreting, it is not doing so rapidly, and over time the area cycles back and forth between erosion and accretion.

3) A study (Reed 1997) examined the differences in texture and color between the Corps' nourishment sand at Atlantic Beach and the native sand. These differences allowed tracking of nourishment as a "tracer" and determined that the net transport was quite low, much lower than wave hindcast studies suggest.

3.4.6 Historical Erosion Rates

Rates of erosion/accretion were estimated for all sections of Bogue Banks using both volumetric measures of change, where previous data existed, and linear rates of shoreline change from aerial photography. [The methods are detailed in Appendix G5 and the results tabulated in Table G5-1 in Appendix G5. Final classifications of erosion rates are illustrated in Figure G5-2 in Appendix G5.] There is considerable variability in the results between very different methods, but all methods show an overall slow erosion. The bottom line is that most communities on Bogue Banks have slow but continuing erosion rates (on the order of 1 ft/yr shoreline retreat). However, the erosion does not occur at a steady rate, but in episodic events during storms. The net result of storm erosion (average of 15 ft retreat during Hurricane *Floyd*) and the following recovery is a slow retreat of the shoreline.

3.4.7 Beach Surveys

No island-wide surveys are available prior to 1999 that measure representative profiles from the foredune to the lower foreshore. One set of wading-depth profiles is available from a USACE survey (unpublished) in 1978. As part of the Corps planning for disposal of sediments from navigation projects in Beaufort Inlet, they have completed detailed profile surveys along Fort Macon State Park and Atlantic Beach out to the ~30-ft contour (USACE 1992).*

*[*In early 2001, the Corps initiated a feasibility study of erosion and contracted for surveys encompassing the entire Bogue Banks oceanfront in April 2001. These data were not available in time for inclusion in the present analysis.]*

Given the dearth of surveys along the entire island for volumetric erosion analyses, the applicants contracted with CSE Baird-Stroud (1999) to establish a network of 111 transects at ~1,000-ft spacing along Bogue Banks. These were first surveyed from the foredune/ backshore to the outer bar (800-1,100 ft offshore) in June 1999. Figure 3.1 shows the general location of survey lines, and Figure 3.2 illustrates eight representative profiles. These data were juxtaposed with USACE 1978 wading depth profiles for purposes of computing volumetric changes over the 21-year period (1978-1999, Fig 3.3). The results confirmed low rates of change along most of the island. An important implication of this result for the proposed project is that low background erosion rates improve the chance of success of nourishment and reduce the frequency of damaging erosion along backshore habitats.

Soon after completion of the county-sponsored shoreline assessment, Hurricanes *Dennis* and *Floyd* impacted Bogue Banks. CSE-Stroud (2001) resurveyed 18 profiles in September 1999 and all lines in June 2000. Representative profiles are given in Figure 3.4. *Floyd* caused average recession at the toe of the foredune of ~14 ft. In contrast, the mean high water contour (~+2 ft NGVD) shifted seaward by ~25 ft immediately after the storm (Fig 3.5). Between September 1999 and June 2000, the toe of the foredune (+9 ft NGVD contour) shifted seaward (mainly as a result of dune scraping), and the mean high water contour shifted landward. The net result on average was a restoration of the dune volume by artificial means and return of the recreational beach to its prestorm (eroded) condition along most of the island. Overall, between June 1999 and June 2000, there was negligible net change in the average contour position or in the total volume of sand in the littoral zone along Bogue Banks.

Survey Lines and Reach Boundaries

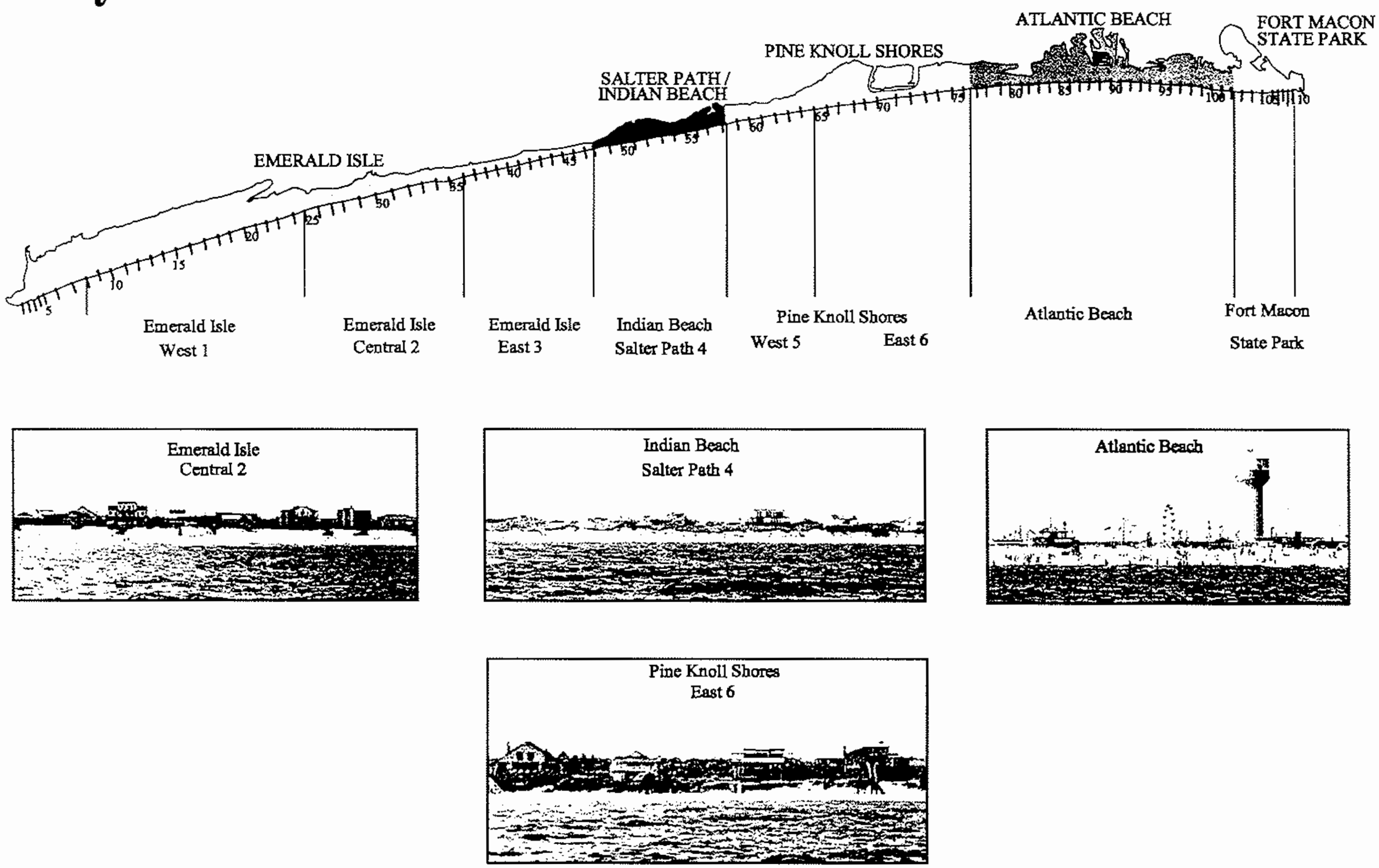


FIGURE 3.1 Location of beach and inshore profiles established and surveyed by the project team in June 1999 and June 2000. About 20 percent of the profiles were resurveyed one week after Hurricaine Floyd in September 1999.

CSE Baird

STROUD ENGINEERING

Bogue Banks
Beach Nourishment
North Carolina

Carteret County
North Carolina

Fig 3.1

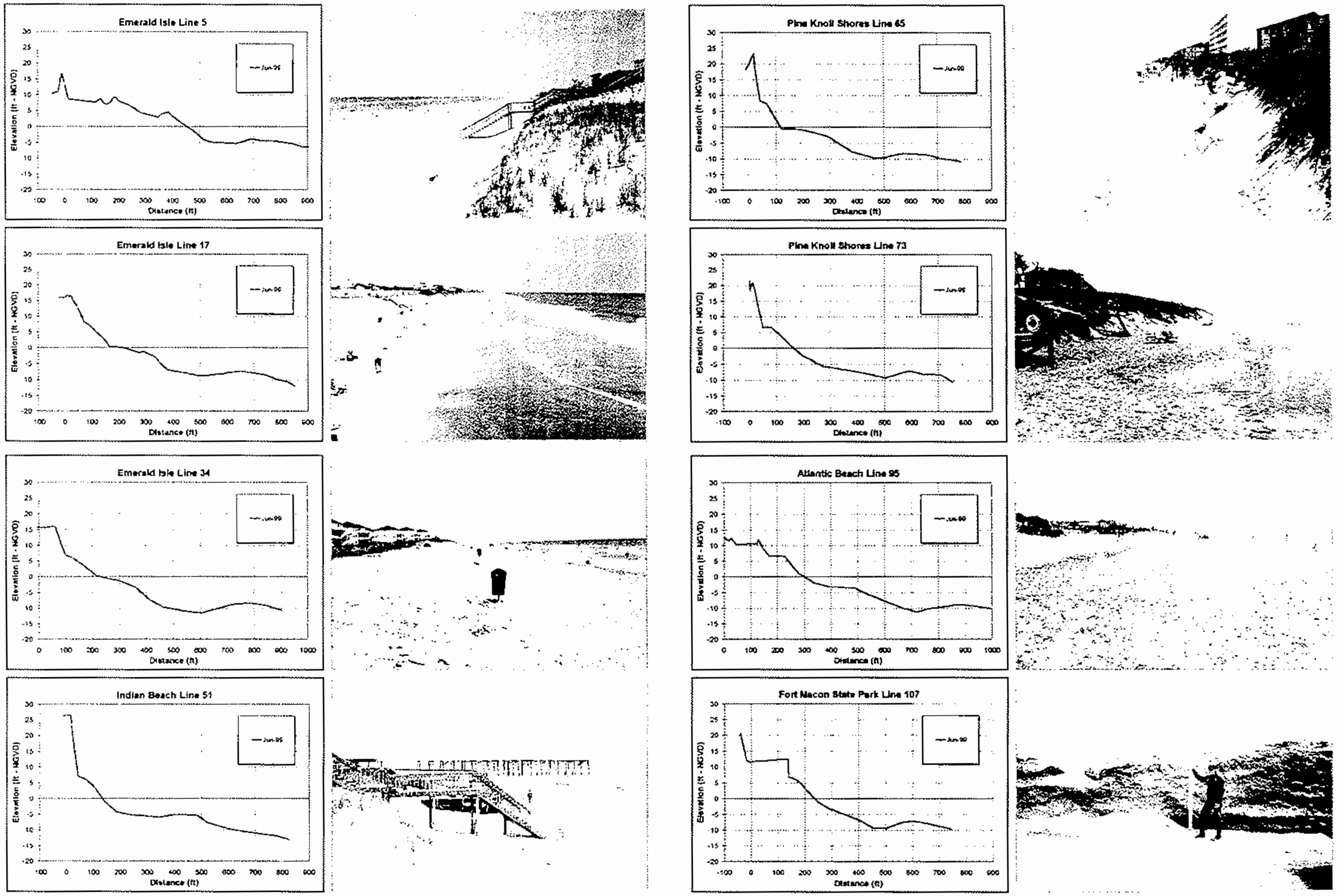
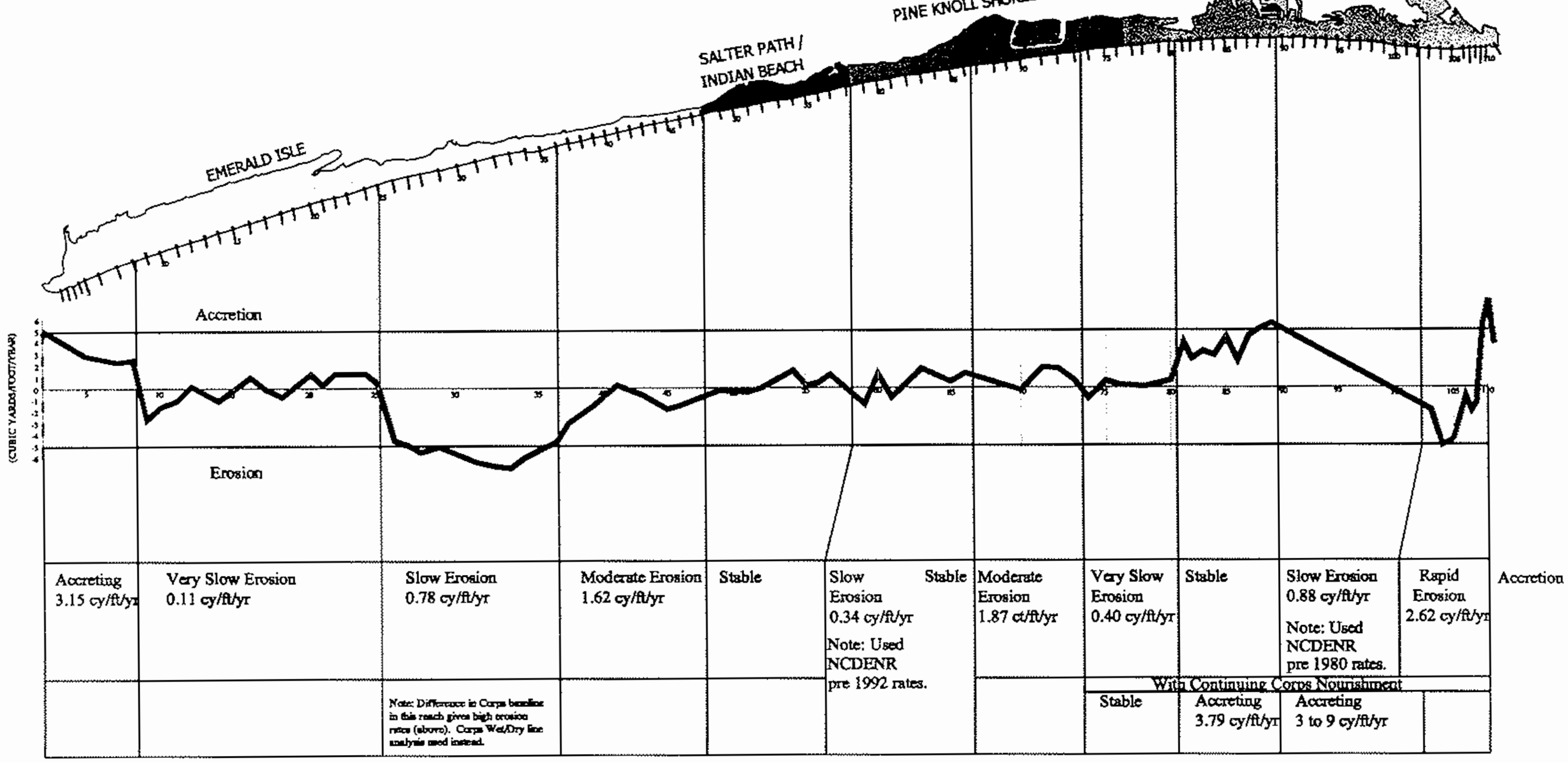


FIGURE 3.2. Representative profiles for Bogue Banks obtained by CSE Baird-Stroud (1999).

1978-1999 Volumetric Erosion



Volume Change Rates 1978 - 1999
(to 4 ft depth, from comparison of
1978 COE profiles and 1999
CSE profiles)

KEY

<0.5 cy/ft/yr	Very Slow Erosion
0.5-1.0 cy/ft/yr	Slow Erosion
1-2 cy/ft/yr	Moderate Erosion
>2 cy/ft/yr	Rapid Erosion

FIGURE 3.3 Volumetric erosion rates estimated to the outer bar, based on (1) extrapolation of comparative wading depth profiles and (2) extrapolation of linear shoreline movement (vegetation lines and dry-sand/wet-sand lines on aerial photography).

CSE
Baird
P.O. Box 8056
Columbia, South Carolina USA 29202
TEL 803 799-8949
FAX 803 799-9481

STROUD ENGINEERING

Bogue Banks
Beach Nourishment
North Carolina

Prepared For:
Carteret County
North Carolina

Fig 3.3

CSE Project Number 9853-04
Date August, 1999

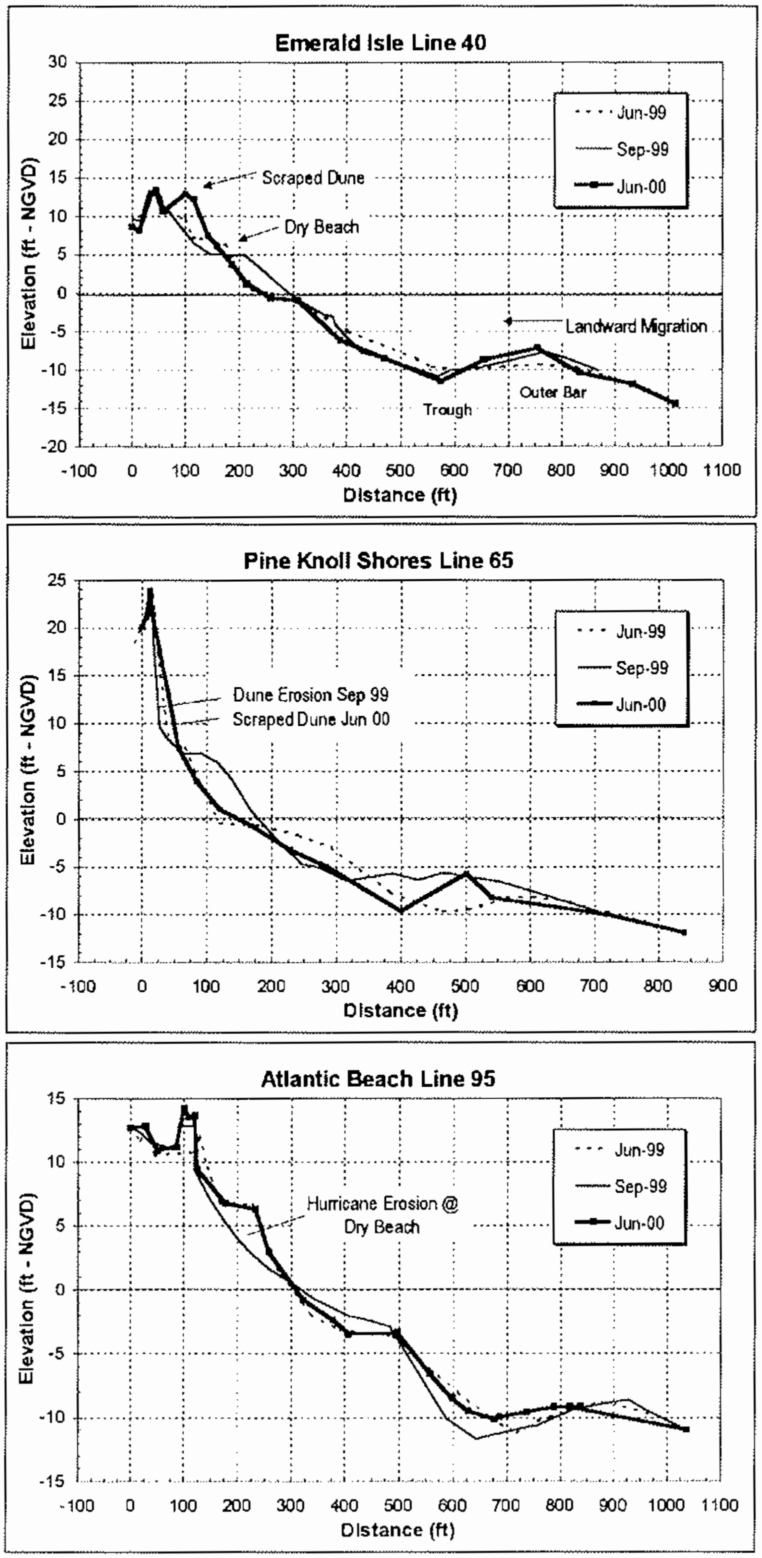
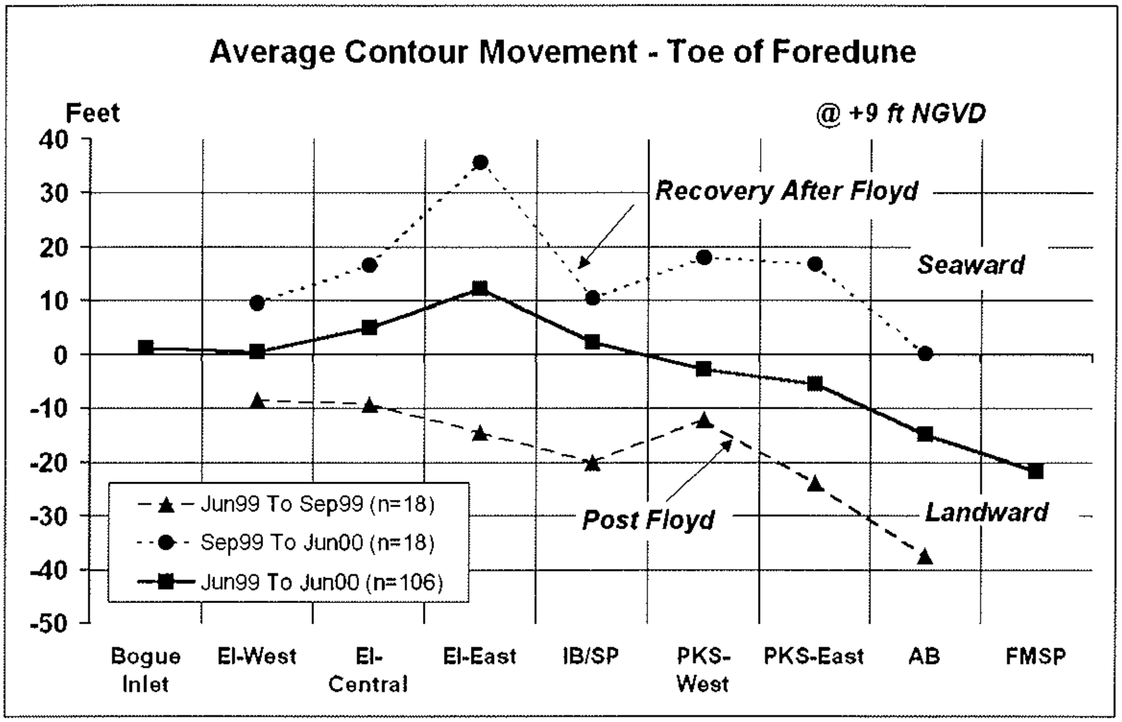


FIGURE 3.4. Representative profiles along Bogue Banks in June 1999, September 1999 (post *Floyd)*, and June 2000. See CSE-Stroud (2001) for detailed results.



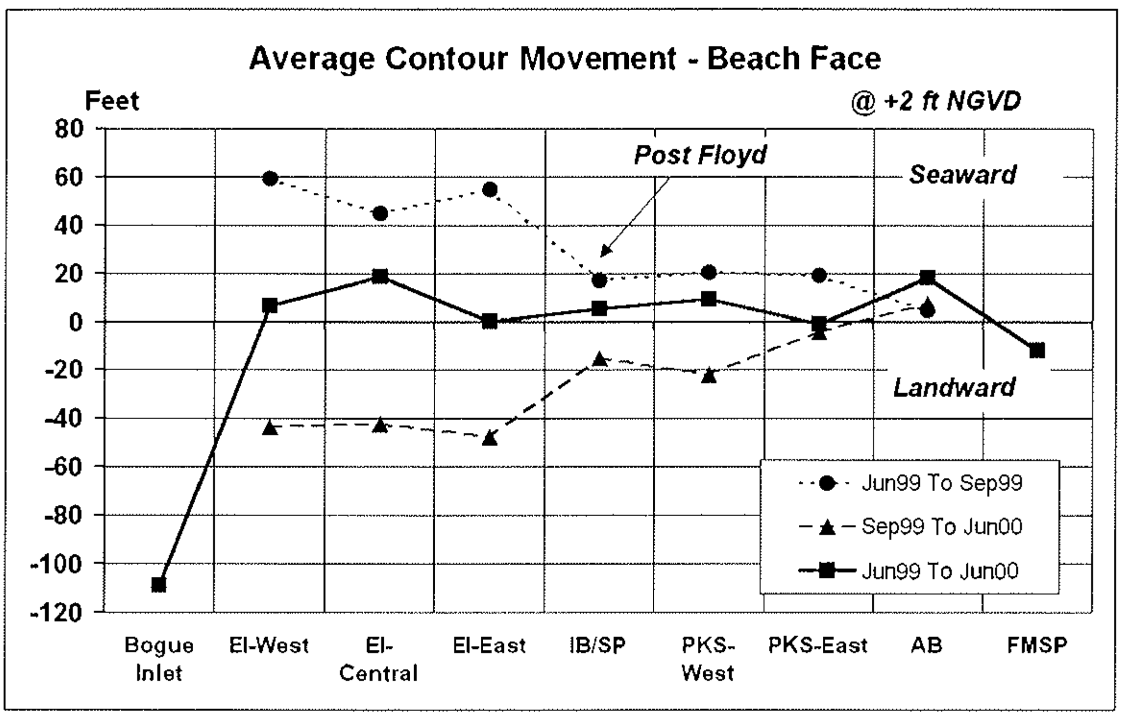
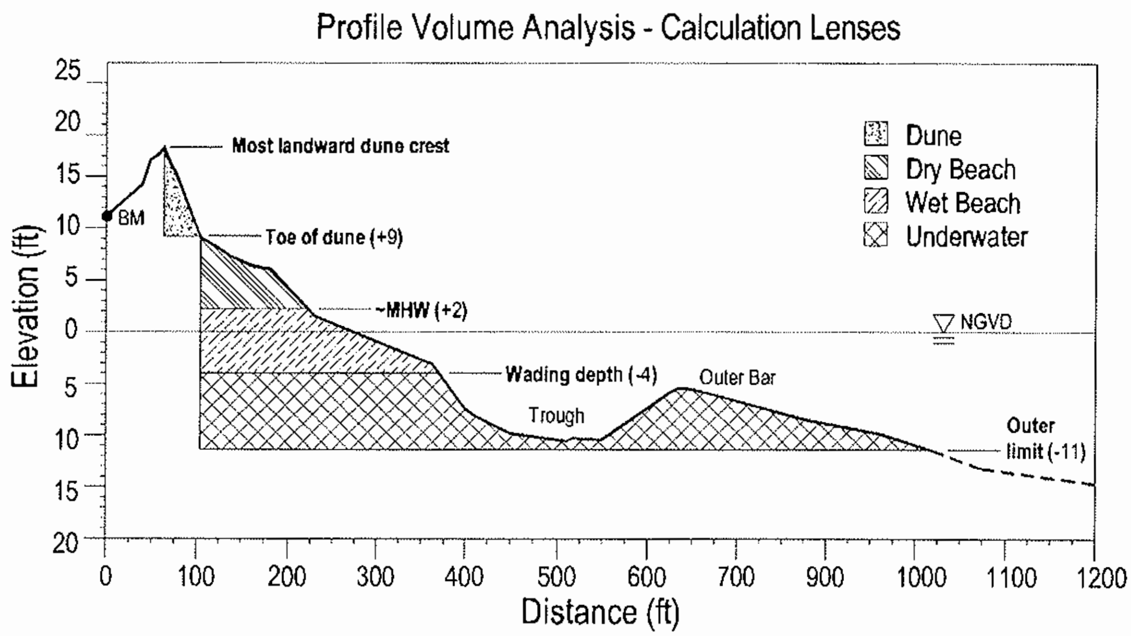


FIGURE 3.5. Average contour movement by reach for the available survey intervals (upper) at the toe of the foredune and (lower) near MHW along the upper beach face. Net change from June 1999 to June 2000 is the solid black line.

3.4.8 Volumetric Change

CSE Baird-Stroud (1999) and CSE-Stroud (2001) developed detailed volumetric analyses of Bogue Banks profiles for purposes of comparing the relative condition of the beach from one reach to another. Four reference "lenses" were evaluated as defined in Figure 3.6. These lenses represent the volume in the foredune (from crest to +9 ft NGVD), the volume on the "dry beach," and the volume in the intertidal "wet beach" and "underwater" to the outer bar. Lens datums are arbitrary but generally reflect distinct morphologic units of the beach and incorporate most of the zone of active profile change from year to year.



Foredune — Defined as the cross-section (unit volume) from the most landward foredune crest (among available surveys) to +9 ft NGVD. Note that +9 ft was determined to be a typical elevation for the base of the foredune and slightly higher than the highest dry beach.

Dry Beach — Defined as the section between +9 ft and +2 ft NGVD. The latter datum approximates local mean high water (MHW). While portions of this zone are wetted due to wave runup and setup, it generally represents the prime recreation area of the beach.

Wet Beach — Defined as the section between +2 ft and -4 ft NGVD. This area incorporates the breaker and swash zone, low-tide terrace, and inner bars out to low-tide wading depth.

Underwater — Defined as the section between -4 ft and -11 ft NGVD. The lower datum was selected based on the typical limits of the data sets. It generally encompasses the outer bar (which varies from about -5 ft to -10 ft NGVD at its crest).

FIGURE 3.6. Calculation lenses used in the analysis of Bogue Banks profiles. Unit volumes are derived by extrapolating cross-sectional areas (and area changes) over one unit length of shoreline. Reach volumes are computed by extrapolating unit volume over distances between profiles using the average-end-area method.

Figure 3.7 shows island-wide trends in unit volumes. The upper half of Figure 3.7 references the 16.8-mile reach encompassing the Towns of Pine Knoll Shores, Indian Beach, and Emerald Isle, specifically the area between beach profile lines 8 and 76 (see Fig 3.1). The lower half of Figure 3.7 incorporates results from all available profiles (1 to 111), and these results show:

- Most of the "beach" volume is underwater and along the wet beach.
- Hurricane *Floyd* caused erosion of the foredune and outer bar, and a gain along the dry beach and wet beach.
- By June 2000, unit volumes for each lens had returned to nearly identical values as June 1999 before *Floyd*.
- There is significantly less sand in the profiles from Pine Knoll Shores to Emerald Isle than occurs in other sections of Bogue Banks.

Based on available data, Hurricane *Floyd* did not produce a major net loss of sand along Bogue Banks. The dominant effect on the beach from the hurricane was a temporary cross-shore redistribution of sand. Unfortunately, the temporary effect caused loss of dune habitat and extensive damage to structures in some reaches as detailed in a later section. Poststorm survey data confirm that the majority of volume change along Bogue Banks occurs above the –11-ft contour. The hurricane, on average, did not produce a measurable buildup of the underwater profile or the inshore area beyond the outer bar. This goes against conventional wisdom (eg, Pilkey et al 1998), but supports CSE-Stroud's (2001) conclusion that closure depth (depth of measurable profile change) along Bogue Banks is substantially shallower than –30 ft NGVD at decadal scales.

On a site-specific basis, there were differences in the volumetric changes during *Floyd* and over the one-year survey period. Figure 3.8 shows averages for nine reaches, six of which represent 16.8 miles of the proposed project area (transect 8 to transect 77) — Emerald Isle west (EI-W) to Pine Knoll Shores east (PKS-E). The greatest volume loss during *Floyd* occurred along Atlantic Beach with erosion averaging ~18 cy/ft. By contrast, some reaches along the western half of Bogue Banks gained sand during *Floyd*. (Nearly all the gain occurred below mean high water.) By June 2000, most of the sand volume losses had been replaced naturally. Atlantic Beach regained over 13 cy/ft within the computation boundaries, leaving a net loss of about 5 cy/ft between June 1999 and June 2000. A similar result occurred along Pine Knoll Shores and portions of Emerald Isle. Remaining reaches experienced net gains in sand volumes (as measured out to the –11-ft NGVD contour) such that the island-wide volume change from June 1999 to June 2000 was essentially zero. This further support our conclusion that erosion rates along Bogue Banks are low compared to many beaches.

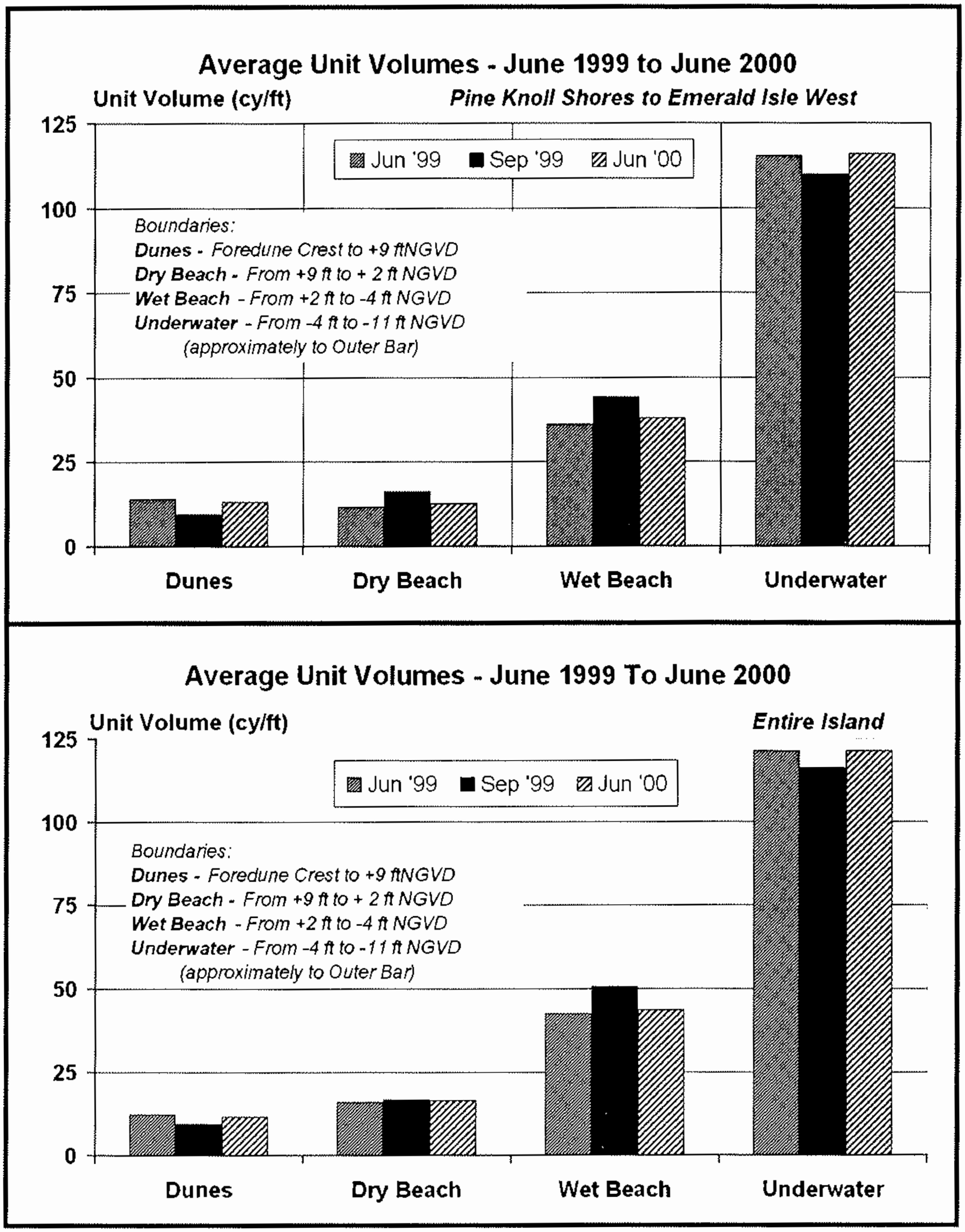


FIGURE 3.7. Island-wide trends in average unit volumes by lens for June 1999, September 1999, and June 2000. Note loss of volume in September 1999 in both the dune and the underwater lenses. Hurricane *Floyd* caused dune recession, but it also appeared to erode the outer bar and shift sand landward into the wet beach lens. There was little net change in volume island-wide as surveyed to the outer bar.

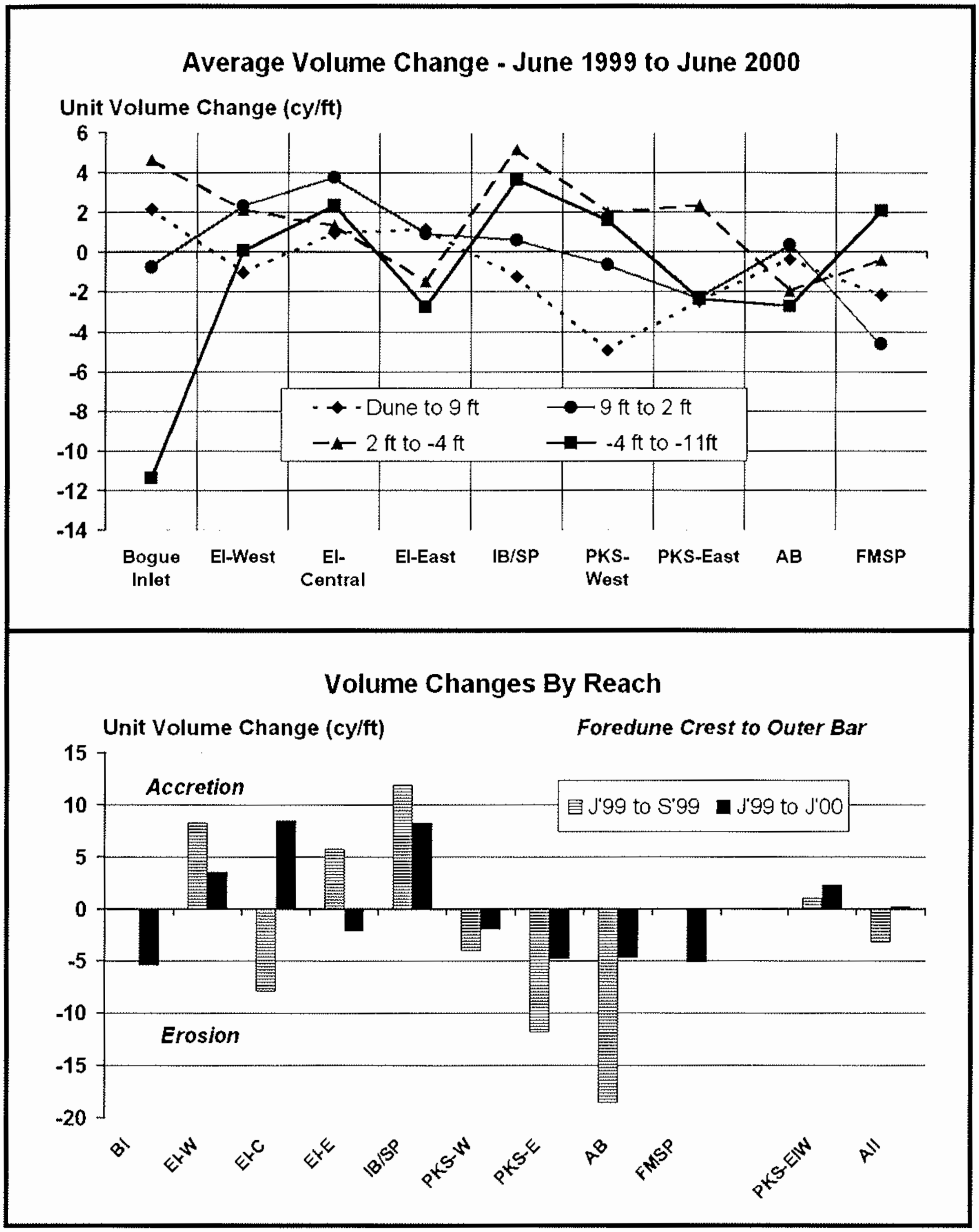


FIGURE 3.8. Average unit volume changes by lens (upper) and for all lenses combined (lower, foredune to outer bar). Greatest net losses from June 1999 to June 2000 were measured along Bogue Inlet, PKS-East, Atlantic Beach, and Fort Macon State Park. Net change for the 16.8-mile project reach (EI-West to PKS-East) was a **gain** of the order 2.35 cy/ft during the past year. The gain is believed to result from onshore movement of sediment from deeper water as well as longshore advection from Atlantic Beach.

3.4.9 Sand Volume Deficit

Profile volumes provide an objective measure of beach condition in the absence of historical data (Kana 1993). The surveys described above were used to calculate profile deficits for specific reaches along Bogue Banks. Figure 3.9 illustrates the basic concept. It is possible with profile volumes to define, on a site-specific basis, the minimum section volume necessary to accommodate a normal range of beach and inshore changes without adverse impact to backshore habitats and development. In the case of armored shorelines such as Atlantic Beach in the mid 1970s, an eroded profile means loss of dry beach area, exposure of seawalls, or chronic recession of dunes, leaving escarpments that inhibit habitat development. One utility of such analyses is that the unit volume integrates the small-scale perturbations and cross-shore variations of the profile and, therefore, can yield similar results regardless of the timing of surveys. It is a direct measure of the quantity of sand in the littoral zone (if surveys to closure are made) rather than a theoretical calculation based on the concept of equilibrium profiles (eg, Dean 1991).

CSE Baird-Stroud (1999) found that the reaches between profile 77 (Atlantic Beach/Pine Knoll Shores town line) and profile 8 (western Emerald Isle), 98 percent of which are unarmored, contained about 20-35 percent less sand than Atlantic Beach. In quantitative terms, the difference was ~30 cy/ft to 50 cy/ft. This is illustrated in Figure 3.10.

Casual observations show differences between the beach conditions of the proposed project area and Atlantic Beach. Most of Emerald Isle and all of Indian Beach and Pine Knoll Shores have negligible dry beach. Atlantic Beach, by contrast, had a 100-200 ft berm prior to Hurricane *Floyd* and nearly the same width nine months after *Floyd*. The deficit quantified by CSE Baird-Stroud (1999) became the basis for formulating the proposed nourishment project. The plan calls for nourishing the six reaches where there is a measurable deficit such that a minimum profile volume of 175 cy/ft (measured to approximately -11 ft NGVD) is achieved (see Fig 3.10). To this quantity, additional volume would be added to account for estimated yearly erosion losses over a ten-year period, differences in sediment quality between borrow sources and the native beach, and estimated volumes needed beyond the available survey limits out to closure depth. In short, the condition of Atlantic Beach was the model for restoration of other reaches along Bogue Banks because it has faired exceedingly well through five hurricanes.

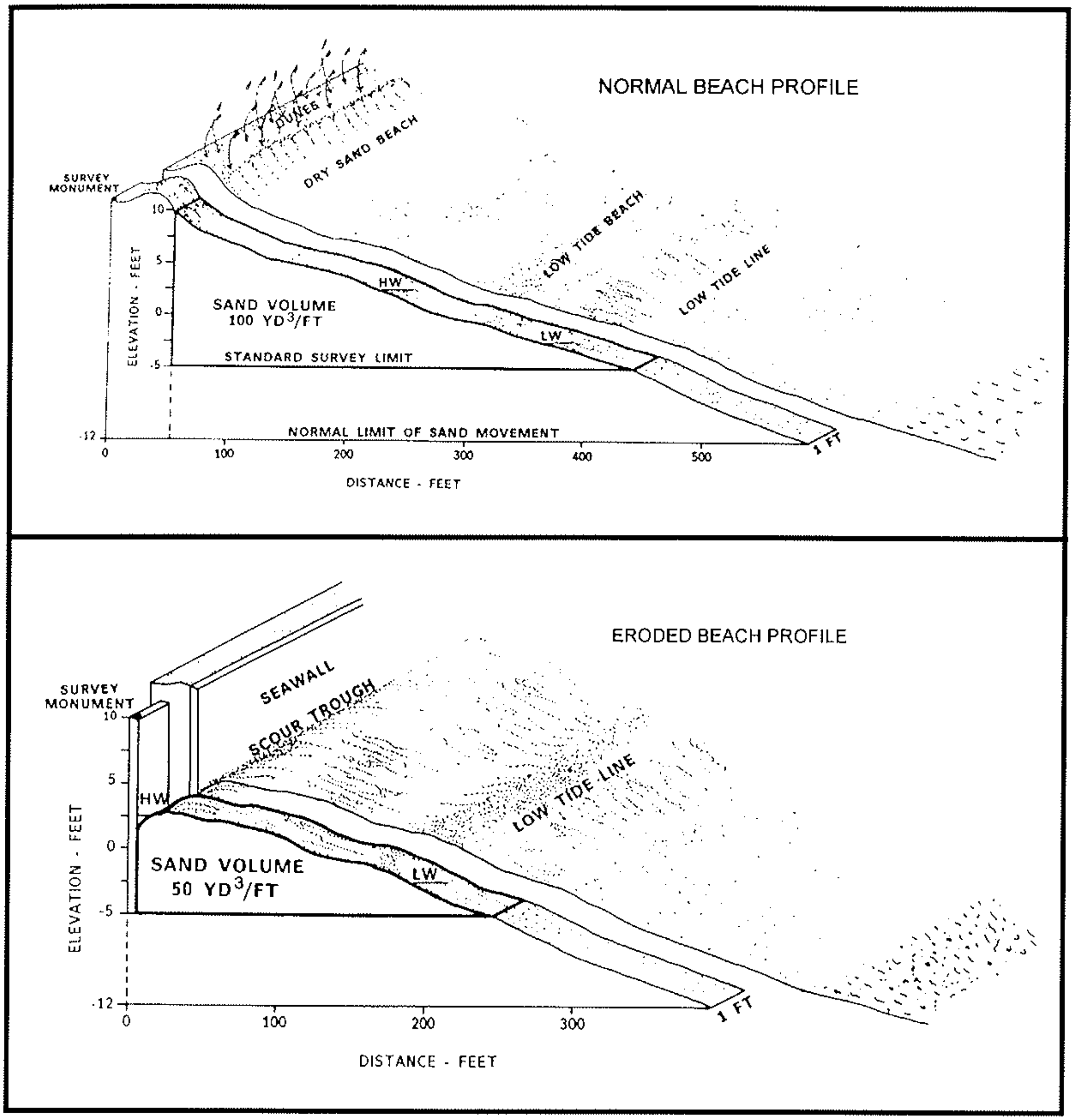


FIGURE 3.9. The concept of unit sand volume along the beach, which provides a quantitative measure of beach condition and changes before and after nourishment. The normal limit of measurable sand movement ("profile closure depth") along Bogue Banks is thought to occur at depths of about 20-30 ft (CSE-Stroud 2001; App G). The present surveys end around the outer bar in depths of ~12 ft about 800-1,000 ft from the foredune. Therefore, the data encompass the majority, but not all, of the active littoral zone. [After Kana 1990]

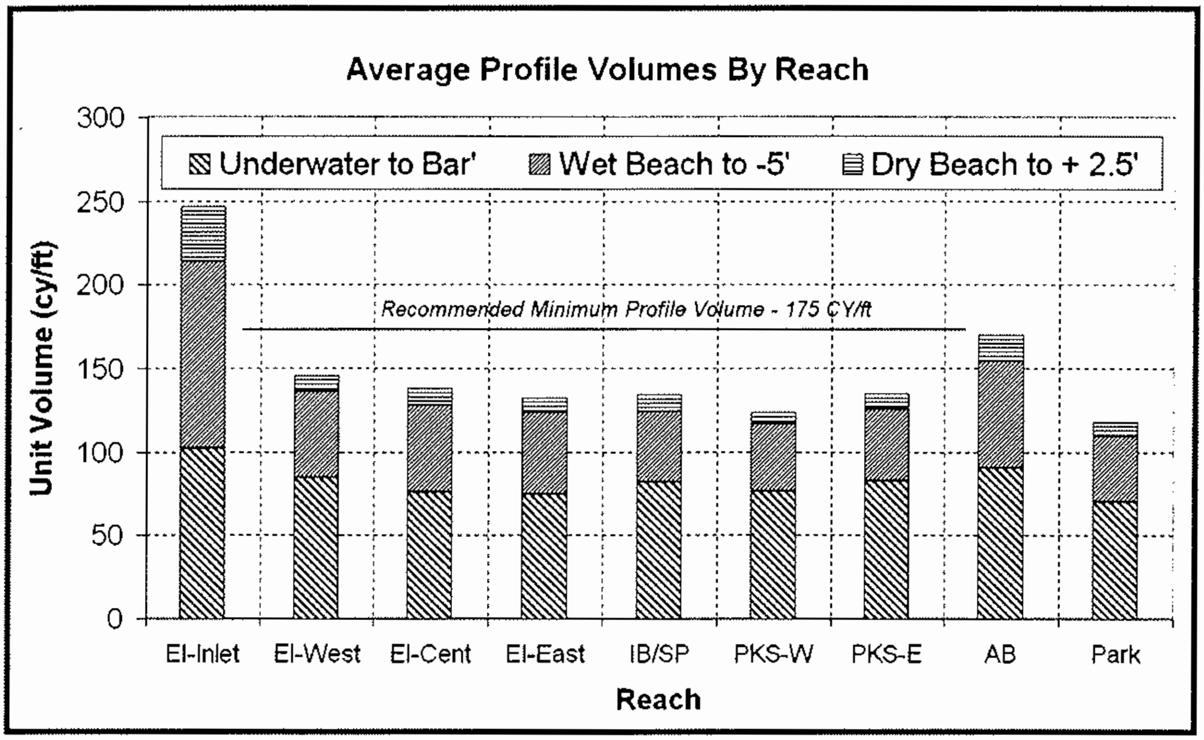


FIGURE 3.10. Average profile volumes by reach along Bogue Banks in June 1999. Atlantic Beach is healthier and contains a wider dry beach than all but one other reach. It serves as a model for the minimum profile volume needed along the island.

3.4.10 Post-*Floyd* (September 1999) Conditions

Protection of property is one of the principal objectives of the beach nourishment project. Based on an inspection by CSE of beachfront properties in the project area in September 1999 following Hurricane *Floyd*, a large number of residential structures were determined to be in immediate danger (Figs 3.11-3.14). Immediate danger was defined as suffering severe damage as a result of the loss of a protective dune or, in the case of residential single and multi-family structures, if a portion of the building was within the CAMA setback limits, the exposed units were determined to be endangered. CAMA rules for beachfront structures require that, if the structure is damaged in excess of 50 percent of its value, it cannot be repaired or replaced without meeting the required oceanfront setbacks. If there is not adequate lot depth to permit required setbacks from the street and beach, the structure and lot are assumed to be a total loss and are required to be moved to another lot.

The economic analysis used as a basis for the analysis of alternatives (Appendix F.) was based on the number of endangered structures identified in the post-*Floyd* survey. The number of endangered structures in each community is listed below:

	Single Family	Condominium	Mobile Home Lots
Emerald Isle	156	36	17
Indian Beach	10	32	15
Salter Path	15	45	7
Pine Knoll Shores	4	58	0

The post-*Floyd* survey included a visual assessment of damage within the project limits and along the nourished beach of the Town of Atlantic Beach. There were no endangered structures identified in Atlantic Beach after *Floyd*. Additionally, the level of damage to beachfront access structures (such as decks and walkways) was minimal in Atlantic Beach. By comparison, an estimated 90 percent of the beachfront structures in the Pine Knoll Shores, Indian Beach, and Emerald Isle project area suffered significant damage. As a result of the erosion associated with Hurricane *Floyd* and other smaller subsequent storms, scraping of the beach in the project area has occurred along an estimated 85 percent of the shoreline. The scraping has been repeated twice during the winter and spring months along much of the shoreline since 1999 at further expense to the ecology of the beach.

FIGURE 3.11. Emerald Isle at low tide on 21 September 1999, six days after Hurricane *Floyd* impacted the area. [UPPER LEFT] Condominiums at 26th Street. [OTHER VIEWS] Residential area between 1st Street and 21st Street.

FIGURE 3.12. Indian Beach-Salter Path area six days after Hurricane *Floyd* in September 1999. [UPPER] Campground. [LOWER] Hoffman Road.

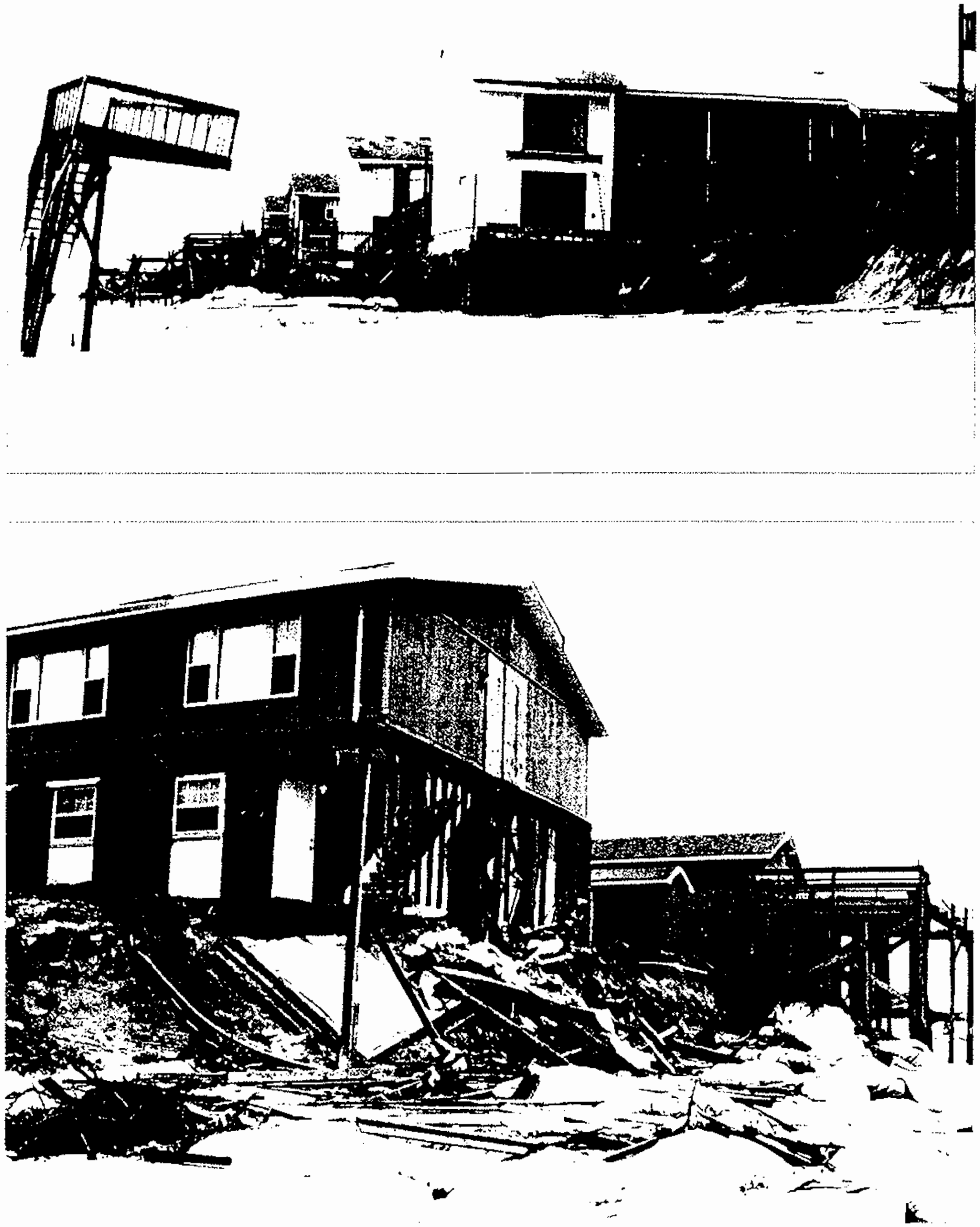


FIGURE 3.13. Pine Knoll Shores area at Pine Knoll Townes condominiums, one week after Hurricane *Floyd* at low tide. (Salter Path Road and Pine Knoll Boulevard between CSE lines 69 and 70.)

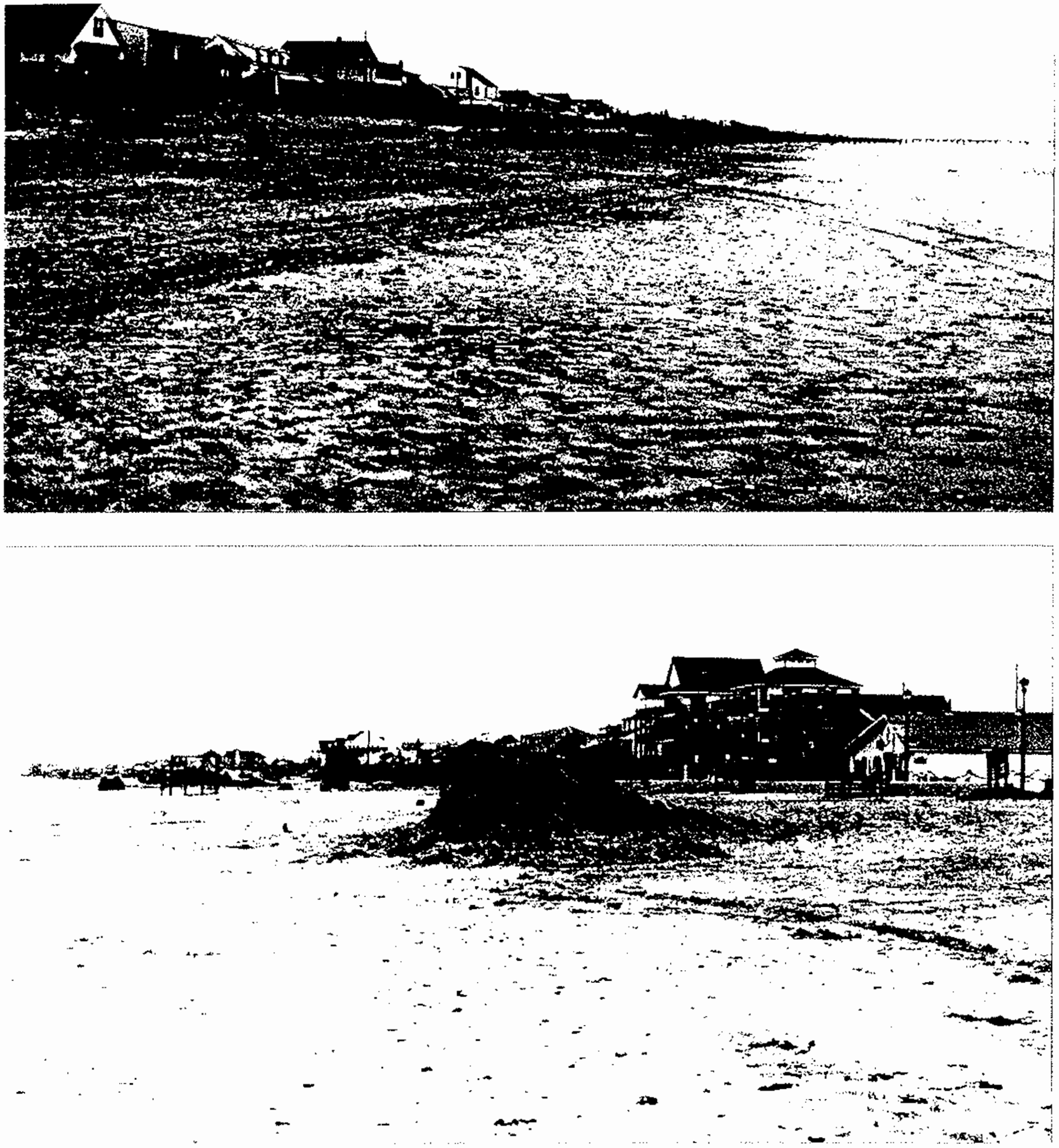


FIGURE 3.14. Atlantic Beach, one week after Hurricane *Floyd* at low tide. [UPPER] Minor escarpment in foredune around Raleigh Street beach access; houses are 75-125 ft landward of the escarpment. [LOWER] Amusement park area. Note remnant of incipient dune. Dry beach in this area is backed by a 25+ year-old seawall (low wall at right middle of photo) which was exposed >8 ft prior to the 1986 and 1994 nourishment projects. Atlantic Beach sustained little damage during *Floyd* compared to Pine Knoll Shores, Indian Beach, and Emerald Isle.

3.4.11 Present Shoreline Conditions (May 2001) Related to Development and Impacts On Threatened and Endangered Species

Based on a visual survey of the project area by CSE in November 2000 and again in May 2001, it is estimated that in excess of 85 percent of the shoreline has been bulldozed for the purpose of rebuilding dunes lost in Hurricane *Floyd* and due to continuing chronic erosion. The Town of Emerald Isle issued 139 CAMA permits for bulldozing from 1996 to present. The Town of Pine Knoll Shores issued 78 CAMA permits for bulldozing during the same period. In contrast, for the portions of Bogue Banks that have been nourished, the Town of Atlantic Beach issued only two CAMA permits for bulldozing from 1996 to present (Kelly Sheppard, Town of Atlantic Beach, pers comm, June 2001).

Recent surveys show bulldozing continuing in Emerald Isle, Indian Beach and Pine Knoll Shores on a massive scale even though there have been no serious storm events since Hurricane *Floyd*. Figure 3.15 shows the typical bulldozed beach and dune that exist along most of the project area. The beaches of Pine Knoll Shores are, for the most part, characterized by high, natural, heavily vegetated frontal dunes and absence of a dry beach berm with an escarpment at the toe of the dunes. The dunes consist of unnaturally coarse sand. There is no dry beach. These beaches are what are commonly called low-tide beaches. The summer wave climate will reshape the beaches creating a berm, but it will be limited in width, frequently overtopped, and will provide limited protection for plants to thrive near the toe of the dunes where wave swash will reach.

Division of Coastal Management rules for beach bulldozing allow removal of a maximum of one vertical foot of sand from the berm for dune building. Observations of the magnitude of sand quantities scraped and impacts on mean waterline position (as detailed in Section 2) would indicate that this rule is rarely adhered to by the property owners and scraping contractors. Figure 3.16 shows a recently bulldozed section of beach in Pine Knoll Shores where bulldozing and removal of beach sand has permitted the surf zone to move landward to less than 50 ft from the toe of the dune at low tide. Figures 3.17 and 3.18 show other representative portions of the project area where bulldozing has severely altered the natural beach and dune system.

Areas where property owners have chosen not to bulldoze the beach are characterized by steep frontal dune faces, no berm, and no high-tide beach (Fig 3.19). Further, the high elevations that characterize nearly all of Bogue Banks mean that chronic erosion leaves escarpments in the foredune, not washovers or deposits of sand landward of the shore.

In contrast to beach conditions in the project area, nourished portions of the western end of Bogue Banks (eg, Atlantic Beach near the Ocean Ridge area) are characterized by a wide dry berm and a natural frontal dune system that has required no scraping (Fig 3.20). The proposed project seeks to duplicate the favorable conditions of Atlantic Beach in the 16.8-mile reach encompassing Pine Knoll Shores, Indian Beach, and most of Emerald Isle. Without the project, scraped dunes will quickly erode again and have to be rescraped. If another hurricane impacts the area before the proposed project, many structures will be severely damaged. None of the existing conditions in the project area are favorable for beach-dune habitat preservation.

3.5 PUBLIC LANDS

The "Public Trust Doctrine" and the State Property Sovereignty Rules preserve the rights of all citizens of North Carolina for use of resources located below the mean high water line. Submerged lands, or waters of the state, commence waterward of the mean high waterline.

3.6 RECREATIONAL AND SCENIC AREAS

The beaches of Atlantic Beach, Emerald Isle, Indian Beach, Salter Path and Pine Knoll Shores are known as the Crystal Coast. This designation probably refers to the color of the ocean waters on clear calm days at the beach. The beaches of Bogue Banks provide a variety of excellent scenic and recreational opportunities for the public. Popular activities include, but are not limited to, surf fishing, swimming, surfing, walking, shell hunting, sunbathing, bird watching, and boating. Scenic vistas of the ocean are many. With erosion of the beach there has been significant losses of dry beach areas limiting many beach activities to low tide periods.

3.7 AREAS OF ARCHAEOLOGICAL OR HISTORIC SIGNIFICANCE

The maritime history of Beaufort, Morehead City and the Cape Lookout area goes back to the late 1600s and early 1700s when whalers established bases of operations on Shackleford Banks and Cape Lookout. The stability and depth of Beaufort Inlet offered a safe, deep channel for ship traffic. Not all vessels were successful navigating the inlet. In November 1718, the pirate Blackbeard lost two vessels on or near the sand bar at Beaufort Inlet.

Around 1841, John Motley Morehead, governor of North Carolina, envisioned establishing a port facility at the eastern terminus of the Atlantic and North Carolina Railroad. In 1855, the decision was made to locate the port at Sheppard's Point. By 1858, and much to the chagrin of the people of Beaufort, the Morehead City port was prospering. Ships called continually, loading cargo directly to and from rail cars.

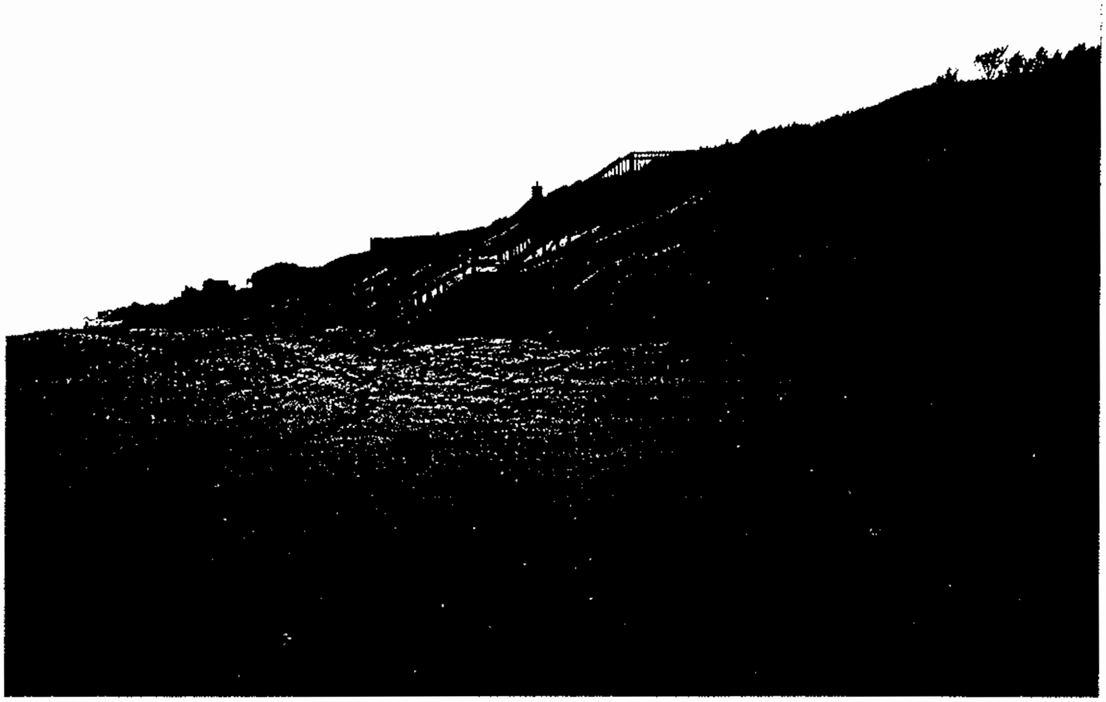


FIGURE 3.15. Typical bulldozed beach and dune conditions, Pine Knoll Shores and Indian Beach, Photo taken May 11, 2001, 5:30 p.m., near low tide. The high-tide swash line typically reaches the toe of the dune in these localities.

FIGURE 3.16. Condition of low tide beach in area of Pine Knoll Shores, recently bulldozed. Note location of swash zone relative to toe of dune. Photo taken May 15, 2001, 8:00 a.m.

FIGURE 3.17. Bulldozed beach and dune in Indian Beach (recently bulldozed dune in background, dune scraped last season in foreground). Photo taken May 11, 2001, 5:30 p.m.

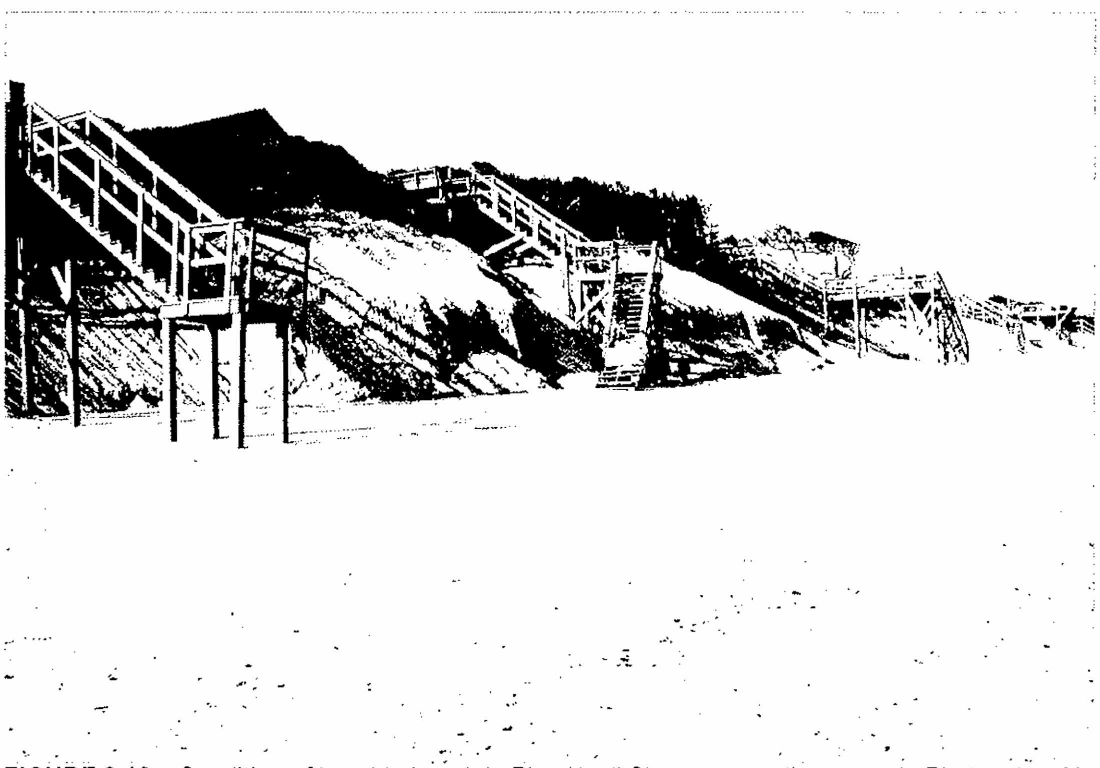


FIGURE 3.18. Condition of low tide beach in Pine Knoll Shores, recently scraped. Photo taken May 11, 2001, 5:30 p.m.

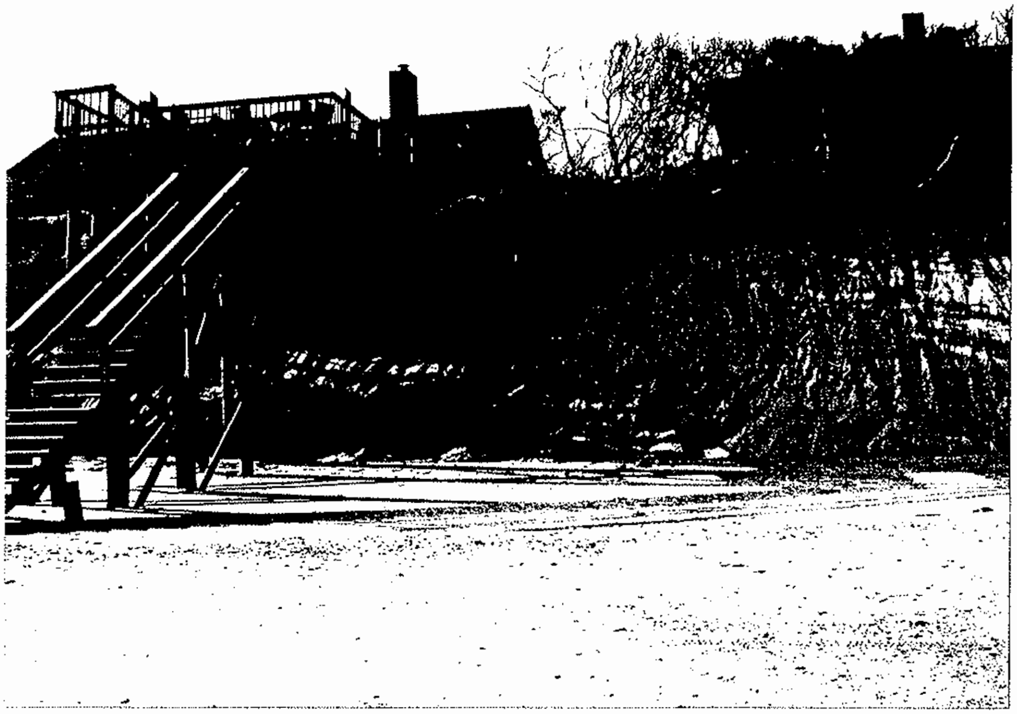


FIGURE 3.19. Condition of low-tide beach in Pine Knoll Shores (no bulldozing). Photo taken May 11, 2001, 5:30 p.m.

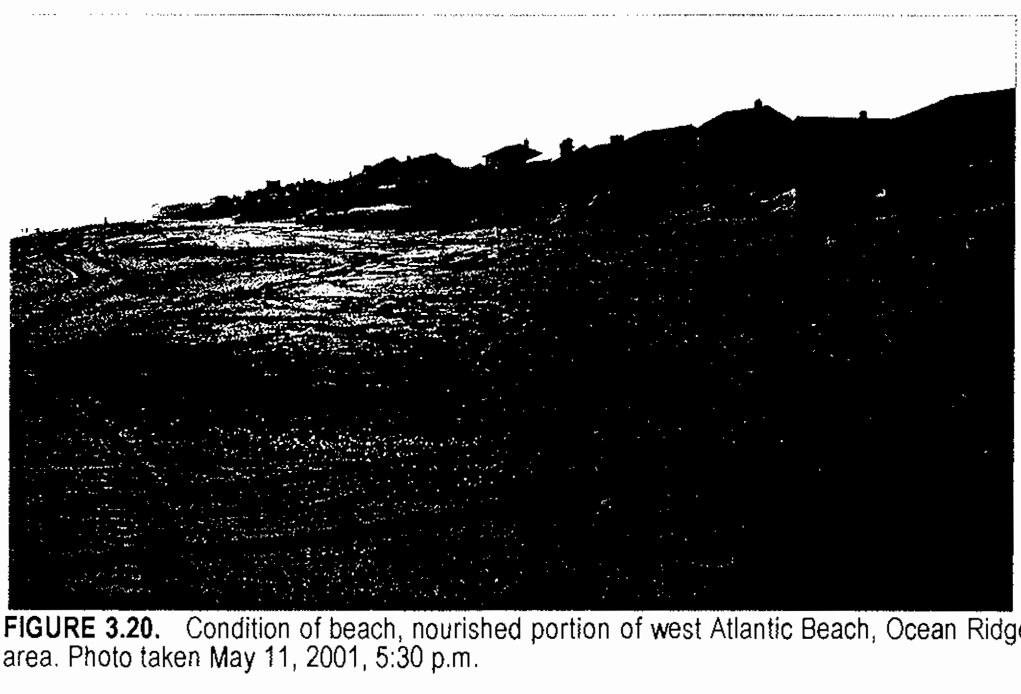


FIGURE 3.20. Condition of beach, nourished portion of west Atlantic Beach, Ocean Ridge area. Photo taken May 11, 2001, 5:30 p.m.

Development of the Morehead City port was disrupted by the Civil War. In March 1862, Union forces occupied Morehead City, the Newport River and Beaufort. Soon afterwards, Fort Macon fell under Union control. The occupation of Fort Macon provided Union forces with access to a deep-water port and a place of rendezvous to support the blockading squadron during the remainder of the war. Beaufort harbor served as a staging area for the fleets under the command of Admiral David Porter for his assault on Fort Fisher in Wilmington, the last major confederate stronghold in North Carolina. During the war, there were a number of vessel losses near Cape Lookout. Not all vessel losses were attributable to military actions. Several vessels ran aground in rough weather near Beaufort Inlet or were lost due to machinery failures.

Six years after the Civil War, the federal government instituted measures to reduce the severity of maritime losses along the coast. In 1874, seven stations were established along the North Carolina coast by the US Lifesaving Service. Stations were established along Core Banks, at Fort Macon and at Cape Lookout.

Growth of the Morehead City port was slow during the late nineteenth and early twentieth century. In the 1880s, the federal government began work to improve Beaufort Inlet in hopes of increasing maritime trade to the port communities. By 1889, jetties were constructed on Shackleford Banks and on Fort Macon to stabilize the Beaufort Inlet. Between 1905 and 1907, the channel across Beaufort Inlet was deepened to 20 ft at mean low water. Several Corps of Engineers reports between 1907 and 1914 indicated that both Morehead City and Beaufort were growing centers of maritime trade.

Many vessels transiting the North Carolina coast became victims of maritime hazards. Between July 1889 and June 1908, 82 vessels were reported lost off the North Carolina coast. To prevent vessels from wrecking off of Cape Lookout, a lightship was placed at Lookout Shoals. Mariners had complained that the lighthouse at Cape Lookout was difficult to see.

During World War I, Cape Lookout Bay served as a rendezvous area for convoys headed to Europe. Morehead City was occasionally used as a distribution point for war supplies. From 1926 to 1938, the federal government made considerable improvements to the port of Morehead City including increasing the Beaufort Inlet channel depth to 30 feet. Hostilities were evident in the Cape Lookout vicinity during World War II. German submarines sank four tankers in the Cape Lookout Area during March 1942. Since the war, Morehead City Harbor has undergone continuous improvement to its present-day condition as a deep-water port with several large vessels calling at the port each month.

The long maritime history of Beaufort Inlet and the areas near Cape Lookout indicate the possibility that shipwrecks or other valuable submerged historic resources could exist on the offshore borrow areas proposed for this project. The National Historic Preservation Act of 1966 and the Archeological and Historic Act of 1979 establish criteria for identification, documentation and assessment of submerged cultural resources. Compliance with submerged cultural resource legislation is administered by the North Carolina Division of Archives and History and the US Department of the Interior.

Tidewater-Atlantic Research, Inc (Washington NC) was contracted to conduct a remote sensing survey of the offshore borrow areas. The scope of the survey was to locate, identify and assess the significance of any underwater cultural material in the project areas. The details of the survey and report of findings are included as part of this document in Appendix B.

The North Carolina Department of Cultural Resources' State Historic Preservation Office has reviewed the proposed project and has identified six historic wreck/debris sites along the project shoreline (letter dated 29 June 2001 in the attached correspondence file). The state office has provided coordinates for the objects and instructions for notifying them in the event that debris is observed. The state noted that they have ". . . no objection to deposition of additional sand on the archaeological sites as it will serve to better protect them." The contractor for the project will be instructed to keep heavy equipment away from the designated areas.

3.8 AIR QUALITY

The air quality section of North Carolina Department of Environment and Natural Resources has jurisdiction over air quality in Carteret County. According to the Wilmington District Office, ambient air quality in Carteret County is in compliance with the National Ambient Air Quality Standards.

3.9 WATER RESOURCES

Water quality around Bogue Banks is generally high due to large tidal flows and resultant flushing associated with Bogue Inlet and Beaufort Inlet. Waters of Bogue Sound west of a line from the mouth of Gales Creek to Rock Point in Indian Beach are classified as outstanding resource waters (ORW), which are waters of the state that are unique and of a special state or national recreational or ecological importance that require special protection to maintain existing uses. Waters east of Rock point in Bogue Sound are classified SA. SA waters are suitable for shellfishing for human consumption. Ocean waters of Onslow Bay off of Bogue Banks are of high quality. This quality is due to the fact that no rivers draining large urbanized watersheds discharge directly into Onslow Bay. The White

Oak River in the western end of the county and the Newport River in the east have relatively small agricultural, forested, and lightly developed watersheds.

3.10 GROUNDWATER RESOURCES

Groundwater is plentiful throughout Bogue Banks. It is near the surface in many places, especially in the early spring and winter. The underlying limestone deposits of the Castle Hayne formation are the source for water supplies on Bogue Banks. These formations are below the surficial aquifers in the island consisting of a freshwater lens which varies in depth depending on rainfall amounts and has water that is often salty or has high concentrations of dissolved iron and hydrogen sulfide.

3.11 INTRODUCTION OF TOXIC SUBSTANCES

No chemical analysis of the borrow area materials has been done to date. It is unlikely that the borrow area sediments have accumulated any toxic or hazardous substances regulated by CERCLA or RCRA. There have been no known spillage, storage, treatment or disposal of regulated toxic materials within the borrow areas. There are no known discharges to Onslow Bay that could be a source of contaminants. For this reason, it is doubtful that chemical analysis of the borrow area material would contain heavy metals exceeding the EPA standards. The borrow area sediments consist of medium sands with shell fragments and low mud percentage (detailed in Section 3.16). These types of inert mineral materials do not typically trap contaminants.

3.12 NOISE LEVELS

Noise levels in the project areas are relatively low. No commercial or industrial activities exist in the project areas that create increased ambient noise levels. However, Bogue Air Base (USMC Cherry Point) is located on the mainland in Bogue Community. This base is utilized by Harrier jets that periodically conduct military training exercises. Generally, noise levels in the project areas are those associated with public use. The residential nature of the ocean shoreline areas generally equates to low ambient noise levels.

3.13 WATER SUPPLY AND WASTEWATER SYSTEMS

3.13.1 Water Supply

Potable water supply on Bogue Banks is provided by municipal water systems and by privately owned public utility companies. Bogue Banks Water Corporation supplies water to the Town of Emerald Isle. Carolina Water Service provides water to Indian Beach and Pine Knoll Shores. The Town of Atlantic Beach operates and maintains the water supply and distribution system for the town. The water source for all systems is deep wells to aquifers of the Castle Hayne limestone formations which run beneath Bogue Banks. The water is hard but is otherwise of excellent quality.

3.13.2 Wastewater Systems

Wastewater treatment and disposal on Bogue Banks is regulated by the Carteret County Environmental Health Department for systems less than 2,000 gallons per day, and by the NC Department of Environment and Natural Resources, Division of Water Quality for systems larger than 2000 gallons per day. Treatment and disposal of wastewater on Bogue Banks is accomplished in many conventional and innovative ways. Single family residential systems are nearly all conventional septic tanks with subsurface nitrification fields. In some areas, where soils are not suitable for conventional septic systems, septic tanks with on-site low pressure pumped (LPP) subsurface disposal is employed. Multi-family residential developments and hotels utilize collection systems with centralized treatment and disposal facilities. Treatment is generally by package plants employing extended aeration and on-site subsurface LPP disposal. There are no known direct effluent discharges to Bogue Sound or Onslow Bay from wastewater treatment facilities on Bogue Banks.

3.14 MARINE RESOURCES

The first two regions below are commonly divided by the breaker zone. That is, offshore refers to the area between the breakers and the edge of the continental shelf, and nearshore is the region between breakers and the mean low water line that is the lower boundary of the intertidal zone (CERC 1984). For purposes of examining environmental impacts, it is more sensible and more common to examine "nearshore" resources out to the depth of closure, rather than the moving boundary of a breakpoint. That is, the boundary between nearshore and offshore will be (for the purposes of this EA) the seaward limit of sediment motion (by waves), termed the "depth of closure" for beach surveys. Exactly what that depth is for this site is examined in detail in Appendix G2 and is summarized in the "Depth of Closure" part of Section 3.4. Borrow Areas A, B1, and B2 are outside closure depth.

3.14.1 Offshore Resources

3.14.1.1 ***Sediment*** — Offshore areas in North Carolina have been described as more stable than the nearshore zone, because of the lack of sediment motion by waves. USEPA (1983) describes the offshore region as fine sand with low-to-moderate relief, scattered among hard bottom. Studies for the present project characterize the offshore sediments by means of grab samples, cores, long vibracores, sidescan sonar survey, and a magnetometer survey. In addition to identification of potential cultural resources in the borrow areas, the sidescan sonar survey was used to identify any large natural features (rocks). None were found in the borrow areas. The offshore sediment conditions are described in Section 3.16 below and in Appendix E.

3.14.1.2 ***Biology*** — Biological resources in the offshore region of the Carolinas have been categorized as having low biomass, high diversity, and large seasonal variability (USEPA 1983). The latter characteristic of seasonal variability has a significant impact on monitoring plans and is the reason for our plan of sampling on several dates, detailed below.

3.14.1.3 ***Vertebrates*** — Assessment of the significance of the offshore mining of sands for the renourishment involves evaluation of potential impacts on demersal fishes and crustaceans at the borrow site. The fish and crustacean community changes seasonally, so sampling is needed to document presence and relative abundance of demersal fish and crustaceans and to describe their utilization of benthic invertebrate prey. Trawl sampling was conducted in late fall 1999, coincident with the sampling of the benthos. The results of sampling the fish and mobile crustacean community at and around the proposed offshore borrow sites are included here in a report as Appendix C (revised report by UNC Institute of Marine Science). Two additional trawl samplings were completed later in winter 2000 to document over-winter use of the borrow sites by fishes. [Trawl results are included in Appendix C.] Analysis includes not only the information on fish and crustacean abundances, but also a description of their diet from gut contents in the late fall 1999 and winter 2000 collections.

Table 4 in Appendix C presents the results of trawling for fishes and crustaceans. The sampling detected relatively large numbers of demersal fish occupying the sea-floor habitat during this period. Offshore areas were dominated by spot, which accounted for more than 50 percent of total catch and was sufficiently abundant there to create a pattern of slightly higher fish densities offshore than inshore. In addition to spot, pinfish, pigfish, and croaker were the most common species offshore. Inshore fishes were dominated by croaker, silver perch, silversides, and sea mullet.

3.14.1.4 ***Invertebrates*** — The benthic invertebrate community at the offshore borrow sites changes across the seasons. The applicants have initiated sampling in fall and spring to assess impacts and recovery. An initial set of samples was collected in the fall of 1999 to provide fall baseline data to characterize the benthic invertebrate community at the prospective offshore borrow sites and at nearby control sites that will not be excavated prior to any disturbance from the renourishment project. Also included is an analysis of composition of surface sediment samples in each of the borrow sites and control sites, so as to characterize the sedimentary habitat in which the invertebrates live. The fall 1999 invertebrate data set and summary statistics are given in Appendix C.

The applicants retained the firm of Coastal Science Associates, Inc (CSA) (Dr. Bart J. Baca) to perform a pre-nourishment biological sampling following standard protocols for projects of this type. CSA conducted detailed samplings of the beach and offshore areas in June 2001 according to the scope of work given in Appendix A-4. Preliminary results include a power analysis to demonstrate the adequacy of the sampling scheme to detect changes. The applicants plan to conduct another prenourishment biological monitoring by CSA in early November 2001. Postnourishment sampling will then be performed in June and November for 2002, 2003, and 2004 (following each phase of the project). More details on the biological monitoring plan are given in Appendix A-4.

Results from the fall 1999 sampling are summarized in Table 2 of Appendix C. Results suggest slightly higher macrofaunal abundances in the borrow areas than in their respective control areas. The polychaetes accounted for more than 50 percent of the total macrofauna in these late-fall 1999 samples. Other common phyla in order of abundance were molluscs, nemerteans, crustaceans, and echinoderms. Table 3 of Appendix C shows the analysis of the 40 belt transects for larger benthic invertebrates. The inshore borrow areas revealed higher numbers of these larger invertebrates than the offshore sites. No consistent difference appeared between borrow and control areas in these data. Gastropods were the most common taxon represented in these samples.

3.14.2 Nearshore Resources

3.14.2.1 ***Sediment*** — Sediment sampling of the nearshore (inland of the borrow sites, but subtidal) occurred at several locations along the project area. The appropriate sample numbers to reference in Appendix E from west to east are C21a1, C20a1, C16a1, C12a1, C9a3, and C7a2. Sample C4a1 was taken in Atlantic Beach outside the project area. Sieve analyses, mud content, and carbonate content are detailed in Appendix E.

3.14.2.2 ***Biology*** — Alterations to seabed sediments in the surf zone will be essentially the same as on the dry beach, except that there will be sorting into a finer size. Quantification of submarine organisms inshore of the borrow areas will thus rely on the dry-beach and intertidal sampling program outlined below. A baseline study of benthos in nearshore waters of South Carolina by Van Dolah and Knot (1984) found that infaunal assemblages at nearshore subtidal areas were more complex than those at intertidal areas. These data are expected to be comparable to those of the Bogue Banks project area. Based on their sampling, 243 species representing 24 major taxa were found. Dominant species were polychaetes and amphipods with oligochaetes, pelecypods, and decapods highly represented. Benthos in the area were identified as those that serve as food for commercially important species and were essential in marine food chains. Commercially important species include adult spots which are benthic feeders, primarily eating polychaetes and benthic copepods, and Atlantic croaker that are also bottom feeders preying on polychaetes and bivalves. Pink and white penaeid shrimp also prefer benthos (USFWS 1992a). The nearshore benthic communities offshore of North Carolina have been characterized by benthic infaunal assemblages with low abundance and high diversity (USEPA 1983).

3.14.3 Intertidal Resources

3.14.3.1 ***Sediment*** — Six native-beach samples were taken on the low-tide terrace at six different transects along the island. Sieve analyses, mud content, and carbonate content are detailed in Appendix E. A total of 20 samples (2 on the dune, 6 on the berm, 6 on the beach face, and the 6 low-tide terrace) was used to determine a composite native-beach size distribution. These were later supplemented with an additional 64 samples (32 pairs) described in Section 3.16 and in Appendix E.

3.14.3.2 ***Vertebrates*** — Twice-yearly sampling by seine of fish in the surf zone will be conducted as part of the biological monitoring for the project (see Appendix A-4). Fish densities are intermittent and generally fluctuate greatly within the surf zone because of the tendency for shoaling by various species. Approximately

15 fish species have been observed in the surf zone in the project area (Peterson et al. 2000), with Florida pompano (*Trachinotus carolinus*), Gulf kingfish *(Menticirrhus littoralis*), and two species of silversides (*Menidia menidia* and *Membras martinica*) accounting for around 99% of the total fish population sampled in summer 1998. Other species observed include bay anchovy, pinfish, bluefish, mullet, flounder and filefish.

3.14.3.3 ***Invertebrates*** — Organisms in the high-energy sandy intertidal environment include mole crabs, coquina clams, amphipods, isopods, and polychaetes. Although none of these species are commercially important, they constitute considerable biomass and serve as important food source for surf-feeding fish and shore birds. A June 2001 sampling has been completed to serve as the first of two "before-renourishment" monitoring data for the intertidal invertebrates of Bogue Banks beaches. The invertebrate community of the intertidal beaches is strongly seasonal; therefore, two representative seasons have been selected to monitor impacts of the project. The applicants plan to perform sampling in June and November before and after each phase of construction. An initial preproject sampling was conducted in June 2001 (see Appendix A-4).

UNC Institute of Marine Science collected data on abundances of intertidal beach invertebrates from all along Bogue Banks from 1997-1999 from studies conducted by L. Manning and others (unpubl: see Table 9 of Appendix C for example). The applicants initiated prenourishment sampling in June 2001 and have scheduled a second prenourishment sampling in early November 2001. Postnourishment sampling will be performed twice per year after completion of each phase of the project (June and November) for comparative purposes according to the biological monitoring plan outlined in Appendix A-4.

3.14.4 Beach and Terrestrial Resources

3.14.4.1 ***Sediment*** — The width of the berm at the base of the dune system varies considerably with location along the island and with season. Along most of the project area, the winter berm is nonexistent, because of the continuing erosion. Dune habitat is now also decreasing due to the erosion of the base or toe of the dunes by waves that travel unimpeded over the eroded wet beach to directly attack the dunes. As a result of the nourishment project, the beach is the one resource area that is expected to have beneficial impacts on the species present, primarily due to increased habitat area. Native-beach samples were taken on the dune, berm, beach face, and low-tide terrace at 22 different transects along the island, along with two dune samples. Sieve analyses, mud content, and carbonate content are detailed in Appendix E. A total of 84 samples was used to determine a composite native-beach size distribution.

3.14.4.2 ***Biology*** — The dunes along the beach are covered with American beach grass and sea oats. The dominant vegetation along the ocean side of the dune system also includes grassed areas, shrubs, and ornamental trees. Wildlife found along the ocean side of the island is limited as a result of development. Animals present in the project area are primarily those that can customarily tolerate man's presence, such as sea gulls, pigeons, starlings, house sparrows, and small rodents. The beach and dune system serves as an important nesting and food-source area for certain shorebirds (USFWS 1992a). Baseline sampling of the nourishment sites and control sites was initiated by the applicants in June 2001.

3.15 THREATENED AND ENDANGERED SPECIES

Species to be considered in this environmental assessment were provided by USFWS and the NMFS and are listed in the following table, followed by a description of these species. (Section 4 contains a description of potential impacts to these species as a result of the proposed beach nourishment project.)

Common Name	Scientific Name	Status	Habitat present?	Known observation*
Mammals				
Eastern cougar	*Felis concolor couguar*	E	no	no
Finback whale	*Balaenoptera physalus*	E	no	no
Humpback whale	*Megaptera novaeangliae*	E	yes	yes**
Right whale	*Eubaleana glacialis*	E	yes	yes**
Sei whale	*Baleanoptera borealis*	E	no	no
Sperm whale	*Physeter catodon*	E	no	no
West Indian manatee	*Trichechus manatus*	E	yes	no
Birds				
Piping plover	*Charadrius melodus*	T	yes	no
Red-cockaded woodpecker	*Picoides borealis*	E	no	no
Roseate tern	*Sterna douglallii*	E	no	no
Wilson's plover	*Charadrius wilsonia*	SR	yes	no
Reptiles				
American alligator	*Alligator mississippiensis*	T(S/A)	no	no
Green sea turtle	*Chelonia mydas*	T	yes	yes**
Hawksbill sea turtle	*Eretmochelys imbricata*	E	yes	yes**
Kemp's ridley sea turtle	*Lepidochelys kempi*	E	yes	yes**
Leatherback sea turtle	*Dermochelys coriacea*	E	yes	yes**
Loggerhead sea turtle	*Caretta caretta*	T	yes	yes
Fish				
Shortnose sturgeon	*Acipenser brevirostrum*	E	no	no
Plants				
Rough-leaf loosestrife	*Lysimachia asperulaefolia*	E	no	no
Seabeach amaranth	*Amaranthus pumilus*	T	yes	yes
Moundlily yucca	*Yucca gloriosa*	SR	yes	yes

KEY

Status	Definition
E	A taxon "in danger of extinction throughout all or a significant portion of its range."
T	A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."
T(S/A)	Threatened due to similarity of appearance - a species that is threatened due to similarity of appearance with other rare species and is listed for its protection. These species are not biologically endangered or threatened and are not subject to Section 7 consultation.
SR	State designation. Species designated as being very rare, generally with 1-20 populations in the state. These species are not subject to Section 7 consultation and are not considered in the biological assessment.

* Observation according to NC Natural Heritage Program data.

** Species is known to migrate along the coast of NC (Wynne 1999).

The presence of these species in the project area depends on the availability and abundance of appropriate habitat. Since the Bogue Banks project area does not contain any freshwater or forested areas, the eastern cougar, red-cockaded woodpecker, American alligator, shortnose sturgeon, and roughleaf loosestrife are not likely to be found at this site. Listed species that could potentially be located at Bogue Banks are the whale species, West Indian manatee, piping plover, sea turtle species, and seabeach amaranth.

On 5 July 20001, a final biological assessment was submitted to the USFWS and the NMFS, pursuant to Section 7 of the Endangered Species Act of 1973. This assessment determined that the proposed action may affect the hawksbill sea turtle, leatherback sea turtle, Kemp's ridley sea turtle, green sea turtle, loggerhead sea turtle, and the seabeach amaranth. Other federally listed endangered or threatened species would not be affected. Endangered species coordination with the Protected Resources Division was completed 26 July 2001 with a letter from JE Powers (NMFS, St Petersburg) to Col JW DeLoney (USACE, Wilmington) and by a letter from USFWS dated 20 September 2001.

3.15.1 Mammals

3.15.1.1 ***Right Whale, Finback Whale, Humpback Whale, Sei Whale, and Sperm Whale*** – Humpback whales are often found in protected waters over shallow banks and shelf waters for breeding and feeding. They migrate toward the poles in summer and toward the tropics in winter and visit the North Carolina coast during seasonal migrations, especially between December and April (Conant 1993). They eat schooling fish such as herring and can consume up to 1.5 tons per day of krill. Right whales swim very close to the shoreline and are often noted only a few hundred meters offshore (Schmidly 1981). They feed primarily on copepods and euphausids. While this whale usually winters in the waters between Georgia and Florida, it can on occasion be found in the waters off North Carolina. Sighting data provided by the Right Whale Program of the New England Aquarium indicates that 93 percent of all North Carolina sightings between 1976 and 1992 occurred between mid-October and mid-April (Chris Slay 1993). The number of right whales documented in the vicinity of Morehead City during a single season ranges from 2 to 25 (USACOE 1989).

3.15.1.2 ***West Indian Manatee*** – The manatee is an occasional summer resident of the North Carolina coast. The species can be found in shallow (5 feet to usually less than 20 feet), slow-moving rivers, estuaries, saltwater bays, canals, and coastal areas (USFWS 1991). The West Indian manatee is herbivorous and eats aquatic plants such as hydrilla, eelgrass, and water lettuce (USFWS 1999). During winter months, the United States' manatee population confines itself to the coastal waters of the southern half of peninsular Florida and to springs and warm water outfalls as far north as southeast Georgia. They are sighted frequently in southeastern North Carolina with most records occurring in July, August, and September, as they migrate up and down the coast (Clark 1993). However, scattered records of this species in the region span all seasons. Based on this data, the manatee is considered a year-round resident with a maximum population in the late summer months. Manatee population trends are poorly understood, but deaths have increased steadily. A large percent of mortality is due to collisions with water crafts, especially of calves. Another closely related factor in their decline has been the loss of suitable habitat through incompatible coastal development, particularly destruction of sea grass beds by boating facilities.

3.15.2 Birds

3.15.2.1 *Piping Plover* – The Atlantic Coast piping plover population breeds on coastal beaches from Newfoundland to North Carolina (and occasionally in South Carolina) and winters along the Atlantic Coast from North Carolina south, along the Gulf Coast, and in the Caribbean (USFWS 1996). Since being listed as threatened in 1986, the population has increased from approximately 800 pairs to almost 1350 pairs in 1995, although most of this increase may be attributable to an increase in surveying intensity. Piping plovers nest above the high tide line on coastal beaches, sand flats at the ends of sand spits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, sparsely vegetated dunes, and washover areas cut into or between dunes (USFWS 1996). Feeding areas include intertidal portions of ocean beaches, washover areas, mud flats, sand flats, wrack lines, and shorelines of coastal ponds, lagoons, or salt marshes. Loss and degradation of habitat due to development and shoreline stabilization have been major contributors to the species' decline.

Most piping plovers at Bogue Banks have been observed at the west end of Emerald Isle as predominantly a migratory and winter resident (David Allen, pers. comm.). During a 1991 USFWS International Piping Plover Census (winter), four piping plovers were observed and during a 1996 winter census, one individual was observed. In addition, both Bogue and Beaufort inlets contain intertidal flats exposed at low tide that are prime feeding and roosting habitats for a variety of shorebirds and colonial waterbirds including pelicans, cormorants, terns, and black skimmers. These areas may be used by piping plovers as well.

3.15.2.2 *Roseate Tern* – Roseate terns breed primarily on small offshore islands, rocks, cays, and islets. Rarely do they breed on large islands. They have been reported nesting near vegetation or jagged rock, on open sandy beaches, close to the waterline on narrow ledges of emerging rocks, or among coral rubble (USFWS 1999). This species is primarily observed south of Cape Hatteras, particularly at Cape Point within Cape Hatteras National Seashore, during the months of July and August.

3.15.3 Reptiles

3.15.3.1 *Hawksbill Sea Turtle* – Hawksbill sea turtles are found mainly in tropical waters of the Atlantic, Pacific and Indian Oceans. Nesting in the United States for this species occurs in spring and is generally restricted to Florida. Although it is not considered common along the North Carolina coast, the hawksbill may be found in North Carolina waters all year and can be present in inshore waters April through December (Epperly et al 1995). The hawksbill is found along submerged rocky areas, reefs, shallow coastal areas, lagoons of oceanic islands and narrow creeks (USFWS 1991). It is not often seen in water over 65 ft deep. Its diet includes algae, fish, mangrove, barnacles, clams, sponges, snails, and sea urchins.

3.15.3.2 ***Leatherback Sea Turtle*** – Leatherback sea turtles are found mainly in tropical waters of the Atlantic, Pacific and Indian Oceans. Nesting in the United States for this species occurs in spring and is generally restricted to Florida. Although it is not considered common along the North Carolina coast, the leatherback may be found in North Carolina waters all year and can be present in inshore waters April through December (Epperly et al 1995). The leatherback is an open-ocean species that sometimes moves into shallow bays, estuaries, and even river mouths. The preferred diet is jellyfish and may also include sea urchins, squid, shrimp, fish, blue-green algae, and floating seaweed. It is also found along the Atlantic coastline from Massachusetts southward to Brazil.

3.15.3.3 ***Kemp's Ridley Sea Turtle*** – Kemp's ridley sea turtles inhabit shallow coastal and estuarine waters, often in association with subtropical shorelines of red mangrove. The entire population nests on ~15 miles of beach in Mexico between the months of April and June (USFWS 1991). Outside of nesting, the major habitat for adult Kemp's ridleys is the near-shore and inshore waters of the northern Gulf of Mexico, especially Louisiana waters. However, immatures have been observed along the Atlantic coast as far north as Massachusetts. Although the Kemp's ridley has been documented to nest in North Carolina only once, juveniles of the species are known to migrate in estuarine and oceanic waters off of the North Carolina coast (Schwartz 1977; Epperly et al 1995). Overharvesting of both eggs and adults for food and the skin has been a major factor in their decline. Currently the major threat is drowning when inadvertently caught in shrimp nets. The total population is currently estimated to be 1500 to 3000 individuals.

3.15.3.4 ***Green Sea Turtle*** – With an estimated population of no more than 600,000 adults worldwide, the green turtle exists in both tropical and temperate seas and oceans (USFWS 1992). The North American distribution ranges from Massachusetts to Mexico, and from British Columbia to Baja California. Green sea turtles generally favor protected waters inside reefs, bays, estuaries, and inlets. Primary habitat appears to be lagoons and shoals supporting an abundance of marine grass and algae. These turtles are predominantly herbivorous, feeding upon marine algae and shallow beds of marine grasses. However, additional food sources may include mollusks, sponges, crustaceans, and jellyfish. The major reasons for the decline in green turtle numbers include over-exploitation of eggs and meat for food, commercial fishing and dredging operations, and nesting habitat destruction associated with outer beach development (USFWS 1992). Green sea turtle nesting habitat consists of open beaches with a sloping platform and minimal human disturbance. Eastern United States nesting is primarily limited to Florida's east coast (300 to 1000 nests reported annually). Although occasional nesting has been documented as far north as North Carolina and false crawls have been documented at Emerald Isle Beach, no nests have been observed within the project site. However, juvenile green sea turtles are known to migrate in estuarine and oceanic waters off of the North Carolina coast (Schwartz 1977; Epperly et al 1995).

3.15.3.5 ***Loggerhead Sea Turtle*** – The loggerhead turtle utilizes the Bogue Banks upper beach fronts for its seasonal (March-October) nesting events. Off the Carolina coast these turtles commonly occur at the edge of the continental shelf when they forage around coral reefs, artificial reefs, and boat wrecks. They feed on benthic invertebrates including mollusks, crustaceans, and sponges (Morrimen 1982). They have also been found to eat fish, clams, oysters, sponges, jellyfish, shrimp, and crabs when near shore. Research has shown that the turtle populations have greatly declined in the last 20 years due to loss of nesting habitat along the beachfront and by incidental drowning in shrimp trawl nets. Dredging activities in the warmer months of the year could impact the sub-adults but this has not been well documented. It appears that the combination of poorly placed nests coupled with unrestrained human use of the beach by auto and foot traffic has impacted this species greatly. Eroding steep beach escarpments, lights, sand fences, and other physical barriers (debris) often cause the mature females to select poor nesting sites at the dune toes which causes higher nestling mortality rates. Loggerhead turtles are known to regularly nest from Bogue Inlet to Beaufort Inlet, including the entire stretch of the project site. Between 1995 and 1999, an average of 28 nests per year were recorded within the project area (Ruth Boettcher, pers. comm.). In addition, juveniles are known to migrate in estuarine and oceanic waters off of the North Carolina coast (Schwartz 1977; Epperly et al 1995).

3.15.4 Fish – ***Shortnose Sturgeon*** – This species ranges along the Atlantic seaboard from southern Canada to northeastern Florida (USFWS 1999). The shortnose sturgeon feeds on invertebrates and stems and leaves of macrophytes. From historical accounts, it appears that this species was once fairly abundant throughout North Carolina waters, however, many of these early records are unreliable due to confusion between this species and the Atlantic sturgeon (*Acipenser oxyrhynchus*). Because of the lack of suitable freshwater spawning areas in the project area and the requirement of low salinity waters by juveniles, any shortnose sturgeons present would most likely be non-spawning adults.

3.15.5 Plants – ***Seabeach Amaranth*** – Seabeach amaranth is an annual herb that occurs on beaches, lower foredunes, and overwash flats (Fussell 1996). Weakley (1986) found that in North Carolina the plant is most common on overwash flats on accreting ends of barrier islands. This species occupies elevations ranging from 0.2 to 1.5 m above mean high tide (Weakley and Bucher 1992). Historically, seabeach amaranth was found from Massachusetts to South Carolina. But according to recent surveys (USACE 1992-1995), its distribution is now restricted to North and South Carolina with several populations on Long Island, New York. The decline of this species is caused mainly by development of its habitat, such as inlet areas and barrier islands, and increased ORV and human traffic which tramples individuals (Fussell 1996).

Between 1992 and 1995, annual surveys of amaranth were conducted all along the North Carolina coast including Bogue Banks (NCNHP 1995). The results are as follows:

	# Plants Observed at Bogue Banks	# Plants Observed within Project Area
1992	2,556	159
1993	3,762	232
1994	1,181	182
1995	14,776	391

No survey was conducted in 1996 because of early summer hurricanes that washed away or buried most of the plants. In 1997, certain sections of Bogue Banks were surveyed, but were found to support very low numbers of amaranth. In August of 2000, staff of Land Management Group, Inc., performed an amaranth survey along the beaches of Bogue Banks from Bogue Inlet to Beaufort Inlet. Approximately 40 individuals were found. Most plants were located along Atlantic Beach, in areas that have received nourishment in the last ten years. The individuals were located on the foredune at and above the dune toe. On the remaining beach, including Pine Knoll Shores, Salter Path, Indian Beach, and Emerald Isle, six plants were observed (Fig 3.21). These individuals were located several feet above the dune toe in an area were extensive beach scraping has occurred.

3.15.6 Other Species

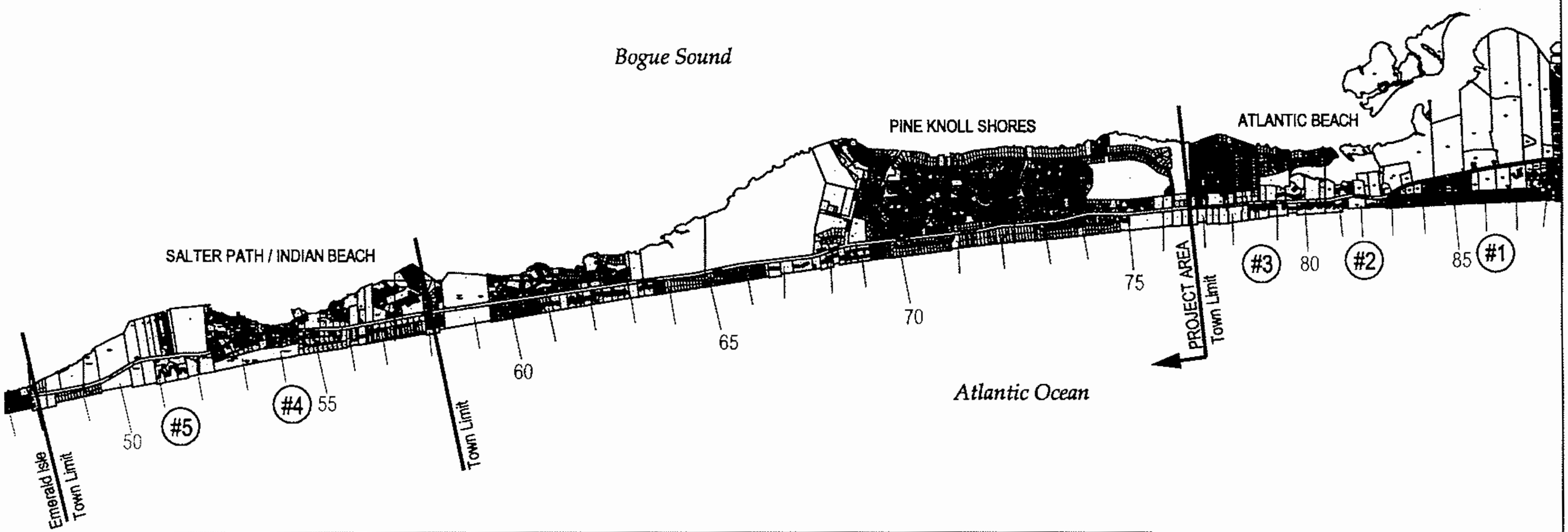
In addition to the federally listed species, two other species with a state status of significantly rare (SR) have been observed in the proposed project area and are discussed here. The Wilson's plover is a state "watch list" species (categories W1 and W5), indicating that it is known to be declining and that there are threats to its habitat. It has been observed on the eastern side of Bogue Inlet (NCNHP data). This coastal bird species breeds along the coast from Maryland southward and winters from the Gulf Coast and Florida southward (Fussell 1996). In North Carolina, this species breeds primarily from Portsmouth Island southward. Wilson's plovers breed mostly on barrier islands and on dredged material islands within estuaries. This species is often found breeding at sites having similar habitat to those preferred by piping plovers; however Wilson's plovers utilize a broader range of habitat, including habitat with greater vegetative cover. The moundlily yucca plant has also been observed within the proposed project site. It was observed at Indian Beach in 1992 by NC Natural Heritage personnel and is generally found in moist depressions in sand dunes (Radford et al 1964).

3.16 GEOLOGICAL SETTING AND PROPOSED BORROW AREAS

As part of the planning for the proposed project, CSE-Stroud (2001) completed a detailed investigation of potential borrow areas. Via a combination of literature review and over 200 borings, three offshore borrow areas were identified for use in the proposed project. This section summarizes results of the literature review and field sampling of offshore sediments.

3.16.1 Geologic Setting

Numerous scientific studies address the geology, geomorphic history, and sediments of the North Carolina coast (Table 3.1). In contrast, relatively few reports present field data on these topics for the area of Bogue Banks and immediate offshore zone (Table 3.2). The salient points of these studies with respect to nourishment planning and identification of viable borrow areas include:



SEABEACH AMARANTH LOCATIONS

Area # 1 - Atlantic Beach			Area # 2 - Atlantic Beach			Area # 4 - Salter Path		
Specific Area	**~ Line #**	**# of plants**	**Specific Area**	**~ Line #**	**# of plants**	**Specific Area**	**~ Line #**	**# of plants**
At ~600 Ocean Ridge Dr.	83	2	Behind the Coral Bay Club	82	16	On the beach (homes present)	54	1
At mile marker ~2.9	84	1	**Area # 3 - Atlantic Beach**			**Area # 5 - Indian Beach**		
At 701 Ocean Ridge Dr.	85	3	**Specific Area**	**~ Line #**	**# of plants**	**Specific Area**	**~ Line #**	**# of plants**
At mile marker ~3.3	86	1	Behind old tan hotel	79	1	On dunes near campground	52	1
At ~1101 Ocean Ridge Dr.	87	3	Behind Dunescape 2 Condos	80	4	behind condos		
At ~1200 Ocean Ridge Dr.	88	2	Behind Dunescape 5 Condos	81	1			

—— 70 CSE Beach Transects

(#3) Amaranth Localities (see chart)

Note: No Amaranth plants observed in Emerald Isle (beach transects 8-48)

NORTH

SCALE (ft)

0 5,000

Seabeach Amaranth Survey Results

Source: Land Managment Group

Date of survey: August 2000

PROJECT NAME:
Bogue Banks Beach Nourishment Project

CSE
Coastal Science & Engineering, LLC

APPLICANT:
Carteret County
Supplement to March 2001 Application

Fig 3.21

TABLE 3.1. Selected references providing background information on the geology, geomorphic history, and sediments of the North Carolina coast (not specific to Bogue Banks).

NOTE: While by no means a complete list, these references provide an excellent overview of geologic processes, landforms, and sediments along the North Carolina coast. Their authors tend to be the researchers who frequently appear in the literature. Many remain active in the profession and continue to offer new insights regarding shoreline evolution. The list focuses on publications having relatively wide distribution. We particularly recommend *Geology of Holocene Barrier Island Systems* (R.A. Davis, editor, Springer-Verlag 1994) for its collection of synthesis papers under one cover.

Blackwelder, B.W., I.G. MacIntyre, and O.H. Pilkey. 1982. Geology of the continental shelf, Onslow Bay, North Carolina, as revealed by submarine outcrops. Bull. AAPG, Vol. 66, pp. 44-56.

Cleary, W.J., and P.E. Hosier. 1979. Geomorphology, washover history, and inlet zonation: Cape Lookout, NC, to Bird Island, NC. In S.P. Leatherman (ed), *Barrier Islands*, Academic Press, New York, NY, pp. 237-271.

Hayes, M.O. 1994. The Georgia Bight barrier system. Chap. 7 in R. Davis (ed), *Geology of Holocene Barrier Island Systems*, Springer-Verlag, Berlin, pp. 233-304.

Langfelder, L.J., P.B. Stuffard, and M. Amein. 1970. Coastal erosion in North Carolina. Jour. Waterways and Harbors Div., Proc. ASCE, Vol. 96(NWW2), pp. 531-545.

Luternauer, J.L., and O.H. Pilkey. 1967. Phosphorite grains: their application to the interpretation of North Carolina shelf sedimentation. *Marine Geology*, Vol. 5, pp. 4, 314-320.

Meisburger, E.P. 1979. Reconnaissance geology of the inner continental shelf, Cape Fear region, North Carolina. CERC, Tech. Paper 79-3, 135 pp.

Moslow, T.F., and S.D. Heron, Jr. 1979. Quaternary evolution of Core Banks, North Carolina: Cape Lookout to New Drum Inlet. In S.P. Leatherman (ed), *Barrier Islands*, Academic Press, New York, NY, pp. 211-236.

Moslow, T.F., and S.D. Heron, Jr. 1981. Holocene depositional history of a microtidal cuspate foreland cape: Cape Lookout, North Carolina. *Marine Geology*, Vol. 41, pp. 251-270.

Moslow, T., and D. Heron. 1994. The Outer Banks of North Carolina. Chap. 2 in R. Davis (ed), *Geology of Holocene Barrier Island Systems*, Springer-Verlag, Berlin, pp. 47-74.

Pearson, D., and S. Riggs. 1981. Relationship of surface sediments on the lower forebeach and nearshore shelf to beach nourishment at Wrightsville Beach, North Carolina. Shore & Beach, Vol. 49, pp. 26-31.

Pierce, J.W., and D.J. Colquhoun. 1970. Holocene evolution of a portion of the North Carolina coast. Geol. Soc. Amer. Bull. Vol. 81, pp. 3697-3714.

Pilkey, O.H., L. Blackwelder, E. Doyle, and M. Terlecky. 1969. Aspects of carbonate sedimentation on the Atlantic Continental Shelf off of southern United States. Jour. Sed. Petrol., Vol. 39(2), pp. 744-769.

Riggs, S., W. Cleary, and S. Snyder. 1995. Influence of inherited geologic framework on barrier shoreface morphology and dynamics. *Marine Geology*, Vol. 126, pp. 213-234.

Susman, K.R., and S.D. Heron, Jr. 1979. Evolution of a barrier island, Shackleford Banks, Carteret County, North Carolina. Geol. Soc. Amer. Bull., Vol. 90, pp. 205-215.

Swift, D.J.P. 1975. Barrier-island genesis: evidence from the central Atlantic shelf, eastern U.S.A. *Sed. Geology*, Vol. 14, pp. 1-43.

Swift, D.J.P., J.W. Kofoed, F.P. Saulsbury, and P. Sears. 1972. Holocene evolution of the shelf surface, central and southern Atlantic shelf of North America. In Swift et al (eds), *Shelf Sediment Transport, Process and Pattern*, Dowden, Hutchinson and Ross, Stroudsburg, PA, pp. 499-574.

Thieler, R., W. Cleary, C. Hobbs, and R. Gammisch. 1995. Geology of the Wrightsville Beach, North Carolina, shoreface: implications for the concept of shoreface profile equilibrium. *Marine Geology*, Vol. 1126, pp. 271-287.

TABLE 3.2. Reports and publications containing site-specific data and relating to geology and sediments in the Bogue Banks section of the North Carolina coast. The papers by Hine and Snyder (1985) and Heron et al (1985) along with the thesis by Reed (1997) were particularly helpful during the planning of the 1999 field survey.

Batten, W. 1962. The sediments of the Beaufort Inlet area, North Carolina. *Southeastern Geology*, Vol. 2, pp. 191-205.

Fisher, J.J. 1967. Development pattern of relict beach ridges, Outer Banks barrier chain, NC. Unpublished dissertation, Univ. North Carolina, Chapel Hill.

Goff, T.W. 1977. Sedimentation in a modern tidal inlet: Bogue Inlet, North Carolina. Unpublished thesis, Univ. North Carolina, Chapel Hill.

Heron, D., T. Moslow, W. Berelson, J. Herbert, K, Steele, and K. Susman. 1984. Holocene sedimentation of a wave-dominated barrier island shoreline: Cape Lookout, North Carolina. *Marine Geology*, Vol. 60, pp. 413-434.

Hine, A., and S. Snyder. 1985. Coastal lithosome preservation: evidence from the shoreface and inner continental shelf off Bogue Banks, North Carolina. *Marine Geology*, Vol. 63, pp. 307-330.

Mixon, R.B., and O.H. Pilkey. 1976. Reconnaissance of the submerged and emerged coastal plain province: Cape Lookout quadrangle, North Carolina. U.S. Geol. Survey Paper 859, 45 pp.

Reed, A. 1997. Sediment distribution patterns offshore of a replenished beach: Atlantic Beach and Fort Macon State Park, North Carolina. M.S. Thesis, Dept. Geology, Univ. North Carolina, Chapel Hill, 74 pp. + app.

Sarle, L.L. 1977. Processes and resulting morphology of sand deposits within Beaufort Inlet, Carteret County, North Carolina. M.S. Thesis, Dept. Geol., Duke Univ., Durham, NC, 149 pp.

Steele, G.A. 1980. Stratigraphy and depositional history of Bogue Banks, North Carolina. Ph.D. Thesis, Duke Univ., Durham, NC, 201 pp.

Thieler, R. 1996. Shoreface processes in Onslow Bay. Carolina Geological Survey 1996 Fieldtrip Guidebook, pp. 23-32.

USACE. 1976. Morehead City Harbor, NC. General Design Memorandum, U.S. Army Corps of Engineers, Dept. Army, Wilmington Dist., NC, 327 pp.

USACE. 1990. Feasibility report and environmental assessment. Morehead City Harbor improvement, Morehead City, NC, 79 pp.

USACE. 1993. Environmental assessment and findings of no significant impact. Disposal of dredged material on the ocean reach of Bogue Banks from combined maintenance — dredging and deepening of Morehead City Harbor inner navigation channels and pumpout of Brandt Island upland diked disposal site, Carteret County, NC, 37 pp.

USACE. 1994. Environmental assessment: designation and use of a placement area for underwater nearshore berm. Morehead City Harbor project, Morehead City, NC, 50 pp.

- Bogue Banks is a Holocene barrier island within the less exposed western "limits" of the Cape Lookout cuspate foreland with strikingly different topography and profile compared to the northeastern-limit barriers, Core Banks and Portsmouth Island (Heron et al 1984).

- During Quaternary times, the shoreline off Bogue Banks was transgressive under the influence of deglaciation and rapid sea-level rise across the gently sloping continental shelf of the Carolinas.

- Whether or not Bogue Banks existed as a single or series of subaerial barriers prior to 4000 years ago, only a thin sediment cover remains offshore--most of the inner continental shelf consists of outcropping Tertiary hard bottom (Fig 3.22) (Hine and Snyder 1985).

- As sea-level rise slowed and approached its present elevation about 4000 ago, Bogue Banks began to accumulate sediment from reworked paleo-inlet deltas and littoral sources (Hine and Snyder 1985).

- Bogue Banks became a "regressive barrier" accreting seaward and vertically via build-up of the shoreface for several thousand years up to this century.

- Accumulation of littoral sediments in the area of present-day Bogue Banks, infilled paleochannels (inlets), the most recent of which were (Fisher 1967):
  - Prehistoric relict inlet near the causeway to Atlantic Beach.
  - Two relict inlets (noted on Fig 3.22 as #1 and #2) in eastern Emerald Isle, approximately 0.1 and 2.0 miles west of Indian Beach, respectively.
  - Relict Cheeseman Inlet (closed sometime between 1860 and 1886) along west Atlantic Beach about one mile east of Pine Knoll Shores.

- With the exception of a short-term breach in the low area of eastern Emerald Isle during Hurricane *Donna* (1960), Bogue Banks has existed as a contiguous ~25-mile-long barrier island for almost 150 years.

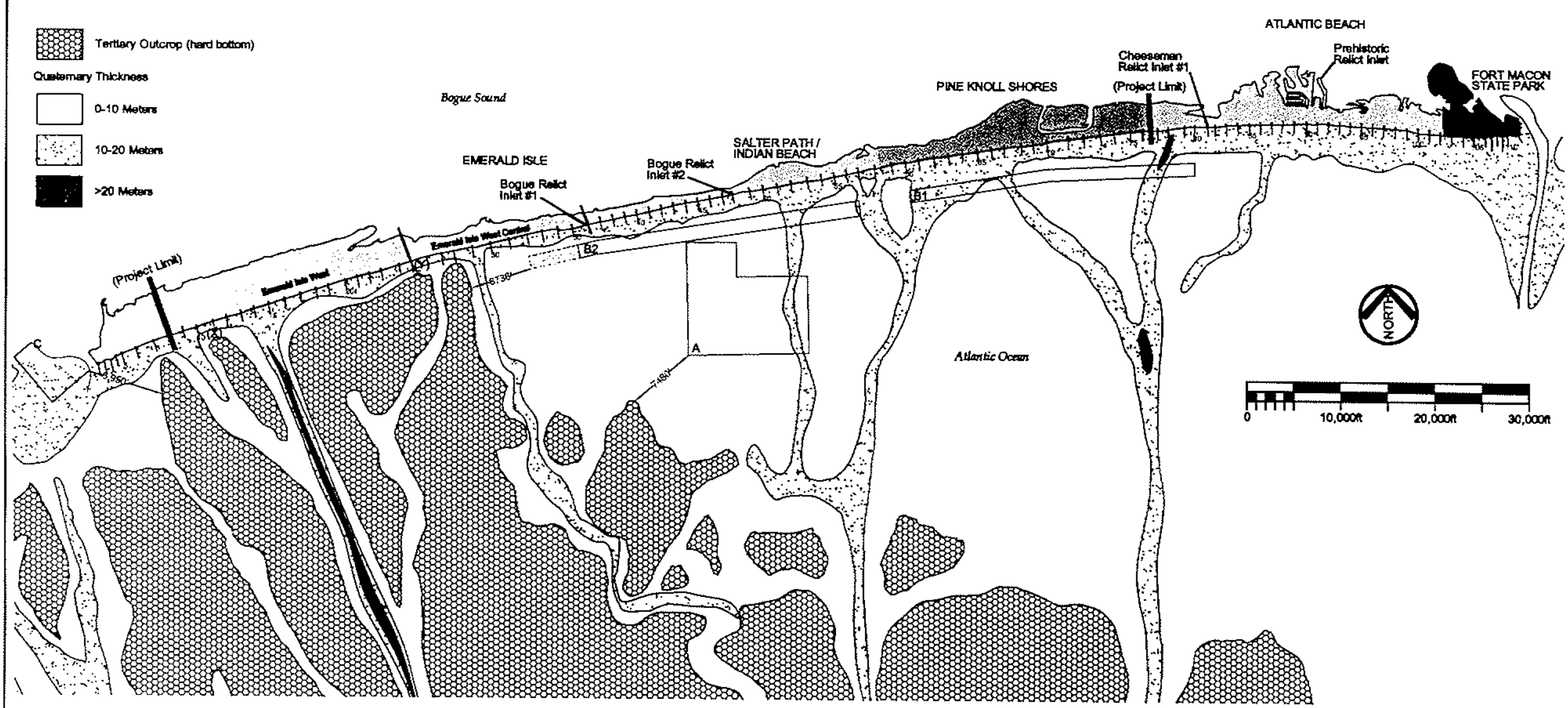
- Bogue Inlet to the west and Beaufort Inlet to the east constitute the primary boundaries of the Bogue Banks littoral cell.

- Bogue Banks's bounding inlets contain huge reservoirs of littoral sand in the form of ebb- and flood-tidal deltas.

- Bogue Banks' positional stability allowed accretion of high dune ridges--in some areas, exceeding 40 feet (ft) above sea level and along most of the shoreline reaching 20 ft. Relief and absolute elevations across Bogue Banks are much greater than Core Banks and Portsmouth Island.

- High relief along Bogue Banks inhibits formation of washovers. Low longshore transport rates lessen the rate of sand loss to the inlets compared to east-facing barrier islands in other parts of Carteret County. Average erosion rates have been low (0-5 ft/yr) since 1939 according to all available published reports.

- Subaerial sediments range from medium to coarse sand and crushed shells along the upper beach to fine sand in the dunes to mixtures of sand, coarse shells, and mud in back-barrier areas. The foreshore sediments coarsen toward the step (inshore breakpoint), then fine to the inner trough and bar. Seaward of a shore-parallel bar situated about 400 ft offshore, sediments fine along the lower shoreface (USACE 1992).



Interpretation of Tertiary (hard bottom) outcrops and estimated Quaternary layer thickness (of unconsolidated sediments) based on Hine and Snyder (1985, Figure 6). Infilled paleochannels comprise the thickest deposits but have limited areal extent and highly variable sediment texture including high percentages of fines. Potential borrow areas A, B1, B2, & C identified in the present study are superimposed. Ground truth surveys conducted by CSE (2000) indicate there is no exposed hard bottom inside the -35 ft contour along western Emerald Isle. The closest hard bottom to the project area is estimated to be at least 3000 ft offshore in the vicinity of transect 20-28.

Closest distance to Tertiary outcrop

Borrow area A..................7500ft
Borrow area B2................6700ft
Borrow area C..................6,950ft

Project Reach

Emerald Isle West (Y)........1600ft (from outer bar)
Emerald Isle Central (X).....1600ft (from outer bar)

STROUD ENGINEERING

CSE Coastal Science & Engineering, LLC

Figure 3.22

Interpretation of Tertiary (hard bottom) outcrops and estimated Quaternary thickness

3.16.2 Survey Design

Despite a limited supply of beach-quality sand offshore of Bogue Banks as inferred from the literature (see Table 3.2), more detailed confirmation was required before ruling out alternative borrow areas. The applicants initiated a reconnaissance-level survey during initial planning of the Bogue Banks restoration project based on the following desirable criteria:

- Viable sand deposits closer to the project areas than Beaufort or Bogue Inlets could potentially yield very large cost savings for the project.
- Sediments that are somewhat coarser (on average) than the native beach and coarser than the material typically available from channel maintenance would improve the durability of the nourishment projects.
- Deposits with lower mud/fine-sand content than previously used in Corps disposal projects would reduce the rate of fill losses and minimize turbidity in nearshore waters.
- If broad, shallow areas (at least 1-2 ft thick) could be confirmed, hopper dredges or alternate equipment could be used for excavations, and the rate of environmental recovery might be more rapid based on experience elsewhere (Jutte et al 1999a,b).

The sediment survey encompassed the following field sampling over three phases between June 1999 and November 2001:

- *Beach sampling and textural analysis* (June 1999) to quantify native material — 20 samples divided among dune (2), berm (6), beach face (6), and low-tide terrace (6) at CSE-Stroud transect 10 (west Emerald Isle), transect 30 (central Emerald Isle), transect 50 (Indian Beach), transect 70 (Pine Knoll Shores east), transect 90 (Atlantic Beach), transect 110 (Coast Guard Station); spacing of transects was approximately 20,000 ft. These were supplemented by 64 additional beach samples (32 analyzed pairs) between transects 48 and 78 in May 2001 following a request for more data from the USFWS (interagency meeting of 11 May 2001–detailed results submitted 24 May 2001 with letter to Garland Pardue, USFWS, Raleigh, NC).
- *Phase I borrow source sampling* (June 1999) — *offshore reconnaissance* — 53 short cores by divers in a regional grid pattern encompassing a 16-mile length of coast from central Atlantic Beach to central Emerald Isle and extending between ~0.25 and 3 miles offshore. Generally consisted of shore-perpendicular transects of 3-5 boring locations at approximate two-mile intervals in the longshore direction. Additional, more closely spaced cores were collected 0.5-1 mile from the most promising sites. Cores average about 2 ft long. Other potential sources were sampled but rejected for various reasons as detailed in the EIS for the project. Three offshore borrow areas (A, B1, and B2) were tentatively identified for further sampling (CSE Baird-Stroud 1999).

- *Phase II confirmation sampling* (November 1999)
  - *Borrow area A (western half)* — 46 borings (averaging ~2.3 ft) at ~1200-1500 ft spacing; eight vibracores (3-9 ft) at ~3000 ft spacing.
  - *Borrow area B1* — four diver borings (~2.8 ft); three vibracores (7.5-11 ft).
  - *Borrow area B2* — seven diver borings (~2.9 ft); three vibracores (~9-10 ft).
  - Phase II sampling formed the basis of proposed borrow areas A, B1, and B2 as shown on the permit application for the project (P/N ID #200000362).

- *Phase III borrow area refinement sampling* (November 2000-March 2001)
  - *Borrow area A)* — 13 additional borings (averaging ~2 ft)
  - *Borrow area B1* — 32 additional borings (averaging ~3.4 ft)
  - *Borrow area B2* — 25 additional borings (averaging ~3.0 ft)

  Phase III sampling serves as the basis for further refining the borrow areas proposed for the project as detailed herein. (Note: The refined areas are fully within the boundaries specified in the permit application for the project.)

CSE Baird performed all Phase I sampling and the diver sampling for Phase II. Athena Technologies, Inc. (Columbia, SC) performed the vibracore sampling under subcontract to CSE Baird.

The only known borings prior to the 1999 survey in the primary offshore region (central Bogue Banks) were those collected in the early 1980s by university researchers (Dr. SR Riggs and Dr. AC Hine, principal investigators, as reported in Hine and Snyder 1985) (Fig 3.23). That regional survey of Onslow Bay included approximately 20 vibracores on the inner shelf inside the 20-meter depth contour off Bogue Banks. The Hine and Snyder (1985) borings generally describe a shore-parallel line about 3-3.5 miles offshore. Several borings were made closer to shore in presumed paleochannels off the western end of Atlantic Beach and western Emerald Isle (Fig 3.23). Hine and Snyder noted for the area thin layers of Holocene sands and crushed shell overlying more heterogeneous Pleistocene sediments. Paleochannels (Fig 3.23) reportedly contained admixtures of mud, sand, shells, and phosphatic material.

The applicants' studies focused on the uppermost ~2-3 ft layer for three reasons:

1) Preliminary evidence suggested that the "Holocene" section was more likely to contain beach-quality sediments.

2) Hopper dredges reportedly work most efficiently in borrow areas where the depth of cut is of the order 1-2 ft (E. Elefson, August 1999, Weeks Marine, pers. comm.).

3) Given a fixed budget for offshore surveys, many more shallow borings could be obtained by divers working out of small craft compared to the number of vibracores possible using much larger equipment.

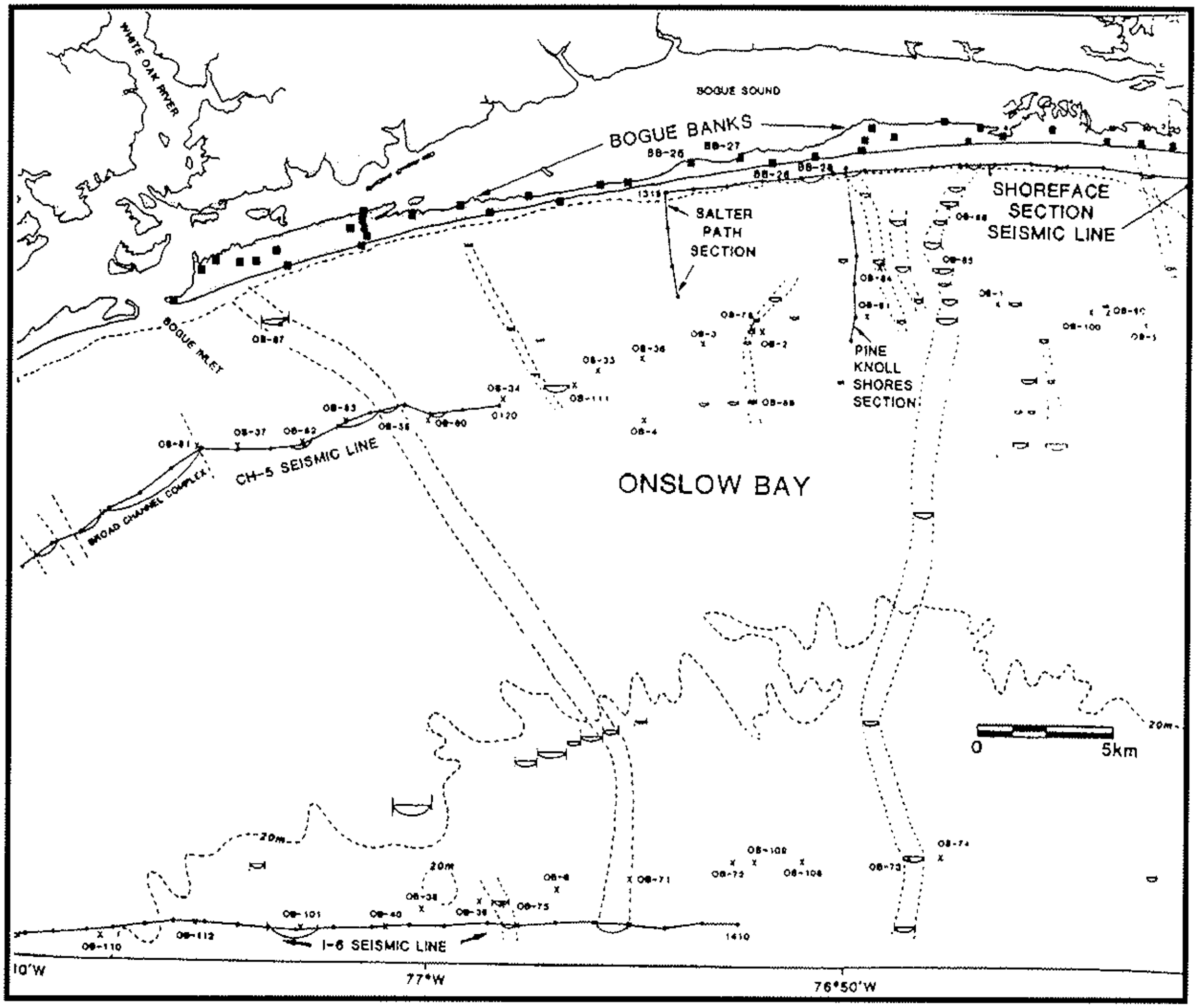


FIGURE 3.23. Vibracore locations and inferred positions of buried paleochannels (dashed lines perpendicular to the shoreline) offshore of Bogue Banks. Outer depth contour is 20 meters (~65 ft). [From Hine and Snyder 1985, Fig 2]

The study design provided for a three-phased search whereby preliminary borrow areas would be defined using a coarse regional grid of samples, then refined in Phase II and Phase III by a more detailed search. Phase II also provided for a representative sampling of thicker sections using a large vibracore rig sufficient to recover ~10-ft samples.

In total, the 1999-2001 surveys accomplished the following:

- Characterized the upper 2-3 ft of sediments in an approximate 50 square mile area off Bogue Banks.
- Identified potential offshore borrow areas representing approximately 10 square miles.

- Confirmed sediment in potential borrow areas in sufficient detail to develop isopach maps of textural properties.

- Obtained ~90 percent of the borings in the most promising four square miles, yielding an average ~40 borings per square mile in the proposed borrow areas. This density of borings is unprecedented for projects of this type.

3.16.3 Laboratory Analysis

Sediment samples were collected and stored as follows.

Diver cores — two-inch aluminum barrels driven by hammer to refusal, cut, and temporarily capped in situ; then decanted, cut to sediment level, and recapped in the field noting penetration depth and recovery thickness; stored vertically for transport to the lab.

Vibracores — 2½-inch steel barrels driven remotely via large-scale vibrator to the depth of refusal; removed, cut, capped, and measured for penetration depth and recovery thickness.

Grab samples (beach) — hand samples from the upper three inches placed in sample bags.

Samples were logged, split, and analyzed as follows.

1) **Diver and vibracore cores** — split by saw, logged, and one-half sampled as a single or multiple composite; the remaining core half was sealed in plastic in its half barrel and archived.

   Phase I samples — visual estimates of mud percentages; then washed, dried, and dry-sieved using 0.25 phi (ϕ) intervals from -1ϕ to 4ϕ – that is, granule (2 mm) to very fine sand (0.0625 mm); fractions retained >2 mm and <0.0625 mm were noted.

   Phase II and Phase III samples — same handling and grain-size analysis procedures as Phase I samples except nearly all tested for percent mud and percent carbonate via subsampling.

   - *Percent mud* was determined by drying an undisturbed sample (composite from the length of the core), weighing it, rewetting and disagregating the sample, decanting the mud fraction until the water ran clear, redrying the sample, then reweighing it. Percent mud is computed from the difference in dry weight of the unwashed and washed samples.

   - *Percent calcium carbonate* was determined from a 20-gram subsample that had been washed and dried, then treated with repeated quantities of 10 percent dilute HCL for several hours until all reactions stopped. Samples were redried and reweighed for comparison with the untreated sample weight, and the percentage of carbonate material is computed.

2) **Native beach samples** — representative splits were obtained, washed, dried, and dry-sieved at 0.25ϕ intervals. No mud analyses were performed because the grab samples were void of mud. Percent calcium carbonate was determined via the same procedure for Phase II cores and groupings of native beach samples (ie, physical composites of multiple berm, beach face, etc, samples).

Raw data were entered into spreadsheets and analyzed via custom software (CSE's BPAS system) which automates computation of standard statistical parameters [including moment measures and the graphic parameters of Inman (1952) and Folk and Ward (1957)]. Grain-size distributions (GSDs) were graphed as frequency and cumulative frequency distributions using phi (ϕ) and millimeter (mm) axes for cross-reference. To facilitate evaluation and comparison with other engineering sieve sizes, Figure 3.24 shows the general relationships of grain size (mm), phi value, sediment classification, and ASTM sieve mesh sizes.

Sediment quality and compatibility for beach nourishment were based on the technique of James (1975) (CERC 1984), whereby a population of potential borrow area samples is compared statistically with the native beach size distribution.

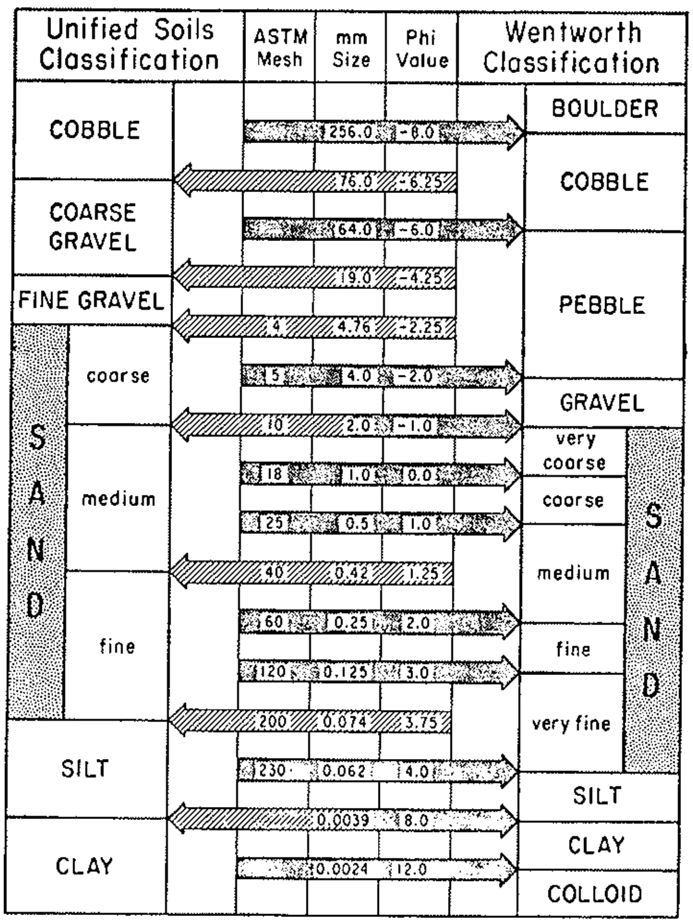


FIGURE 3.24. Grain-size scales (soil classification).

James (1975) presents methodology for computing the overfill ratio (R_A), which represents how similar a particular size distribution of sediments is compared to the native population of sediments. R_A's of nearly 1.0 suggest the sample will perform more or less equal to the native population. Higher R_A's represent the ratio of non-native "borrow" material required to perform as 1.0 unit of native material. Thus, an R_A equal to 2.0 suggests it will take twice as much material to equal 1.0 unit of native sediment.

The concept of overfill ratios is not a perfect predictor of nourishment performance, but it remains perhaps the most useful and proven technique for comparing nourishment sediments (NAS 1995). The primary factors considered are mean grain size and sorting (standard deviation measure of the size distribution). Experience has shown that borrow sources at least as coarse as the native beach (Dean 1991, CERC 1984) or having significant coarse fractions (Kana and Mohan 1998) perform equal to or better than native sediments (as measured by durability of the dry beach). Borrow sediments that are finer than native or that contain high percentages of fine material perform worse (NAS 1995). This response is related to profile adjustment (function of wave energy and wave steepness) as well as the background erosion rate. Obviously, the concept of R_A as a predictor of performance assumes that the scale of the nourishment is relatively large and covers a reasonable length of shoreline. Short projects do not perform as well for another reason– because end losses cause spreading away from the nourishment "bulge" (NAS 1995).

For purposes of the present study, we determined R_A's following standard practice, using the James (1975) nomogram in CERC (1984). Sediment quality and borrow area suitability was based on the R_A's, mean grain size and sorting parameters, percent mud, percent carbonate, percent coarser than 2 mm (ie, granule, or larger), and proximity to the project area. Isopach maps of various sediment size and quality parameters are given in Appendix A.

3.16.4 Sediment Results

This section provides a summary of results and refers to data sets contained in the EIS (CSE-Stroud 2001) and various supplements (eg, 24 May 2001 letter and data set to Garland Pardue, USFWS; 19 June 2001 letter to Col. J. DeLony, USACE). These previously submitted data sets include core locations, beach sample locations, and offshore core sediment characteristics (grain-size distribution curves and statistics).

3.16.4.1 ***Beach Composites*** – Native-beach size distributions were established using statistical composites of physical composite results of individual samples. Table 3.3 contains the individual sample results (primary statistics) from 21 dune/beach/low-tide terrace samples distributed in six transects along Bogue Banks collected in 1999 and 64 (32 pairs) supplementary samples collected in May 2001. Of the three dune samples from 1999, only two were considered representative of natural dunes, which tend to have finer sediment than beach-face samples. At stations CSE-Stroud 30, CSE-Stroud 50, and CSE-Stroud 70, repeated dune scraping has introduced anomalously coarse sands from the berm. Therefore, these stations were not sampled at the dune. At station 110 (Coast Guard station), nourishment via Corps spoil projects has introduced a coarse sediment which similarly does not reflect native dune sands; therefore, it was eliminated from the 1999 composites (top half of Table 3.3). The supplementary samples in 2001 yielded nearly identical composite statistics based on 28 or 32 samples depending on how many dune samples are included in the analysis (bottom of Table 3.3).

TABLE 3.3. Beach sediment characteristics and composites. [Revised May 2001]

Bogue Banks — Beach Sediment Characteristics — Updated 22 May 2001

Profile # - Locality	Sample	ID	Grain Size Distributions			Sediment	%CaCo3	Notes
June 1999 Samples			*Mean (mm)*	*Std Dev. (mm)*	*Skewness*	Description*		
10 - Emerald Isle	Berm	BB10B	**0.365**	0.630	-0.299	MS,mws,sym		
10	MBF	BB10C	**0.290**	0.622	-0.496	MS,mws,sc-s		
10	LTT	BB10D	**0.380**	0.525	-0.482	MS,ms,sc-s		
30 - Emerald Isle	Dune	BB30A	**0.246**	0.740	-0.034	FS,ws,sym		
30	Berm	BB30B	**0.384**	0.619	-0.149	MS,mws,sym		
30	MBF	BB30C	**0.312**	0.714	-0.495	MS,ws,sym		
30	LTT	BB30D	**0.270**	0.709	-0.646	MS,ws,sym		
50 - Indian Beach	Berm	BB50B	**0.418**	0.544	-0.439	MS,ms,sc-s		
50	MBF	BB50C	**0.302**	0.760	-0.455	MS,ws,sym		
50	LTT	BB50D	**0.215**	0.693	-0.683	FS,ws,c-s		
70 - Pine Knoll Shores	Berm	BB70B	**0.338**	0.566	-0.733	MS,ms,sc-s		
70	UBF	BB70C	**0.475**	0.517	-0.288	MS,ms,c-s		
70	LTT	BB70D	**0.288**	0.669	-0.744	MS,mws,c-s		
90 - Atlantic Beach	Dune	BB90A	**0.234**	0.750	0.074	FS,ws,sym		Nourished Section
90	Berm	BB90B	**0.228**	0.708	-0.830	FS,ws,c-s		Nourished Section
90	UBF	BB90C	**0.244**	0.630	-0.614	FS,mws,c-s		Nourished Section
90	LTT	BB90D	**0.243**	0.636	-0.569	FS,mws,c-s		Nourished Section
110 - Coast Guard Station	Dune1***	BB110A	**0.801**	0.432	-0.090	CS,ps,sym		Spoil Area
110	Berm	BB110B	**0.541**	0.514	-0.169	CS,ms,c-s		Spoil Area
110	MBF	BB110B	**0.457**	0.472	-0.347	MS,ps,c-s		Spoil Area
110	LTT	BB110B	**0.200**	0.599	-1.247	FS,mws,c-s		Spoil Area
Composites -1999	Dune***	(2)	**0.240**	0.745	0.390	FS,ws,sym	ND	
Composites	Berm	(6)	**0.368**	0.552	-0.460	MS,ms,c-s	16.1	Based on Physical
Composites	Beach Face	(6)	**0.357**	0.574	-0.634	MS,ms,c-s	11.8	Composites
Composites	LTT	(6)	**0.265**	0.602	-0.717	MS,mws,c-s	17.0	
Comp - 1999 - Omit 1 Dune	All***	(20)	**0.302**	0.585	-0.648	MS,mws,c-s	ND	
****Note: BB110A Omitted from Composites*								
Supplementary Samples	May-01							
Sta 48-50	Dune	B4850a	**0.262**	0.742	-0.213	MS,ws,c-s	3.2	Sta 48 Scraped Dune
Sta 48-50	Berm	B4850b	**0.266**	0.758	-0.078	MS,ws,sym	3.2	
Sta 48-50	Beach Face	B4850c	**0.278**	0.770	0.089	MS,ws,f-s	4.4	
Sta 48-50	LTT	B4850d	**0.460**	0.557	-0.397	MS,ms,c-s	15.2	
Sta 52-54	Dune	B5254a	**0.250**	0.732	-0.426	FS,ws,c-s	2.2	Sta 52 Scraped Dune
Sta 52-54	Berm	B5254b	**0.224**	0.766	0.276	FS,ws,sym	2.2	
Sta 52-54	Beach Face	B5254c	**0.314**	0.675	-0.425	MS,mws,sym	6.1	
Sta 52-54	LTT	B5254d	**0.329**	0.619	-0.563	MS,mws,c-s	7.2	
Sta 56-58	Dune**	B5658a	**0.321**	0.636	-0.719	MS,mws,sym	9.3	Sta 56 & 58 Scraped
Sta 56-58	Berm	B5658b	**0.227**	0.717	0.280	FS,ws,f-s	2.6	
Sta 56-58	Beach Face	B5658c	**0.348**	0.756	0.230	MS,ws,f-s	11.9	
Sta 56-58	LTT	B5658d	**0.374**	0.575	-0.495	MS,ms,c-s	17.1	
Sta 60-62	Dune**	B6062a	**0.500**	0.559	-0.410	MS,ms,sc-s	27.9	Sta 60 & 62 Scraped
Sta 60-62	Berm	B6062b	**0.274**	0.770	-0.066	MS,ws,sym	4.1	
Sta 60-62	Beach Face	B6062c	**0.347**	0.610	-0.563	MS,mws,c-s	11.0	
Sta 60-62	LTT	B6062d	**0.346**	0.585	-0.610	MS,mws,c-s	13.7	
Sta 64-66	Dune**	B6466a	**0.310**	0.735	-0.216	MS,ws,sym	12.9	Sta 64 Scraped Dune
Sta 64-66	Berm	B6466b	**0.231**	0.727	0.243	FS,ws,sym	4.4	

TABLE 3.3. (continued) Beach sediment characteristics and composites. [Revised May 2001]

Sta 64-66	Beach Face	B6466c	**0.293**	0.779	0.166	MS,ws,f-s	5.4	
Sta 64-66	LTT	B6466d	**0.382**	0.527	-0.545	MS,ms,sc-s	43.0	
Sta 68-70	Dune	B6870a	**0.245**	0.711	0.112	FS,ws,sym	2.8	Sta 68 Scraped Dune
Sta 68-70	Berm	B6870b	**0.222**	0.774	0.129	FS,ws,sym	2.2	
Sta 68-70	Beach Face	B6870c	**0.422**	0.541	-0.521	MS,ms,sc-s	31.5	
Sta 68-70	LTT	B6870d	**0.348**	0.606	-0.622	MS,mws,c-s	13.1	
Sta 72-74	Dune**	B7274a	**0.279**	0.649	-0.896	MS,mws,c-s	6.2	Sta 72 & 74 Scraped
Sta 72-74	Berm	B7274b	**0.258**	0.747	-0.320	MS,ws,c-s	3.2	
Sta 72-74	Beach Face	B7274c	**0.326**	0.537	-0.834	MS,ms,sc-s	8.8	
Sta 72-74	LTT	B7274d	**0.268**	0.617	-0.842	MS,mws,sc-s	8.1	
Sta 76-78	Dune	B7678a	**0.233**	0.726	-0.418	FS,ws,c-s	2.9	
Sta 76-78	Berm	B7678b	**0.236**	0.787	-0.112	FS,vws,c-s	2.1	
Sta 76-78	Beach Face	B7678c	**0.492**	0.522	-0.375	MS,ms,sc-s	40.3	
Sta 76-78	LTT	B7678d	**0.293**	0.597	-0.596	MS,mws,c-s	11.7	
							Ranges %CaC03	
Composites -2001	Dune	(8)	**0.291**	0.636	-0.694	MS,mws,c-s	2.2 - 27.9	
Composites	Dune**	(4)	**0.247**	0.725	-0.204	FS,ws,c-s	2.2 - 2.8	
Composites	Berm	(8)	**0.242**	0.746	0.060	FS,ws,sym	2.1 - 4.1	
Composites	Beach Face	(8)	**0.347**	0.603	-0.734	MS,mws,c-s	4.4 - 40.3	
Composites	LTT	(8)	**0.346**	0.571	-0.560	MS,ms,c-s	7.2 - 43.0	
Comp - 2001 - All	Comp 32	(32)	**0.303**	0.614	-0.704	MS,mws,c-s	2.1 - 43.0	
Comp - 2001 - Omit 4 Dune	Comp 28**	(28)	**0.298**	0.617	-0.714	MS,mws,c-s	2.1 - 43.0	

*CS coarse sand; MS madium sand; FS fine sand; ms moderately sorted; mws moderately well sorted; ws well sorted; ps poorly sorted;
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym symmetrical size distribuiton;
MBF mid beach face; UBF upper beach face; LTT low tide terrace

**Note: B5658a, B6062a, B6466a, & B7274a omitted from composite

[Note: Scraped dunes at stations 30, 50, & 70 not representative; spoil at station 110 dune contains non-natural coarse material]

SUMMARY

1) As Reported In SEPA Final EIS dated 4 April 2001

Native Composite (20 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)

Mean = 1.725 phi (Mn) ***Std dev = 0.773 phi (SDn)*** ***Skewness = -0.648***

Mean = 0.302 mm ***Std dev = 0.585 mm*** ***Skewness = -0.648***

Native Composite (12 samples at berm, beach face)

Mean = 1.466 phi (Mn) ***Std dev = 0.830 phi (SDn)*** ***Skewness = 0.542***

Mean = 0.362 mm ***Std dev = 0.563 mm*** ***Skewness = 0.542***

2) Based On May 2001 Supplementary Beach Sampling For Beach Transects 48 - 78

Native Composite (28 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)

Mean = 1.747 phi (Mn) ***Std dev = 0.696 phi (SDn)*** ***Skewness = -0.714***

Mean = 0.298 mm ***Std dev = 0.617 mm*** ***Skewness = -0.714***

3) Average of June 1999 and May 2001 Results

Native Composite (48 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)

Mean = 1.736 phi (Mn) ***Std dev = 0.735 phi (SDn)*** ***Skewness = -0.681***

Mean = 0.300 mm ***Std dev = 0.601 mm*** ***Skewness = -0.681***

Review of the results confirmed coarsest sediments tend to reside on the berm and beach face (medium sand, moderately sorted, coarse-skewed) with finer sediments occurring along undisturbed dunes and low-tide terrace (typically fine sand, well sorted). Composite "12" (from the initial 1999 samples) yielded a mean grain size of 0.362 mm (1999 samples) along the beach face and berm, whereas composite "20" yielded a mean size of 0.302 mm. Considering that the proposed nourishment is designed to widen the recreational beach including part of the underwater profile, we elected to use the composite "20" as a "native" beach (1999 samples). This weights the composite toward the coarse sizes common along the beach face, berm. and low-tide terrace where the majority of the nourishment sand will be placed.

Also, it was elected not to include samples over the outer bar or further offshore (even if these areas are part of the littoral zone), because they tend to be much finer than the beach face and would weight the "result" toward less stable sediment sizes. Similarly, it was elected to only include two dune samples in composite "20" because a relatively small percentage of nourishment sediments will be subject to aeolian processes or contribute to dune building after construction. These results were updated with additional samples in 2001, and it was found that virtually the same mean grain size and sorting resulted for the 28- or 32-sample composites (bottom of Table 3.3). Combining the 1999 samples and 2001 samples yielded a composite of 48 beach samples as follows: mean = 0.300 mm, standard deviation = 0.601 mm. These latter values were adopted as the revised native beach composite.

The "native" composite selected for a baseline in the 1999 study is considerably coarser than the native sediment distribution used by the USACE (1976) in planning for potential disposal projects along Atlantic Beach. The Corps sampled at 2-ft intervals from the berm to -30 ft mean low water (MLW) along four transects at the eastern end of Bogue Banks. Their statistical composites yielded a mean grain size of 0.17 mm (2.52ϕ) and standard deviation of 0.77ϕ. The Corps results confirm the fining of sediments offshore but tend to weight the result toward less stable material. The native composite that was chosen is more conservative for beach nourishment planning because it eliminates from consideration certain fine deposits that characterize the area seaward of the bar. Use of a coarser "native" size distribution lowers the amount of potentially beach-compatible material in our search areas. At the same time, it better distinguishes beach-compatible sediment from marginally acceptable sediment.

3.16.4.2 ***Phases I-III Offshore Core Samples*** – The Phase I through Phase III sediment test results are presented in Table 3.4 and in Figures 3.25-3.26 (overfill ratios only). Detailed isopach maps of mean grain size, percent mud, percent calcium carbonate material, and percent coarser than 2 millimeters (mm) are given in Appendix E.

3.16.4.3 ***Proposed Borrow Areas*** – Offshore borings were used to delineate three potential borrow areas: A, B1, and B2 offshore of Pine Knoll Shores, Indian Beach, and Emerald Isle as described in the permit application (ID 200000362). As a result of additional sampling in January-March 2001, the potential borrow areas were further refined as shown by shading on Figures 3.25-3.26 based on the following general criteria:

- R_A's should be as low as possible, approaching 1.0.
- Mud percent should be as low as possible and generally less than 5 percent.
- Calcium carbonate percentage should be at least 20 percent to match the native beach.
- Borrow sediments should be coarse-skewed, with a significant portion of granular-sized sediments to improve stability and match the coarse sediments in the lower beach face/step along Bogue Banks.

Based on this review, the preferred borrow sediment is a combination of sediments from portions of borrow areas A, B1, and B2 as shown by shading and as given by specific coordinates in Figures 3.25 and 3.26.

The revised borrow areas total 2,810 acres and are represented by 133 borings. Table 3.5 summarizes key sediment parameters (averages of individual sample results). The mean grain size in borrow area:

- A ranges from 0.51 mm to 0.54 mm (coarse sand).
- B1 averages 0.28 mm (medium sand).
- B2 averages 0.313 mm (medium sand).

Note that the native beach averages 0.30 mm. Percent mud in each borrow area ranges 3.1 to 4.0 (federal standard is 10 percent). The percentage of shell material (calcium carbonate) ranges 27-45 percent. Approximately 7-20 percent of each deposit considered for use as borrow sediment consists of granular-shelly material with grain diameters of >2 mm.

TABLE 3.4. Potential borrow area sediment quality and compatibility factors (RA). Revised May 2001

Bogue Banks		**Sediment Compatibility**			Prepared January 2000			**Revised May 2001**		
		Individual Samples vs Overall Beach Composites (incl Dune & LTT samples)								
Revised 5/01	**Note:**	*Native Composite (48 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)*								
		Mean=1.736 phi (Mn)			*Std dev=0.735 phi (SDn)*			*Skewness=-0.681*	MS,mws,c-s	
		Mean=0.300 mm			*Std dev=.601 mm*			*Skewness=-0.681*		

Beach Samples Jun-99 Transect - Locality	Sample ID	Type	Recovery Length(ft)	Interval (feet)	Sediment Description**	% Mud***	Moment Measures Mean phi	Std Dev phi	Skewness	
10 - Emerald Isle	BB10B	Berm	n/a	n/a	MS,mws,sym	0	1.455	0.667	-0.299	
10	BB10C	MBF	n/a	n/a	MS,mws,sc-s	0	1.785	0.684	-0.496	
10	BB10D	LTT	n/a	n/a	MS,ms,sc-s	0	1.395	0.930	-0.452	
30 - Emerald Isle	BB30A	Dune	n/a	n/a	FS,ws,sym	0	2.023	0.435	-0.034	
30	BB30B	Berm	n/a	n/a	MS,mws,sym	0	1.379	0.693	-0.149	
30	BB30C	MBF	n/a	n/a	MS,ws,sym	0	1.680	0.486	-0.495	
30	BB30D	LTT	n/a	n/a	MS,ws,sym	0	1.887	0.497	-0.646	
50 - Indian Beach	BB50B	Berm	n/a	n/a	MS,ms,sc-s	0	1.258	0.878	-0.439	
50	BB50C	MBF	n/a	n/a	MS,ws,sym	0	1.727	0.395	-0.455	
50	BB50D	LTT	n/a	n/a	FS,ws,c-s	0	2.128	0.529	-0.683	
70 - Pine Knoll Shores	BB70B	Berm	n/a	n/a	MS,ms,sc-s	0	1.564	0.821	-0.496	
70	BB70C	UBF	n/a	n/a	MS,ms,c-s	0	1.073	0.953	-0.288	
70	BB70D	LTT	n/a	n/a	MS,mws,c-s	0	1.794	0.581	-0.744	
90 - Atlantic Beach	BB90A	Dune	n/a	n/a	FS,ws,sym	0	2.094	0.415	0.074	Nourished Section
90	BB90B	Berm	n/a	n/a	FS,ws,c-s	0	2.131	0.499	-0.830	Nourished Section
90	BB90C	UBF	n/a	n/a	FS,mws,c-s	0	2.036	0.666	-0.614	Nourished Section
90	BB90D	LTT	n/a	n/a	FS,mws,c-s	0	2.041	0.654	-0.569	Nourished Section
110 - Coast Guard Station	BB110A	Dune	n/a	n/a	CS,ps,sym	0	0.321	1.212	0.090	Spoil Area
110	BB110B	Berm	n/a	n/a	CS,ms,c-s	0	0.855	0.961	-0.169	Spoil Area
110	BB110B	MBF	n/a	n/a	MS,ps,c-s	0	1.130	1.083	-0.347	Spoil Area
110	BB110B	LTT	n/a	n/a	FS,mws,c-s	0	2.320	0.739	-1.247	Spoil Area
Supplementary Beach Samples	May-01									
IB Sta 48-50	B4850a	Dune	n/a	n/a	MS,ws,c-s	0	1.934	0.431	-0.213	
Sta 48-50	B4850b	Berm	n/a	n/a	MS,ws,sym	0	1.910	0.400	-0.078	
Sta 48-50	B4850c	Beach Face	n/a	n/a	MS,ws,f-s	0	1.848	0.377	0.089	
Sta 48-50	B4850d	LTT	n/a	n/a	MS,ms,c-s	0	1.119	0.844	-0.397	
IB Sta 52-54	B5254a	Dune	n/a	n/a	FS,ws,c-s	0	2.002	0.450	-0.426	
Sta 52-54	B5254b	Berm	n/a	n/a	FS,ws,sym	0	2.156	0.384	0.276	
Sta 52-54	B5254c	Beach Face	n/a	n/a	MS,mws,sym	0	1.671	0.566	-0.425	
Sta 52-54	B5254d	LTT	n/a	n/a	MS,mws,c-s	0	1.604	0.691	-0.563	
IB Sta 56-58	B5658a	Dune	n/a	n/a	MS,mws,sym	0	1.639	0.654	-0.719	
Sta 56-58	B5658b	Berm	n/a	n/a	FS,ws,f-s	0	2.138	0.480	0.280	
Sta 56-58	B5658c	Beach Face	n/a	n/a	MS,ws,f-s	0	1.523	0.404	0.230	
Sta 56-58	B5658d	LTT	n/a	n/a	MS,ms,c-s	0	1.419	0.798	-0.495	
PKS Sta 60-62	B6062a	Dune	n/a	n/a	MS,ms,sc-s	0	1.001	0.838	-0.410	
Sta 60-62	B6062b	Berm	n/a	n/a	MS,ws,sym	0	1.867	0.378	-0.066	
Sta 60-62	B6062c	Beach Face	n/a	n/a	MS,mws,c-s	0	1.528	0.714	-0.563	
Sta 60-62	B6062d	LTT	n/a	n/a	MS,mws,c-s	0	1.532	0.774	-0.610	
PKS Sta 64-66	B6466a	Dune	n/a	n/a	MS,ws,sym	0	1.691	0.445	-0.216	
Sta 64-66	B6466b	Berm	n/a	n/a	FS,ws,sym	0	2.112	0.460	0.243	
Sta 64-66	B6466c	Beach Face	n/a	n/a	MS,ws,f-s	0	1.771	0.361	0.166	
Sta 64-66	B6466d	LTT	n/a	n/a	MS,ms,sc-s	0	1.389	0.923	-0.545	
PKS Sta 68-70	B6870a	Dune	n/a	n/a	FS,ws,sym	0	2.029	0.493	0.112	
Sta 68-70	B6870b	Berm	n/a	n/a	FS,ws,sym	0	2.173	0.369	0.129	
Sta 68-70	B6870c	Beach Face	n/a	n/a	MS,ms,sc-s	0	1.243	0.885	-0.521	
Sta 68-70	B6870d	LTT	n/a	n/a	MS,mws,c-s	0	1.522	0.720	-0.622	
PKS Sta 72-74	B7274a	Dune	n/a	n/a	MS,mws,c-s	0	1.844	0.623	-0.896	
Sta 72-74	B7274b	Berm	n/a	n/a	MS,ws,c-s	0	1.952	0.421	-0.320	
Sta 72-74	B7274c	Beach Face	n/a	n/a	MS,ms,sc-s	0	1.615	0.898	-0.834	
Sta 72-74	B7274d	LTT	n/a	n/a	MS,mws,sc-s	0	1.898	0.696	-0.842	
AB Sta 76-78	B7678a	Dune	n/a	n/a	FS,ws,c-s	0	2.099	0.461	-0.418	
Sta 76-78	B7678b	Berm	n/a	n/a	FS,vws,c-s	0	2.081	0.345	-0.112	
Sta 76-78	B7678c	Beach Face	n/a	n/a	MS,ms,sc-s	0	1.024	0.937	-0.375	
Sta 76-78	B7678d	LTT	n/a	n/a	MS,mws,c-s	0	1.772	0.745	-0.596	

TABLE 3.4. (continued) Potential borrow area sediment quality and compatibility factors (RA). Revised May 2001

Revised Overfill Ratios Based On Additional Beach Sampling - May 2001

Borrow Area	Sample ID	Type	Recovery Length(ft)	Interval (feet)	Sediment Description**	% Mud***	Moment Measures M-phi-b	Sigma-b	X (Mb-Mn)/SDn	Y (SDb/SDn)	Revised RA May-01	SEPA EIS Overfill RA (SPM '84)
A	10A-4	Core	2.5	0-2.5	MS,ps,sc-s	~5	1.717	1.125	-0.03	1.53	1.21	1.20
Preliminary	11A-1	Core	3.0	0-3.0	CS,ps,sym	<5	0.761	1.662	-1.33	2.26	1.11	1.10
	12A-3	Core	2.5	0-2.5	CS,ps,sym	<2	0.871	1.707	-1.18	2.32	1.14	1.14
Jun-99	13A-2	Core	2.7	0-2.7	CS,ps,sym	~2	0.819	1.501	-1.25	2.04	1.08	1.08
Samples	13A-1	Core	2.7	0-2.7	CS,ps,sf-s	~5	0.337	1.554	-1.90	2.11	1.04	1.04
	13B-1	Core	1.9	0-1.9	CS,ps,f-s	~2	0.394	1.396	-1.83	1.90	1.03	1.02
	14A-2	Core	2.0	0-2.0	CS,ps,sym	~5	0.819	1.501	-1.25	2.04	1.08	1.08
	14A-3	Core	2.3	0-2.3	CS,ps,c-s	<5	0.979	1.518	-1.03	2.07	1.12	1.11
	14A-4	Core	1.6	0-1.6	CS,ps,c-s	<2	0.945	1.627	-1.08	2.21	1.14	1.13
	14B-1	Core	1.9	0-1.9	CS,ps,sf-s	<2	0.244	1.338	-2.03	1.82	<1.02	<1.02
	14B-2a	Core	2.4	0-1.8	MS,ps,sc-s	<5	1.161	1.645	-0.78	2.24	1.19	1.18
	14B-2b	Core		1.8-2.4	VCS,vws,c-s	<5	-0.927	0.166	-3.62	0.23	<<1.02	<<1.02
										Avg	*1.114*	*1.108*
A	A-02	Core	2.8	2.8	CS,ps,sym	4.3	0.824	1.497	-1.24	2.04	1.09	1.09
Supplementary	A-03s1	Core	2.7	0-.1.0	CS,ps,c-s	<1	0.852	1.235	-1.20	1.68	1.03	1.03
Nov-99	A-03s2	Core		1.0-2.7	CS,ps,f-s	21.5	0.814	1.465	-1.25	1.99	1.08	1.08
Samples	A-04	Core	3.6	3.6	MS,ps,sc-s	6.4	1.506	1.416	-0.31	1.93	1.22	1.21
	A-05	Core	2.7	2.7	MS,ps,sc-s	5.6	1.392	1.554	-0.47	2.11	1.23	1.22
	A-09	Core	2.8	2.8	CS,ps,sym	4.1	0.841	1.390	-1.49	1.89	1.04	1.04
	A-10	Core	2.3	2.3	CS,ps,f-s	2.9	0.297	1.224	-1.96	1.67	<1.02	<1.02
	A-11s-1	Core	7.1	0-3.3	MS,ps,sc-s	7.5	1.312	1.407	-0.58	1.91	1.16	1.15
	A-11s-2	Core		3.3-7.1	CS,ps,sym	3.0	0.660	1.543	-1.46	2.10	1.07	1.07
	A-12	Core	2.6	2.6	CS,ps,c-s	3.9	0.911	1.506	-1.12	2.05	1.10	1.10
	A-14	Core	1.7	1.7	CS,ps,sf-s	3.9	-0.172	1.233	-2.60	1.68	<1.02	<1.02
	A-15	Core	1.2	1.2	CS,ps,sym	1.8	0.813	1.480	-1.26	2.01	1.08	1.08
	A-16	Core	1.8	1.8	CS,ps,c-s	1.7	0.892	1.128	-1.15	1.53	1.02	1.02
	A-17	Core	2.0	2.0	MS,ps,sc-s	3.4	1.584	1.201	-0.21	1.63	1.17	1.16
	A-18	Core	2.4	2.4	MS,ps,c-s	3.3	1.103	1.439	-0.86	1.96	1.12	1.12
										Avg	*1.108*	*1.105*
	A-20	Core	8.8	0-4.8	CS,ps,f-s	3.5	0.608	1.504	-1.53	2.05	1.06	1.05
	A-21	Core	1.6	1.6	CS,ps,c-s	5.9	0.871	1.527	-1.18	2.08	1.10	1.09
	A-22s-1	Core	5.8	0-3.0	MS,ps,sc-s	1.7	1.488	1.337	-0.34	1.82	1.20	1.18
	A-22s-2	Core		3.0-4.8	CS,ps,sf-s	2.9	0.291	1.489	-1.97	2.03	1.03	1.03
	A-23	Core	1.5	1.5	CS,ps,sym	3.2	0.705	1.539	-1.40	2.09	1.07	1.07
	A-24	Core	1.4	1.4	CS,ps,sf-s	3.8	0.454	1.551	-1.74	2.11	1.05	1.04
	A-26	Core	2.0	2.0	CS,ps,c-s	2.2	0.961	1.380	-1.05	1.88	1.08	1.08
	A-27	Core	1.6	1.6	CS,ps,c-s	5.4	1.022	1.497	-0.97	2.04	1.12	1.11
	A-28	Core	1.8	1.8	CS,ps,f-s	4.9	0.457	1.308	-1.74	1.78	1.02	1.02
	A-29	Core	1.8	1.8	MS,ps,sc-s	2.0	1.212	1.410	-0.71	1.92	1.13	1.13
	A-30	Core	1.6	1.6	CS,ps,sf-s	3.9	0.103	1.441	-2.22	1.96	1.02	1.02
	A-32	Core	2.0	2.0	MS,ps,sc-s	3.8	1.194	1.615	-0.74	2.20	1.19	1.18
	A-33	Core	3.2	3.2	CS,ps,sym	3.4	0.655	1.330	-1.47	1.81	1.04	1.04
	A-34	Core	2.5	2.5	CS,ps,c-s	2.4	0.887	1.501	-1.16	2.04	1.09	1.09
	A-35s-1	Core	5.6	0-2.4	FS,ms,sc-s	0.9	1.964	0.999	0.31	1.36	1.36	1.35
	A-35s-2	Core		2.4-5.6	CS,ps,f-s	3.6	0.512	1.508	-1.67	2.05	1.05	1.04
	A-36	Core	2.4	2.4	MS,ps,sc-s	3.2	1.701	1.244	-0.05	1.69	1.25	1.30
	A-36	Core	1.6	1.6	MS,ps,sc-s	4.6	1.813	1.377	0.10	1.87	1.36	1.34
										Avg	*1.123*	*1.120*
	A-40	Core	1.8	1.8	MS,ps,sc-s	4.1	1.361	1.519	-0.51	2.07	1.21	1.20
	A-41	Core	2.1	2.1	MS,ps,sc-s	3.0	1.349	1.484	-0.53	2.02	1.20	1.19
	A-42	Core	1.9	1.9	CS,ps,sf-s	3.3	0.086	1.329	-2.24	1.81	<1.02	<1.02
	A-44	Core	2.2	2.2	MS,ps,sc-s	3.2	1.070	1.682	-0.91	2.29	1.19	1.17
	A-45	Core	1.5	1.5	MS,ps,sc-s	3.5	1.515	1.569	-0.30	2.13	1.31	1.27
	A-46	Core	5.7	5.7	CS,ps,sym	3.9	0.819	1.603	-1.25	2.18	1.11	1.10
	A-47	Core	1.5	1.5	MS,ps,sc-s	3.4	1.889	1.283	0.21	1.75	1.38	1.35
	A-48	Core	2.6	2.6	MS,ps,sc-s	4.4	1.228	1.547	-0.69	2.10	1.18	1.17
	A-50	Core	4.4	0-3.0	FS,ms,sc-s	8.8	2.413	1.160	0.92	1.58	1.04	1.03
	A-51	Core	1.8	0-1.3	CS,ps,c-s	1.9	0.746	1.499	-1.35	2.04	1.08	1.07
	A-52	Core	2.1	2.1	MS,ps,sc-s	2.2	1.355	1.461	-0.52	1.99	1.19	1.18
	A-53	Core	2.7	2.7	CS,ps,f-s	4.1	0.614	1.545	-1.53	2.10	1.07	1.06
	A-54	Core	2.8	2.8	CS,ps,f-s	4.3	0.662	1.560	-1.46	2.12	1.08	1.07
	A-58	Core	4.1	0.0-.5;2-4.1	CS,ps,sym	~23	0.701	1.491	-1.41	2.03	1.07	1.06
	A-59	Core	2.0	2.0	MS,ps,sc-s	3.0	1.437	1.552	-0.41	2.11	1.24	1.23
										Avg	*1.168*	*1.154*
	A-60	Core	1.8	1.8	CS,ps,sym	3.3	0.330	1.201	-1.91	1.63	<<1.02	<<1.02
	A-61	Core	3.0	0-2.5	CS,ps,c-s	5.4	0.937	1.515	-1.09	2.06	1.11	1.10
	A-63	Core	3.5	0-.5	FS,ps,sc-s	6.6	2.020	1.269	0.39	1.73	1.49	1.47
	A-64	Core	1.8	1.8	MS,ps,sc-s	5.7	1.462	1.393	-0.37	1.90	1.23	1.20
	A-65	Core	1.9	1.9	CS,ps,f-s	2.5	0.706	1.649	-1.40	2.24	1.10	1.09
	A-66	Core	3.3	3.3	MS,ps,sc-s	4.2	1.707	1.509	-0.04	2.05	1.34	1.33
	A-67	Core	1.7	1.7	CS,ps,sf-s	1.9	0.078	1.315	-2.26	1.79	<<1.02	<<1.02
	A-68	Core	2.1	2.1	CS,ps,sym	3.7	0.845	1.581	-1.21	2.15	1.11	1.10
	A-69	Core	2.0	2.0	MS,ps,sc-s	3.3	1.182	1.428	-0.75	1.94	1.13	1.13
	A-70T	Core	2.8	0-1.25	VCS,ps,f-s	2.0	0.000	1.056	-2.36	1.44	<<1.02	<<1.02
	A-70B	Core		2.05-2.8	CS,ps,f-s	~30	0.481	1.367	-1.71	1.86	1.03	1.02
										Avg	*1.193*	*1.180*

TABLE 3.4. (continued) Potential borrow area sediment quality and compatibility factors (RA). Revised May 2001

A	BA-01	Core	0.9	0.9	CS,ps,sc-s	3.3	0.323	1.432	-1.92	1.95	1.03	1.02
Supplementary	BA-02	Core	2.9	2.9	CS,ps,c-s	2.2	0.847	1.535	-1.21	2.09	1.09	1.08
Nov-00	BA-04	Core	1.8	1.8	MS,ps,sc-s	ND	1.124	1.377	-0.83	1.87	1.10	1.10
Samples	BA-05	Core	2.2	2.2	MS,ps,c-s	ND	1.121	1.316	-0.84	1.79	1.09	1.08
	BA-06	Core	2.0	2.0	MS,ps,c-s	1.1	1.228	1.473	-0.69	2.00	1.16	1.15
	BA-07	Core	2.1	2.1	CS,ps,sym	1.1	0.252	1.179	-2.02	1.60	<<1.02	<<1.02
	BA-08	Core	1.7	1.7	CS,ps,f-s	3.1	0.496	1.406	-1.69	1.91	1.03	1.03
	BA-09	Core	2.2	2.2	CS,ps,f-s	ND	0.487	1.456	-1.70	1.98	1.04	1.04
	BA-10	Core	1.7	1.7	MS,ps,sc-s	3.7	1.291	1.535	-0.61	2.09	1.19	1.18
	BA-11	Core	2.1	2.1	MS,ps,sc-s	1.2	1.781	1.153	0.06	1.57	1.22	1.19
	BA-12	Core	1.6	1.6	CS,ps,sym	2.2	0.799	1.269	-1.27	1.73	1.03	1.03
	BA-13	Core	1.8	1.8	CS,ps,c-s	2.6	1.053	1.327	-0.93	1.81	1.08	1.08
	BA-14	Core	1.9	1.9	CS,ps,f-s	2.2	0.279	1.292	-1.98	1.76	<1.02	<1.02
										Avg	*1.096*	*1.089*
B1	6A-1	Core	2.9	0-2.9	FS,ps,sc-s	<2	2.157	1.077	0.57	1.47	1.60	1.62
Preliminary	7A-2	Core	2.8	0-2.8	FS,mws,c-s	<2	2.648	0.829	1.24	1.13	6.00	7.00
Jun-99	7A-1	Core	1.0	0-1.0	MS,ps,sc-s	<5	1.761	1.442	0.03	1.96	1.35	1.34
Samples	8A-1	Core	3.4	0-3.4	FS,ps,sc-s	<2	2.165	1.209	0.58	1.64	1.61	1.60
	9A-3	Core	2.3	0-2.3	FS,mws,c-s	<2	2.660	.830	1.26	1.13	6.00	6.50
	10A-1	Core	2.9	0-2.9	FS,ms,sc-s	<2	2.355	1.018	0.84	1.39	2.10	2.20
	10B-1	Core	4.7	0-3.6	MS,ps,sc-s	<5	1.522	1.537	-0.29	2.09	1.27	1.26
										Avg	*2.847*	*3.074*
B1	B-1-1	Core	2.9	2.9	FS,mws,c-s	2.8	2.594	0.894	1.17	1.22	4.00	4.50
Supplementary	B-1-2	Core	2.6	2.6	MS,ps,sc-s	2.3	1.753	1.326	0.02	1.80	1.31	1.30
Nov-99	B-1-3	Core	3.1	3.1	FS,ps,sc-s	3.2	2.058	1.349	0.44	1.84	1.54	1.50
	B-1-4	Core	2.5	2.5	FS,ps,sc-s	2.2	2.233	1.144	0.68	1.56	1.73	1.75
	ATHB08	Core	11.2	0-4.0	FS,ps,sc-s	2.2	2.262	1.066	0.72	1.45	1.85	1.80
	ATH-9s1	Core	9.0	0-3.8	FS,ps,sc-s	1.6	2.03	1.284	0.40	1.75	1.49	1.48
	ATH-9s2	Core	2.9	3.8-9	FS,mws,c-s	0.9	2.711	0.734	1.33	1.00	>10.0	>10
	ATHB10	Core	7.5	0-2.2	MS,ps,sc-s	2.0	1.813	1.402	0.10	1.91	1.36	1.34
B1										*Avg*	*1.897*	*1.953*
Supplementary	B1-01	Core	3.1	3.1	FS,ms,sc-s	2.3	2.574	0.949	1.14	1.29	3.00	3.50
Nov-00	B1-02	Core	3.8	3.8	FS,ps,sc-s	2.1	2.231	1.301	0.67	1.77	1.72	1.70
Samples	B1-03	Core	3.4	3.4	FS,ms,sc-s	1.8	2.498	1.116	1.04	1.52	2.35	2.40
	B1-04	Core	3.5	3.5	FS,ms,sc-s	2.3	2.596	1.058	1.17	1.44	2.90	3.40
	B1-05	Core	4.1	4.1	FS,ps,sc-s	2.0	2.334	1.260	0.81	1.74	1.85	1.83
	B1-06	Core	3	3	FS,mws,c-s	2.7	2.821	0.829	1.48	1.13	9.00	9.90
	B1-07	Core	4	4	FS,ms,sc-s	2.9	2.601	0.914	1.18	1.24	3.90	4.50
	B1-08	Core	2.1	2.1	FS,ms,sc-s	3.1	2.178	1.031	0.60	1.40	1.69	1.71
	B1-09	Core	3.8	3.8	FS,ms,c-s	2.3	2.406	1.077	0.91	1.47	2.18	2.20
	B1-10	Core	2.6	2.6	FS,ms,sc-s	3.8	2.486	0.985	1.02	1.34	2.70	2.85
	B1-11	Core	2.9	2.9	FS,ps,sc-s	3.6	2.275	1.109	0.73	1.51	1.82	1.80
	B1-12	Core	3.2	3.2	MS,ps,sc-s	2.8	1.648	1.320	-0.12	1.80	1.25	1.24
	B1-13	Core	3.2	3.2	FS,ps,sc-s	2.6	2.039	1.258	0.41	1.71	1.50	1.48
	B1-14	Core	3.4	3.4	FS,mws,c-s	2.7	2.604	0.829	1.18	1.13	5.00	6.50
	B1-15	Core	3.4	3.4	MS,ps,sc-s	2.1	1.801	1.512	0.09	2.06	1.40	1.38
	B1-16	Core	3.5	3.5	FS,ps,sc-s	2.1	2.028	1.279	0.40	1.74	1.49	1.46
	B1-17	Core	3.3	3.3	MS,ps,sc-s	3.4	1.663	1.357	-0.10	1.85	1.27	1.26
	B1-18	Core	2.9	2.9	FS,ps,sc-s	4.8	2.084	1.112	0.47	1.51	1.51	1.50
	B1-19	Core	3.8	3.8	MS,ps,sc-s	3.0	1.904	1.322	0.23	1.80	1.40	1.40
	B1-20	Core	3.5	3.5	MS,ps,sc-s	2.5	1.899	1.281	0.22	1.74	1.38	1.39
	B1-21a	Core	3.9	0-2.4	MS,ps,c-s	4.9	1.497	1.338	-0.33	1.82	1.20	1.19
	B1-21b	Core		2.4-3.9	MS,ps,sc-s	4.2	1.953	1.263	0.30	1.72	1.41	1.39
	B1-22	Core	2.8	2.8	FS,ms,c-s	3.0	2.517	0.905	1.06	1.23	3.30	3.50
	B1-23a	Core	4.6	0-2.4	MS,ps,sc-s	2.2	1.756	1.366	0.03	1.86	1.33	1.31
	B1-23b	Core		2.4-4.6	MS,ps,sc-s	3.9	1.760	1.422	0.03	1.93	1.35	1.32
	B1-24	Core	3	3	MS,ps,sc-s	3.3	1.816	1.194	0.11	1.62	1.30	1.28
	B1-25a	Core	4.1	0-2.8	MS,ps,sc-s	2.6	1.825	1.268	0.12	1.73	1.33	1.31
	B1-25b	Core		2.8-4.1	FS,ps,sc-s	3.5	1.366	1.438	-0.50	1.96	1.19	1.18
										Avg	*2.204*	*2.353*
B1	B1-27	Core	3.2	3.2	MS,ps,c-s	3.9	1.294	1.417	-0.60	1.93	1.16	1.15
Supplementary	B1-28	Core	2.8	2.8	CS,ps,sym	3.2	0.982	1.291	-1.03	1.76	1.06	1.05
Mar-01	B1-29	Core	3.1	3.1	MS,ps,sc-s	3.7	1.534	1.414	-0.27	1.92	1.24	1.22
Samples	B1-30	Core	3.05	3.05	MS,ps,sc-s	6.7	1.724	1.443	-0.02	1.96	1.33	1.32
	B1-33	Core	3.75	0-2.05	CS,ps,sym	2.6	0.945	1.637	-1.08	2.23	1.14	1.13
	B1-37	Core	2.9	0-2.0	MS,ps,sc-s	5.7	1.599	1.546	-0.19	2.10	1.31	1.30
	B1-40	Core	3.2	3.2	MS,ps,sc-s	3.3	1.841	1.453	0.14	1.98	1.40	1.38
B2										*Avg*	*1.234*	*1.221*
Preliminary	11A-2	Core	1.6	0-1.6	CS,ps,c-s	~10	0.498	1.098	-1.68	1.49	<<1.02	<<1.02
Jun-99	12A-1	Core	3.1	0-3.1	FS,mws,c-s	<2	2.523	.662	1.07	0.90	10.00	10.00
Samples	12A-2	Core	1.8	0-1.8	MS-ps,sc-s	~10	1.577	1.438	-0.22	1.96	1.26	1.25
	14A-1	Core	2.4	0-2.4	MS,ps,c-s	~2	1.367	1.438	-0.50	1.96	1.19	1.18
	15A-1	Core	2.0	0-2.0	MS,ps,sc-s	~10	1.422	1.626	-0.43	2.21	1.26	1.25
	16A-1	Core	1.9	0-1.9	FS,mws,sc-s	<2	2.378	.833	0.87	1.13	3.00	3.70
	17A-1	Core	1.0	0-1.0	FS,ws,sym	<5	2.807	.523	1.46	0.71	>>10	>>10

TABLE 3.4. (continued) Potential borrow area sediment quality and compatibility factors (RA). Revised May 2001

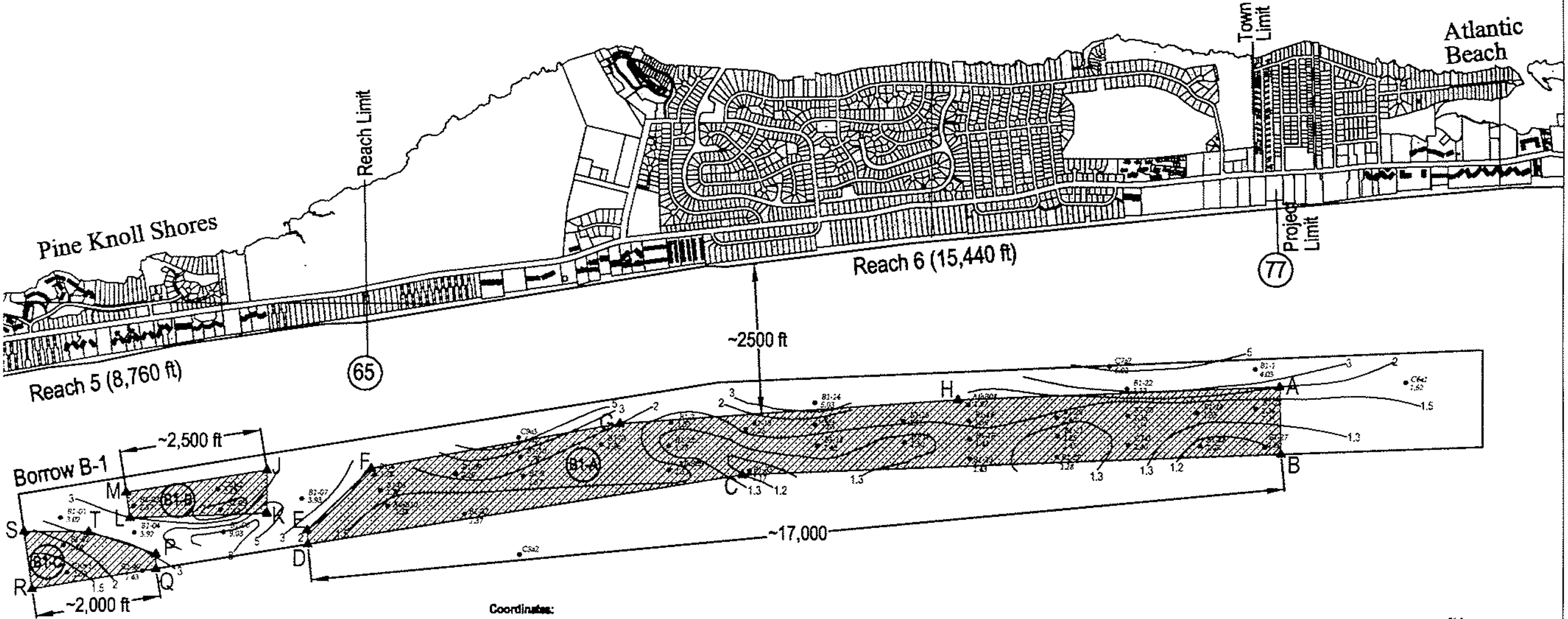
B2										*Avg*	*3.342*	*3.476*
Supplementary	B-2-1	Core	3.7	3.7	FS,ps,sc-s	8.7	2.099	1.347	0.49	1.83	**1.56**	1.15
Nov-99	B-2-2	Core	4.0	4.0	FS,ps,sc-s	3.0	2.216	1.312	0.65	1.79	**1.68**	1.11
Samples	B-2-3	Core	1.9	0-1.9	FS,ps,sc-s	2.1	2.101	1.068	0.50	1.45	**1.54**	1.05
	B-2-4s1	Core	2.2	0-0.9	CS,ps,c-s	1.2	.661	.992	-1.46	1.35	**<<1.02**	<<1.02
	B-2-4s2	Core		.9-2.2	MS,ps,sc-s	3.4	1.866	1.416	0.18	1.93	**1.40**	1.38
	B-2-5	Core	1.8	1.8	FS,ps,sc-s	1.9	2.264	1.214	0.72	1.65	**1.77**	1.75
	B-2-6	Core	3.1	3.1	MS,ps,sc-s	2.2	1.532	1.552	-0.28	2.11	**1.28**	1.27
	* B-2-7	Core	2.3	2.3	MS,ps,sc-s	2.5	1.598	1.470	-0.19	2.00	**1.28**	1.27
	* ATHB11	Core	10.0	0-6.8	FS,ps,sc-s	4.1	2.423	1.168	0.93	1.59	**2.10**	2.05
	* ATHB12	Core	10.2	0-1.7	CS,ps,c-s	3.0	1.047	1.322	-0.94	1.80	**1.08**	1.07
	* ATH13s1	Core	9.6	0-2.0	FS,ws,sym	1.8	2.727	.539	1.35	0.73	**>10**	>10
	ATH13s2	Core		2.0-5.6	MS,ps,sc-s	2.5	1.618	1.504	-0.16	2.05	**1.31**	1.28
B2										*Avg*	*1.500*	*1.338*
Supplementary	B2-08a	Core	4.1	0-1.75	CS,ps,sym	1.3	.865	1.330	-1.19	1.81	**1.05**	1.05
Jan-01	B2-08b	Core	-	1.75-4.05	FS,mws,c-s	2.8	2.822	.746	1.48	1.01	**>10**	>10.0
Samples	B2-09	Core	3.0	3.0	MS,ps,sc-s	2.9	1.947	1.423	0.29	1.94	**1.44**	1.43
	B2-10	Core	2.7	2.7	FS,ps,sc-s	3.7	2.062	1.450	0.44	1.97	**1.58**	1.55
	B2-11a	Core	4.9	0-3.0	FS,ps,sc-s	4.4	2.258	1.301	0.71	1.77	**1.75**	1.75
	B2-11b	Core	-	3.0-4.85	MS,ps,sc-s	5.2	1.846	1.478	0.15	2.01	**1.40**	1.40
	B2-12	Core	3.0	3.0	FS,ms,sc-s	3.5	2.633	.928	1.22	1.26	**4.00**	4.50
	B2-13	Core	2.3	2.3	FS,ps,sc-s	4.8	2.265	1.289	0.72	1.75	**1.75**	1.75
	B2-14	Core	3.2	3.2	FS,ps,sc-s	3.0	2.124	1.299	0.53	1.77	**1.60**	1.57
	B2-15	Core	3.2	3.2	MS,ps,sc-s	3.2	1.590	1.592	-0.20	2.17	**1.32**	1.32
	B2-16	Core	3.0	3.0	FS,ps,sc-s	5.3	2.325	1.319	0.80	1.79	**1.85**	1.80
	B2-17	Core	3.0	3.0	MS,ps,sc-s	4.9	1.970	1.405	0.32	1.91	**1.47**	1.45
	B2-18	Core	3.2	3.2	FS,ms,sc-s	4.9	2.475	1.058	1.01	1.44	**2.45**	2.45
	B2-19	Core	3.2	3.2	FS,ps,sc-s	7.1	1.986	1.189	0.34	1.62	**1.42**	1.41
	B2-20	Core	2.3	2.3	FS,ps,sc-s	2.6	2.183	1.209	0.61	1.64	**1.65**	1.63
	B2-21	Core	2.3	2.3	MS,ps,c-s	5.1	1.391	1.246	-0.47	1.70	**1.13**	1.07
	B2-22	Core	2.3	2.3	MS,ps,sym	5.3	1.285	1.276	-0.61	1.74	**1.12**	1.11
B2										*Avg*	*1.686*	*1.703*
Supplementary	B2-23	Core	2.7	2.7	MS,ps,sc-s	4.9	1.881	1.337	0.20	1.82	**1.39**	1.37
Mar-01	B2-24	Core	3.3	3.3	MS,ps,sc-s	4.2	1.997	1.414	0.36	1.92	**1.49**	1.46
Samples	B2-25	Core	2.6	2.6	MS,ps,sc-s	3.5	1.918	1.586	0.25	2.16	**1.48**	1.45
	B2-26	Core	2.7	2.7	FS,ps,sc-s	3.5	2.260	1.314	0.71	1.79	**1.75**	1.72
	B2-27	Core	2.8	2.8	MS,ps,sc-s	5.3	1.698	1.431	-0.05	1.95	**1.32**	1.31
	B2-28	Core	3.2	3.2	MS,ps,sc-s	5.6	1.268	1.492	-0.64	2.03	**1.18**	1.16
	B2-29	Core	3.0	3.0	MS,ps,sc-s	10.7	1.756	1.455	0.03	1.98	**1.36**	1.30
	B2-30	Core	2.7	2.7	FS,ps,sc-s	3.8	2.327	1.280	0.80	1.74	**1.85**	1.80
	B2-31	Core	3.1	3.1	MS,ps,sc-s	5.9	1.762	1.199	0.04	1.63	**1.27**	1.25
	B2-32	Core	3.1	3.1	MS,ps,c-s	5.2	1.322	1.325	-0.56	1.80	**1.14**	1.13
										Avg	*1.423*	*1.395*
									Note: Following RAs based on Final EIS Native Beach (Mz=1.725 phi; Std Dev.=.773 phi)			
Borrow Area	Sample ID	Type		Interval (feet)	Sediment Description*	% Mud***	Moment Measures M-phi-b	Sigma-b	X (Mb-Mn)/SDn	Y (SDb/SDn)		RA (SPM '84)
C	BI-2	Grab		upper 0-5 ft	CS,ms,c-s	0	.269	.837	-1.88	1.08	N/A	<<1.02
Preliminary	BI-3A	Grab		upper 0-5 ft	FS,mws,c-s	0	2.001	.521	0.36	0.67	N/A	4.10
Jun-99	BI-3B	Grab		upper 0-5 ft	FS,ms,sym	0	1.276	.953	-0.58	1.23	N/A	1.02
Samples	BI-3C	Grab		upper 0-5 ft	FS,ws,c-s	0	2.217	.571	0.64	0.74	N/A	6.70
	BI-4A	Grab		upper 0-5 ft	FS,vws,sym	0	2.484	.274	0.98	0.35	N/A	>>10
	BI-4B	Grab		upper 0-5 ft	FS,vws,sym	0	2.358	.367	0.82	0.47	N/A	>>10
C	C-01	Grab/Hole		upper 0-5 ft	MS,mws,sc-s	0	1.857	.747	0.17	0.97	N/A	1.25
Supplementary	C-02	Grab/Hole		upper 0-5 ft	FS,mws,sc-s	0	1.946	.629	0.29	0.81	N/A	2.00
Nov-99	C-03	Grab/Hole		upper 0-5 ft	CS,ps,c-s	0	.356	1.025	-1.77	1.33	N/A	<<1.02
Samples	C-04	Grab/Hole		upper 0-5 ft	CS,ps,c-s	0	.568	.994	-1.50	1.29	N/A	<1.02
	C-05	Grab/Hole		upper 0-5 ft	MS,mws,sc-s	0	1.769	.803	0.06	1.04	N/A	1.10
	C-06	Grab/Hole		upper 0-5 ft	FS,vws,sym	0	2.417	.297	0.90	0.38	N/A	>>10
Bogue Sound	BS1	Grab		upper 2 ft	FS,vws,sym	ND	2.346	.356	0.80	0.46	N/A	>>10.0
	BS2	Grab		upper 2 ft	FS,vws,c-s	ND	2.049	.440	0.42	0.57	N/A	>10.0
	BS3	Grab		upper 2 ft	FS,ws,c-s	ND	2.078	.510	0.46	0.66	N/A	5.50
Corps Disposal	BD1	Grab		upper 2 ft	MS,cs,c-s	ND	1.204	1.117	-0.67	1.45	N/A	1.04
	BD2	Grab		upper 2 ft	FS,ws,sym	ND	2.607	.451	1.14	0.58	N/A	>>10.0
	BD3	Grab		upper 2 ft	FS,ws,sym	ND	2.672	.413	1.23	0.53	N/A	>>10.0
	BD4	Grab		upper 2 ft	FS,ws,sym	ND	2.597	.500	1.13	0.65	N/A	>10.0
Composite Groups	A-11	Cores	Borrow A		MS,ps,scs		1.363	1.416	-0.51	1.93	1.18	
	B1-29	Cores	Borrow B1		MS,ps,scs		1.789	1.390	0.07	1.89	1.34	
	B2-22	Cores	Borrow B2		MS,ps,scs		1.664	1.441	-0.10	1.96	1.31	
	A-B1-B2	Cores	A-11, B1-29	B2-22	MS,ps,scs		1.669	1.421	-0.09	1.93	1.30	
	A-B1	Cores	A-11	B1-29	MS,ps,scs		1.672	1.410	-0.09	1.92	1.30	
	A-B2	Cores	A-11	B2-22	MS,ps,scs		1.564	1.439	-0.23	1.96	1.25	
	ComRev		A-B1-B2	omit fines/crs	MS,ps,scs		1.814	1.204	0.11	1.64	1.30	

*These samples have a limiting acceptable depth for excavation based on recovered cores (ie, underlying material is considered less suitable for nourishment).

***CS coarse sand; MS medium sand; FS fine sand; ms moderately sorted; mws moderately well sorted; ws well sorted; ps poorly sorted;*

c-s coarse skewed; sc-s strongly skewed; f-s fine skewed; sym symmetrical size distribution

***To indicated sample level

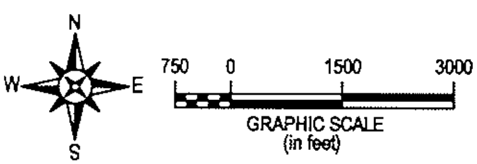


Revised Borrow Areas

Section	Square ft	Acres	Volume (cubic yards)
B1 (total)	22.65 million	520	2.2 million

* Based on excavations averaging 3.0 ft

Note:
15% of area will be undredged to leave wildlife corridors to accelerate recruitment from undisturbed areas.



Coordinates:

Point	Northing	Easting	Latitude	Longitude
A	348605.2557	2666134.6425	34.4115	-76.4702
B	347409.8717	2666159.1377	34.4103	-76.4702
C	347008.3828	2656669.9058	34.4101	-76.4856
D	345759.0444	2649015.3457	34.405	-76.5028
E	346004.5306	2649003.1957	34.4053	-76.5028
F	347096.9645	2650130.0346	34.4103	-76.5014
G	347901.9841	2654507.0932	34.411	-76.4921
H	348349.5919	2660472.1212	34.4113	-76.4810
J	347060.5727	2648298.2076	34.4103	-76.5036
K	346295.4758	2648298.2078	34.4056	-76.5036
L	346211.1102	2645897.2672	34.4055	-76.5105
M	346664.5224	2645830.2584	34.4100	-76.5106
P	345583.6625	2646352.2255	34.4049	-76.5100
Q	345324.3835	2646352.2255	34.4047	-76.5100
R	344968.9196	2644174.3371	34.4044	-76.5126
S	345965.4451	2644029.2487	34.4053	-76.5127
T	345969.4256	2645170.9857	34.4053	-76.5114

Borrow Areas

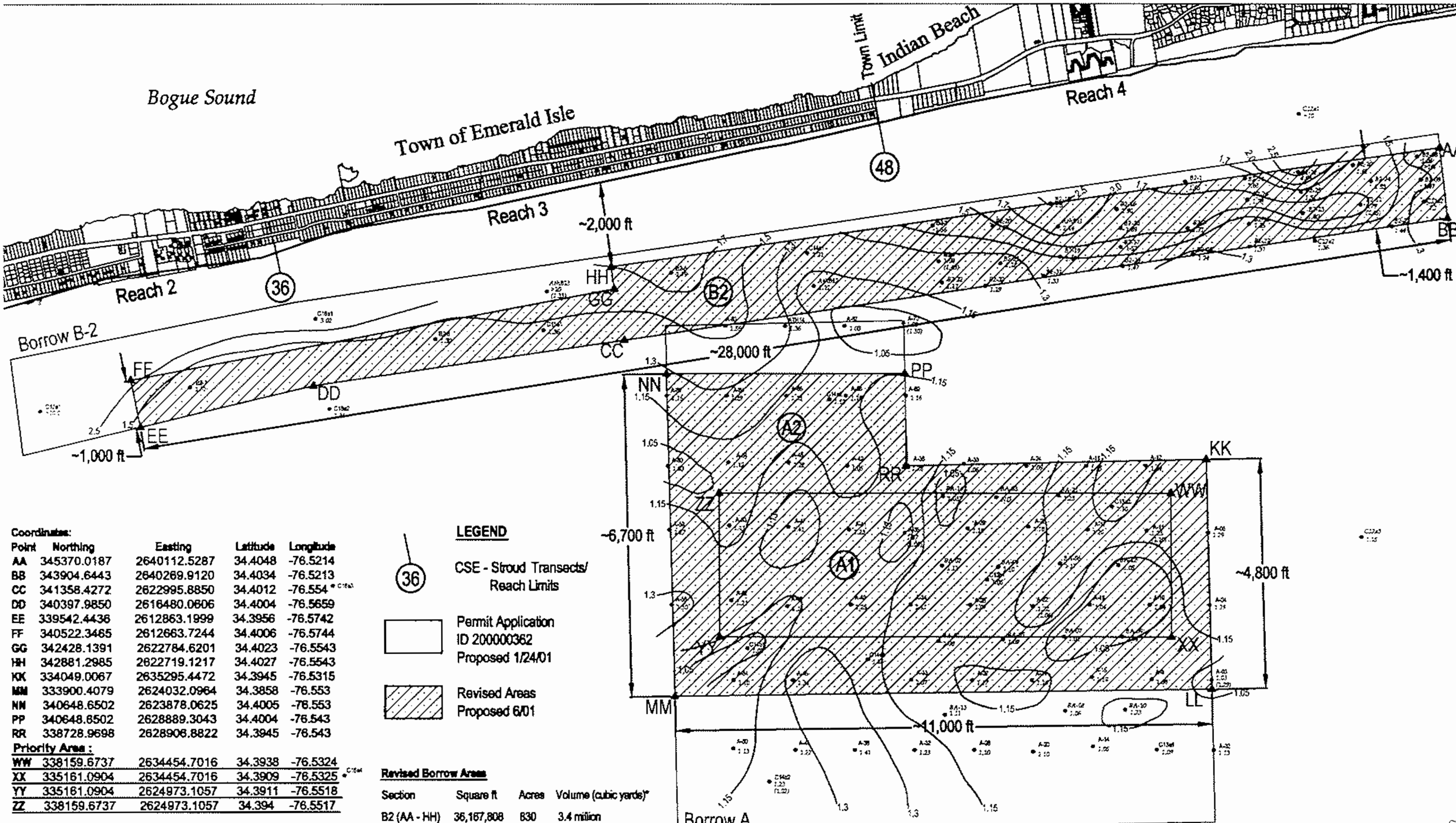
36 — CSE - Stroud Transects (Reach Limits)

Permit Application ID 200000362 Proposed 1/24/01

Revised Areas Proposed 6/01

Figure 3.25 Overfill Ratios

Revised and updated 24 May 2001



Coordinates:

Point	Northing	Easting	Latitude	Longitude
AA	345370.0187	2640112.5287	34.4048	-76.5214
BB	343904.6443	2640269.9120	34.4034	-76.5213
CC	341358.4272	2622995.8850	34.4012	-76.554
DD	340397.9850	2616480.0606	34.4004	-76.5659
EE	339542.4436	2612863.1999	34.3956	-76.5742
FF	340522.3465	2612663.7244	34.4006	-76.5744
GG	342428.1391	2622784.6201	34.4023	-76.5543
HH	342881.2985	2622719.1217	34.4027	-76.5543
KK	334049.0067	2635295.4472	34.3945	-76.5315
MM	333900.4079	2624032.0964	34.3858	-76.553
NN	340648.6502	2623878.0625	34.4005	-76.553
PP	340648.6502	2628889.3043	34.4004	-76.543
RR	338728.9698	2628906.8822	34.3945	-76.543
Priority Area:				
WW	338159.6737	2634454.7016	34.3938	-76.5324
XX	335161.0904	2634454.7016	34.3909	-76.5325
YY	335161.0904	2624973.1057	34.3911	-76.5518
ZZ	338159.6737	2624973.1057	34.394	-76.5517

LEGEND

36 — CSE - Stroud Transects/ Reach Limits

Permit Application ID 200000362 Proposed 1/24/01

Revised Areas Proposed 6/01

Revised Borrow Areas

Section	Square ft	Acres	Volume (cubic yards)*
B2 (AA - HH)	36,167,808	830	3.4 million
A2 (KK - RR)	35,162,490	807	1.7 million (excluding A1)
A1 (WW - ZZ)	28,431,356	653	1.4 million

* See text for explanation

GRAPHIC SCALE (in feet): 750 0 1500 3000

N W E S

Figure 3.26 Overfill Ratios

Revised and updated 24 May 2001

TABLE 3.5. Summary R_A's and representative statistics for revised borrow areas A, B1, and B2, based on Phases I-III samples. See Figures 3.25-3.26 for revised borrow area delineations and coordinates.

Borrow Area	# Samples	Mean Grain Size (mm)	Mean Grain Size (ϕ)	% Mud	R_A's Revised
A1	22	0.509	0.974	3.2	1.14
A2	35	0.539	0.890	3.9	1.15
B1	36	0.276	1.729	3.1	1.58
B2	40	0.313	1.255	4.0	1.50
Native Beach	48	0.300	1.736	<1	1

Borrow Area	Area Acres	% Calcium Carbonate	% >2mm (granular)	Average Core Length (ft)	Confirmed Borrow Volume (cubic yards)
A1	653	45	17	2.3	*1.4 million
A2	807	45	20	2.2	*1.7 million
B1	520	27	7	3.2	**2.2 million
B2	830	30	8	2.9	**3.4 million
Native Beach		~15-20	~5		* @ 2 ft cut ** @ 3 ft cut

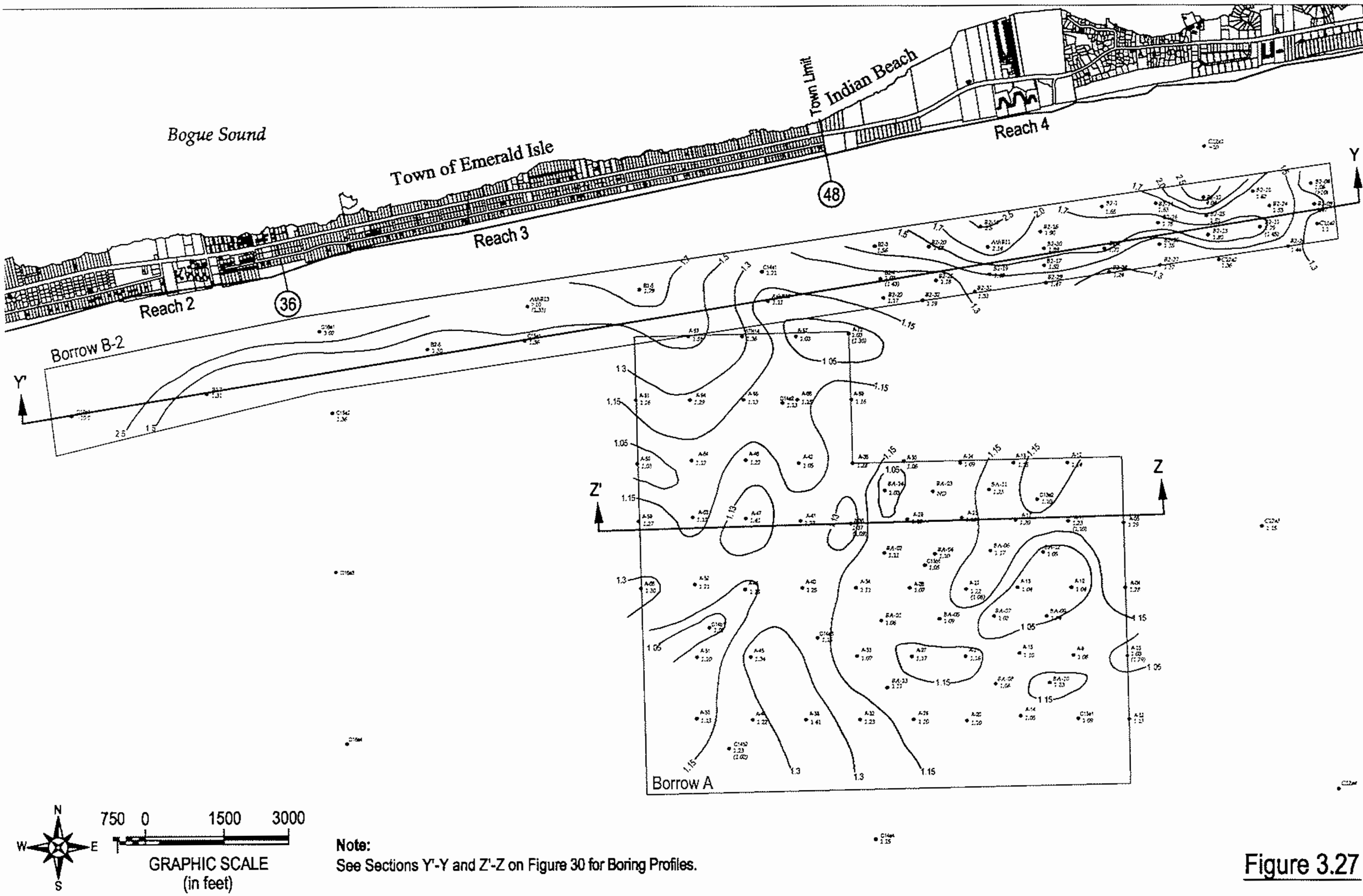
The confirmed borrow volumes represent the potential maximum volume of material that could be obtained from the indicated borrow areas. In keeping with best management practice, more source sediment must be confirmed so that some undisturbed areas can be left around each dredge cut to promote rapid recruitment of species after the project is complete. The above volumes assume 33 percent of the indicated Areas in A1 and A2 will not be dredged for purposes of wildlife recruitment, and 15 percent of the B1 and B2 will not be dredged for purposes of wildlife recruitment. Details of the Phase I excavation plan and anticipated Phase II plan are given in another section of the report.

Figures 3.27-3.29 show three typical cross-sections along borrow areas A, B1, and B2 – illustrating the sediments in the profile. Based on available borings, sediments are confirmed to approximately 10 ft in borrow areas B1 and B2 with more detailed confirmation in the upper 3-4 ft. Borrow area A is confirmed to ~5.5 ft with more detailed confirmation in the upper 2-2.5 ft. Based on these data and the project goal of limiting the depth of excavations to shallow cuts of the order 2-3 ft, a limit of ~3 ft for excavations in borrow areas B1 and B2 and ~2 ft for excavations in borrow area A has been set.

Applying the respective cut limits for each borrow area yields a total of ~8.7 million cubic yards. As noted in Table 3.5, these estimates assume that at least 15 percent of revised borrow areas B1 and B2 will not be dredged and at least 33 percent of revised borrow areas A1 and A2 will not be dredged. The purpose of leaving some undredged corridors running through each borrow area is twofold:

1) Undredged corridors leave undisturbed areas in close proximity to each cut such that natural recruitment of biota is accelerated after construction (Jutte et al 1999a,b).

2) The anticipated type of dredging equipment (hopper dredges) reportedly works more efficiently if gaps are left between each cut (E. Elefson, Weeks Marine, August 1999, pers. comm.).



Note:
See Sections Y'-Y and Z'-Z on Figure 30 for Boring Profiles.

Figure 3.27

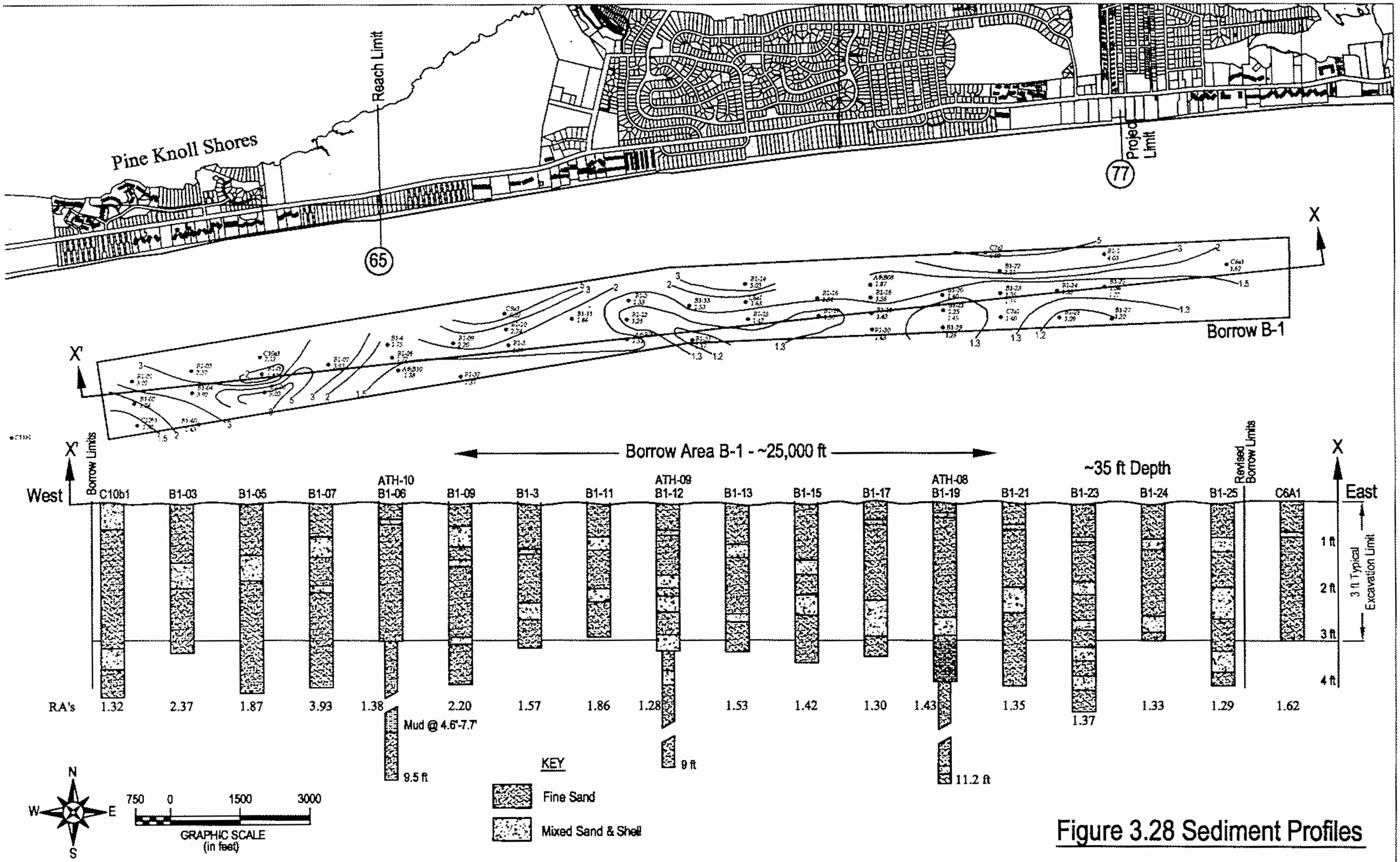


Figure 3.28 Sediment Profiles

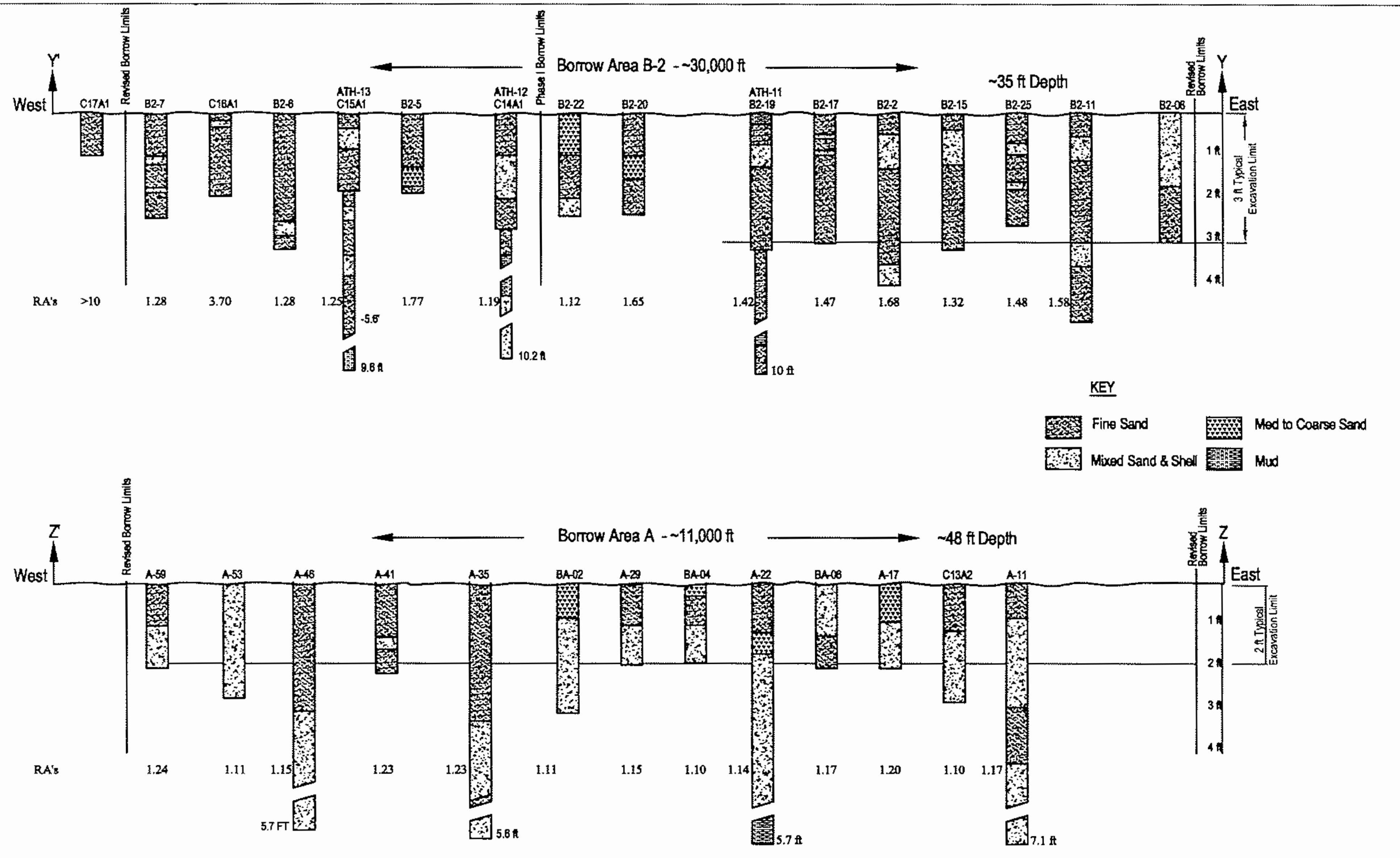


Figure 3.29 Sediment Profiles

The effect of these undredged corridors will be to reduce the total acreage impacted in the offshore area. A further reduction in impacted area will result if a lesser fill quantity is needed for the project than requested in the permit. Following standard practice, we have identified and confirmed approximately 25 percent more borrow area sediment than required (Figs 3.25-3.29 and Table 3.5). These factors are anticipated to reduce the total acreage impacted directly by excavations to ~731 acres in borrow area A* (A1 and A2), 330 acres in borrow area B1, and 530 acres in borrow area B2 (total ~1,591 acres or ~2.5 square miles).

[**NOTE: Borrow area A in this document refers to A1 and A2.*]

3.16.4.4 *Sediment Compatibility* – Groups of samples for each potential borrow area were compared with the native beach. Using the method of James (1975), borrow composites were compared with native beach composites to yield an overfill (R_A) factor for each borrow area (see Table 3.4). The results, using beach composites of 48 samples, show that the majority of samples have R_A's under 2.0. R_A's for revised borrow area A* were 1.15. Revised borrow areas B1 and B2 had slightly finer sands on average, yielding R_A's of 1.58 and 1.50 (respectively).

Upon further review of the sediment quality data and specific requirements of the project, it was determined that the optimal borrow sediment will be a combination of sands from borrow areas A* and B1 or A* and B2. Borrow areas B1 and B2 contain more fine sand and are slightly less stable for nourishment than borrow area A* (ie, approximately 33 percent of the B1 and B2 deposits will serve as overfill). The finer sands in these areas will migrate to the outer bar after placement and will build up the underwater profile (a desired outcome). Sediments in borrow area A* are slightly coarser than the native beach (lower end of the coarse sand range). These sediments will be more stable in the berm and beach face and will serve to improve the longevity of the dry beach.

As shown in Table 3.5, approximately 65 percent of the borrow sediment is anticipated to be derived from revised borrow areas B1 and B2. The remaining 35 percent would be excavated from borrow area A*. The purpose of combining sediments from borrow areas A* and B1 and B2 is to more closely match the native beach. Using these approximate proportions, composite grain-size distributions were developed for representative combinations of borrow areas A* and B1 or A* and B2 as detailed in previous correspondence (letter and attachments dated 19 June 2001 in response to 1 June 2001 comments from USFWS). Table 3.6 and Figure 3.30 provide example results. The use of statistical composites follows standard practice and is used to characterize the average size distribution that will result when sediments are delivered to the beach. Using 62 representative cores from borrow areas B1, B2, and A*, composite grain-size distributions for combinations of borrow areas A* and B1 and A* and B2 were computed. This simulates the effect of combining sediments during placement. The composite size distributions resulting from each combination yield overfill ratios of 1.25 to 1.3 (Table 3.6). Grain-size distribution curves for the composites are given in Figure 3.30. The native beach composite is given in Figure 3.31. Only 25-30 percent more borrow sand would be required in these cases to match the performance of the native beach. As NAS (1995) and experience suggest, borrow areas with R_A's under 1.5 are generally considered to be good matches with the native beach.

The selected borrow areas have several advantages:

1) They are in close proximity to the project site and will result in lower transportation costs and more rapid construction.
2) They contain a broad range of sediment sizes that fully encompass the natural variation that presently exists on the beach.
3) They have relatively low mud content (<4 percent on average).
4) They contain a sizable portion of granular material which will be more stable on the beach.
5) They are relatively free of large shell clasts. Most of the shell material consists of *Donax* sp., which is thinner walled and more friable than heavy shell such as *Crassostrea* sp.
6) They are situated in water depths of 30-50 ft, beyond the limit of normal sediment exchange with the beach.

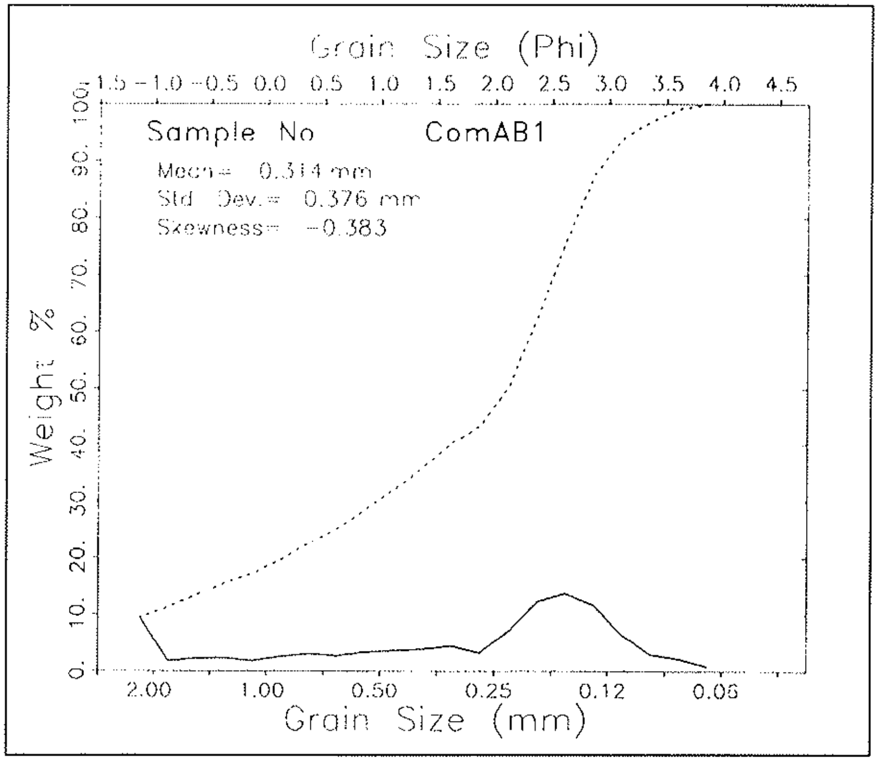
The result of the above-listed refinements of the proposed borrow areas for the proposed project is to yield a beach-compatible sediment. Final plans and specifications for contractors will direct hopper dredges (the anticipated equipment) to alternate between borrow areas A and B1, or A and B2 in proportion to the volumes prescribed for each area. Construction will be monitored closely by the applicants' engineer with frequent sand sampling for quality control.

TABLE 3.6. Example composite overfill ratios for borrow areas B1 and A and borrow areas B2 and A, assuming combination of sediment to yield a more compatible fill. (Example to simulate combination of ~65 percent B1 and 35 percent of A or 65 percent of B2 and 35 percent of A.) See CSE response letter dated 19 June 2001 to USACE for more details. [*See Table 3.5 for definitions.]

Composite Groups	Number of Samples	Sediment Description*	Mean ϕ (mm)	Standard Deviation	R_A
A–11	11	MS,PS,SCS	1.363	1.416	**1.18**
B1–29	29	MS,PS,SCS	1.789	1.390	**1.34**
B2–22	22	MS,PS,SCS	1.664	1.441	**1.31**
A–B1	40	MS,PS,SCS	1.672	1.410	**1.30**
A–B2	33	MS,PS,SCS	1.564	1.439	**1.25**
Native Beach	48	MS,MWS,C-S	1.736	0.735	N/A

Cores used in composites for borrow areas A, B1, and B2

Borrow Area A*	Borrow Area B1	Borrow Area B2
BA-02	C7A1	C11A2
BA-04	C8A1	C12A2
BA-06	C10A1	B2-08 S1
BA-11	C10B1	B2-09
A-11 s-1	B 1-02	B2-10
A-17	B 1-05	B2-13
A-23	B 1-12	B2-15
A-29	B 1-13	B2-17
A-35 s-1	B 1-15	B2-19
A-41	B 1-16	B2-21
A-47	B 1-17	B2-22
	B 1-18	B2-24
	B 1-19	B2-25
	B 1-20	B2-26
	B 1-21 S1	B2-27
	B 1-23 S1	B2-28
	B 1-24	B2-29
	B 1-25 S1	B2-30
	B 1-27	B2-31
	B 1-28	B2-32
	B 1-29	B-2-2
	B 1-30	B-2-4
	B 1-33	
	B 1-37	
	B 1-40	
	B-1-2	
	B-1-3	
	ATH-B-09	
	ATH-B10	



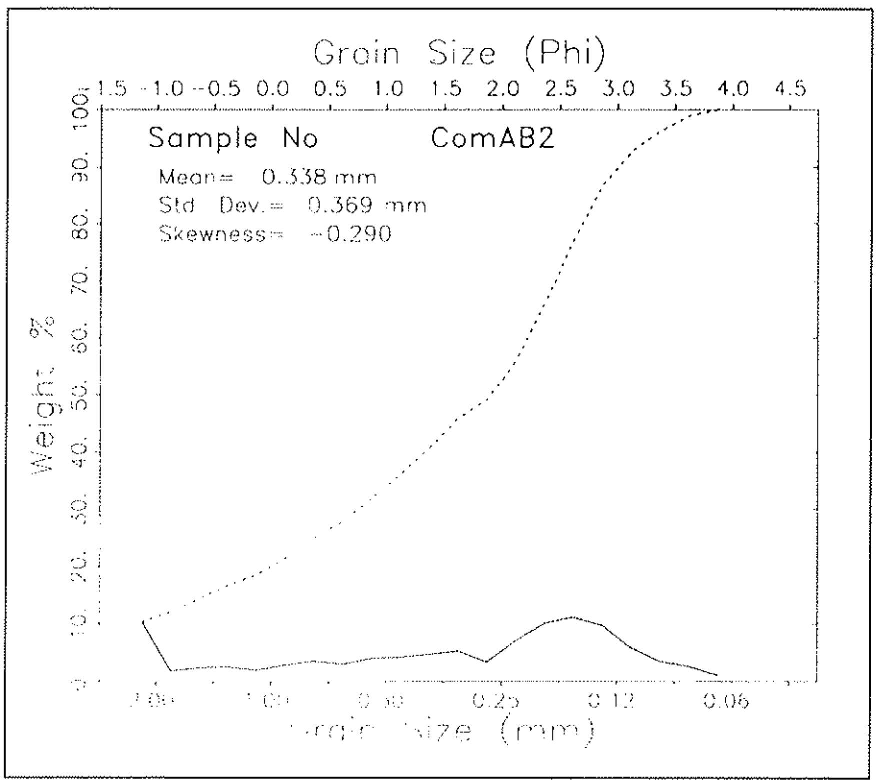


FIGURE 3.30. Example composite grain-size distributions for borrow areas A and B1 and A and B2, combining sediments in the approximate ratios as the indicated volumes in each deposit.

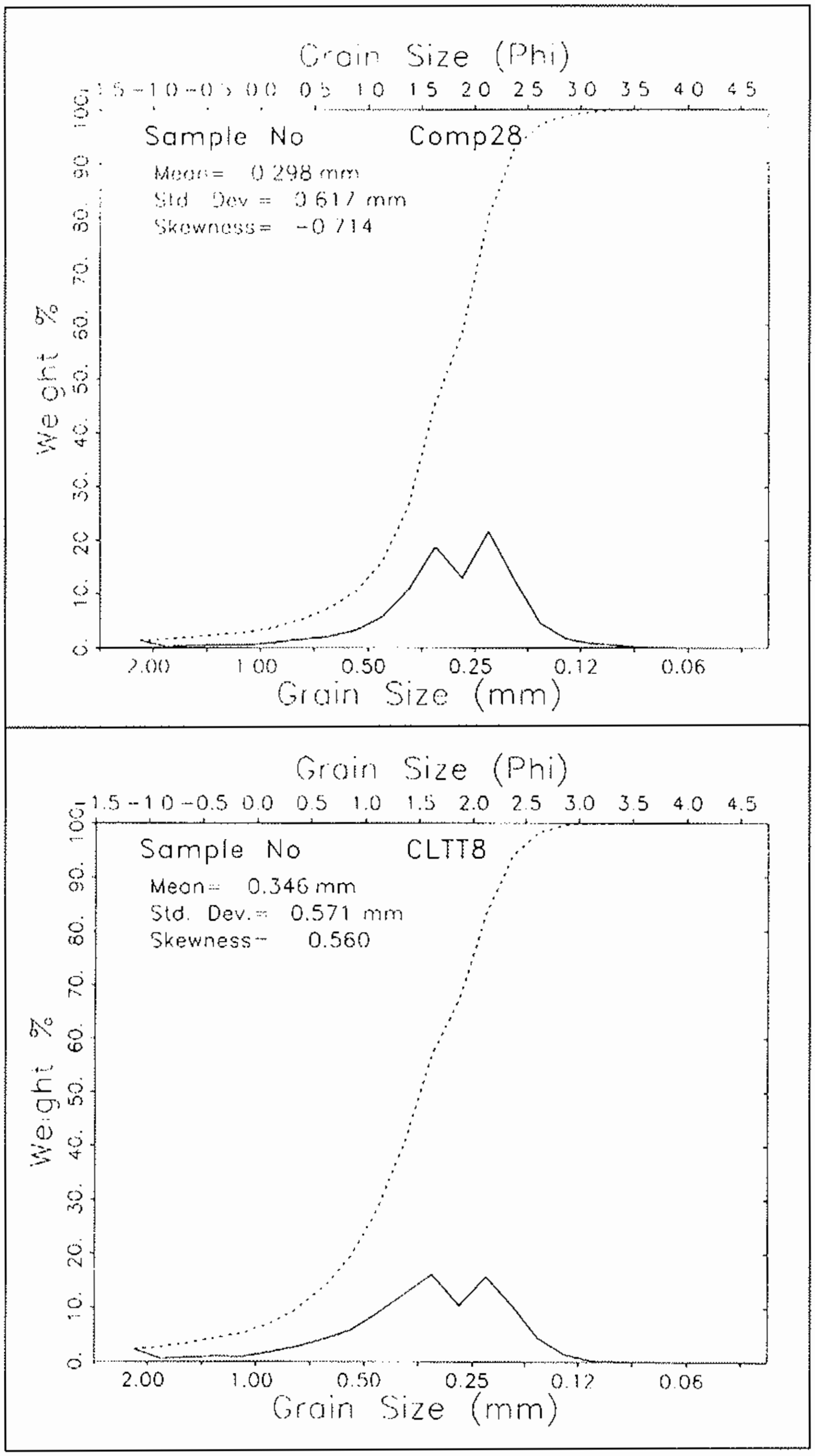


FIGURE 3.31. Example beach composites for Bogue Banks, based on 1999 and 2001 samples. Comp28 is a composite of dune, berm, beach face, and low-tide terrace (LLT) samples as detailed in Table 3.4. CLTT8 is a composite of eight LLT samples. Based on these results, borrow area sediments less than 0.12 mm (see Fig 3.30) are likely to represent the portion winnowed from the fill. The overfill ratios define this unstable portion as representing ~15-35 percent of the fill (ie, R_A's = 1.15 to 1.35).

4.0 ENVIRONMENTAL CONSEQUENCES

4.1 LAND USE IMPACTS

Nourishment of the Bogue Banks beach will not change the land use patterns. Development of the shoreline is governed by zoning regulations of the municipalities and County and by the CAMA Land Use Plans approved for each governmental entity. Ocean front development will remain primarily single family residences with patches of multi-family and hotel development. The beach nourishment project is consistent with the approved CAMA Land Use plans for Carteret County, and the Towns of Pine Knoll Shores, Indian Beach and Emerald Isle.

4.2 SOCIAL IMPACTS

The beach nourishment project will produce temporary and short-lived impacts on existing beach use, rental of property, and beach access only during construction. Impacts will be isolated to the immediate areas of construction at any particular time during execution of each phase of the project. This may adversely affect rentals for certain properties during the project. Similar impacts are believed to have occurred to properties in the project area as a result of five hurricanes since 1996 and the requirement to evacuate during storms. Following the project, the impacts of reduced rentals and beach use are expected to diminish. An improved beach is expected to attract people to the area, maintain rentals and beach use, and reduce the time for beach cleanup and recovery after storms.

4.3 ECONOMIC IMPACTS

The proposed project will provide ten-year benefits, substantially exceeding costs as described in Section 2 compared with the "no-action alternative" and the "abandonment and relocation alternative." The ratio of benefits to costs has not been calculated but is expected to greatly exceed 2:1, based on conservative assumptions (see Section 2). An accurate accounting of benefits and costs depends on the final cost of construction and the actual life of the nourishment which is not quantifiable until erosion rates of the fill are computed from surveys. The applicant has applied for a permit based on the expectation that the tangible as well as intangible benefits of the project greatly exceed the costs. A certain portion of the project budget will be recycled to the community by way of local purchases by the contractor of supplies (eg, fuel, machine parts, etc), lodging, and food. An estimated 95 percent of the project will be paid out of local (municipal) and 5 percent out of state funds (limited to the project area owned by the State of North Carolina in Reach 4). The project will restore and improve the public beach. This is expected to attract more visitors and contribute favorably to the local economy over a ten-year period. The project will reduce damages due to storms and the cost of repairs to the dunes (eg, beach scraping), walkovers, and existing shore-protection structures. The project is expected to sustain the tax revenues (ie, 43 percent) of the Carteret County receipts.

The USACE-Wilmington District reviewed the economics analysis given in the SEPA EIS and concluded that it was "adequate and thorough" (memorandum dated 18 May 2001 prepared by Bob Finch, economist). Additional economic information has been developed and incorporated into the present document in response to USACE comments.

4.4 CULTURAL RESOURCES IMPACTS

To determine the impact of the proposed dredging and beach fill operation on potentially significant submerged cultural resources, a remote sensing survey of the proposed borrow areas was conducted by Tidewater Atlantic Research, Inc. (TAR) of Washington (NC). The survey report prepared by TAR is provided in Appendix B. The survey was designed to locate and identify submerged cultural resources in the study areas, generate sufficient data to make an initial assessment of each target's significance, and provide insight into the necessity for avoidance or additional investigation. The survey was carried out between 7 and 13 December 1999. No magnetic or acoustic anomalies were identified in either borrow area A or borrow area B-1. In borrow area B-2, ten magnetic anomalies were identified near the western end of survey area. Seven of those targets contained signature characteristics indicative of submerged cultural resources. Because they could be associated with an historic shipwreck, either avoidance or additional investigation to positively identify the nature and significance of the material generating the seven anomalies was recommended. To avoid the areas of the seven anomalies identified by the survey, the western portion of borrow area B-2 has been eliminated as a potential source of sand for the proposed project.

The NC Department of Cultural Resources (NCDCR) has reviewed the project and has identified six archaeological sites along Bogue Banks beaches (letter dated 7 May 2001 from David Brook to Doug Huggett). NCDCR has recommended and the applicants agree to avoid the sites and report any evidence of unknown vessel remains in the course of construction. NCDCR will be contacted to inspect such discoveries, and work will cease in the immediate vicinity of found artifacts until cleared by NCDCR officials. While the possibility exists that a designated or unknown artifact may be exposed during construction operations, the proposed project is expected to benefit each site by the placement of additional sediment, further burying them and increasing their preservation.

4.5 UTILITY IMPACTS

There will be no permanent changes in utilities as a result of the project. The nourished beach is expected to provide an unquantified benefit to existing infrastructure and utilities near the beach in the form of increased protection during storms. Nearly all energy usage during construction will be self-contained on the dredge and via self-propelled equipment on the beach. There will be no significant demand on the local electrical grid. Purchases of diesel fuel will impact local suppliers by temporarily increasing demand. The construction workforce will number around 75 individuals who will not significantly alter the demand for water, sewer, electricity, transportation, or communication services.

Water Supply and Wastewater Systems — There are no activities associated with this project that will impact existing wastewater collection, treatment, or disposal systems. No activities of this project will impact potable water well sources or distribution systems on Bogue Banks or in Carteret County.

4.6 PHYSICAL ENVIRONMENT IMPACTS

4.6.1 Wetlands

No impacts to existing coastal wetlands or 404 wetlands will result from this project. No fill will be placed in 404 or coastal wetlands as part of this project.

4.6.2 Unique Agricultural Lands

The beach nourishment project will result in no impacts to agricultural lands, unique or otherwise.

4.6.3 Public Lands

The project will not reduce the existing public rights and use of the beach resources. The "Public Trust Doctrine" and the State Property Sovereignty Rules preserve the rights of all citizens of North Carolina for use of resources located below the mean high water line. Additionally, Carteret County and local municipalities will obtain permanent easements from oceanfront property owners within the project limits. The easements will grant access for construction and measurement, and will establish permanent rights for the public to cross lands above the mean high water line if those lands are created by filling operations financed with public funds.

Public Access to Beach Resources — Public access to the beach strand has been developed extensively by the Towns of Emerald Isle, Indian Beach and by Carteret County for the unincorporated area of Salter Path. As part of implementation of this project, the Town of Pine Knoll Shores is independently developing public access that will meet the USACE guidelines for public access to federally maintained beaches. Before construction begins, the county will require that all municipalities within the project limits meet the Corps of Engineer's guidelines for public access. In March 2001, the Town of Pine Knoll Shores secured oceanfront property that is improved to accommodate ~100 vehicles for the general public. This is consistent with a specific recommendation from the US EPA in a comment letter dated 13 April 2001 (reproduced in Correspondence Section).

4.6.4 Recreational and Scenic Areas

Construction of a ~100-ft-wide berm, dry beach area will enhance the beach by providing areas on the beach for activities during all tidal conditions. This is a benefit to Bogue Banks' communities which rely on the beaches and opportunities for beach activities to attract visitors.

The fall season is the peak period for surf fishing on Bogue Banks with activities tapering off during November and December. The beach restoration operations are scheduled to occur between the months of November and April. Surf fishing will not be limited along the beach except in the immediate vicinity of the discharge pipe and earthmoving equipment. Studies of recreational and commercial fisheries impacts in New Jersey (USACE–Burlas et al 2001) showed no significant change or decline in these activities as a result of a major nourishment project along 25 miles of the northern New Jersey shoreline. Some important fish species (such as kingfish) were attracted to the slurry discharge whereas others (such as bluefish) tended to avoid the discharge point.

4.6.5 Groundwater Quality

No action proposed as part of this project will have an impact on surficial or deep aquifer groundwater.

4.7 LITTORAL PROCESSES IMPACTS

4.7.1 Tides

Dredging borrow areas A, B1, and B2, and filling the beach between transects 8 and 77 will take place along the open coast, so no changes in tidal conditions will occur.

4.7.2 Hurricanes

Dredging the offshore borrow areas will not change hurricane surge levels, since surges are changes in water-surface elevations. The project will increase the shoreline protection from hurricanes because of the wider beach. A wider beach due to the project will protect dunes and lessen erosion by waves and surges generated by hurricanes. Currently there is very little distance between the base of the dunes and the water. In most reaches, peak monthly tides encroach on the toe of the foredune. During the 1999 hurricanes, the dunes on Bogue Banks retreated an average of about 15 ft, with some areas retreating more than 30 ft. In a few low-lying areas there was washover of the foredune and deposition in the swale between the first and second dunes. Since the toe of the dune is now close to the water, hurricane surge raises the water level sufficiently for waves to directly impact the dune toe and erode it away. Almost all areas of Bogue Banks have sufficiently high dunes to withstand 100-year surges. Existing narrow beaches allow waves to erode the toe, thus causing the entire dune to retreat, leaving vertical escarpments after storms.

4.7.3 Waves

Possible changes to waves caused by altering topography in the borrow areas was examined by use of wave shoaling models. The Wave Information Study database of waves from wind-wave models was used as a data source for the shoaling studies over borrow areas A, B1, and B2. Waves were shoaled over A, B1, and B2 for both existing and dredged conditions, with all results shown in Appendix G. The conclusions are: (1) there will be a temporary increase in wave heights for the sections of the island along the borrow areas of less than 1 percent or 0.1ft, and (2) error bars in the wave directional component of the database are very large. (The error can be seen in contradictory predictions of energy flux, depending on which versions of the WIS database are used.) Thus, error in the longshore energy flux predictions (used in estimating potential for longshore sediment transport) is many times larger than the model's predicted 8-9 percent increase in longshore energy flux caused by dredging the borrow areas. Any anticipated effects on wave changes are expected to be short-term and minimal.

4.7.4 Dimensions of Littoral Zone (Depth of Closure)

Appendix G analyzes the depth to which there is active motion of sediment. Different methods produced results varying between 13 and 30 ft below the mid-tide level (methods 1, 2, 4, and 6). Methods 3 and 5 were used to gauge the most extreme condition possible, the time of only a few hours duration when a hurricane was in the immediate vicinity and produces depth-limited waves of 7 meters. Methods 3 and 5 indicated seabed activity between 32 and 36 ft. Only during these extreme hurricane conditions does sediment move in the closest inshore borrow areas B1 or B2, and even then only in the most landward portion of the borrow areas. The conclusion is that sand in the borrow areas is not within the littoral system, but a relict of past events, such as lowered sea level and relict inlets. These results are further supported by beach profile surveys in June and September 1999 and June 2000 which generally show closure inside the –15 ft NGVD contour (CSE-Stroud 2001).

4.7.5 Littoral Transport

Effects of the dredging operation and the beach nourishment on longshore transport of sediment should be considered, since alterations in the transport patterns result in changes to the beach. The usual method for evaluating transport-pattern effects of topographic changes is to include the changes in a model which uses accurate measures of directional waves. Unfortunately, the usual data for computing the potential for long-shore sediment transport, measured directional waves, do not exist for this area.

As detailed in Appendix G on waves, the particular data set that was used for examining the effects of borrow-area dredging resulted in a 8-9 percent increase in longshore energy flux. However, comparisons of the different databases and their effects on littoral transport in Appendix G show that both direction and magnitude of transport are solely a function of which database is used. Thus error in the databases far exceed the numerical values of any predictions to the change in longshore energy flux.

The best indicator of effects of the nourishment on longshore transport is the behavior of the Corps' nourishment project at Atlantic Beach. When only one stretch of beach is nourished, there are often effects on the neighboring unnourished beaches. Usually the neighboring beaches receive benefits of nourishment sand moving out of the nourishment-project areas, regardless of whether they are on the net updrift or downdrift sides. The reason that updrift beaches also receive sand is that longshore transport occurs in both directions, at different times, and the beach is only updrift in a net-transport sense. Problems can occur, however, if the current patterns are so drastically altered that an already eroding neighboring beach suffers. There is some evidence (Roessler 1998) from detailed modeling of the current patterns at Atlantic Beach and Pine Knoll Shores that this has, in fact, happened. The obvious solution to such a problem is to not allow such drastic longshore variation in nourishment volumes, especially when a neighboring eroding beach receives no sand at all. The plan for the proposed project is to nourish all of the eroding unnourished parts of Bogue Banks, so this problem does not occur. The beach to the east of the proposed project (Atlantic Beach) is already nourished, and the beach to the west (Emerald Isle near Bogue Inlet) is slowly accreting (about 3 ft/yr). The project is expected to beneficially create a more uniform shoreline in terms of its recreational potential, storm protection, and beach habitat.

4.7.6 Erosion Rates

Uses of erosion rates in examining environmental impacts include:

- Erosion is one of the factors used in computing nourishment volumes, so the total impact to the borrow areas and nourishment areas depends on erosion rates.
- Erosion rates indicate how rapidly detrimental impacts of the "no action" alternative will affect the oceanfront properties, infrastructure, and tax base.
- After nourishment, erosion rates help to determine how long beneficial impacts will last, both for people, fauna, and flora (eg, increased dry beach width for turtle nesting).

The erosion rates summarized in Section 3 and Appendix G were one of the factors used to compute nourishment volumes for this project. The three components of the total nourishment volume are:

- *"Volume deficit"* is the sand needed to increase the beach volume up to some desirable level. The selected level for Bogue Banks is 175 cy/ft, which was the average volume in profiles of Atlantic Beach prior to 1999 hurricanes. The details of computing this volume goal are described in Section 3 and in the last section of Appendix G entitled "Beach Erosion Analysis Used to Determine Nourishment Requirement." This component is the largest volume of the three components.

- *"Advance nourishment"* is the volume determined from the erosion rates that is necessary to advance the beach enough to counteract the anticipated future erosion. Various scenarios were computed, and for this project, the ten-year protection was selected. This does not mean that in ten years the nourishment sand will be gone. Rather in ten years, the "advance nourishment" component of the project will be gone. That is, ten years after the project construction the beach will have eroded back to the still healthy Atlantic Beach-type volume of 175 cy/ft. Of course, if erosion is currently higher than the historical average, as some have argued, then the beach will erode back to the 175 cy/ft Atlantic Beach profile sooner than in ten years. The quality of historical data is inadequate to accurately predict the time over which advance nourishment will erode.

- *"Overfill ratio"* is a ratio of how many cubic yards from a borrow area will be needed to produce one cubic yard of material that matches the native beach sand. These ratios have been computed for the different borrow areas, so the total amount of material placed on a section of beach will depend on which borrow areas are used. Section 3 of this report details which borrow areas will be used and in what proportions.

Duration of beneficial impacts of the project (protecting oceanfront properties, providing a recreational beach, increasing habitat for beach fauna) depend on erosion rates. The erosion rates and selected nourishment volumes show beneficial impacts well in excess of ten years, since the "volume deficit" component of the project is the largest component. As an example, the central reach of Emerald Isle has erosion rates that are roughly average for the island. Duration of the project using a safety factor of two (to account for 100 percent uncertainty in computed erosion rates) is (10 yrs/2)(766,958 cy nourishment)/ (226,902 cy advance nourishment) = 17 years. (Note: This computation would be modified only slightly by modifications in the phasing and advance nourishment quantities detailed in Section 2.4 of this report.

4.7.7 Sediment Compatibility

The sediments on the beach are admixtures of sands and shell fragments. Mud has been winnowed out because it is unstable in the surf zone. Compared to fine sand beaches along the southern coast of North Carolina, Bogue Banks beaches have a much broader size distribution ranging from pockets of coarse, granular sediment in the step or lower beach face to fine sand in undisturbed foredunes and the outer bar. Seaward of the outer bar along the lower foreshore to about -30 ft, sediments are finer still as shown in Corps navigation studies for Morehead City Harbor and for disposal projects along Atlantic Beach (eg, USACE 1992, 1993). Sediments in borrow areas B1, B2, and A were, at one time, littoral sediments. They exhibit a similar gradation in sizes with the primary difference being a broader, flatter distribution because of the presence of slightly more shell and small percentages of mud.

The accepted standard for quantifying compatibility is the overfill factor, R_A (CERC 1984). This is a measure of how similar a borrow sediment is to the native beach. Section 3 reports R_A's for individual borrow samples ranging from <1.02 to >10.0 with means of about 1.15 in revised borrow area A, 1.58 in revised borrow area B1, and 1.50 in revised borrow area B2. As shown in Section 3, it is possible to obtain sediment that more closely matches the native sediment distribution in terms of grain size distribution, percent shell and percent coarser material by alternating excavations between borrow area A* and borrow areas B1 and B2 in proportions of approximately 1:2. This yields a composite R_A of about 1.3-1.35. Shell content for an example composite of 62 borings is approximately 32 percent (see Table 3.5 and Appendix E). A further advantage of the borrow areas chosen is the slightly broader size distribution than the native sediment. This is important from an engineering standpoint because it means the borrow sediment will be more stable and last longer, a primary goal of the project. Borrow areas with narrow size distributions will generally not perform as well even if the mean grain size matches the native sediment (USACE 1995a).

The example composite size distribution of 62 borings from borrow areas A, B1, and B2 is expected to be modified favorably after placement on the beach because of the following factors:

- Construction by hopper dredge (the 95 percent most probable dredging method) will eliminate nearly all mud before pump-out onto the beach (D. Hussin, Great Lakes Dredge & Dock, pers. comm., April 2001), thus shifting the mean grain size to a slightly coarser value.

- Shell material in the cores contains high proportions of friable thin shell (eg, *Donax* sp.) which is expected to be broken into smaller shell hash fragments in the swash zone, narrowing the size distribution.

- Natural sorting in the littoral zone of a broad distribution of sediments will maintain the distinct difference between the offshore bar (fine sand), beach face (medium to coarse sand and shell), and dune (fine sand). Presently, there are portions of the profile such as the horns of beach cusps containing >70 percent shell material.

Unlike some Southeast coast barrier islands, the native beach along Bogue Banks contains a broad size distribution. The proposed borrow areas have been selected to provide sediments that are compatible with the native beach.

As part of the postproject monitoring plan, the applicants plan to obtain yearly sediment samples from a minimum of six beach transects and conduct textural analysis for comparison with the prenourishment condition. Grain-size data will be prepared using the same methods and parameters reported herein for prenourishment samples. The results of these sediment tests will be included in annual monitoring reports of project performance and will be submitted to regulatory and resource agencies for review.

The USACE-Wilmington District has reviewed the geotechnical data for the project (memorandum dated 17 August 2001 from Ben Lackey to Mickey Sugg) and has concluded that the proposed borrow material is ". . . of a quality that would be recommended for U.S. Army Corps of Engineers beach projects."

4.7.8 Alteration of the Beach Profile

The shape and slope of beach profiles evolves in relation to wave energy and sediment grain size (Bascom 1951; Komar 1976). Tide range also plays an important role because it controls the elevations over which waves act on the profile. Where sediments are uniform across the foreshore, there tends to be less topography, particularly in the fine to very fine sand ranges. In settings like Bogue Banks, where there is a relatively broad range of sediment grain sizes, profiles tend to have more complex morphology. Bars and troughs are more common, and berms tend to be more mobile (Hayes 1976). By using a graded deposit of similar-sized sediments from borrow areas A, B1, and B2, the nourished profile is expected to adjust to a morphology similar to the existing beach. Nourishment will displace the profile seaward (including the offshore bar and trough) and not simply infill the trough as depicted on reference cross-sections in the permit application (Appendix A-2).

Evidence from other studies (eg, USACE 1995) suggest that if a narrow, borrow size distribution is used, the resulting profile will be more uniform. This is not what is desired for the proposed project because the existing profile contains complex cross-shore topography. The profile illustrations in the permit application are idealized to show the relative scale of the fill sections. These are easier to visualize than a complex profile that is expected to develop across the littoral zone to closure depth (approximately −30 ft NGVD) after the fill has time to equilibrate.

The applicants will conduct annual profile surveys of the beach and inshore zone to document the evolution and fate of the nourishment. Profiles will be compared with prenourishment surveys and evaluated for unit-width volumes, volumetric change, beach widths, slope changes, and longshore advection. Annual reports on the performance of the project will be prepared and submitted to the regulatory agencies.

4.7.9 Chemical Alteration and Cementation of the Fill Material

None of the sediments to be dredged and placed on the beach are highly reactive. While calcium carbonate material breaks down much faster than quartz and feldspar, the process is not rapid. Shell fragments from the borrow area generally require many decades to centuries to break down completely and dissipate from the beach. Meanwhile, new shell material is forming in situ through normal biological processes. Cementation is not likely to occur, because the fill will be placed within the active surf zone and will not contain high proportions of muddy material. Hydraulic fills have the advantage of producing a slurry that runs down the profile during construction. Fine-grained material is selectively sorted and winnowed in the surf during placement. Reports of sites (eg, Edisto Beach, SC, as quoted in USFWS correspondence dated 1 June 2001 to Col James W DeLony) where cementation may have occurred generally involved placement of unwashed sediments above the spring swash line. [Note: The problem at Edisto Beach was mitigated by bulldozing the berm seaward and leaving it at a lower elevation so that subsequent wave swash could rebuild the profile to a more natural configuration (CSE, unpublished data)] Hardpan is generally not a problem with hydraulic fills, which are placed without containment berms. To avoid future problems, compaction tests will be performed along the backshore, comparing with natural conditions and tilling the berms if compaction becomes a problem.

The postproject sediment and analysis that will be performed by the applicants are detailed in Section 4.12.7. Shell content will be measured as part of this effort following the same methodology as preproject sampling.

4.7.10 Alteration of the Borrow Area

The planned dredging depth is specified such that similar sediments will be left exposed below each cut. As noted on Figures 3.27-3.29, borrow areas B1 and B2 are dominated by fine sand but become coarser in the composite due to the presence of mixed sand and shell layers of varying thickness. Borrow area A is much more variable with surficial sediments ranging from fine sand to granular material. Underlying sediment at 2 ft is similarly variable such that the excavations in borrow area A will maintain a distribution of substrate sediments like the ones that presently exist at the surface. Diver observations indicate that intermittent patches of fluid mud exist and appear to migrate into and out of the proposed borrow areas. Of ~150 cores from the designated borrow areas, only three (B2-19, A-24, A-54) had a surficial layer (typically upper 0.3 ft) of soupy mud. Such unconsolidated mud is expected to dissipate quickly during excavations and wash out of the hopper or through the surf zone. Consolidated mud, by contrast, has the potential to form mud rollers during placement and produce chronic releases of clays as mud rollers are abraded. The proposed borrow areas have been chosen because they lack significant sections of consolidated clays (see Figs 3.27-3.29).

As part of the applicants' monitoring of the project, representative sediment samples will be obtained in the excavated sections of the borrow area at approximately 20 percent of the previously sampled stations in Years 1, 2, and 3 after construction. Samples will be analyzed and compared with the prenourishment condition to document changes in the substrate.

4.8 WATER QUALITY AND TURBIDITY IMPACTS

Temporary increases in turbidity are associated with both dredging operations and the washing of fine sediments by waves on the nourished beach. The applicants received a 401 Water Quality Certification on 23 March 2001. The certification references General Water Quality Certification Number 3274 as the applicable standard for the project.

Published measurements of turbidity during beach nourishments are rare. Reference (USACE 1993, p 6) is made to turbidity measurements for pipeline discharge of nourishment sediment on Atlantic Beach. Turbidity was a function of distance from the discharge pipe. Measurements ranged up to 250 NTUs in the vicinity of the pipe, but decreased rapidly with distance. That sediment pumped from Brandt Island had a much higher overfill ratio and mud percentage than the borrow areas proposed for this project, so turbidity is expected to be lower for this project.

A fairly comprehensive set of measurements was made for another project with mud percentages more similar to the one proposed here by Hanes (1994). Table 5 in that publication lists measured turbidities for times during and after nourishment and for both the project area and a control site uninfluenced by the nourishment. Turbidities were not measured in the immediate vicinity of the discharge pipe, but rather seaward of the breakers along the nourished stretch of beach. Values are listed for surface, mid-depth, and near bottom in the water column. The control site must have had slightly different conditions, because the after-nourishment numbers showed an average ratio of 0.6 of nourishment site to control site. (The nourished area had less turbidity than the control site well after construction.) But the numerical values were low for this post-construction period: 2.8 to 4.4 NTUs for the nourished area and 4.4 to 9.2 for the control site.

Natural turbidities are usually lower in Florida, where this study occurred, than they are in North Carolina. During construction the nourishment area showed turbidities averaging 50 percent higher than the control site, but again the numerical values were low, ranging between 4.6 and 7.5 NTUs in the nourishment area. These studies show that for turbidities associated with nourishment:

- Turbidities may be quite high in the immediate vicinity of discharge. However, the WQC standard pertains to "outside the area of construction or construction related discharge."

- Neither of the two studies showed turbidities exceeding 25 NTUs outside the discharge area.

- Outside the discharge area, but in the ocean along the same stretch of beach, turbidities increased about 50 percent, but the reported increases are less than 10 NTUs.

- Natural variation in turbidities associated with storms is larger than these increases outside of the discharge area.

Increases in sedimentation associated with nourishment are of concern because of possible impacts on benthic fauna. In the Hanes (1994) study sedimentation rates of fine sediments were compared between the nourished and control sites. The ratio of sedimentation rates between nourished and control was 0.8 before nourishment, 1.3 during, and 1.1 after. Numerical values were in the 15-25 mg/cm^2/day range for all sites. Statistical computations (the Binomial Sign test) which test for the probability that the observed differences were the result of random chance resulted in the conclusion (p 3029) that "there were no significant differences in fines sedimentation rates." Significant differences were observed in sand sedimentation rates, but the wave heights were one-third higher at the nourishment sites with 75 percent higher energies. That increased energy between the sites "is probably the reason for the relatively higher sand sedimentation rates."

Other anecdotal evidence suggests that the impact of the proposed project on turbidity will fall well within the natural range occurring along Bogue Banks in the surf zone and around the borrow areas.

The SEPA EIS for the project (CSE-Stroud 2001) did not elaborate on background turbidity off Bogue Banks because such information is highly site- and time-specific. Turbidity varies by several orders of magnitude and varies exponentially down the water column. A full accounting of suspended-sediment distribution is well beyond the scope of projects such as this. Based on diver observations during the collection of over 200 cores under fair-weather conditions (eg, seas at <4 ft), the following can be stated anecdotally:

- There was generally zero visibility at the bottom between the 15 ft and 30 ft contours (ie, landward of any borrow areas).
- Maximum visibility for any station sampled at any time at the bottom was no more than 15 ft.
- Typical visibility at the bottom was less than 2 ft.
- Visibility was greatest in borrow area A where a portion of the bed was floored with granular-shelly sediments and average depths are ~48 ft.
- The exposed surficial sediments off Bogue Banks between the 15 ft and 50 ft contours are highly variable and include areas with a nepheloid layer of soupy mud which is easily resuspended, areas with coarse granular material free of mud in the upper 1-3 ft, and areas with all sizes in between.
- Turbidity around the surf zone and inshore area has been observed by CSE personnel during beach surveys to fluctuate by orders of magnitude. Surface waters close to shore experience high turbidity events in storms and during periods of strong onshore breezes as evidenced by zero visibility and the chocolate brown color of the water. This is attributed primarily to resuspension of fines from the bed because there are no major rivers discharging nearby.

The sediments that will be released into the water column by dredging and nourishment are expected to be the same as occur naturally. They were once part of the active littoral zone when sea level was lower. They contain similar admixtures of sands, silts, clays, and carbonate material. Persistent turbidity results when discrete clay-sized particles are in suspension. Silt and fine sand have settling velocities orders of magnitude faster than clay. Clay-sized material will be a fraction of the "mud" fraction which will total an estimated 4 percent of the borrow material (see Appendix E).

Low percentages of mud are ubiquitous in the nearshore zone off Bogue Banks and account for the chronic resuspension during storms and large seas. The proposed project is not likely to produce permanent elevated turbidity levels because the amount of clay-sized material that will be mobilized by dredging an approximate 2.5-square-mile area is dwarfed by the volume of free mud on the ocean floor over other sections of the inner shelf in this locality. The applicant has chosen the borrow areas so as to avoid areas off Bogue Banks that have higher concentrations of mud on the sea floor.

It is possible to assess the relative magnitude of turbidity released by the project with the background levels by a simple volume accounting. Based on casual observations, high turbidity levels are observed to occur naturally as a result of resuspension of clays and silts at the bed. A typical suspended-sediment concentration one meter above the bed in zero visibility conditions is estimated to be approximately 1 gm/liter (1 kg/m^3). To produce this concentration over the 16.8-mile project area within 2 miles of the beach in the lower ~1 m of the water column would require ~2 million cubic meters of mud. The proposed project will release ~10 percent of this quantity in the form of mud. Because the source of mud released during nourishment is derived from the same source that produces resuspension, there will be no net change in mud content in the nearshore zone as a result of the project.

The mud that will be released during the planned excavation will be released incrementally, thus reducing its overall impact compared to resuspension of free mud in the nearshore zone. Therefore, mud released by the project is expected to make up only a small fraction of the total volume. Turbidity changes associated with the project are expected to be difficult to distinguish from the background suspended sediment load.

Other data on turbidity associated with beach nourishment are given in Burlas et al (USACE July 2001) for the northern New Jersey project conducted by the USACE-New York District. The results of measurements over six, 3-4 day periods in 1997 found:

- ". . . the effects of beach fill operations on short-term turbidity conditions appear to be limited to a relatively narrow swath (less than 500 m) of beach front."
- ". . . observed concentrations appeared to decline rapidly with dispersal through the surf zone."

- "The maximum NTU values measured near the fill operations do not appear to be outside the range that organisms would be exposed to during periods of high wave energies."
- Except in the immediate swash zone, "the magnitude of elevation (of turbidity) above ambient conditions appears to be negligible."
- "Measured TSS concentrations outside the swash zone seldom exceeded 25 mg/ℓ, which is comparable to concentrations that many of the dominant fish and invertebrate species of the northern New Jersey shore experience in estuaries."

NOTE: It is not possible to convert TSS units to NTUs with confidence because one is a direct measure (TSS) where the other (NTUs) is an indirect measurement dependent on site-specific calibration and detailed knowledge of the suspended sediment characteristics. For one study in Brevard County (Florida), Raymond and Antonius (1997) correlated average turbidity readings of 92 NTUs with TSS values averaging about 110 mg/ℓ (ie, approximately 1:1 correspondence).

Beach and Sternberg (1992) using OBS sensors estimated the mean background suspended sediment concentration 54 cm above the bed on an Oregon Beach to be ~500 mg/ℓ. Kana (1979) calculated the "washload" of suspended sediment (ie, particles <0.063 mm) to average less than 50 mg/ℓ on two South Carolina beaches near Charleston. Total suspended sediment (including sand-sized particles) fluctuated by three orders of magnitude (from ~50 mg/ℓ to 25,000 mg/ℓ) in the surf zone at Bulls and Capers Island (SC) under a variety of daily (nonstorm) conditions based on over 1,000 in-situ TSS samples. Kana and Ward (1980) found a similar three-order range of natural variations in total suspended sediment in the Duck (NC) surf zone under fair-weather and northeast storm conditions. These studies indicate the natural concentration of suspended solids in the surf zone greatly exceed the EPA criteria of 25 NTUs.

One study that does suggest turbidity can be higher during nourishment is Reilly and Bellis (1978). Based on only two TSS samples from the surf zone during nourishment at Fort Macon State Park (~6 miles east of the proposed project area), they found concentrations one order higher than a reference beach at Emerald Isle (~1.7 g/ℓ and 4.7 g/ℓ versus 0.10 g/ℓ and 0.09 g/ℓ). The authors noted these high readings may have been due to the presence of a high percentage of clay in the dredged material because it was derived from a channel-deepening project associated with the Morehead City navigation project. The sampling by Reilly and Bellis (1978) is considered inadequate to draw conclusions because it involved only four discrete samples.

Other research conducted by Schubel (1977), the Corps' dredging research program, and others show limited and short-lived increases in turbidity due to dredging. Schubel's studies were in the Chesapeake Bay where the dredged sediments were muddier. The consensus of studies to date regarding turbidity in the nearshore is that suspended sediment varies by orders of magnitude under the normal range of conditions and that "the spatial scales of elevated turbidity conditions associated with beach fill operations are relatively small (USACE-Burlas et al 2001).

The majority of the proposed project will be constructed over 5 miles from Bogue Inlet and 7 miles from Beaufort Inlet. Emerald Isle west is considered the least likely reach to be completed and will require the smallest fill sections given its condition (see Section 2 of this report). The project will leave a one-mile or greater buffer from the end of the project (Reach 1) to Bogue Inlet. This is expected to prevent a measurable rise in turbidity in Bogue Sound because of (1) the exponential decay in turbidity with distance from the nourishment discharge point and (2) the low percentage of mud in the borrow areas. Emerald Isle west (Reach 1) will introduce ~50,000 cy total mud into the water column out of about 1 million cubic yards scheduled for that reach. It is anticipated that the majority of this quantity will be returned to the borrow area during dredging operations because a hopper dredge will be required for that reach. (A pipeline dredge will only be economical if an alternate borrow area is located outside of borrow areas A, B1, or B2, such as the shoals of Bogue Inlet.)

4.9 NATURAL RESOURCE IMPACTS

4.9.1 Impacts to Offshore Resources

Fish, plankton, and other motile animals in the vicinity of the borrow areas during dredging are least likely to be affected during dredging, because of their ability to avoid the disturbed areas. Fish species have been observed to leave the area temporarily during dredging operations and return when dredging ceases (Pullen and Naqvi 1983). A study of nearshore borrow areas after dredging offshore of South Carolina revealed no long-term impacts to fisheries, both fish and planktonic organisms, as a result of the dredging (Van Dolah et al 1992). Creation of new habitat and the uncovering and suspension of food that attract fish during dredging have been attributed to dredging offshore borrow areas (Naqvi and Pullen 1982). Dredging of the bottom sediments in the borrow areas can be expected to attract fish over the short term (after the dredge leaves) as a result of suspension of bottom material. Impacts to fishery resources will occur with removal of benthic organisms (food source). These impacts are expected to be minimal with the recolonization (return) of the benthic organisms. Impacts to anadromous fish and other estuarine-dependent organisms are not expected to be significant or long term, since construction-related activities in the offshore borrow areas would be localized.

Benthic organisms in the immediate area being dredged will be largely eliminated during dredging. However, initial recolonization of the dredged areas by opportunistic species is expected to occur soon after cessation of any dredging activities. Further recovery is expected from recolonization from migration of benthic organisms from adjacent areas and by larval transport. Monitoring studies of post-dredging effects and recovery rates of borrow areas indicate that most borrow sites show significant recovery by benthic organisms approximately one year after dredging (Naqvi and Pullen 1982; Bowen and Marsh 1988; Van Dolah et al 1992; USACE-Burlas et al, 2001). To encourage recolonization by organisms from undisturbed substrates, the borrow areas will not be "swept clean." Undisturbed corridors will be left between dredge furrows such that an estimated 15 percent of borrow areas B1 and B2 and 33 percent of borrow area A will be available for recruitment. The proposed depth of excavation is 3 ft or less so as to minimize changes in the bottom topography.

4.9.2 Impacts to Special Aquatic Sites

Hard bottom is found offshore of Bogue Banks away from the borrow areas. The only hard bottom encountered was at two stations off western Emerald Isle (C18a1 and C18a2). A thin (<1 cm) veneer of silt was present at those sites and was easily resuspended. Because these areas did not contain beach-quality sand, they were abandoned in favor of more promising sites. The hard bottom detected is more than 20,000 ft from the Phase I reaches at Pine Knoll Shores and Indian Beach and about 4,500 ft off the central Emerald Isle reach in water depths greater than 30 ft. Excavations in the borrow areas will involve shallow dredge cuts so as to avoid any underlying hard bottom as documented by approximately 140 borings in the proposed borrow areas. Fill along the beach is not expected to produce any adverse impacts on hard bottom because of the distance offshore and the depth of water beyond the normal limit of littoral transport.

4.9.3 Impacts to Nearshore Resources

In view of the high mobility of fish, it is expected that fish will leave nearshore areas in close proximity to the nourishment on the beach. However, USACE-Burlas et al (2001) documented attraction to active construction areas by certain species such as kingfish on the New Jersey coast. Impact on fishing resources in the nearshore zone will be minimized simply by the fact that sand-placement operations will take place at any one location for only a few days and then move further along the beach. Short-lived increases in turbidity will occur during the fill placement operation (a few days at each location) and will alter the water column conditions sufficiently that it causes most mobile species to leave the area. Return is expected to be rapid. Studies have found that speed of return of mobile species is more dependent on the return rate of their prey than on the rapid return of normal turbidity levels.

4.9.4 Impacts to Intertidal Resources

Impacts on intertidal macrofauna in the immediate vicinity of the nourishment project are expected as a result of discharges of nourishment sediment on the beach. A study by Reilly and Bellis (1983) was conducted on Bogue Banks and is used as a seminal study on beach projects throughout the southeastern United States. "The Ecological Impact of Beach Nourishment with Dredged Materials on the Intertidal Zone at Bogue Banks, North Carolina" concluded that beach nourishment virtually destroys existing intertidal macrofauna, but that recovery is rapid once the pumping operation ceases. In most cases, recovery occurs within one or two seasons following the sediment placement. Reilly and Bellis stated, ". . . a speedy recovery largely depended on recruitment from pelagic larval stocks." Most species fell into this category. The few that did not, and recruited instead from neighboring beaches, were slower to recover. Recent Florida, South Carolina, and New Jersey studies of nourishment impacts suggest that beach recovery rates are typically measured in weeks to months rather than months to years (RK Van Dolah Aug'99, pers comm). The New Jersey experience is documented in USACE-Burlas et al (2001) who found that benthic populations generally recovered to predredging conditions in 2-6 months. The South Carolina experience is documented in Jutte et al (1999).

4.9.5 Impacts to Beach and Terrestrial Resources

The project will introduce new sediments to the littoral profile seaward of the base of existing dunes and escarpments. Therefore, it is not expected to have an adverse impact on dune and terrestrial resources. It will add beach-quality sediment to the existing beach profile and mix with native sediment under normal littoral processes. Placement by hopper dredge is expected to reduce the percentage of mud below the average of ~4 percent that occurs in borrow areas prior to discharge on the beach. Fine-grained sediments will be further sorted during placement and subsequent fill adjustment with most washing seaward into the surf zone in the slurry discharge. Upon completion, the dry beach will provide fine sand for aeolian transport and natural nourishment of the foredune.

Project construction will result in disturbance and removal of some of the existing vegetation along the seaward side of the existing dune. Dune stabilization with vegetative planting will take place only in the isolated sections of the project where new dunes are built. Most of the project has vegetated dunes. The project is intended to widen the base of the dunes and the beach face, not build up the dune itself. Thus, replanting makes sense only for those areas where new dune will be built. The Reilly and Bellis (1983) study that focused on the intertidal zone also encompassed dry-beach sampling. Most species, including all of the larger organisms such as crabs, recruited from pelagic larvae and thus recovered rapidly (one or two seasons). The project will provide beneficial impacts in the form of creation of additional dry beach and foredune habitat.

4.10 THREATENED AND ENDANGERED SPECIES IMPACTS

In accordance with the requirements for federal review of the proposed project, the following section has been prepared. Threatened and endangered species for eastern North Carolina are given in North Carolina Heritage Program data and in Wynne (1999) for species migrating along the coast.

The presence of threatened and endangered species in the project area depends on the availability and abundance of appropriate habitat. Because the Bogue Banks nourishment project area does not contain any freshwater or forested areas, the eastern cougar, American alligator, red-cockaded woodpecker, and roughleaf loosestrife are not likely to be found at this site and will not be affected by the proposed actions.

Listed species that could potentially be located at Bogue Banks during the proposed action are the finback whale, humpback whale, right whale, sei whale, sperm whale, West Indian manatee, piping plover, roseate tern, green sea turtle, hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, loggerhead sea turtle, and seabeach amaranth.

Species assessments follow.

4.10.1 Right Whale, Finback Whale, Humpback Whale, Sei Whale, and Sperm Whale

Effect Determination – Of the five species of whales being considered, only the right whale and humpback whale would normally be expected to occur within the project area during the construction period. Therefore, the other species of whales are not likely to be affected. Since sections of this beach area have received fill material in the past, this project will not significantly alter nearshore physical conditions. While some food resources may be initially affected by either dredging activities or burial associated with the beach nourishment, most invertebrates are expected to reestablish quickly from adjacent unaffected areas or through recruitment processes. Furthermore, the presence of a hopper dredge in this area should pose no more of a collision threat to migrating whales than normal commercial ship traffic. As prescribed in the NMFS 26 July 2001 and the September 1997 Regional Biological Opinion to reduce the potential for accidental collision, a whale observer with at-sea large whale identification experience will be present on the hopper dredge from the beginning of hopper dredge use through April 30 to conduct daytime observations. Because habitat conditions and food supplies will be maintained in their current states and the potential for accidental collisions with hopper dredges will be minimized, it has been determined that the proposed project is not likely to adversely affect these whale species.

4.10.2 West Indian Manatee

Effect Determination – Because the proposed dredging work is currently scheduled to occur during the time of year when manatee populations are expected to be minimal, it is unlikely that there will be any manatees in the project area during the proposed project. Therefore, it has been determined that the dredging of the borrow areas and the subsequent beach nourishment are not likely to adversely affect the West Indian manatee. All conditions as prescribed in the NMFS Regional Biological Opinion (September 1997) will be implemented to insure protection of these species.

4.10.3 Piping Plover

Effect Determination – Within Bogue Banks, only the west end of Emerald Isle has been documented to support piping plovers. This area is not located within the project boundaries and will not be affected by beach nourishment or dredging activities. Therefore, the proposed project is not likely to adversely affect the piping plover. After the project, some nourishment sand is expected to migrate west into the Bogue Inlet area and contribute to the maintenance and possible enhancement of sandy spit habitat. Thus, the project could benefit this species by potentially expanding plover habitat over the ten-year life of the project.

4.10.4 Roseate Tern

Effect Determination – The roseate tern has never been observed within the project site. Bogue Banks is most likely too large and too developed an island to provide appropriate habitat for the roseate tern. Additionally, when the tern is observed in North Carolina, it is mostly during summer months, when the project is not scheduled to occur. Therefore, the project is not likely to affect the roseate tern.

4.10.5 Hawksbill, Leatherback, Kemp's Ridley, and Green Sea Turtles

Effect Determination – The hawksbill, leatherback, and Kemp's ridley sea turtles do not regularly nest along North Carolina coasts. The green sea turtle nests sporadically in North Carolina but has not been observed nesting in the project area. Therefore, beach nourishment activities are not likely to adversely affect any of these sea turtle species. However, all of these species migrate within North Carolina waters throughout the year, mostly between April and December. Hopper dredges will be used to dredge material from borrow areas located within these migratory waters and transport it to the shore. Construction activities are planned to occur between November and April to avoid the majority of nesting and migrating turtles. However, because turtles may be found in the offshore area within this time period, dredging activities may occur during moderate levels of sea turtle migration.

Hopper dredges move rapidly over the bottom sediments and can injure or kill juvenile turtles lying on the sea bottom. To prevent adverse effects to these species, all precautionary measures and conditions prescribed in the Regional Biological Opinion (25 September 1997) will be implemented pursuant to Section 7 of the ESA under NMFS purview. Observers will be on hopper dredges for the periods prescribed by NMFS to document any takes of turtle species and to ensure that turtle deflector dragheads are used properly.

4.10.6 Loggerhead Sea Turtle

Effect Determination – The proposed project could potentially affect loggerhead sea turtles in three ways. First, dredging activities proposed to occur offshore may occur in areas used by migrating juveniles. The act of dredging material with a hopper dredge may adversely affect juvenile turtles. Second, nourishing the beach with the fill material may affect nesting activities by altering nesting habitat. If the beach becomes too hard through the compaction of deposited nourishment sediments by construction equipment, it could present a physical barrier to turtle nest digging. Furthermore, beach nourishment may influence physical characteristics of beaches such as sand-grain size and shape, silt-clay content, sand compaction, moisture content, porosity/ water retention, gas diffusion rates, and color of sand grains which could alter the temperature of the beach. These factors could reduce reproductive success of nests laid in nourished areas (Crain et al 1995, Ackerman 1996). The applicants plan to alleviate impacts to nesting sea turtles in the project area by implementing steps that are now common practice or commonly listed as conditions on permits (to be determined by regulatory agencies), such as sediment quality monitoring, compaction tests, leveling scarps in the fill, and monitoring for nests. The third way the project could potentially affect loggerhead sea turtles is by increasing the area of stable dry beach (nesting habitat) and reducing the frequency of dune escarpments and beach scraping.

With the implementation of NMFS conditions during aquatic measurements and USFWS conditions when on land, loggerhead species are not expected to be adversely affected by this project. By planning to perform the majority of the project during off-season months, monitoring beach hardness, and relocating nests found in unsuitable habitat if project completion delays occur, impacts to nesting loggerhead sea turtles will be minimized. In addition, NMFS and ACOE hopper dredge protocol will be followed to minimize impacts to migrating loggerheads caused by dredges. However, because of the possibility of missing a sea turtle nest during the nest monitoring program, inadvertently breaking eggs during relocation, or injuring a migrating loggerhead with a hopper dredge, it has been determined that the project is not likely to adversely affect the loggerhead sea turtle.

Turtle Sightings Addendum – Records of public offshore sightings of various turtle species are maintained for Onslow and Raleigh Bays by the National Marine Fisheries Service in Beaufort, North Carolina. Records of public sightings were provided by Joanne B. McNeill and are given in Appendix E (Table 1) of the biological assessment report (CSE 2001) for the period April 1988 to April 2001. There were 1,233 recorded offshore sightings of sea turtles at various life stages, sizes, and species during the period of record. A summary of Onslow Bay sightings by month is listed below. The asterisk indicates dredging month for beach nourishment.

Month	No. of Sightings	Month	No. of Sightings
Jan*	0	Jul	84
Feb*	18	Aug	108
Mar*	12	Sep	79
Apr*	69	Oct	127
May	445	Nov*	103
Jun	173	Dec*	15
		TOTAL	**1233**

Reports of observed, estimated stranded lethal take levels of sea turtles at various life stages show that, by a considerable margin, trawling activities result in the highest levels of sea turtle mortality. Dredging and channel maintenance activities by the Army Corps of Engineers over the period evaluated accounted for the takings of 100 turtles in the Atlantic region. Comparatively, trawling accounted for 14,450 takings in the Atlantic and

Gulf of Mexico regions (NOAA 2001, Table 2 of Appendix 2). No data are provided for takings resulting from beach nourishment and other beach disturbing activities. Table 2 of the referenced NOAA report is provided in Appendix E of the biological assessment report (CSE 2001). It is the intent of this project to follow the same protocol for turtle protection employed by the Corps of Engineers for dredging and channel maintenance projects. Following that protocol and performing the proposed work in the period indicated should result in a similar conservative impact to both offshore and beach bound turtle populations.

4.10.7 Shortnose Sturgeon

Effect Determination – It is unlikely that the shortnose sturgeon occurs at the offshore dredging sites (F. Rohde 2000, pers comm; 26 July 2001 letter by NMFS). However, should it occur, its habitat would be only minimally altered by project construction and maintenance. This species feeds on a wide variety of invertebrates and while some food resources may be initially affected by either burial associated with beach nourishment, most invertebrates will quickly reestablish from adjacent unaffected areas or through recruitment processes. Although hopper dredges have been known to impact shortnose sturgeons, this species is not likely to be present in the project area and, therefore, impacts from dredges are not anticipated to occur. Because of the unlikelihood of shortnose sturgeon being present in the project area and because of the precautions being taken with the hopper dredges, it has been determined that the actions of the proposed project are not likely to affect the shortnose sturgeon.

4.10.8 Seabeach Amaranth

Effect Determination – Since dredging of the borrow areas will be done offshore, no impacts to amaranth plants will occur from this action. Furthermore, since beach nourishment will occur in winter months, when amaranth exists as seeds, immediate impacts from filling will be reduced. However, deeply burying existing seeds could negatively affect the amaranth population in later seasons. Assuming that seeds are located in the general position of former parent plants observed in past surveys, they may be covered by proposed beach nourishment activities. Research on the consequences of beach nourishment to amaranth seeds is somewhat inconclusive. The USACE (1995b) found that amaranth at Masonboro Inlet was more abundant in areas that recently received dredged material. In addition, 1995 survey data from the NC Natural Heritage Program found a section of Bogue Banks that was used as a disposal zone in 1994 had an increase in population from 100 to 7300 plants. Dredging activities could uncover buried seeds and allow them to germinate in deposited areas. (This benefit is unlikely to occur during this project if dredged material is supplied from areas offshore that do not contain amaranth seeds.) In contrast, Hancock (1995) concluded that amaranth seedlings generally do not emerge from depths of sand greater than 1 cm. Therefore, the added sand may be detrimental if placed on top of seeds. However, the beach nourishment that is to take place along the coast of Bogue Banks will occur on areas suffering from erosion and should ultimately expand potential habitat for the plant species.

The USACE has instituted a long-term seabeach amaranth monitoring program at every beach in North Carolina which routinely receives dredged material from federally funded projects. The program is to be conducted until such a time that enough data are available to allow a reasonable prediction of the actual impacts of each planned disposal action on the species in the future. After this beach nourishment project is complete, the project area will be monitored by the applicant to see if and where seeds survived. Within a few monitoring seasons, these data will help predict ultimate impacts of beach nourishment on amaranth at Bogue Banks and will be made available to the Corps' monitoring program. The project is not likely to adversely affect seabeach amaranth, provided measures as stated in USFWS letter dated 20 September 2001 are followed.

4.10.9 Summary Effect Determination

This assessment has examined the potential impacts of the proposed project on listed species of plants and animals which are, or may be, present in the project area. Both primary and secondary impacts to habitat have been considered. With the implementation of NMFS conditions during aquatic measurements and USFWS conditions when on land, it has been determined that the project is not likely to adversely affect the hawksbill sea turtle, leatherback sea turtle, Kemp's ridley sea turtle, green sea turtle, loggerhead sea turtle, and seabeach amaranth.

4.10.10 Summary of Protective and Mitigative Measures

To minimize impacts to nesting sea turtles and vegetative-stage seabeach amaranth, work is planned to occur during the winter months with contingencies in place for project completion beyond this period. Furthermore, sand will be placed in areas suffering from erosion, minimizing impacts to suitable sea turtle nesting habitat and expanding potential habitat for seabeach amaranth. All material will be monitored to determine beach hardness and areas where the post-disposal beach is harder than 500 CPU's will be tilled.

If any work on the project occurs between May 1 and 1 November, a beach monitoring and nest relocation program for sea turtles will be implemented. This program will include daily patrols of disposal areas at sunrise, relocation of any nests laid in areas to be impacted by fill placement, and monitoring of hatching success of the relocated nests. Sea turtle nests will be relocated to an area suitable to both the USFWS and the NC Wildlife Resources Commission's Sea Turtle Coordinator.

To reduce impacts from hopper dredges to whales, fish, and sea turtles that may be in the area of proposed dredging, NMFS and ACOE hopper dredge protocol will be followed. An observer will be present on the hopper dredge to document any takes of sea turtle species, except when water temperatures are cold enough to ensure that sea turtles will not be present (during January and February), to watch for and alert the dredge operator of whales in the area (from the beginning of hopper dredge use through March 31 for daytime observations), and to ensure that turtle deflector dragheads are used properly. Limits on take set by the USACE will be strictly followed.

Based on existing biological opinions for beach nourishment and discussions with federal resource agencies between May and August 2001, it is anticipated the following monitoring of the project will be performed.

1) *Condition Surveys* – Profile surveys for volumetric erosion changes to -15 ft NGVD or closure depth – pre and post dredging; annually for minimum for five years; ~100 profile lines.

2) *Environmental Sampling Surveys* – Borrow areas and beach as proposed by CSA plan 23 August 2001 with revisions as required by resource agencies (see Section 5.0 and Appendix A-4).

3) *Seabeach Amaranth Surveys* – Annually for minimum of 3 years in July/August.

4) *Beach Compaction Tests* – Annually prior to 1 April at 500 ft spacing along upper beach (two or three positions along profile), three replicates each at 6-inch, 12-inch, and 18-inch depths via cone penetrometer. Tilling will be performed if measurements exceed USFWS compaction criteria (typically 500 psi).

5) *Sediment Sampling* – Annual postnourishment beach and borrow area sampling at ~15 stations to compare post dredging/beach fill sediment quality with predredging condition.

6) *Turtle Nest Monitoring* by community observers (ongoing in season) to document numbers and success rates of nests/hatchlings.

4.11 VISUAL IMPACTS

The proposed project will improve the aesthetic quality of the Bogue Banks shoreline by widening the recreational beach, reducing the frequency and need for beach scraping, and allowing natural dunes to develop and become vegetated. The nourishment will decrease the slope of the land between the existing foredune and the low-tide line, thus softening the edge along the coast. Native vegetation is expected to propagate down the face of the dune over time as the dunes are fed finer sand compared to that which has been scraped into place after storms over the past five years.

Construction activities will detract from the natural vistas and provide temporary disruption over ~1-2 mile reaches at any given time. Upon initial placement, sediments from the ocean bottom will be darker than the existing beach. Experience indicates that sediment mixing and bleaching to the natural colors of sand and shell material will occur rapidly over the course of several weeks.

4.12 CONSTRUCTION IMPACTS

4.12.1 Air Quality

Discharges of pollutants into the air will occur as a result of the operation of dredging equipment offshore and earth moving equipment on the beach. The discharges will be temporary and localized and are not expected to result in any significant impact to ambient air quality standards along Bogue Banks or in Carteret County. The emissions from the portion of the project authorized by this permit fall below prescribed *deminimus* levels and, therefore, no Clean Air Act conformity determination is required.

4.12.2 Noise Levels

Dredging equipment in the ocean and earthmoving equipment on the beach will result in increased noise levels in the vicinity of the equipment during beach building operations. Beach filling and shaping operations will progress down the beach at a rate of about 500 ft per day ensuring that no single location will experience increased noise levels for more than several days.

4.12.3 Hazardous Materials and Waste

No action proposed as part of this project will cause an intentional discharge of hazardous materials or general waste into the environment. Insignificant discharges of hazardous substances could possibly occur as a result of operation of mechanical equipment on the dredging platform or by earthmoving equipment operating on the beach. State and federal regulations place a high burden of responsibility on the owner and operator of such equipment to prevent hazardous discharges. Regulations for reporting and dealing with discharges are administered by the US Coast Guard. As part of their normal operations, Coast Guard personnel will conduct safety inspections of vessels and equipment operating in the coastal waters. Those inspections include identification of possible discharges of hazardous substances. Contractors will be required to dispose general waste according to existing laws and regulations of the local municipalities, Carteret County, the State of North Carolina, and the United States.

4.13 CUMULATIVE IMPACTS

The Council on Environmental Quality (CEQ) defines cumulative impact as:

> *the impact on the environment which results from the incremental impact of the action when added to other past, present and reasonably foreseeable actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.* 40 CFR 1508.7

This assessment of cumulative impacts of the proposed action is based on recent analyses by the USACE for the proposed Dare County (NC) nourishment project. It will first focus on impacts of dredging from the proposed ocean borrow sites, and second on impacts of placement of sand material on the beach.

This assessment is also based on review of an Environment Report prepared for and published by the U.S. Department of the Interior, Minerals Management Service, entitled "Use of Federal Offshore Sand Resources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware, and Virginia," dated November 1999 (DOI 1999). The potential cumulative impacts of dredging operations for beach nourishment can be considered with respect to time-crowded perturbations, and space-crowded perturbations, as defined below.

- Time-crowded perturbations – repeated occurrence of one type of impact in the same area.
- Space-crowded perturbations – a concentration of a number of different impacts in the same area.

4.13.1 Dredging Impacts

With dredging offshore areas for beach nourishment sand, there is a concern for potential cumulative impacts as a result of repeated dredging in the borrow area within short periods of time such that the benthic community, in particular, may not have sufficient time to recover. Dredging in subsequent areas close to one another may result in impacts to potential adult recruitment to the dredged area, further lengthening recovery time (DOI, 1999).

4.13.1.1 ***Site-Specific Impacts*** – Plans for potential use of borrow sites A, B1 and B2 for project construction are shown on Figures 2.1, 3.25 and 3.26. Under the proposed plan all borrow areas (2810 acres available) would be used up to three times during cold-month construction windows only. Only a portion of the available area would be dredged for the project construction, directly impacting about 1650 acres (2.58 square miles). Dredging would be conducted over three phases (yearly dredging windows). The impacts of this activity on ocean invertebrates are discussed in section 4.9. Assuming that the borrow areas are not impacted after three phases are complete by continued dredging, unusually high sedimentation rates, or some other disturbance, a natural succession of species composition should occur, potentially restoring the area to its original levels of abundance and biomass within 1-2 years (Jutte et al 1999; USACE-Burlas et al 2001).

Excavation, performed in three phases, would average about 550 acres per year over a three year period. There will be no subsequent maintenance dredging under the proposed project. Assuming a two year recovery period, an estimated 50% of the dredged area (~825 acres) may experience time-crowded perturbation for the anticipated three-season dredging period. After completion of the project, this would no longer produce cumulative impacts.

4.13.1.2 *Local Impacts* – Cumulative impacts from space crowded perturbations would occur at a local scale, resulting from the use of A, B1 and B2 for project construction. Based on a 3-Year construction schedule, the largest area of effect would be at year 2002 when 700 acres (42.4% of project area in Phase I) are in recovery. After 2002 the area in recovery would range between 295 (Phase II) and 483 acres (Phase III).

4.13.1.3 *Statewide Impacts*

Existing Sites – There is only one existing North Carolina ocean borrow site. It is located in the nearshore ocean off of Kure Beach (about 70 miles South). Dredging requirements are about 766,000 cy every three years. Assuming that the addition of the proposed project would cause an increase in impact area apportioned over the 3-year construction period of the project,(~550 acres/year),the cumulative impact area from space crowded perturbations statewide is estimated to be about 800 acres, then decline to ~255 acres/year after year three.

Potential Sites – The USACE-Wilmington District is in the early reconnaissance planning stage of the Dare County Beaches (Hatteras to Ocracoke portion) Study. While no details are available at this stage and any assumptions are highly speculative, consideration of potential beach nourishment that may come from this study was considered prudent for a worst case assessment. Public concerns have identified
6 "hot spots" of beach erosion where potential beach nourishment is proposed. It is assumed for this analysis that 10 miles of beach nourishment could occur as early as 2008. This project could cover about 70% of the beach area (14.2 miles) proposed for the Bodie Island portion of the study area with a resulting use of approximately 260 acres annually for borrow.

4.13.1.4 Project Vicinity Impacts

There are no known similar projects within a ~50 mile radius of the project area.

The following tables graphically illustrate the relationship of the proposed borrow areas to the available habitat in the area. The available habitat area is estimated by multiplying the shoreline length of the area of consideration, by the distance from the shore of the offshore limit of proposed borrow areas. It is recognized that other methods could be used to establish an area of available habitat, but this method is considered to be both reasonable, and conservative, given the broad geographic range of the species discussed.

Local Cumulative Impact Area (A, B1 & B2)

Impact Area		Available Habitat			% Impacts	
Proposed	Potential	Shoreline length	Offshore Extent	Area-Acres, Square Miles	Proposed	Potential
1650 acres (2.58 sq. mi.)	0 acres (0 sq. mi.)	16.8 miles	3 miles	32,400 ac. (50 sq mi)	5.1%	0%

Project Vicinity Cumulative Impact Area (~50 mile radius) A, B1, B2
Ocracoke Island to North Topsail Beach

Impact Area		Available Habitat			% Impacts	
Proposed	Potential	Shoreline length	Offshore Extent	Area-Acres, Square Miles	Proposed	Potential
1650 acres (2.58 sq. mi)	0 acres (0 sq.mi)	100 miles	3 miles	192,000 ac, (300 sq.mi.)	0.9%	0%

Statewide Cumulative Impact Area
Kure Beach NC, Dare County (Hatteras to Ocracoke)

Impact Area		Available Habitat			% Impacts	
Existing & Proposed	Potential	Shoreline Length	Offshore Extent	Area-Acres,Square Miles	Existing & Proposed	Potential
2096 acres (3.28 sq. mi)	706 acres (1.1 sq.mi)	320 miles	3 miles	614,400 acres (960 sq mi)	.3%	0.1%

4.13.2 Summary of Dredging Impact on Significant Resources

Based on comments from resource agencies including National Marine Fisheries Service, Fish and Wildlife Service, NC Division of Marine Fisheries, NC Marine Fisheries Commission and others, the primary concern with the proposed use of the offshore borrow sites A, B1 and B2 is the potential for adverse impacts on important commercial fish species. The concerns are given in the correspondence section and include potential impacts to benthic food sources, impacts due to turbidity and impacts due to altered substrate.

The following EA sections describe potential impacts associated with this and other similar projects that are pertinent to this analysis.

3.14 Marine Resources
4.0 Environmental Impacts
4.7.7 Sediment Compatibility
4.8 Water Quality and Turbidity Impacts
4.9 Natural Resource Impacts
4.9.1 Impacts to Offshore Resources
4.9.2 Impacts to Special Aquatic Sites

4.9.3	Impacts to Nearshore Resources
5.0	Environmental Commitments and Mitigation
App A-1	Correspondence
App C	UNC-IMS Environmental Monitoring Study
App D	Essential Fish Habitat Report

Concern for fish species has been raised regarding turbidity, entrainment and other impacts related to operational activities. These impacts are discussed in the EA sections listed above, and were considered in preparation of this cumulative impact analysis. Of particular concern to the agencies is a cumulative degradation of habitat with an associated loss of benthic food resources. These are primary issues addressed in this analysis.

Resource Threshold Levels – There are no known and established thresholds regarding the extent of ocean bottom that can be disturbed without significant population level impacts to fisheries. Therefore, a comparison of cumulative impacts to established thresholds is not made. It is clear from the above analysis however, that the potential impact area is small relative to the area of available similar habitat on a local, vicinity and statewide basis. It is expected that there is a low risk that the direct and cumulative impacts of the proposed action and other known similar activities would reach a threshold with potential for population level impacts on important commercial fish stocks. The following discussion provides support for this conclusion.

The DOI (1999) reports that

> *The pelagic/anadromous fisheries include those marine species that are free-swimming or highly migratory and therefore can avoid the areas of dredge activity. Direct impacts to this fishery could result from noise, entrainment, gill clogging, depletion of benthic food sources, and loss of relict shoal areas that may be utilized as navigation points for some migratory marine species (T. Goodger, NMFS, pers. comm., April, 1999). The importance of benthic communities in marine food webs leading to exploitable yields of pelagic and anadromous fish is widely recognized. Decimation of benthic community populations could result in a depletion of food source for the pelagic species (e.g., red drum, weakfish, silver hake) that rely on these organisms for sustenance (Newellet al. 1998a). Yet, the mobility of these fish species enables them to avoid the dredging operational areas and obtain food sources in other unaffected forage areas incurring insignificant adverse impacts to the fishery (T.Goodger, NMFS, pers. comm., April, 1999). There is also evidence that dredging operations may benefit fish species that feed within the water column by suspending food material (Courtenay et al. 1972). Bordering regions of dredge activity could provide suitable fishing grounds due to the resuspension of food particles. Spawning, egg dispersal, and juvenile development for these species occurs inshore and away from the study area resulting in minimal impacts to the stresses already imposed upon future stock abundance.*

This is further supported by recent studies in New Jersey by the USACE Burlas et al (2001) report that certain species (eg kingfish) were attracted to the dredge slurry in New Jersey, whereas others (eg bluefish) tended to avoid areas where active dredging was occurring. In regard to physical habitat alterations it is expected that alterations in depths and bottom sediment will be minor for the proposed project because of the shallow depth of excavations and the fact that the underlying sediments closely match the surficial sediments. The election to restrict dredging to shallow cuts results from indications in other jurisdictions that recovery rates of benthic organisms in borrow areas tend to be more rapid compared with deep cuts (Dr. RK Van Dolah, SC DNR, pers comm, August 1999). Site modifications are expected to be within the range of tolerance by the species utilizing the areas and, although man-altered, consistent with natural variations in depth and sediment within the geographic range of the wintering grounds and EFH for these species.

It is acknowledged that some uncertainty regarding these potential impacts exists and therefore the proposed project plan includes preconstruction and postconstruction monitoring. The details of the monitoring plan are given in Appendix A-4 and are being developed in coordination with the concerned fisheries agencies.

4.13.3 Beach Impacts

Three major sources of beach impacts are considered in this cumulative assessment. These include local maintenance activities, disposal of dredged material from navigation projects and disposal of dredged material from offshore borrow areas for beach nourishment.

4.13.3.1 *Local Maintenance Activity*

Under the existing condition the project area is subjected to repeated and frequent maintenance disturbance by individual homeowners and local communities following major storm events. These efforts are primarily made to protect adjacent shoreline property. Such repairs consist of dune rebuilding using sand from beach scraping. Limited fill and sandbags are generally used to the extent allowable by CAMA Permit. Such activities occur not only in the project area but also along all other developed North Carolina beaches. These frequent maintenance efforts could keep the natural resources of the barrier island ecosystems from reestablishing a natural equilibrium with the dynamic coastal forces of the area.

4.13.3.2 *Beach Disposal*

Throughout North Carolina, maintenance dredging of navigation channels places sand along the state's shoreline. The placement of such material occurs within the 320 miles of beachfront along the North Carolina coastline. Maintenance activities are summarized below by mileage and maintenance schedule. The summary differentiates between beach disposal and nourishment. This breakdown is necessary to delineate between material placed in the swash zone versus on the upper beach and dune system. Calculations are based on estimated actual mileage used during any given disposal event. For instance, an approved 5-miles of ocean beach may be designated for disposal; however, during a given event only 0.4 to 1 mile of beachfront may be impacted. The assessment is made based on a 16-year period (2000-2015) and area impacts are discussed relative to the total length of North Carolina shoreline habitat available (320 miles).

Federal navigation projects have specific dimensions which are set by their authorizing documents and which remain constant until such time as their authorizations are modified through acts of Congress or specific authorities delegated to the Chief of Engineers. However, natural accumulation of sediment in the channels and harbors of these projects reduces their effective dimensions and impairs safe, predictable, and economic navigation. Therefore, maintenance dredging must be accomplished periodically in order to remove the shoals and restore the dimensions. Amounts of shoal material vary from year to year in response to the forces of nature, so dredging and disposal quantities and disposal lengths will vary likewise. Lengths reported are based on normal conditions.

Beach quality sand is a valuable resource that is highly sought by beach communities to provide wide beaches for recreation and tourism, as well as to provide hurricane and wave protection for public and private property in these communities. When beach quality sand is dredged from navigation projects, it has become common practice of the USACE to make this resource available to beach communities, to the maximum extent practicable. Placement of this sand on beaches merely represents return of material which eroded from these beaches, and is, therefore, replenishment with native material. The design of beach placement sites is very simple, generally starting at the high tide line and proceeding seaward, with a crest elevation not exceeding mean high water. Widths of beach placement zones generally reflect the wishes of the local government relative to the choice between a long, narrow beach or a shorter, wider beach.

4.13.3.3 *Beach Nourishment*

The proposed project is considered a typical beach nourishment project, although the length is greater than existing North Carolina projects. The impacts of the proposed project are littoral processes impacts discussed in Section 4.7. The impacts of beach disposal on other North Carolina beaches are considered to be similar to those described herein. The degree of cumulative impact would increase proportionally with the total length of beach impacted.

The North Carolina ocean beach (320 miles) can be divided based on the potential that a beach nourishment project will be proposed for various reaches. The Coastal Area Management Act (CAMA) applies to all North Carolina Coastal Counties. Proper beach nourishment or disposal or local maintenance as described above is generally regulated under CAMA and Corps permitting authorities alone, and for this analysis, are labeled CAMA protected. Approximately 37 percent of North Carolina beaches are in this category. It could reasonably be expected that any developed and eroding beach in this category is likely experiencing local maintenance and may be considered for disposal or nourishment in the future. Other North Carolina ocean beach areas are unlikely to be considered for beach disposal. These are beaches within the Coastal Resources Barrier System (CBRS) (19 percent), or beaches that are owned and managed by either the state (4 percent) or federal government (40 percent), primarily as national or state parks.

CRBA restricts the expenditure of federal funds in designated areas. The large majority of existing or projected disposal and nourishment projects described below are federal, with less than 2 percent of the activities conducted by private groups. While most CRBA lands are undeveloped, local maintenance activities would be expected in any developed portions. Federal and State parks allow highly restricted disposal under special use permit and conduct nourishment only as required to protect resources, such as at Assateague Island as described above. Only ~10 percent of all existing or projected disposal/nourishment in North Carolina are on beaches within this category. Of that number, 8 percent are potential nourishment projects in the early planning stage, which are highly speculative but included for worst case analysis.

This analysis quantifies these impacts in terms of the percent of North Carolina beach affected on an annual and total basis by sand disposal for maintenance of federal navigation channels, and existing, proposed or potential beach nourishment projects. Activities of others are also considered.

4.13.3.4 *Statewide Impacts*

The following summaries are statewide impacts as calculated from information available from the USACE which shows Wilmington District activities. In addition similar activities by others exist or are proposed and considered in this assessment. These activities include Figure 8 Island where private beach nourishment has occurred on about 2 miles of beach on 4 occasions between 1985 and 1999. The same area may be impacted by disposal as early as 2001 for inlet relocation. The Marine Corps currently proposes beach nourishment on about 1 mile of West Onslow Beach. Future nourishment of this site is possible.

Disposal Activities

- Average/year – 8.0 miles or 2.5 percent of total NC ocean beach (320 miles)
- Minimum for any year – 3.5 miles or 1 percent of total NC ocean beach
- Total beach affected is 22.4 miles or 7.0 percent of total NC ocean beach

Existing Beach Nourishment

- Average of 2.9 miles or 1 percent of North Carolina ocean beach
- Minimum of 0 (possible that no beach nourishment in any given year)
- Total beach affected 9.8 miles which is 3 percent of NC ocean beach
- Inclusion of Figure 8 Island (2 miles) – total beach affected 11.8 miles or 3.7 percent of North Carolina beach

4.13.3.5 *Proposed Beach Nourishment*

These numbers are highly speculative and subject to change. Includes best guess for projects that are in early study phases, i.e. study requested but not funded, & reconnaissance. Appendix A-5 contains additional information on proposed USACE nourishment projects.

- Average of 16.9 miles or 5.3 percent of North Carolina ocean beach
- Minimum would be 0 (possible none would occur in a given year)
- Maximum of 85.0 miles which is 26.6 percent of North Carolina ocean beach
- Inclusion of Onslow Beach (1 miles) and Kitty Hawk North (2.2 miles) – total beach affected 88.2 miles or 27.5 percent of North Carolina ocean beach

4.13.3.6 *Cumulative (disposal and nourishment projects existing and future)*

- Average annual impact from existing disposal and nourishment 11.0 miles, 3.4 percent of North Carolina beach.
- Maximum impact (worst case) from existing beach disposal and nourishment activities 32.2 miles, 10.1 percent of North Carolina ocean beach.
- Average impact from existing disposal and nourishment projects and proposed projects 27.8 miles, 8.7 percent of North Carolina ocean beach.
- Maximum impact (worst case) from Wilmington District existing disposal and nourishment and potential beach nourishment 119.4 miles, 37.3 percent of North Carolina ocean beach.
- Inclusion of Onslow Beach (1 miles) and Figure 8 Island (2 miles) – total beach affected 122.4 miles or 38 percent of North Carolina ocean beach.

It should be noted that only Onslow Beach and Atlantic Beach (where the Wilmington district has occasionally disposed dredge spoils from the Beaufort Inlet/Morehead City Navigation Project) are situated within 25 miles of the proposed project shoreline. There are an estimated 80 miles of protected shoreline east and north of Beaufort Inlet that are not likely to require any nourishment activities and about 15 miles of protected shorelines west of the project area that are not likely to require any nourishment activities.

It is interesting to note that ~5 percent of the North Carolina ocean beach is not regulated beyond CAMA and the Corps and is not proposed for beach nourishment or disposal. The future of this area is undetermined. Due to extreme development pressure, however, these are likely to be developed in the future unless additional protection is provided at a state or Federal level.

Beach disposal/nourishment activities are relatively limited under the base condition, 34 miles (~10 percent). These activities could potentially increase to 122 miles as early as 2013; over a threefold increase in the next 13 years. Incrementally, the proposed project would account for ~10 percent of the increase.

4.13.3.7 *Project Level Impacts* (16.8 mile project area)

a. Local Maintenance:
   - Under existing conditions approximately 15 miles (90 percent) are expected to experience frequent local maintenance, in the form of beach scraping and bulldozing, etc.
   - With the proposed project, 16.8 miles (100 percent) would be restored to conditions approaching those of about 20 years ago (circa 1980). The proposed project would increase the beach width and sand volume available on the beach to respond to the full range of littoral processes and normal beach cycle. Natural dune building is expected as a result of the influx of new sediment thus reducing the need for local maintenance activities. Experience indicates that beach disposal projects along Atlantic Beach in 1986 and 1994 by the Wilmington District significantly reduced local maintenance activities as well as storm damage compared with unnourished areas of Bogue Banks as detailed in Section 3.4. After

the project, for a period of approximately 10 years, local maintenance activities are expected to be reduced to about 10 percent of present levels (i.e. ~2 miles of shoreline).

b. Disposal Activities: None

c. Existing Beach Nourishment: None

d. Proposed Beach Nourishment: 16.8 miles or 67 percent of Bogue Banks ocean shoreline

e. Cumulative Impacts:
- 16.8 miles or 67 percent of Bogue Banks area proposed for nourishment
- Remainder ~6 miles or ~25 percent subject to USACE navigation channel and disposal activities

4.13.3.8 ***Vicinity Impacts*** [50 Miles North and South of the project (100) miles]

a. Local Maintenance:
- Under existing conditions, ~20 miles (20 percent) are expected to experience frequent local maintenance
- With project 16.8 miles (17 percent) would be nourished one time with negligible maintenance for ~10 years

b. Disposal Activities: 5 miles or .05 percent of the ocean beach in the project vicinity

c. Existing Beach Nourishment: None

d. Proposed Beach Renourishment: 16.8 miles, or 17 percent of study area proposed for nourishment

e. Cumulative Impacts:
- Existing condition includes 5 miles of beach disposal
- With all proposed and existing disposal and nourishment impacts, 21.8 miles or 22 percent of the beaches in the vicinity would be impacted.

4.13.4 Summary of Beach Disposal Impact on Significant Resources

Based on comments from resource agencies and others, the primary concern with the proposed beach disposal is the potential for adverse impacts on important commercial fish species due to disposal impacts on larvae and indirect impacts to fish and birds due to impacts on beach invertebrates. The concerns are typified by comments from the NCDMF for similar projects.

> *The Division is concerned with the adverse impacts that will occur from the project. Biological resources will be affected by dredging of material for initial project construction and by placement of material on the beach. These impacts will reoccur as the area is renourished. As stated in the document the surf zone and the nearshore waters are utilized by kingfishes, spot, croaker, bluefish, weakfish, spotted sea trout, summer flounder, striped bass, spiny dogfish, Atlantic sturgeon and other commercially and recreationally important species.*

The following EA sections describe potential impacts associated with this and other similar projects that are pertinent to this analysis.

4.9.4	Impacts to Intertidal Resources
4.9.5	Impacts to Beach and Terrestrial Resources
4.10.6	Loggerhead Sea Turtle
4.10.8	Seabeach Amaranth
4.10.10	Summary of Protective and Mitigative Measures

Concern for fishery resources have been raised regarding turbidity impacts. These impacts are fully discussed in EA Section 4.8 listed above and were considered in preparation of this cumulative impact analysis. Of particular concern to the agencies is a cumulative degradation of habitat with an associated loss of benthic food resources for fish and birds. These are primary issues addressed in this analysis.

Resource Threshold Levels – There are no known established thresholds regarding the extent of ocean beach that can be disturbed by beach disposal/nourishment without significant population level impacts on birds and fisheries that rely on the beach invertebrates for food. Therefore, a comparison of cumulative impacts to established thresholds is not made. A relatively small portion of North Carolina beaches is presently affected by these activities, about 11 percent. With the proposed action the impact area would increase to 15 percent. The existing and proposed sites are distributed in northern and southern parts of the state with existing nourishment sites in New Hanover County and a proposed action in Dare County. It is unlikely that cumulative impacts from space crowded perturbation are occurring or will occur with the construction of this project because the adjacent barrier islands are wilderness preserves (e.g. Bear Island, Shackleford Banks, Cape Island, Core Banks). The analysis suggests that the potential impact area from the proposed and existing actions is small relative to the area of available similar habitat on a vicinity and statewide basis. These areas are expected to recover food resources, which should continue to be available. It is expected that the risk that the direct and cumulative impacts of the proposed action and other existing similar activities, would reach a threshold with high potential for population level impacts on important commercial fish stocks and birds is low. The following discussion provides support for this conclusion.

DOI (1999) reports that

> *As with benthic organisms living in borrow areas, benthic organisms are significantly impacted by beach nourishment activities (Nelson 1985; Van Dolah et al. 1992). These impacts, however, are considerably shorter in duration than the impacts observed in offshore borrow areas. Because benthic organisms living in beach habitats are adapted to living in high energy environments, they are able to quickly recover to original levels following beach nourishment events; sometimes in as little as three months (Van Dolah et al. 1994; Levison and Van Dolah 1996). This is again attributed to the fact that intertidal organisms are living in high energy habitats where disturbances are more common. Because of a lower diversity of species compared to other intertidal and shallow subtidal habitats*

(Hackney et al. 1996), the vast majority of beach habitats are recolonized by the same species that existed before nourishment (Van Dolah et al. 1992; Nelson 1985; Levison and Van Dolah 1996; Hackney et al. 1996). Rakocinski et al.

The above comments are further supported by results of a seven-year monitoring program for the northern New Jersey project which found that the typical time to complete recovery of benthic populations on the beach after nourishment were 2-6 months (USACE-Burlas et al 2001).

It is acknowledged that some uncertainty regarding the rate of repopulation of food organisms and the potential for reduced population levels due to continual sand deposition exists. The proposed project plan therefore includes preconstruction and postconstruction monitoring of beach fauna. The details of the monitoring plan are given in Appendix A-4 and will be developed in coordination with the concerned fisheries agencies.

4.14 ENVIRONMENTAL COMMITMENTS AND MITIGATION

Commitments – The environmental goal of this project is to avoid and minimize adverse impacts to the extent practicable. These commitments have been divided into two categories: offshore dredging and beach disposal.

Offshore Dredging and Beach Disposal – These activities will be conducted before, during, and/or after construction.

1) No expansion of borrow area will be made._Excavation depths will be restricted to 4 ft or less in areas B1 and B2, and 3 ft or less in A.

2) Agency concerns regarding use of offshore borrow sites within an area that is wintering grounds and Essential Fish Habitat (EFH) for important commercial and sport species indicate that some additional monitoring is justified. The applicant will address these issues through the development and implementation of an integrated monitoring plan as described in Appendix A-4. The first preproject sampling has already been performed in June 2001. The second preproject sampling is scheduled for November 2001. Postproject sampling will be performed as described in Appendix A-4. The applicant will provide results of the sampling and coordinates for excavated portions of all borrow areas to the resource agencies so the areas can be considered for sampling as a part of the other research activities.

3) The applicant proposes to conduct additional physical and environmental monitoring of the project including seabeach amaranth surveys, beach compaction surveys, beach profile surveys, and sediment sampling to document changes along the beach and in the borrow areas, as detailed in Section 5.

5.0 COMMENTS AND COORDINATION

5.1 PLANNING AND COMMUNITY MEETINGS THROUGH JUNE 2001

The proposed project results from planning and community meetings initiated by the Carteret County Beach Preservation Task Force* in 1997. The task force was convened partly in response to accelerated erosion during Hurricanes *Bertha* (1996) and *Fran* (1996). Following is a chronology of the project through June 2001.

1996	– Hurricanes *Bertha* and *Fran*
1997-1999	– Periodic public meetings of Beach Preservation Task Force
August 1998	– Hurricane *Bonnie*
May 1999	– Initiate shoreline erosion assessment
June 1999	– Beach and inshore survey
	– Initiate sand search
September 1999	– Shoreline assessment and preliminary beach restoration plan
	– Plan presented to the community (CSE Baird-Stroud 1999)
	– Hurricanes *Dennis* and *Floyd*
18-22 September 1999	– Post-*Floyd* beach surveys and damage assessment
12 October 1999	– Interagency scoping meeting with USACE, USFWS, NMFS, NCDCM NCDMF, municipal officials
	– County commission presentation
November 1999	– Initiate project design and surveys
	– County contracts with CSE Baird (now Coastal Science & Engineering LLC) to engineer project
	– County contracts with UNC-IMS (Dr Peterson) to initiate environmental monitoring
1 November 1999	– Coordination meeting with county council, public forum
2-3 November	– Coordination meeting with NMFS (Sechler and Hardy), UNC-IMS (Peterson and Wells)
10 November 1999	– Coordination meetings with FEMA (post-*Floyd*)
November-December 1999	– Offshore geotechnical, cultural resources, and environmental surveys
6 January 2000	– Public forum on project – Pine Knoll Shores

---

*Carteret County Beach Preservation Task Force Members (1999)

Carl Huff (chairman, Harkers Island)
Bill Donnelly, Jr. (Atlantic Beach)
Grady Fulcher (Pine Knoll Shores)
Jack Goldstein (Indian Beach Hospitality Assn.)
Thomas R. Hoover, Jr. (councilman, Emerald Isle)
Reese Musgrave (mayor, Pine Knoll Shores)
Prof. Mike Orbach (director, Duke Marine Lab)
Bill Price, II (Pine Knoll Shores)
Jonathan Robinson (county commissioner)
Richard Stanley (Chamber of Commerce, Beaufort)
Sam Stell (county commissioner, Emerald Isle)
Roy Stevens (Ports Committee, Morehead City)
Dr. Ruth E. Sweeney (North Carolina Shore & Beach)
Prof. John Wells (director, UNC Marine Lab)
James N. Willis, III (Atlantic Beach)

and ex-officio members:
Karren Brown (park director, U.S. Park Service)
Jody Merritt (superintendent, Fort Macon State Park)
Robert Murphy (county manager, Carteret County)

February-March 2000	–	Numerous newspaper articles, television and radio pieces describing project and upcoming county funding referendum
6 March 2000	–	Draft SEPA EIS submitted to NCDCM/NCDENR
7-9 March 2000	–	Three community forums on project at White Oak Elementary School, Atlantic Beach Town Hall, and Smyrna Elementary School
19 March 2000	–	Community forum at Broad Creek Community Center
21 March 2000	–	County funding referendum fails
April-May 2000	–	SEPA EIS coordination meetings with NCDENR agencies
June 2000	–	Second annual beach/inshore survey
August-September 2000	–	SEPA EIS coordination meetings with North Carolina agencies – comments and responses
September 2000	–	Town of Pine Knoll Shores assumes responsibility for planning for Reaches 5 and 6 of county project
	–	UNC-IMS submits environmental monitoring report (Appendix C of SEPA EIS)
October 2000	–	Town of Pine Knoll Shores contracts with Coastal Science & Engineering LLC (CSE) to design Reaches 5 and 6
31 October 2000	–	Revised draft SEPA EIS with approvals from NCDENR agencies submitted to North Carolina Clearinghouse
November 2000	–	Supplementary geotechnical surveys and coastal process measurements (November 2000 to May 2001)
December 2000	–	Town of Indian Beach contracts with CSE to design Reach 4
January 2001	–	Supplementary geotechnical surveys
9 January 2001	–	Public hearing on Pine Knoll Shores bond referendum
24 January 2001	–	Permit application submitted to USACE and NCDCM for project by Carteret County
13 February 2001	–	Community forum on project – Pine Knoll Shores Town Hall
14 February 2001	–	Community forum on project – Indian Beach Town Hall
27 February 2001	–	Community forum on project – Pine Knoll Shores Town Hall
6 March 2001	–	Pine Knoll Shores funding referendum passes
16 March 2001	–	Public notice on permit application ID 200000362 published
26 March 2001	–	Town of Pine Knoll Shores and Town of Indian Beach meet with USDA to discuss requirements for project financing under a Rural Development Loan
April 2001	–	Two federal agencies (NMFS, USFWS) request that USACE require new EIS under NEPA after state reviews and approvals of Final SEPA EIS.
	–	Applicants request waiver of NEPA EIS requirement because *no federal grants* will be involved
	–	Applicants retain Coastal Science Associates Inc (CSA) (Dr Bart Baca) to conduct pre and postproject environmental monitoring surveys
2 April 2001	–	UNC-IMS resigns from project
4 April 2001	–	Final SEPA EIS complete under state review
24 April 2001	–	Indian Beach funding referendum passes
25 April 2001	–	Draft environmental monitoring plan submitted to USACE for review (revised in May and June)
11 May 2001	–	Federal interagency meeting (with USACE, USFWS, NMFS) to discuss remaining environmental assessment requirements – additional beach sampling requested by USFWS

May 2001	– Towns of Pine Knoll Shores and Indian Beach contract with CSE to perform additional beach sampling as required by USFWS
24 May 2001	– Additional sediment data submitted to USFWS – no material change in results from SEPA EIS data
6 June 2001	– USDA submits Class II environmental assessment on the project
14 June 2001	– USFWS requests stand-alone "Biological Assessment" on which to base their required biological opinion – information in SEPA EIS to be incorporated into report
June 2001	– CSA completes first of two preproject environmental samplings in borrow areas and along beach
5 July 2001	– Biological Assessment Report submitted to USACE, USFWS, and NMFS

The preceding chronology documents extensive public involvement in the proposed project since 1997. To date, the following have occurred.

- Over a dozen meetings of the Carteret County Beach Preservation Task Force.

- Approximately ten community forums and information meetings convened by Carteret County; the municipalities of Pine Knoll Shores, Indian Beach, and Emerald Isle; and citizens groups including CAST (Citizens Against Sand Tax).

- Three community funding referendums:
  - Carteret County failed because of opposition to funding formula by residents of the mainland.
  - Town of Pine Knoll Shores passed by a margin of ~2:1.
  - Town of Indian Beach passed by a margin of ~8:1.

- Two interagency scoping meetings (October 1999 and May 2001).

- Numerous articles and letters in local and regional newspapers.

- Several television and radio programs including call-in shows.

In addition, the applicants have made available for public review and comment copies of all reports associated with the project. Copies of the SEPA EIS and project reports have been distributed to nongovernmental organizations such as the North Carolina Coastal Federation for review and comment.

5.2 COMMENTS AND RESPONSES

The correspondence section of this document includes copies of comments and responses by various federal, state, and other organizations/individuals. The final state EIS under the state's SEPA review process incorporates revisions to the project and responses to comments from all corresponding state agencies.

Following submittal of the final SEPA EIS (4 April 2001), the applicants received additional comments from federal agencies and others. Responses to these comments were subsequently submitted to the USACE and are included in the correspondence section.

5.2.1 Federal Agencies

5.2.1.1 *U.S. Environmental Protection Agency*

The U.S. Environmental Protection Agency (EPA) provided comments by letter dated 13 April 2001 from William L. Cox to Colonel James W DeLony (USACE) during the commenting period. The applicant responded to comments and concerns by letter from Dr. Timothy W. Kana (consultant for the applicants) to Colonel James W DeLony on 25 April 2001, and by additional analyses and proposed mitigation measures detailed in the Biological Assessment Report and present EA. The EPA expressed concerns about the project as follows, and recommended that the concerns be addressed prior to project authorization.

A) The EPA recommended that other alternatives and a 50-year planning time frame be considered. The applicant addresses this concern in the EA with additional discussion of each alternative. Given the existing density of development, the proposed plan is considered the only practicable solution at this time. The applicant proposes to monitor the performance of the project over the first decade of its lifetime and reevaluate the economics of each alternative before implementing additional projects. In addition, the USACE-Wilmington District initiated planning in 2001 for a long-range project for Bogue Banks under a cooperative agreement with local sponsoring agencies. Results of this study will include detailed economics analyses of alternatives, and estimated costs and benefits over a 50-year design life.

B) The EPA expressed concern regarding coordination of the project with multiple political jurisdictions. The phasing and coordination of the project among the three municipal sponsors and Carteret County (co-applicant) are described in detail in the EA (Section 2.4) and in the applicant's response to comments.

C) The EPA expressed concern regarding nonpoint-source runoff and land planning. The applicant addresses this concern in the response to comments by stating there is relatively little drainage toward the ocean along Bogue Banks. Most drainage over the barrier island is directed toward the lagoon or directly into the groundwater table by percolation.

D) The EPA expressed concerns regarding impacts to hard bottom communities. The applicant addresses this concern in the EA and in responses to comments. There is presently no hard bottom believed to be in close proximity to the borrow areas and beach areas that fall within the zone of active littoral transport.

E) The EPA recommended that all agency comments be addressed in the completion of the state EIS for the project, prior to authorization. The applicant has addressed the EPA concerns and other federal and state agency concerns in the final SEPA EIS (dated 4 April 2001), various responses to comments (see correspondence section), the Biological Assessment Report, and the present EA.

5.2.1.2 *U.S. Fish & Wildlife Service*

The U.S. Fish & Wildlife Service (USFWS) provided comments at an interagency meeting on 11 May 2001 and by letters dated 1 June 2001 and 20 September 2001 from Garland Pardue to Colonel James W. DeLony. The applicant responded to comments and concerns by letter from Timothy Kana (consultant to the applicants) to Dr. Garland Pardue on 24 May 2001; by submission of a Biological Assessment Report dated 5 July 2001 (prepared by Coastal Science & Engineering, LLC, Consultant to the applicants) under the NEPA review process; and by letters from the applicants to Colonel James W. DeLony dated 21 September 2001 (Mr. Pete Allen, Carteret County), 24 September 2001 (Mayor Reese Musgrave), 24 September 2001 (Mayor Buck Fugate), and 24 September 2001 (Mr. Frank Rush, Emerald Isle Town Manager). The USFWS found the project is not likely to adversely affect any Federally-listed endangered or threatened species provided certain conservation measures are implemented as follows:

A) The project must be conducted between November 16 and April 30.

B) All fill material placed on beaches must be sand that is similar to that already existing at the beach in both coloration and grain size distribution and be free of construction debris, rocks, organic materials other foreign matter and shall not contain, on average, greater than 10 percent fines and shall not contain, on average, greater than 5 percent coarse gravel or cobble, exclusive of shell material.

C) A daily, early-morning sea turtle nest monitoring program must be implemented.

D) Sand compaction along the back beach must be monitored prior to 1 April for three subsequent years after fill placement and tilling to 36 inches depth be performed if results show compaction exceeds USFWS criteria as listed in their 20 September letter.

E) Sand compaction along the back beach must be measured prior to fill placement.

F) Visual surveys for escarpments in the fill must be made immediately after fill placement and prior to 1 April for three subsequent years, and grading be performed as necessary according to USFWS protocols as listed in their 20 September letter.

G) Seabeach amaranth surveys must be conducted before and after fill placement for a period of three years, and the general location of plants protected by a buffer zone.

H) No construction equipment or pipes shall be stored on the beach from 1 May through 15 November.

The applicants have agreed to all of the above conservation measures.

The USFWS also expressed concerns about the adequacy of sediment sampling for purposes of defining the native beach, and sediment compatibility, particularly with regard to grain size distribution, color, shell content and angularity of shell material. The applicant addressed these concerns by performing additional beach sampling and analyses (see letter and attachments dated 24 May 2001 from TO Kana to Garland Pardue, Biological Assessment Report dated 5 July 2001, and the present EA) and the above referenced correspondence. The applicant has also addressed these concerns by the following design parameters and restrictions.

1) Dredging will be restricted to those portions of borrow areas A, B1 and B2 having sediments that most closely match the native beach in terms of size distribution, shell content and overfill ratios. The areas will also fully comply with the guidelines given in USFWS comment letter dated 20 September 2001. Overfill ratios for all of area B1 and B2 were originally calculated to range from 1.97 to 2.16 as detailed in the SEPA EIS (Section 3.16.4). Additional borings were obtained which allowed delineation of selected areas within B1 and B2 that yield overfill ratios ranging from 1.50 to 1.58. Overfill ratios in borrow area A range 1.14-1.15 (Biological Assessment Report dated 5 July 2001, Table 5).

2) The contractor will be required to alternate excavations in A and B1 or A and B2 such that sediments from the two areas will be mixed on the beach. In so doing, the average overfill ratio will range 1.25-1.30 thus more closely matching the size distribution of the native beach (Biological Assessment Report, Table 6).

3) It is anticipated the project will be constructed by hopper dredge because of the requirement to alternate between borrow areas. Hopper dredges tend to wash the sediments and discharge some of the fines prior to pumping onto the beach. The net result is a reduction of mud discharged into the surf zone, and a narrowing of the grain size distribution upon placement. This is expected to have the effect of improving the match of grain sizes between the nourishment sediment and the native beach, and reducing the overfill ratios of the resulting fill.

4) Sediment color is expected to be the same as the native beach because the source sediments in the borrow areas have the same composition as beach sediments (i.e. predominantly quartz sand and calcium carbonate shell material). Sediments residing in borrow areas tend to be darker because of the reducing environment that exists and the fact that small percentages of silts and clays will tend to color the entire deposit. After mud, which gives borrow sediments their initial dark appearance, is winnowed during excavation and transfer to hopper dredges and further winnowed in the surf zone, the remaining sand and shell material will bleach on the beach. Bleaching is expected as a result of exposure of the fill to sunlight and the oxidizing conditions that occur in the intertidal and subaerial beach zone.

5) Shell content and angularity is expected to be modified as a result of placement in the surf zone. The dominant shell material in A, B1 and B2 consists of thin-walled Donax species. Such shell material will be subject to intense abrasion processes in the surf zone and is expected to be broken into smaller

fragments and rounded over time. The result is expected to be a reduction in the percentage of coarse shell material exceeding 2 mm diameter, a further narrowing of the sediment grain size distribution, and a closer match with the native sediment grain size distribution.

5.2.1.3 *National Marine Fisheries Service*

The National Marine Fisheries Service (NMFS) provided comments dated 20 April 2001(letter from Andreas Mager to Colonel James W. DeLony) during the commenting period, and subsequently on 25 June 2001 (Section 7 Endangered Species Consultation from Andreas Mager, Jr. to Colonel James W. DeLony), on 26 June 2001 (Joseph E. Powers to Colonel James W. DeLony), and 26 September 2001 (Andreas Mager, Jr. to Colonel James W. DeLony). The applicants provided responses to NMFS comments by letter dated 30 April 2001 from Timothy W. Kana (consultant for the applicants) to Colonel James W. DeLony; by letter dated 17 August 2001 from JW Forman (consultant for the applicants) to Colonel James W. DeLony; and by submission of a draft Essential Fish Habitat (EFH) Assessment Report on 10 May 2001, and submission of a Biological Assessment Report dated 5 July 2001 (both prepared by Coastal Science & Engineering, LLC, Consultant to the applicants). The EFH is provided in Appendix D of the present EA.

The NMFS concluded (letter dated 26 June 2001 from Joseph E. Powers to Colonel James W. DeLony) that a hopper dredge(s) will likely be used for most of the proposed activities and that the 25 September 1997 Regional Biological Opinion establishes adequate protocols and monitoring requirements to minimize adverse effects on listed species of concern.

The applicant agrees to abide by the NMFS 1997 Regional Biological Opinion monitoring, terms and conditions, including maintenance of endangered species observers on board the dredge during the prescribed periods.

Other issues of concern raised by NMFS and the applicants' response include the following.

A) NMFS expressed concern regarding sediment compatibility and the percentage of shell material in the proposed borrow areas. The applicant has addressed these concerns in the EA and final project plans and is proposing to combine sediments from borrow areas A, B1 and B2 during construction in such a way as to closely match the existing grain size distribution on the beach. This will entail alternating hopper loads from borrow areas A and B1/B2 at a ratio of approximately 1:2 (See above responses regarding USFWS concerns).

B) NMFS expressed concern regarding the scale and phasing of the project. The applicant has clarified the scope and schedule of work in the Biological Assessment Report (5 July 2001) and in the present EA.

C) NMFS expressed concern regarding resuspension and transport of fill material to or around hard bottom areas. The applicant addressed this concern in the Biological Assessment Report, in the EA (Section 4.8 and 4.9.2) and in responses to comments.

D) NMFS requested revisions to the applicants' proposed environmental monitoring plan and preliminary results of the June 2001 borrow area and beach sampling. The applicant submitted environmental monitoring plans (prepared by Coastal Science Associates, Inc, consultant to the applicants) on 18 April 2001, 28 May 2001, July 2001, and 23 August 2001; and submitted preliminary results from June 2001 samplings in August 2001. NMFS accepted the applicant's proposed environmental monitoring plan with conditions by letter dated 26 September 2001 (from Andreas Mager, Jr. to Colonel James W. DeLony).

E) NMFS expressed concern that the proposed borrow sediment may result in compaction that hampers sea turtle nesting (letter dated 26 September 2001). The applicant has addressed this concern by agreeing to perform compaction monitoring and till the beach according to existing protocols and requirements prescribed by USFWS as well as the state permit for the project.

5.2.2 State and Local Agencies

5.2.2.1 *North Carolina Division of Coastal Management*

The North Carolina Division of Coastal Management (NCDCM) issued a Coastal Area Management Act (CAMA) permit on 5 October 2001. The permit acknowledges the project is consistent with the North Carolina Coastal Management Program provided thirty-nine (39) conditions are met. A copy of the state permit is given in front of the permit application in Appendix A-2. The permit expires on 31 December 2004. Following are some key provisions of the permit.

A) Prior to beach nourishment, the existing mean high water line and the first line of stable vegetation must be surveyed.

B) Nourishment activities may be carried out one time under the permit using borrow areas A, B1 and B2.

C) The dredging operation shall relocate to other areas of the borrow area in the event non-compatible material is encountered.

D) A low protective dune must be pushed up if the nourished area has no protective dune at the time of construction such that the slurry will not run toward existing development. A plan for sand fences or dune plantings must be submitted to NCDCM prior to installation.

E) Endangered species protection measures must be implemented including observers on hopper dredges, use of beach compatible sediment, beach tilling, and grading of escarpments.

F) Biological monitoring must be performed according to NCDMF protocols and requirements.

G) Cultural resources at identified sites must be avoided.

H) A preconstruction conference shall be scheduled with the contractor and NCDCM prior to initiation of dredging activities.

5.2.2.2 *North Carolina Department of Environment and Natural Resources*

The North Carolina Department of Environment and Natural Resources(NCDENR), Division of Water Quality (DWQ) issued a 401 Water Quality Certification for the project on 23 March 2001 (letter from Kerr T Stevens to Robert Murphy, Carteret County Manager), stating that the proposed project (beach fill) is covered under General Water Quality Certification Number 3274. DWQ recommended that the CAMA Permit be conditioned to address all issues raised in the SEPA EIS. The CAMA permit is conditioned accordingly.

The North Carolina Wildlife Resources Commission (NCWRC) submitted comments on the draft SEPA EIS by letter dated 27 April 2000 from Franklyn McBride to Melba McGee (NCDENR). These comments were addressed by the applicants in a letter from J.W. Forman (consultant to the applicants) to Franklyn McBride dated 13 September 2000 and by way of a revised draft SEPA EIS and project plan. NCWRC responded by letter dated 24 October 2000 stating that the information in the revised SEPA EIS addressed their concerns provided the project is scheduled to avoid peak biological activity of invertebrates.

The North Carolina Division of Parks and Recreation (NCDPR) submitted comments on the draft SEPA EIS by letter dated 13 April 2000 from Stephen Hall to Melba McGee (NCDENR). These comments were addressed by the applicants in a letter from J.W. Forman (consultant to the applicants) to Stephen Hall dated 13 September 2000 and by way of a revised draft SEPA EIS and revised project plan. DPR responded by letter dated 30 October 2000 stating that the information provided in the revised SEPA EIS and in the applicant's response has addressed each of their concerns to their satisfaction.

The North Carolina Division of Marine Fisheries (NCDMF) submitted comments on the draft SEPA EIS by letter dated 18 April 2000 from David Taylor and James P. Monaghan to Melba McGee (NCDENR). These comments were addressed by the applicants in a letter from J.W. Forman (consultant to the applicants) to James P. Monaghan dated 13 September 2000 and by way of a revised draft SEPA EIS and revised project plan. DMF responded by letters dated 2 October 2000 to Melba McGee and 27 September 2001 to Doug Huggett (Division of Coastal Management) stating that DMF recommends approval of the project provided four (4) conditions are met:

A) Benthic sampling at each beach station should be conducted during the same portion of the tidal cycle.

B) Additional revisions (unspecified) be made to the environmental sampling design before Phase II and Phase III are implemented.

C) The dredging window for the project shall be 16 November to 15 April.

D) Phase I dredging and pumping shall begin at the eastern end of the project.

Regarding the timing of benthic beach sampling, the applicant's consultant (Coastal Science Associates, Inc.) performed pre-project sampling in June 2001 with all samples collected within 1.5 hours of published low tide (Dr. Bart Baca, pers comm. 4 October 2001). Given the large number of beach samples (several hundred) that are being required by the resource agencies (NCDMF and NMFS), it is not practicable to collect all samples at the exact same time. Tide range is relatively low along Bogue Banks which means the water level does not fluctuate significantly for a couple of hours around low tide when sampling is normally scheduled for logistical reasons.

5.2.2.3 *North Carolina Clearinghouse*

The North Carolina Department of Administration: No Comment

The North Carolina Department of Cultural Resources, State Historic Preservation Office provided comments dated 7 May 2001 by letter from David Brook to Doug Huggett (Division of Coastal Management) and Colonel James W. DeLony listing six (6) archeological sites along the project area and a requirement to avoid these sites. The applicants responded by letter from Timothy W. Kana (consultant to the applicants) to David Brook dated 18 May 2001 and by way of the EA and revised project plan. The CAMA permit is conditioned to require avoidance and protection of the designated sites.

5.2.3 Organizations

5.2.3.1 *Environmental Defense*

The Environmental Defense (ED) provided comments dated 13 March 2001 by letter from Michelle Duval and Daniel J Whittle to Doug Huggett (Division of Coastal Management). The same comments were provided by letter dated 12 April 2001 from Michelle Duval and Daniel Whittle to Mickey Sugg (USACE). The applicants responded by letter dated 4 April 2001 from Timothy W. Kana (consultant to the applicants) to Doug Huggett (Division of Coastal Management) and by letter dated 27 April 2001 from Kana to Mickey Sugg. The applicants also responded by way of the Biological Assessment Report, the EA and the revised project plan. Environmental Defense expressed the following concerns.

A) The ED expressed concern about cumulative and long term impacts. The applicant addressed these concerns in the above referenced correspondence and in the EA.

B) The ED requested clarification regarding how project success would be defined. The applicant addressed this concern in the above referenced correspondence and in the EA documenting design criteria for a "10-year" project based on historical erosion data and beach fill performance at Atlantic Beach among other factors.

C) The ED requested additional consideration and analysis of alternatives. The applicant addressed this concern in the EA and the above referenced correspondence.

D) The ED requested that the project sponsors fund a monitoring program. The applicants are funding a comprehensive, multi-year monitoring program that will periodically sample organisms and quantify changes in beach volumes and sediment quality.

5.2.3.2 *University of North Carolina*

The University of North Carolina (UNC) provided comments by letter dated 15 March 2001 from Charles H. Peterson to Doug Huggett (Division of Coastal Management). The same comments were provided by letter dated 13 April 2001 from Charles H. Peterson to Mickey Sugg (USACE). The applicants responded by letters dated 3 April 2001 from Timothy W. Kana (consultant to the applicants) to Doug Huggett, and dated 27 April 2001 from Kana to Sugg. Additional correspondence is provided in the present EA between Charles Peterson and representatives of the applicants (Section O. in correspondence section). UNC expressed the following concerns.

A) UNC expressed concern that the applicant was not committed to a scientifically rigorous before and after environmental monitoring of the project. The applicants have committed to performing environmental monitoring following established sampling protocols as detailed in the environmental monitoring plan contained in Appendix A-4 of the present EA. The consultant to the applicants for biological monitoring (CSA-Dr. Bart Baca) has completed over a dozen such monitoring projects in Florida, South Carolina and elsewhere. CSA's results have been submitted to resource agencies in those jurisdictions and been accepted as a basis for evaluating rates of recovery of benthic populations. An example report for Daufuskie Island (SC) is given at the back of Appendix A-4.

B) UNC requested a programmatic state EIS be prepared to address cumulative impacts. The applicant responded to this concern in the above referenced correspondence and in the EA.

C) UNC expressed concern regarding the sediment quality. The applicant responded to this concern in the above referenced correspondence, in the Biological Assessment Report, in the EA, and in revisions to the project design whereby borrow areas A and B1/B2 will be combined in a ratio of approximately 1:2 such that the closest practicable match of borrow and native sediment can be obtained. The resulting overfill ratios are expected to average approximately 1.3. The resulting mixture of sediment from borrow areas A, B1 and B2 is expected to closely match the native grain size distribution, percentages of fines and coarse material, and percentages of shell after fill placement and adjustment.

D) UNC requested the period of construction be restricted to 1 December through 31 March. The applicant responded to this concern in the above referenced correspondence.

5.2.3.3 *North Carolina Coastal Federation*

The North Carolina Coastal Federation (NCCF) provided comments by letter dated 12 April 2001 from Jim Stephenson to Mickey Sugg (USACE). The applicants responded by letter dated 27 April 2001 from Timothy Kana (consultant to the applicants) to Mickey Sugg and by way of additional analyses and explanations contained in the Biological Assessment Report and the EA. NCCF expressed the following concerns.

A) NCCF expressed concern that the SEPA EIS did not adequately address alternatives. The applicants responded to this concern by providing additional information and cost comparisons regarding alternatives in the Biological Assessment Report and the EA.

B) NCCF requested the period of construction be restricted to 1 December through 31 March. The applicant responded to this concern in the above referenced correspondence

C) NCCF expressed concern that the environmental monitoring plan was inadequate. The applicant responded to this concern in the above referenced correspondence, the Biological Assessment Report, and the EA.

D) NCCF requested more study of sand suitability for nourishment. The applicant has responded to concerns regarding sediment compatibility in the above referenced correspondence, the Biological Assessment Report, the EA and the revised project plan.

E) NCCF requested the applicant address the issue of cumulative impacts. The applicant responded to this request in the above referenced correspondence and the EA.

F) NCCF listed seven (7) policies their organization recommends regarding beach nourishment. The applicant responded to these guidelines in the above referenced correspondence.

5.2.3.4 *Other*

Citizen Don E. Morris (Newport, NC) provided comments toDoug Huugett (NCDCM) by letter dated 6 February 2001, and to Mickey Sugg (USACE) on 10 April 2001. Mr. Morris expressed concern about public hearings in regard to the SEPA EIS, about beach access along the project area, about beach scraping, and about sea level rise. The applicant addressed these concerns in correspondence dated 27 April 2001 (letter from Timothy Kana, consultant to the applicants, to Mickey Sugg (USACE).

No other comments requiring responses were received from concern citizens.

5.3 ENVIRONMENTAL MONITORING PLAN (see Appendix A-4)

The applicants have committed to performing environmental monitoring of the project and have initiated sampling. The applicants propose to perform semi-annual monitoring of the borrow areas (and adjacent control sites) and the beach (and adjacent control sites) following established methodology and protocols for Southeast (US) nourishment projects (cf, Van Dolah et al 1992). Two sampling months have been established (June and November) for purposes of quantifying impacts and recovery of biota due to the nourishment project. The first preconstruction sampling was performed in June 2001; the second is scheduled for November 2001.

Postconstruction sampling will be performed in June and November 2002 following completion of Phase I. This sampling will also yield prenourishment sampling for Phase II. Postconstruction sampling will continue in June and November 2003 and June and November 2004, and so on until recovery is demonstrated (as described below).

The applicants for Phase I (Town of Pine Knoll Shores and Town of Indian Beach) retained the firm of Coastal Science Associates Inc (CSA) (Dr Bart Baca, Jacksonville FL) to conduct the surveys and analyses. A preliminary sampling proposal dated 18 April 2001 was submitted to NMFS and North Carolina Division of Marine Fisheries (NCDMF) around 25 April. The proposal was discussed at an interagency review meeting on 11 May and was subsequently revised and resubmitted around 28 May. Comments on the revised monitoring plan were submitted to the USACE on 3 June by Dr. Charles Peterson (consultant to NCDMF). Further discussions on the monitoring plan were conducted at NMFS (Beaufort NC) on 20 June. A second revised environmental monitoring plan was submitted by CSA on 26 June.

CSA proceeded with the June 2001 sampling such that baseline conditions could be defined. Sampling followed established protocols for projects of this type. CSA's third revised proposal and preliminary results of the June 2001 sampling were submitted to the resource agencies on 23 August and are given in Appendix A-4.

The purpose of the environmental monitoring is to document the species living in and utilizing the borrow sites and project beach before and after construction and to document whether and when biological populations return to normal levels. The applicants' proposed biological monitoring plan is designed to:

- Quantify the changes in benthic populations in the borrow areas.

- Quantify the changes in benthic populations along the beach.
- Compare impacted areas with unnourished areas.
- Obtain semiquantitative data on fish populations and foraging habits in the surf zone.
- Monitor the recovery and population of ghost crabs and turtle nests in the project area.
- Monitor the occurrence of seabeach amaranth in the project area.

The duration of postproject sampling will be determined by NCDMF in consultation with NMFS. The applicants anticipate performing semi-annual sampling until one or two monitoring periods after construction demonstrate recovery of biota to preproject conditions (cf. conditions # 24-26 of the CAMA permit Number 124-01, letter dated 20 September 2001 from USFWS-Garland Pardue to Colonel James W. DeLony, and letter dated 26 September 2001 from NMFS-Andreas Mager, Jr. to Colonel James W. DeLony). Based on studies of previous nourishment projects, recovery of the beach is expected within one year of construction, and recovery of the borrow areas within two years of construction.

In the July 2001 Biological Assessment, the applicants outlined a commitment to perform up to ten samplings with the first five sponsored by the Towns of Pine Knoll Shores and Indian Beach (in connection with Phase I) and the second five to be funded by Emerald Isle (in connection with and subject to funding authorization for Phase II and III construction).

5.4 SUMMARY OF MITIGATION MEASURES

Based on comments and concerns from the above referenced correspondents and agencies, the applicant proposes to perform the following mitigation measures as required under North Carolina CAMA Permit 124-01 (Appendix A-2) and recommended by USFWS (letter dated 20 September 2001) and NMFS (letter dated 26 September 2001).

1) Semi-annual biological monitoring of borrow areas, beach-fill areas and control areas as detailed in Appendix A-4 and the referenced documents in this section.

2) Perform the work during cold weather months specifically between 16 November and 15 April. Any work required during any portion of the month of April will be reviewed with NCDCM and USACE officials prior to implementation. No work will be performed between 1 May and 15 November.

3) The project will be completed one time with no subsequent renourishment without modification of the permit.

4) All excavations will be confined to the designated areas of borrow area A, B1 and B2 and restricted to the upper 3-4 feet of section in the deposit as detailed in the CAMA permit and the present EA.

5) Temporary dikes will be used to retain and direct the discharge of dredged material along the beach as detailed in the CAMA permit.

6) Only beach quality sand with similar grain size as the existing beach will be used for nourishment. The dredge will move to other sections of the borrow area if non-compatible sediment is encountered.

7) Construction will be monitored by representatives of the applicants at all times.

8) Equipment will be removed from completed sections of the project area as soon as practicable once final grading and profile shaping is completed.

9) The contractor will be required to access the beach by way of existing accesses and restore same to their pre construction condition after use.

10) A low protective dune will be constructed in areas where there is none prior to construction so as to prevent dredge slurry from running landward into developed areas.

11) Dune disturbance will be kept to a minimum and the landward edge of construction be restricted to the area marking the approximate toe of the existing dune at the time of nourishment.

12) Dune fencing and revegetation will be performed in consultation with NCDCM officials.

13) Prior to beach nourishment, exposed remnants of or debris from failed erosion control structures will be removed by the permittee.

14) Nourishment will begin at the eastern end of the project to minimize impacts to the stop net fishery as prescribed in the CAMA permit.

15) An observer will be present on board hopper dredges to monitor takes of sea turtles or other endangered species according to protocols established by NMFS.

16) Beach quality sand suitable for sea turtle nesting and having a similar grain size as the native beach will be used.

17) Beach compaction will be monitored prior to construction and prior to turtle nesting season, and tilling will be performed to a depth of 36 inches as necessary following protocols established by North Carolina Wildlife Resources Commission and USFWS.

18) The post-nourishment beach will be monitored for escarpments and regraded as necessary following protocols established by resource agencies and described in CAMA permit 124-01.

19) The applicant will submit an Erosion and Sedimentation Control Plan at least thirty (30) days prior to the beginning of any land disturbing activity.

20) The contractor will be instructed to avoid cutural resource sites identified in NCDCR correspondence and in CAMA permit 124-01 and will otherwise safeguard any unearthed remains that my occur as a result of the project.

21) The applicant and its contractor will schedule a pre-construction conference with NCDCM representatives prior to initiation of work and review the terms and conditions of the permit.

22) The applicant will perform annual monitoring of the project to track its performance in terms of profile durability and sediment transport out of the area, and document sediment quality.

23) The applicant will submit annual monitoring reports to resource and regulatory agencies documenting the findings of environmental monitoring, and project performance surveys.

DEPARTMENT OF THE ARMY
Wilmington District, Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402

Action ID No. 200000362

October 23, 2001

ENVIRONMENTAL ASSESSMENT, FINDING OF NO SIGNIFICANT IMPACT AND STATEMENT OF FINDINGS

Applicants:

Carteret County
c/o: Mr. Pete Allen
Carteret County Courthouse
Courthouse Square
Beaufort, North Carolina 28516-1898

The Town of Emerald Isle
c/o: Mayor Barbara Harris
7500 Emerald Isle
Emerald Isle, North Carolina 28594

The Town of Indian Beach
c/o: Mayor W.L. Fugate
Post Office Box 306
Indian Beach, North Carolina 28575

The Town of Pine Knoll Shores
c/o: Mayor Reese Musgrave
100 Municipal Circle
Pine Knoll Shores, North Carolina 28512

This document constitutes my Finding of No Significant Impact, Statement of Findings, and incorporates the applicant's October 19, 2001 "Environmental Assessment Bogue Banks Beach Nourishment Project Carteret County North Carolina" as my Environmental Assessment.

This permit action is being taken under authority delegated to the Wilmington District Engineer by the Secretary of the Army and the Chief of Engineers by Title 33, Code of Federal Regulations, Part 325.8, pursuant to:

__X__ Section 10 of the Rivers and Harbors Act of 1899.
__X__ Section 404 of the Clean Water Act.
______ Section 103 of the Marine Protection, Research and Sanctuaries Act.
______ Section 4(e) of the Outer Continental Shelf Lands Act of 1953.
__X__ Section 401 of the Clean Water Act. Water Quality Certification issued by the North Carolina Division of Water Quality.
______ Section 402 of the Clean Water Act. National Pollutant Discharge Elimination System (NPDES) permit issued by the North Carolina Division of Water Quality.
__X__ Section 307 of the Coastal Zone Management Act. Consistency concurred/CAMA permit issued by North Carolina Division of Coastal Management.
__X__ Conforms to the Section 404(b)(1) Guidelines, (40 CFR 230, FR 24 DEC 80).
______ Conforms to the Ocean Dumping Criteria (40 CFR 220-229, FR 11 JAN 77).

Project Description:

Carteret County, Pine Knoll Shores, Indian Beach, and Emerald Isle are proposing to conduct a beach nourishment project on Bogue Banks Island adjacent to the Atlantic Ocean. Specifically, the project boundary will encompass a 16.8-mile stretch, starting at the Atlantic Beach/Pine Knoll Shores Town Limit and terminating near Shipwreck Lane in Emerald Isle, approximately 1.0 mile east of Bogue Inlet. The project has been segmented into three (3) phases and six (6) separate reaches. Phase (1), which consists of Reaches 4, 5, and 6, will include Pine Knoll Shores and Indian Beach Town Limits and the community of Salter Path. This work, conducted from November 2001 to April 2002, will start at the Atlantic Beach/Pine Knoll Shores Town Limit and continue 7.1 miles (approximately 37,600 linear feet of beach) to the Salter Path/Emerald Isle Town Limit. Approximately 3.06 million cubic yards will be used for this phase. The second phase is expected to be constructed from November 2002 to April 2003, and will envelope a 3.0-mile stretch (approximately 15,700 linear feet of beach). The project boundary for this phase includes 2,800 feet of Reach 2 and all of Reach 3, starting at the Salter Path/Emerald Isle Town Limit and terminating at 30th Street. Approximately 1.68 million cubic yards of material will be used for this phase. Phase 3, which is comprised of Reach 1 and the remainder of Reach 2, includes a 6.7-mile stretch (approximately 35,400 linear feet) from 30th Street to Shipwreck Lane. The amount of material used in this phase is estimated at 1.96 million cubic yards.

Plans show the use of approximately 6.7 million cubic yards of material for the entire project. Typical fill sections would add approximately 44 to 113 cubic yards per linear foot of beach and advance the shoreline 50 to 125 feet. The scope of the work consists of utilizing three offshore borrow sites, A, B1, and B2, as a source of dredge material to nourish the beach. Borrow Site A is located approximately 3.0 miles offshore from the Indian Beach/ Emerald Isle Town limits (Reach 3 & 4) and contains approximately 3.1 million cubic yards of usable material. The total area of this borrow site is approximately 1,460 acres. Borrow Site B1 is positioned approximately 2,500 linear feet offshore of Pine Knoll Shores (Reaches 5 & 6). Comprising 2.2 million cubic yards of usable material, this borrow area is approximately 520 acres in size. Borrow Site B2 is located approximately 2,000 linear feet offshore between Borrow Site A and the mainland. This borrow area contains approximately 3.4 million cubic yards of usable material and encompasses an 830 acre area.

Equipment used in the nourishment activity will be a hydraulic dredge. Of these dredges, there is a 95 percent probability that the work will be accomplished using a hopper dredge. The hopper dredge will make cuts 2.0 feet deep in the borrow Site A and 3.0 feet deep in Borrow Sites B1 & B2, with a 1.0 foot margin of error. Once the dredge is full to capacity, the material is transported to a buoyed pipeline anchored near shore and pumped via submerged pipeline to the dry beach. The dredged material will be deposited in an area between the foredune and a temporary dike that will be constructed 150-200 feet seaward of the foredune. This will allow the coarser material to settle out within a contained system while the finer sediment washes into the surf zone. As the material is disposed on the beach, bulldozers will be used to spread the material to an elevation of +7.0 feet NGVD. The dimensions of the beach profile will vary contingent upon site-specific deficits. Daily operations will work within 500 to 1,000 linear foot of shoreline. Upon completion of a section, the submerged pipe and equipment will be relocated to the next section.

The purpose of the project is to restore the recreation beach and its associated habitats in the chronic erosion areas of Bogue Banks, and to preserve property values and the tax base of Carteret County. The shoreline has been severely damaged within the last five years from hurricanes and winter storms, and is expected to show increasing erosion problems that will affect over 395 threatened dwellings if the nourishment project is not completed. This section of Bogue Banks Barrier Island generates critical tourist and tax revenue and the continuing erosion is expected to threaten this valuable public economic resource for Carteret County. The proposed nourishment project is to ensure short and long term protection of this resource.

Environmental Setting:

Bogue Banks is a 25-mile long barrier island that traverses east and west with a southward facing ocean shoreline. The island is between two major tidal inlets, Bogue Inlet to the west and Beaufort Inlet, a major commercial inlet, to the east. Bogue Inlet drains the White Oak River and western Bogue Sound while Beaufort Inlet drains the Newport River, eastern Bogue Sound and portions of the North River. Bogue Sound borders the north side of the island while Onslow Bay of the Atlantic Ocean flanks the south side. Of the 80 miles of Carteret County barrier island shoreline, Bogue Banks is the only developed area.

Environmental Impacts:

(Reference the October 19, 2001 "Environmental Assessment Bogue Banks Beach Nourishment Project Carteret County North Carolina", as "EA" in this document, for details on environmental impacts incurred with this project):

Impacts are expected within the borrow sites, intertidal, and onshore areas. Benthic sessile organisms, predominantly polychaete worms, inhabiting the areas to be dredged will be removed with the use of the hopper dredge or other hydraulic dredges. Once extracted and pumped onto the beach, these organisms will be buried and eliminated. However, impacts to benthic organisms will be minimized with the hydraulic dredge cutting to shallow depths of only 2-3.0 feet and leaving undisturbed strips within the borrow sites. It is anticipated that benthic recolonization of the borrow sites will occur in a range from a few months to 2.0 years.

For benthic invertebrates, such as mole crabs, amphipods, isopods, coquina clams, and polychaete worms, living nearshore and in the intertidal zone, impacts will be immediate. These organisms will be smothered with the placement of dredged material on the beach. However, several studies (as documented in the "EA") have shown benthos populations recovering within 6.5 months after completion of beach nourishment projects. With these results, impacts are expected to be short term.

With the expected short-term impacts to the benthic communities, it is anticipated this will result in some affects to demersal organisms since benthos organisms are a predominant food source, and, in turn, affect pelagic species that feed on demersal species. These organisms, specifically spot, croaker, sea mullet, summer flounder, menhaden, and shrimp species, contain an important commercial value for the fishing industry. However, these impacts are expected to be short lived due to the fact that the borrow area comprise of only 3 percent of the ocean bottom for Bogue Banks Barrier Island. These organisms are mobile, and have the ability to retrieve food and inhabit the surrounding undisturbed ocean bottom and water column. Additionally, the project will take place in three separate phases. This is expected to allow portions of the borrow areas in Phase 1 to recoup some of the losses during a 6.5 month period prior to undertaking Phase 2, likewise with Phase 2 and 3.

Additional impacts to both demersal and pelagic dwellers are expected from the resulting turbidity of the dredging and disposal operation. Turbidity, or suspended particulates, will damage respiratory structures of larvae and juvenile fish inhabiting the borrow sites and the intertidal areas. Additionally, the turbidity is expected to affect feeding activities, in the immediate area, for fish species relying on sight to detect their prey. Although these impacts are unavoidable, the severity of the suspended sediments can be reduced contingent on the percentage of fines (silts and clays) or mud content in the material dredged (NC and Army Corps of Engineers target materials with <10% mud content as a general guideline). The material to be extracted from borrow sites are the following: 1) Borrow Site A contains a mean grain size ranging from 0.51mm to 0.54mm (coarse sand), 2) Borrow Site B1 has a mean grain size averaging 0.28mm (medium sand), and 3) Borrow Site B2 results show an average mean grain size of 0.313mm (medium sand). All three borrow areas contain a percent mud content averaging 3.1 to 4.0. With these results along with natural turbidity occurrences, it is expected that long-term turbidity from the project will not occur; therefore, these impacts should be minimal.

To further protect against any unexpected long-term impacts to the pelagic, demersal, and benthos communities, a comprehensive monitoring plan will be implemented to detect any measurable changes during and upon completion of the three-phased project. The monitoring plan was coordinated with the National Marine Fisheries Service (NMFS) and the North Carolina Division of Marine Fisheries (DMF) to verify its adequacy. The results of the monitoring will not only allow for a post-construction evaluation of this beach nourishment project, but will aid in evaluating future beach nourishment proposals.

With the disposal of material onshore, minor impacts to dry beach wildlife are expected. The dry beach, including the foredune, is utilized mostly by bird species, such as seagull species, pigeons, starlings, sparrows, and black birds. These opportunistic species are accustomed to human populations and are expected to adapt to changes posed by the dredging operation. The project is expected to provide a short-term abundance of invertebrate food source, which will benefit many bird populations, specifically the gull species. Other beach wildlife impacted by the project is a scattered population of ghost crabs along the foredune, and small rodents that live among the vegetated portions of the dune. These impacts are expected to be short term due to the severity of past hurricane damage along these portions of the dry beach and foredune. In fact, these impacts should be negated since additional habitat for these organisms will be created and may result in increasing populations.

Although short-term impacts are expected, long term affects on the mentioned inhabitants of the project area are expected to be minimal. To ensure these impacts are minimal, the work will be restricted to a winter and early spring dredging window. Additionally, a monitoring plan will be implemented immediately to measure any short-term and possible long-term affects on the benthic and demersal populations within the offshore borrow sites and the onshore disposal area.

In regards to threatened and endangered species that occupy or may utilize the area, the species of concern are the whales, Right, Finback, Humpback, Sei, and Sperm; the sea turtles, Hawksbill Leatherback, Kemp's Ridley, and Green; the West Indian Manatee; the Shortnose Sturgeon; the Piping Plover; the Roseate Tern; and the Seabeach Amaranth. To ensure that these species are "not likely to be adversely affected", Section 7 consultation was initiated with both the US Fish and Wildlife Service (USFWS) and the NMFS Protective Resource Division pursuant to the Endangered Species Act. We determined that the species that may be affected were the whales, the turtles, the sturgeon, and the seabeach amaranth. However, through informal consultation with both Federal agencies, conservation measures will be implemented during and after the completion of the project to ensure that the project is "not likely to adversely affect" any of the listed species. In the period from 1996 to present, over (215) CAMA beach bulldozing permits were issued for chronic erosion from Pine Knoll Shores to Emerald Isle, in contrast to (2) CAMA permits for pre-1996 nourished Atlantic Beach. This, and other, pre-documentation of the project site and post documentation from Atlantic Beach nourished area demonstrate that the nourishment is likely to benefit seabeach amaranth populations and sea turtle nesting habitat.

<u>**State Comments**</u>:

1. The North Carolina Division of Water Quality issued 401 General Water Quality Certification Number 3274, dated March 23, 2001, for the authorization to conduct the entire 16.8 miles Bogue Banks Beach Nourishment Project with the following condition:

DWQ staff recommended that the CAMA Permit be conditioned to address all issues raised in the EA or EIS.

2. Coordination with the North Department of Cultural Resources revealed the presence of six archaeological sites along Bogue Banks. To avoid damage to these sites, the coordinates of each one has been sent to the applicant by letter dated June 29, 2001. None of these sites are located within the borrow or disposal areas. In a July 25, 2001 telephone conversation with Mr. Chris Southerly of the Archaeology Underwater Department, he stated that the agency does not object to the project, in fact, beach nourishment provides additional sand material that further protects any site located on the beach. This no objection statement is reiterated in their June 29 letter.

3. The North Carolina Division of Coastal Management determined the project to be consistent with the North Carolina Coastal Area Management Act, by letter dated October 5,

2001, provided the following conditions are met:

a. In addition to the permittee listed above, the Towns of Pine Knoll Shores, Indian Beach and Emerald Isle have all submitted documentation requesting that their municipalities be added as co-applicants to Carteret County's permit application. Consequently, these three Towns are hereby added to this permit as co-permittees, and as such are bound by all permit conditions contained herein.

Beach Nourishment Activities

b. Prior to the initiation of any beach nourishment activity above mean high water (MHW) within the limits of the permittee's jurisdiction (e.g. Pine Knoll Shores), easements from all property owners within that specific community must be obtained.

c. Prior to the initiation of any beach nourishment activity, the existing mean high water line and the first line of stable natural vegetation used as the reference point for measuring future oceanfront setbacks must be delineated and the line approved by representatives from the Division of Coastal Management. The approved lines must be surveyed in and the survey submitted to Division. If nourishment activity for a particular community is not initiated within sixty (60) days and/or there is a major shoreline change prior to the commencement of beach nourishment of beach nourishment, a new survey must be conducted.

d. In order to protect threatened and endangered species and to minimize adverse impacts to offshore, nearshore, intertidal and beach resources no beach nourishment activity may occur from April 1 to November 15 of any year without prior approval from the North Carolina Division of Coastal Management in consultation with the NC Division of Marine Fisheries and the NC Wildlife Resources Commission.

NOTE: The permittee is advised that there may be additional timing restrictions placed on the authorized project by the U.S. Army Corps of Engineers as part of the Federal permit process. Nothing in this State Permit should be construed as overriding or superceding any such Federal permit requirement.

e. This permit authorizes beach nourishment activities to be carried out one (1) time along the entire reach of the requested project area. Any request to carry out additional activities within an area where nourishment activities have been completed will require a modification of this permit.

f. All excavation activities must take place within one of the three borrow areas (A, B1, and B2) as shown on the attached workplat drawings. Excavation from borrow area A shall not exceed –3' below existing contours while excavation from borrow area B1 and B shall not exceed –4' below existing contours.

g. Temporary dikes must be used to retain and direct flow of material parallel to the shoreline to minimize surf zone turbidities. The temporary dikes shall be removed and the beach graded in accordance with approved profiles upon completion of pumping activities within each specific area.

h. Only beach quality sand shall be used for beach nourishment purposes. Furthermore, sand of similar grain size to the existing beach will be used to reduce any changes in physical characteristics of the beach.

i. Should the dredging operations encounter any non-beach compatible sand, the dredge shall immediately cease operation and move to an approved area where suitable material does exist.

j. The seaward nourishment limit varies among the six nourishment plan reaches. However, the seaward nourishment limit for each reach must be conducted in accordance with the approved work plats labeled Nourishment Plan Reach 1 through 6, each dated January 19, 2001 except for reach six which is dated August 29, 2001.

k. In order to prevent leakage, dredge pipes shall be routinely inspected. If leakage is found and repairs cannot be made immediately, pumping of material shall stop until leaks are fixed.

l. Once a section is complete, piping and heavy equipment shall be removed or shifted to a new section and the area graded and dressed to final approved slopes.

m. Land-based equipment necessary for beach nourishment work shall be brought to the site through existing accesses. Should the work result in any damage to existing accesses, the accesses must be restored to pre-project conditions immediately upon project completion in that specific area.

n. Where oceanfront development exists at elevations nearly equal to that of the native beach, a low protective dune will be pushed up along the backbeach to prevent slurry from draining towards the development.

o. Dune disturbance shall be kept to a minimum. Any alteration of existing dunes shall be coordinated with the Division of Coastal Management as well as the pertinent property owner. All disturbed areas must be restored and revegetated immediately following project completion in that specific area.

p. The applicant has committed to the installation of dune fencing and plantings where appropriate. Any such proposal involving sand fence installation shall be submitted to the Division of Coastal Management for approval to insure that such installation does not impede public access or emergency vehicles and does not endanger nesting sea turtles. Any derelict sand fencing shall be immediately removed from the beach.

q. Prior to any beach nourishment activity, all exposed remnants of or debris from failed erosion control structures must be removed by the permittee.

r. The permittee shall begin dredging and pumping at the eastern end of the project to minimize impacts to the stop net fishery, unless consultations with the Division of Marine Fisheries indicate otherwise.

Endangered Species Protection

s. An observer shall be present on the hopper dredge except during the colder months of January and February to document any takes of sea turtles or other endangered species. Any encounters with threatened or endangered species will be recorded and reported to the Division of Coastal Management, the Wildlife Resources Commission, the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service. In addition, a turtle deflector draghead shall be properly used.

t. Only beach quality sand suitable for sea turtle nesting, successful incubation and hatchling emergence shall be used for beach nourishment purposes. Furthermore, sand of similar grain size to the existing beach will be used to reduce any changes in physical characteristics of the beach that may affect nest survival.

u. In accordance with commitments made in the EIS prepared for this project, immediately after completion of any phase of the beach nourishment project, and prior to the next three nesting seasons, beach compaction shall be monitored and tilling shall be conducted as necessary to reduce the likelihood o impacting sea turtle nesting and hatching activities. All tilling must be done to a depth of 36 inches and must be completed no later than May 1. An annual report on the beach compaction monitoring shall be provided to the Division f Coastal Management and the NC Wildlife Resources Commission by June 1st of each year in which monitoring takes place.

v. Should any work take place within the sea turtle nesting period of May 1st to November 15th, sea turtle crawl and nest monitoring will take place each morning. Any necessary nest relocations will be coordinated with the NC Wildlife Resources Commission and carried out by qualified personnel prior to the construction of that project section.

Biological Monitoring Requirements

w. The sampling procedures and protocols described in the August 31, 2001 sampling design submitted by Coast Science Associates will be carried out for the 2001-02 dredging window only. Prior to the initiation of activities any future dredging windows, a sampling design shall be developed in coordination with the N.C. Division of Marine Fisheries (DMF) that further satisfies DMF concerns. A copy of this monitoring protocol, as well as written approval of its acceptance by the DMF, must be provided to the Division of Coastal Management prior to initiation on dredging during these future dredge windows. All conditions and stipulations of this modified monitoring plan must be strictly adhered to.

x. For each sampling period (i.e. June and November), benthic sampling at each beach station shall be conducted during the same portion of the tidal cycle. Beach benthos, especially

Donax spp., migrates along the beach face in response to water level. Sampling all five locations along the transect as close together temporally as possible will prevent sampling the same group of animals twice.

y. Unless altered herein, the permittee shall implement the biological sampling and monitoring program outlined in Appendix C of the Environmental Impact Statement prepared for this project.

Post Nourishment Beach Sediment Monitoring

z. Beach compaction shall be monitored and tilling shall be conducted in any areas where the post nourishment beach is harder than 500 CPU's. The monitoring and tilling shall also be done in accordance with Condition (U) of this Permit.

Sedimentation and Erosion Control

NOTE: An Erosion and Sedimentation Control Plan will be required for this project. This plan must be filed at least thirty (30) days prior to the beginning of any land disturbing activity. Submit this plan to the Department to Environment and Natural Resources, Land Quality Section, 127 Cardinal Drive Extension, Wilmington, NC 28405.

Cultural Resource Protection

aa. The N.C. Department of Cultural Resources (NCDCR) has identified six archaeological sites along the Bogue Banks Reaches. These sites are listed as follows:

001BBB- Iron Steamer Pier Wreck Site
002BBB- Gun Emplacement Site
003BBB- Salter Path Site
004BBB- Cupulo Site
005BBB- Emerald Isle Pier Wreck Site
006BBB- Ocean Reef Site

The exact locations of these six sites may be confirmed by contacting a representative of the NCDCR at (919) 733-4763. All authorized work shall avoid these areas unless prior approval is obtained from NCDCR.

bb. As referenced in the text addendum to the permit application, the western portion of Borrow Area B-2 shall be avoided due to the presence of 10 magnetic anomalies.

cc. There exists the possibility that the authorized activities may unearth a beached shipwreck. Should such a finding occur, the permittee shall immediately move to another area. The NCDCR Underwater Archaeology Branch must also be contacted at (910) 458-9042 to determine appropriate response procedures.

General

dd. The permittee and/or his contractor shall schedule a pre-construction conference with a Division of Coastal Management representative prior to the initiation of any dredging activities. No attempt will be made by the permittee to prevent the full and free use by the public of all navigable waters at or adjacent to the authorized work.

ee. The authorized activity must not cause an unacceptable interference with navigation.

ff. The permittee shall comply with all U.S. Coast Guard regulations.

gg. All commitments made during the environmental review process as found in the Final Environmental Impact Statement must be adhered to, including the basic procedures described in the sampling design dated August 31, 2001 and with the associated Biological Monitoring Proposal.

hh. This permit does not grant any property rights or exclusive privileges to the permittee.

ii. The permittee shall obtain any necessary authorizations or approvals from the USACOE prior to initiation of permitted activity. All conditions of this Federal approval must be adhered to, including the commitment made by the permittee to provide public access consistent with Federal regulations and policies.

jj. The permittee and/or his contractor shall provide for proper storage and handling of all oils, chemicals, hydraulic fluids, etc., necessary to carry out the project.

kk. This permit does not authorize any permanent or long-term interference with the public's right of access and/or usage of all State lands and waters.

NOTE: This permit does not eliminate the need to obtain any additional state, federal, or local permits, approvals or authorizations that may be required.

NOTE: The permittee is advised that the State of North Carolina claims title to all lands raised above the mean high water line.

NOTE: Future nourishment activities may require a modification of this permit. Contact a representative of the Division at (252) 808-2808 prior to the commencement of any such activity for this determination.

NOTE: The permittee and/or his contractor are urged to meet with a representative of the Division prior to project initiation.

NOTE: The N.C. Division of Water Quality has authorized the proposed project under General

Water Quality Certification No. 3274 (DWQ Project No. 010324), which was issued on 03/23/01.

Federal Comments:

1. In an April 13, 2001 letter, US Environmental Protection Agency (EPA) disclosed particular aspects of the project that concerned that agency. First, EPA believes that the applicants should evaluate and formulate a long-range solution, specifically a 50-year planning time frame, instead of a 10-year design. Second, it is their belief that the implementation of this large project by four separate municipalities may result in the following difficulties: coordination of dredging sites, ensuring compliance with the permit, and ensuring that most of the municipalities will complete the project. Other concerns and measures expressed are providing mitigation for project impacts in near-shore areas by municipalities reducing stormwater runoff to these areas, revising and improving land use plans, acquiring undeveloped lots for green space, and potential impacts to nearshore hardbottom.

The applicant selected a 10-year plan due to the presence of over 395 structures, including single family, condominiums, and mobile homes that were identified as endangered in a post-Hurricane Floyd survey and the number of beach bulldozing permits annually requested. Coordination for each phase will be specific in regards to identifying borrow areas, and the applicant's will be responsible to ensure compliance with all mitigation and conservation measures for the entire project. For stormwater runoff concerns, the majority of the runoff drains toward Bogue Sound, away from the ocean, or within isolated depressions on the island. In regards to green space, over 90 percent of the oceanfront on Bogue Banks Island has been developed, with Fort Macon State Park occupying most of the undeveloped area. Avoidance of hardbottom impacts is addressed in the "EA" and EFH assessment.

2. In an April 5, 2001 letter, the US Department of the Interior Office of the Solicitor requested that a disclaimer be obtained from NC to demonstrate no affect on the delimitation of the coastline. Mr. Bobby Poole of the NC State Properties was contacted on June 11 and October 4, 2001 regarding this matter. In the October 4 discussion, Mr. Poole referenced his conversation with the NC Attorney General who stated that a disclaimer could not be legally obtained. The permit will be conditioned that the applicants obtain a NC disclaimer prior to conducting the work.

3. In a July 26, 2001 letter, the NMFS Protective Resource Division concluded informal consultation regarding listed endangered and threatened species, under their purview, within the project area. Their agency believes that any adverse effects have been adequately considered and minimized by the implementation of the terms and conditions established in the 1995 and amended 1997 Regional Biological Opinion, including the placement of observers on the dredge equipment.

4. Pursuant to the Endangered Species Act, formal consultation was initiated due to potential adverse impacts to listed species within the project area. Upon review of the July 2001 Biological Assessment, USFWS developed conservation measures that, outlined in a September

20, 2001 letter, could be implemented for the project and coordinated through informal consultation. In response, the applicants have provided written agreement to execute all identified conservation measures.

5. In a June 1, 2001 letter, USFWS provided comments pursuant to the Fish and Wildlife Coordination Act. The concerns expressed are the following: 1) 404(b)(1) guidelines, 40 CFR 230.10(c), and National Environmental Policy Act (NEPA) has not been satisfied, adding the need to prepare an EIS, 2) need to specify amount of fill volume and elaborate on turbidity and its affects, 3) inadequate sampling design in the monitoring plan, 4) incompatible material, specifically percent calcium bicarbonate, and the potential to harden the beach, 5) impacts to offshore benthos communities, 6) cumulative impacts, and 7) the permit should be modified to avoid, minimize, and mitigate anticipated adverse environmental impacts.

It was determined that a Federal EIS was not required due to the adequate documentation in the applicant's April 4, 2001 State EIS, that included considerable State agency and public input; the July 2001 Biological Assessment for Threatened and Endangered Species, the May 15, 2001 Essential Fish Habitat Assessment, and the supplemental information collected in the permit review process. Additionally, as discussed in the "EA", the implementation of a phased approach, refined borrow sites, shallow cuts in the borrow areas, altering the use of each borrow site to increase sand compatibility, pre- and post-monitoring plan for benthic and demersal organisms, monitoring threatened and endangered species during and post-construction, and routine compaction test are expected to minimize any unknown significant impacts that may occur on the quality of the human environment. Also, in a similar beach nourishment project in New Jersey, the pre-and post- monitoring results, conducted by the US Army Corps of Engineers (ACE) New York District and the Waterways Experiment Station of the USACE, in a 2001 Final Report demonstrated that only short-term affects, not significant, were incurred on the aquatic resources after the beach nourishment activity.

Fill volumes and turbidity have been specified and elaborated on in the "EA". The August 23, 2001 monitoring plan, measuring benthic and demersal impacts, was coordinated with the NMFS and the DMF, with input from Dr. Charles Peterson, and was determined to be adequate. This plan will include the borrow sites and the intertidal zone.

Based on these initial comments concerning sand compatibility, an additional 64 borings were conducted to further refine the borrow sites. Additionally, Mr. Ben Lackey of the Army Corps of Engineers (ACOE) Geotechnical Section and Mr. Phil Payonk of the ACOE Environmental Resources Section reviewed the compatibility results internally. Both Messrs. Lackey and Payonk provided comments concerning the compatibility of the proposed borrow areas. Their overall review showed the material to be compatible, with small differences that will lessen over time. Mr. Payonk provided comments concerning the higher percentage of carbonates and grain size in Borrow Site A, specifically. In conversations with Mr. Payonk, he stated that this difference is not documented to show any adverse affects on nesting turtles, benthic species, or other organisms inhabiting the project site. The project has been designed by the applicant to rotate the use of each borrow area at an approximate 2:1 ratio to reduce the deposit of Borrow Site A material in one long contiguous stretch of beach. For every four (4) loads from Borrow

Sites B1 and B2, there will be two (2) loads from Borrow Site A. This requirement to reduce the percentage of carbonate will result in additional cost to the applicant. In addition, the native beach has been described as an area that contains material with a broad distribution ban. With this broad distribution, it is expected that the material will sort out through natural processes and will be similar to the native beach. Compaction test will be conducted within designated transect to ensure cementation/hardening of the beach is not present. If the test are positive, tilling of the beach and readjusting the borrow areas for Phase II and III will take place. See "EA" addressing cumulative impacts, avoidance, minimization, and mitigation aspects of the project.

6. NMFS Habitat Conservation Division provided their concerns and comments in April 20, June 25, and September 26, 2001 letters. Their initial concerns referenced the presence of EFH within the project area, potential impacts to hardbottoms, the absence and need of monitoring plan (post and pre-construction), problems with suspended sediments (turbidity) and sand compatibility, insufficient NEPA review, and threatened and endangered species consultation under NMFS purview. In response to NMFS concerns, specifically with EFH, a May 15, 2001 EFH assessment was submitted to NMFS, and additional information was sent to their office, in an August 17, 2001 letter, addressing the above-mentioned concerns. Additionally, several meetings were conducted to resolve these issues and the August 23 monitoring plan has been approved.

Other Comments:

1. In an April 10, 2001 letter, a private citizen, Mr. Robert Murphy, expressed his concerns with the proposal. Disclosed in the letter, Mr. Murphy requested that a public hearing be held for public input on the final State EIS, the issue of public access be addressed, and that highly qualified personnel conduct all biological monitoring and paid for by the State to avoid a conflict of interest. In an October 9, 2001 telephone conversation with Mr. Mickey Sugg of my staff, these issues were adequately addressed.

2. The North Carolina Environmental Defense Fund stated, in a April 22, 2001 letter, their objections to the issuance of a permit for the following reasons: 1) the applicant should perform a new, comprehensive Environmental Impact Statement (EIS) for this project, 2) the need to develop a thorough, scientifically defensible cumulative impacts analyses for this and all ongoing and proposed beach engineering projects, and 3) the design and implementation of a statistically valid monitoring plan. It has been determined that a Federal EIS is not required as stated in paragraph (5) of Federal Comments. The applicant has addressed cumulative impacts in the October EA and has developed an approved monitoring plan.

3. In an April 12, 2001 letter, the North Carolina Coastal Federation requested the need for a Federal EIS, a public hearing, documentation examining EFH, additional information on sand compatibility, examination of cumulative impacts for all NC beach nourishment projects, and the inclusion of an adequate monitoring plan and alternative analysis. In addition, concerns were raised with allowing maintenance and potential renourishment in this project and in the applicant's requested November 1 to May 15 dredging window. For reasons stated in paragraph (2), it has been determined that a Federal EIS and public hearing is not required. EFH concerns

have been addressed, 64 additional borings have refined the borrow sites, and a monitoring plan has been approved by the DMF and the NMFS. Furthermore, the economics section of the alternative analysis has been reviewed and verified by an economist in the Planning Department of the Army Corps of Engineers as a thorough and adequate analysis. It has been confirmed that maintenance is not a part of the permit, and that the dredging window, verified by DMF, NMFS, and USFWS, will be November 16 to April 15.

4. Dr. Charles Peterson of the University of North Carolina at Chapel Hill Institute of Marine Sciences expressed his concerns, in an April 13, 2001 letter, regarding the inadequacy of the monitoring plan. Through various revisions of the plan, a final monitoring plan dated August 23, with Dr. Peterson's input, has been approved by the NCDMF and NMFS.

Alternatives:

The applicant has identified and thoroughly discussed three alternatives in its EA: 1) no action; 2) abandon property, retreat, and relocate; and 3) nourish the beach. The applicant also identified and discussed several variations of the beach nourishment alternative, including alternate borrow areas, methods of construction, fill profiles, and construction schedules.

The applicant concluded that neither the no action alternative nor the retreat/relocation alternative would not meet the project purpose of restoring the recreation beach and preserving property values and the tax base of Carteret County. The applicant also provided data on the costs to the applicant of both of these alternatives. I concur that neither the no action nor the retreat/ relocation alternative meets the applicant's purpose and need, and neither is practicable.

The only practicable alternative to ensure storm protection and to secure tax revenue within a 10-year period is to nourish the beach. Upon studying nourishment, several options were identified: lagoon sediments, inlet shoals (both inshore and offshore), nearshore bars, offshore deposits, recycled spoil sediments, accreting spits/beach deposits, attached bar deposits, inland deposits, freshwater pond deposits, fillets at jetties, and imported material. Of these choices, offshore deposits, inlet shoals (inshore and offshore), and recycled spoil sediments were more likely to provide the most compatible material to nourish the beach in the project area. Due to compatibility and other environmental concerns, the offshore deposits were the most practicable alternative as a nourishment source. See Section 2.0 of the "EA" for further details.

Evaluation:

I have reviewed and evaluated, in light of the overall public interest, the documents and factors concerning this permit application as well as the stated views of other interested agencies and the concerned public. In doing so, I have considered the possible consequences of this proposed work in accordance with regulations published in 33 CFR Part 320 to 330 and 40 CFR Part 230. The following paragraphs include my evaluation of comments received and how the project complies with the above-cited regulations.

a. Consideration of Comments: In accordance with policy guidance from the office, Chief of Engineers, Regulatory Guidance Letter 92-1, Federal Agencies Roles and Responsibilities, I have fully considered all agency comments. The proposed project will result in minimum adverse impacts to the waters of the Atlantic Ocean. It is my position that, with the inclusion of appropriate special conditions, all concerns of the responding agencies and public have been satisfied.

b. Evaluation of Compliance with 404(b)(1) Guidelines (Restrictions on discharge, 40 CFR 230.10): (An * is marked above the answer that would indicate noncompliance with the guidelines. No * marked signifies the question does not relate to compliance or noncompliance with the guidelines. An "X" simply marks the answer to the question posed.)

1. Alternatives test:

	Yes	No
	*	
a. Are there available, practicable alternatives having less adverse impact on the aquatic ecosystem and without other significant adverse environmental consequences that do not involve discharges into "waters of the United States" or at other locations within these waters?	___	X
		*
b. If the project is in a special aquatic site in a special aquatic site and is not water dependent, applicant clearly demonstrated that there are no practicable alternative sites available?	X	___

2. Special restriction. Will the discharge:

	Yes	No
	*	
a. violate state water quality standards?	___	X
	*	
b. violate toxic effluent standards (under Section 307 of the Act)?	___	X
	*	
c. jeopardize endangered or threatened species or their critical habitat?	___	X
	*	
d. violate standards set by the Department of Commerce to protect marine sanctuaries?	___	X

e. Evaluation of the EA indicates that the proposed discharge material meets testing exclusion criteria for the following reason(s):

* X Yes ___ No

(X) based on the above information, the material is not a carrier of contaminants.

( ) the levels of contaminants are substantially similar at the extraction and disposal sites and the discharge is not likely to result in degradation of the disposal site and pollutants will not be transported to less contaminated areas.

( ) acceptable constraints are available and will be implemented to reduce contamination to acceptable levels within the disposal site and prevent contaminants from being transported beyond the boundaries of the disposal site.

3. Other restrictions. Will the discharge contribute to significant degradation of "waters of the United States" through adverse impacts to:

a. human health or welfare, through pollution of municipal water supplies, fish, shellfish, wildlife and special aquatic sites?

* ___ Yes X No

b. life stages of aquatic life and other wildlife?

* ___ Yes X No

c. diversity, productivity and stability of the aquatic life and other wildlife or wildlife habitat or loss of the capacity of wetland to assimilate nutrients, purify water or reduce wave energy?

* ___ Yes X No

d. recreational, aesthetic and economic values? | * ___ X Yes No

4. Actions to minimize potential adverse impacts (mitigation). Will all appropriate and practicable steps (40 CFR 230.70-77) be taken to minimize the potential adverse impacts of the discharge on the aquatic ecosystem? | * ___ X Yes No

Summary:

I have reviewed the application, plans, and the environmental assessment furnished by the applicant. I am aware that the project would involve activities within Section 10 and 404 waters of the United States. As previously discussed, I do not consider any of these impacts significant.

After coordination with the appropriate State and Federal agencies and reviewing the application and plans and the public interest record, I find that the proposed work is not controversial, will not have a significant effect on the quality of the human environment, and complies with all requirements of National Environmental Policy Act and the 404(b)(1) Guidelines of the Clean Water Act.

I find that this application is not a major Federal action significantly affecting the human environment; and hence, the preparation of a detailed statement under Section 102(2)(c) of the National Environment Policy Act of 1969 is not required.

I have given full consideration to this application. After weighing favorable and unfavorable aspects, I find that the issuance of a permit to Carteret County, and the Towns of Pine Knoll Shores, Indian Beach, and Emerald Isle will not be contrary to the general public interest provided that it adheres to the conditions incorporated in the permit.

Approved by: Date 26 OCT 01

James W. DeLony
Colonel, U.S. Army
District Engineer

REFERENCES

Ackerman, R.A. 1996. The nest environment and the embryonic development of sea turtles. Pp. 83-106 in The Biology of Sea Turtles (Lutz, P.L. and J.A. Musick, eds.) Boca Raton, FL, CRC Press.

Allen, D. 2000. North Carolina Wildlife Resources Commission. Personal communication regarding the occurrence and distribution of piping plovers and other rare birds in the Bogue Banks area. February, 2000.

Baca, B.J., R.E. Dodge, and C. Mattison. 1991. Predicting environmental impacts from beach nourishment projects. In: Proc. Beach Preservation Technology '91. Florida Shore and Beach Preservation Assoc.

Barnes, J. 1998. *North Carolina's Hurricane History.* The University of North Carolina Press, Chapel Hill & London, 256 pp.

Bascom, W.N. 1951. The relationship between sand size and beach face slope. Trans., Amer. Geophys. Union, Vol. 32, pp. 866-874.

Beach, RA, and RW Sternberg. 1992. Suspended sediment transport in the surf zone: response to incident wave and longshore current interaction. Marine Geology, Vol 108, pp 275.294.

Boettcher, R. 2000. North Carolina Sea Turtle Coordinator, North Carolina Wildlife Resources Commission. Personal communication regarding the number of loggerhead sea turtle nests found in the project area between 1995 and 1999.

Bowen, P.R., and G.A. Marsh. 1988. Benthic faunal colonization of an offshore borrow pit in southeastern Florida. Misc. Rept. No. D-88-5, Dredging Operations Technical Support Program, U.S. Army Corps of Engineers.

CERC. 1984. *Shore Protection Manual.* 4th Edition, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Vir.; U.S. Government Printing Office, Washington, D.C., 2 vols.

CSA. 1999. Daufuskie Island beach nourishment pre-dredge monitoring study. Rep. to Applied Technology & Management, Inc., Charleston, SC. 35pp. + attach.

CSA. 2000. Daufuskie Island beach nourishment final post-dredge monitoring study. Rep. to Applied Technology & Management, Inc., Charleston, SC. 40pp + attach.

CSE. 2000. Survey Report 2000 – Bogue Banks North Carolina. Report prepared for Carteret County, Beaufort, NC; CSE, Columbia, SC, 36 pp + appendices.

CSE. 2001. Biological assessment – Bogue Banks beach nourishment project, Carteret County, North Carolina. Submitted in conjunction with federal review of permit application ID 200000362. Report prepared for USACE-Wilmington, NC; CSE, Columbia, SC, 125 pp + appendices.

CSE Baird-Stroud. 1999. Shoreline assessment and preliminary beach restoration plan: Bogue Banks. Executive Summary Report, 38 pp.

CSE-Stroud. 2001. Environmental Impact Statement, Bogue Banks beach restoration plan. EIS prepared for NC Department of Environment and Natural Resources, Division of Coastal Management; submitted by Carteret County, NC; prepared by CSE and Stroud.

Clark, M.K. 1993. Curator of Mammals, North Carolina State Museum of Natural Sciences. Personal communication regarding seasonal distribution of manatees in the Cape Fear region; p.6, In: Biological Assessment: Channel Realignment Masonboro Inlet, New Hanover County, NC. August 1995. USACOE.

Conant, T. 1993. Humpback whale: *Megaptera novaeangliae*. In *Wildlife Profiles*. Division of Conservation Education, North Carolina Wildlife Resources Commission, Raleigh, NC.

Crain, D.A., A.B. Bolten, and K.A. Bjorndal. 1995. Effects of beach nourishment on sea turtles: Review and research initiatives. *Restoration Ecology* 3(2): 95-104.

Cutler, J.K. and S. Mahadevan. 1982. Long-term effects of beach nourishment on the benthic fauna of Panama City Beach, Florida. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Misc. Report No. 82-2. 94 pp.

Dean, R.G. 1991. Equilibrium beach profiles: characteristics and applications. Jour. Coastal Research, Vol. 7(1), pp. 53-84.

Donaghue, C.R. 1999. The influence of swash processes on *Donax variabilis* and *Emerita talpoida*. Ph.D. dissertation. University of Virginia.

Elefson, E. 1999. Concerning hopper dredges. Personal communication, Weeks Marine, August.

Epperly, S.P., J. Braun, & A. Veishlow. 1995. Sea turtles in North Carolina waters. *Conservation Biology* 9(2): 384-394.

Fisher, JJ. 1967. Development pattern of relict beach ridges, Outer Banks barrier chain, North Carolina. Dissertation, UNC Chapel Hill, NC, 247 pp.

Folk, R.L., and W.C. Ward. 1957. Brazos River bar: a study in significance of grain-size parameters. Jour. Sed. Petrology, Vol. 27, pp. 3-26.

Fussell, J. 1996. Comments about Piping Plover, Beach Amaranth, and Other Declining Species on South Spit of Figure Eight Island. December, 1996.

Gorzelany, J.F. 1983. The effects of beach nourishment on the nearshore benthic macrofauna of Indialantic and Melbourne Beach, Florida. M.S. Thesis. Florida Institute of Technology. 114 pp.

Gorzelany, J.F. and W. G. Nelson. 1987. The effects of beach replenishment on the benthos of a sub-tropical Florida beach. Mar. Environ. Res. 21:75-94.

Hackney, C.T. and M.H. Posey, S.W. Ross, and A.R. Norris. 1996. A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach renourishment. Report to the U.S. Army Corps of Engineers, Wilmington, NC. 111 pp.

Hancock, T.E. 1995. Ecology of the threatened species seabeach amaranth (*Amaranthus pumilus* Rafinesque). M.S. Thesis, University of North Carolina at Wilmington.

Hanes, D.M. 1994. Turbidity and suspended sediment associated with beach nourishment dredging. In Proc. 24th Intl. Conf., Coastal Engineering '94, ASCE, New York, NY, Vol. 3, pp. 3016-3029.

Hayes, M.O. 1976. Lecture Notes. Part 1. In M.O. Hayes and T.W. Kana (eds.), *Terrigenous Clastic Depositional Environments*, AAPG Field Course, Tech. Rept. No. 11-CRD, Univ. South Carolina, Columbia, 131 pp.

Heron, S.D., T.F. Moslow, W.M. Berelson, J.R. Herbert, G.A. Steele, and K.R. Susman. 1984. Holocene sedimentation of a wave-dominated barrier-island shoreline: Cape Lookout, North Carolina. *Marine Geology*, Vol. 60, pp. 413-434.

Hine, A.C., and S.W. Snyder. 1985. Coastal lithosome preservation: evidence form the shoreface and inner continental shelf off Bogue Banks, North Carolina. *Marine Geology*, Vol. 63, pp. 307-330.

Hurme, A.K. and E.J. Pullen. 1988. Biological effects of marine sand mining and fill placement for beach replenishment: lessons for other uses. Marine Mining 7: 123-136.

Inman, DL. 1952. Measures for describing the size distribution of sediments. Jour Sediment Petrol, Vol 22, pp 125-145.

James, W.R. 1975. Techniques in evaluating suitability of borrow material for beach nourishment. Rept. No. TM-60, CERC, U.S. Army Waterways Experiment Station, Vicksburg, Miss.

Jensen, R.E. 1983. Atlantic coast hindcast, shallow-water significant wave information. WIS Rept. No. 9, Waterways Experiment Station, USACE, Vicksburg, MS, 19 pp. + app.

Jutte, P.C., R.F. Van Dolah, and M.V. Levisen. 1999a. An environmental monitoring study of the Myrtle Beach renourishment project: interitdal benthic community assessment — Phase II, Myrtle Beach. Final Report, SC Dept. Natural Resources, Charleston, 34 pp. + app.

Jutte, P.C., et al. 1999b. An environmental monitoring study of the Myrtle Beach renourishment project: physical and biological assessment of offshore sand borrow sites: Phase I, Cherry Grove borrow area. Final Report, SC Dept. Natural Resrouces, Charleston, 79 pp. + app.

Kana, T.W. 1993. The profile volume approach to beach nourishment. In D.K. Stauble and N.C. Kraus (eds.), *Beach Nourishment Engineering and Management Considerations*, ASCE, New York, N.Y., pp. 176-190.

Kana, T.W., and R.K. Mohan. 1996. Profile volumes as a measure of erosion vulnerability. In Proc. 25th Intl Conf., Coastal Engineering '96, ASCE, New York, NY, Vol. 3, pp. 2732-2745.

Kana, T.W., and R.K. Mohan. 1998. Analysis of nourished profile stability following the fifth Hunting Island (SC) beach nourishment project. Jour. Coastal Engineering, Vol. 33, pp. 117-136.

Kana, T.W., R.E. Katmarian, and P.A. McKee. 1997. The 1986-1995 Myrtle Beach nourishment project ten-year performance summary. Shore & Beach, Vol. 65(1), pp. 8-23.

Knowles, C.E., J. Langfelder, and R. McDonald. 1973. A preliminary study of storm-induced beach erosion for North Carolina. Rept. No. 73-5, North Carolina State University, 14 pp. + figs.

Komar, P.D. 1976. *Beach Processes and Sedimentation*. Prentice Hall, Englewood Cliffs, N.J., 429 pp.

Lankford, T.W. and B.J. Baca. 1989. Comparative environmental impacts of various forms of beach nourishment. In: Proc. Coastal Zone Management '89, pp. 2046-2059.

Morrimen, J. 1982. Feeding ecology of sea turtles, Biology and Conservation of Sea Turtles. Smithsonian Institute, Press, Washington, D.C.

Moser, M.L. and S.W. Ross. 1995. Habitat use and movements of shortnose and Atlantic sturgeons in the Low Cape Fear River, North Carolina. Transactions of the American Fisheries Society. 124 (2): 225-235.

NAS. 1995. *Beach Nourishment and Protection.* Committee on Beach Nourishment and Protection, Marine Board, Commission on Engineering and Technical Systems, National Research Council; National Academy Press, National Academy of Sciences, Washington, DC, 334 pp.

NCDEHNR. (Benton, S.B., C.J. Bellis, M.F. Overton, J.S. Fisher, J.L. Hench, and R. Dolan.) 1997. North Carolina long term average annual rates of shoreline change: methods report 1992 update, 20 pp. + app. A-F (North Carolina Department of Environment, Health and Natural Resources).

NCNHP. 1995. Seabeach amaranth survey, July 13-14, 1995, for Figure Eight Island, North Carolina. Unpublished data, NC Natural Heritage Program, Raleigh.

NRC. 1995. Beach Nourishment and Protection. National Research Council, National Academy Press. Washington, DC. 334 pp.

Navqi, S.M., and C.H. Pullen. 1982. Effects of beach nourishment and borrowing on marine organisms. Misc. Rept. No. 82-14, CERC, U.S. Army Corps of Engineers, 44 pp.

Nummedal, D., G.F. Oertel, D.K. Hubbard, and A.C. Hine. 1977. Tidal inlet variability — Cape Hatteras to Cape Canaveral. In Proc. Coastal Sediments '77, ASCE, New York, NY, pp. 543-562.

Peterson, CH, DHM Hickerson, and G Grissom Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of the sandy beach. *Journal of Coastal Research*, Vol. 16 (2), pp. 368-378.

Pilkey, O.H. et al. 1998. *The North Carolina Shore and Its Barrier Islands*. Duke University Press, Durham, NC, 318 pp.

Pullen, E.J., and S.M. Naqvi. 1983. Biological impacts on beach replenishment and borrowing. CERC Reprint 83-3, U.S. Army Corps of Engineers.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1964. *Manual of the Vascular Flora of the Carolinas*. The University of North Carolina Press, Chapel Hill, NC.

Raymond, B, and A Antonius. 1997. Biological monitoring of the John U Lloyd beach restoration project. Final Report to the Broward County Erosion Prevention District, DE Britt Assoc, Inc, 41 pp. (cited in USACE-Burlas et al, 2001).

Reed, A. 1997. Sediment distribution patterns offshore of a replenished beach: Atlantic Beach and Fort Macon State Park, North Carolina. Unpubl. M.S. Thesis, Univ. North Carolina, Chapel Hill, 74 pp. + app.

Reilly, F.J. Jr. and V.J. Bellis. 1978. A study of the ecological impact of beach nourishment with dredged materials on the intertidal zone. Institute for Coastal and Marine Resources Technical Report. No. 4.

Reilly, F.J., and V.J. Bellis. 1983. The ecological impact of beach nourishment with dredged materials on the intertidal zone at Bogue Banks, North Carolina. USACE, CERC, Ft. Belvoir, VA, Misc. Paper 83-3, 74 pp.

Roessler, TS. 1998. Effects of offshore geology and the Morehead City harbor project on eastern Bogue Banks, North Carolina. M.S. Thesis, Univ. North Carolina, Chapel Hill, 112 pp.

Rohde, F. 2000. Biological Supervisor, North Carolina Division of Marine Fisheries. Personal communication about the occurrence of shortnose sturgeon within the project area (February 17, 2000).

Ross, S.W. and J.E. Lancaster. 1996. Movements of juvenile fishes using surf zone nursery habitats and the relationship of movements to beach nourishment along a North Carolina beach: pilot project. National Oceanic and Atmospheric Administration Award No. NA570Z0318.

Saloman, C.H. 1974. Physical, chemical, and biological characteristics of nearshore zone of Sandy Key, Florida, prior to breach restoration. Final Report, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Saloman, C.H., and S.P. Naughton. 1984. Beach restoration with offshore dredged sand: effects on nearshore macrofauna. NOAA Tech. Memo. NMFS-SEF-133, U.S. Dept. Commerce.

Sarle, LL. 1977. Processes and resulting morphology of sand deposits within Beaufort Inlet, Carteret County, North Carolina. M.S. Thesis, Duke Univ., Durham, NC, 171 pp.

Schmidly, DJ. 1981. Marine mammals of the southeastern United States coast and the Gulf of Mexico. USFWS-Office of Biological Services Report No. 80/41, 165 pp.

Schubel, JR. 1977. Sediment and quality of the estuarine environment: some observations. In IH Suffett (ed), *Fate of Pollutants in the Air and Water Environments*, Part I, Vol. 8, John Wiley & Sons, New York, NY, pp 399-423.

Schwartz, FJ. 1977. *Caretta caretta caretta* (Linnaeus), Atlantic loggerhead; *Chelonia mydas* (Linnaeus), Altantic green turtle; *Eretmochelys imbricata imbricata* (Linnaeus), Atlantic hawksbill; *Lepidochelys kempi* (Garman), Atlantic ridley; *Dermochelys coriacea coriacea* (Linnaeus), Atlantic leatherback (pp 303-308). In JE Cooper, SS Robinson, and JB Funderburg (eds.), *1977 Endangered and Threatened Plants and Animals of North Carolina*, NC State Museum of Natural History, Raleigh, NC, 444 pp.

Slay, C. 1993. Right Whale Research Project, New England Aquarium. Personal communication regarding seasonal occurrence of right whales of the Cape Fear region; p.5, In: Biological Assessment: Channel Realignment Masonboro Inlet, New Hanover County, NC. August 1995. USACOE.

Trembanis, AC, HR Valverde, and OH Pilkey. 1998. Comparison of beach nourishment along the U.S. Atlantic, Great Lakes, Gulf of Mexico, and New England shorelines. *Journal of Coastal Research*, Spec Issue #26, pp. 246-251.

USACE. 1989. Supplemental biological assessment: Operation and Maintenance of Morehead City Harbor. Carteret County, North Carolina. July, 1989; pp. 5.

USACE. 1966. Beaufort Inlet to Bogue Inlet, North Carolina. U.S. House Document No. 479, 89th Congress, U.S. Army Corps of Engineers.

USACE. 1976. General design memorandum: Morehead City Harbor, North Carolina. Wilmington District, USACE, 41 pp. + app.

USACE. 1978. Bogue Banks historical beach profile data set. Digital files provided by Tom Jarrett, Wilmington District, U.S. Army Corps of Engineers.

USACE. 1989. Supplemental biological assessment: Operation and Maintenance of Morehead City Harbor. Carteret County, North Carolina. July, 1989; pp. 5.

USACE. 1992-1995. Wilmington District seabeach amaranth surveys. Unpublished data.

USACE. 1992. Design memorandum and environmental assessment: Harbor improvement, Morehead City, North Carolina. US Army Corps of Engineers, 50 pp. + app. A-M.

USACE. 1993. Environmental assessment and finding of no significant impact. Disposal of dredged material on the ocean beach of Bogue Banks from combined maintenance dredging and deepening of Morehead City harbor and pumpout of Brandt Island upland diked disposal site, Carteret County, North Carolina. Wilmington District, U.S. Army Corps of Engineers, 12 pp. + app.

USACE. 1995. *Coastal Engineering Manual: Coastal Engineering and Design: Coastal Geology.* US Army Corps of Engineers, Washington, DC, Manual No. 1110-2-1810.

USACE. 1995. Environmental Assessment: Channel Realignment Maintenance Dredging, Masonboro Inlet, New Hanover County, North Carolina; pp. 9-15.

USACE. 1999. Preliminary Section 111 evaluation, Morehead City Harbor/Pine Knoll Shores, North Carolina. Provided by Tom Jarrett, Wilmington District, U.S. Army Corps of Engineers, 15 pp + figures.

USACE-Burlas, Ray and Clark. 2001. CD rom copy submitted to USACE, Wilmington, via CSE letter dated 7 August 2001 to M. Sugg

USEPA. 1983. Final environmental impact statement (EIS) for Savannah (GA), Charleston (SC), and Wilmington (NC) ocean-dredged material disposal sites designation. U.S. Environmental Protection Agency, Washington, DC.

USFWS. 1991. *Endangered and Threatened Species of the Southeast United States.* U.S. Fish and Wildlife Service.

USFWS. 1992. Threatened and Endangered Species of Texas. Endangered Species Office, Albuquerque, New Mexico.

USFWS. 1992a. Area south of Carolina Beach. Draft Fish and Wildlife Coordination Act Report. Division of Ecological Services, Raleigh Field Office, NC.

USFWS. 1992b. *Threatened and Endangered Species of Texas.* Endangered Species Office, Albuquerque, New Mexico.

USFWS. 1995. Seabeach amaranth technical/agency draft recovery plan, September 1995. U.S. Fish and Wildlife Service, Atlanta, GA, 75 pp.

USFWS. 1996. Piping plover (*Charadrius melodus*), Atlantic coast population, revised recovery plan. Hadley, MA, 258 pp.

USFWS. 1999a. West Indian manatees in North Carolina. http://web.ral.r4.fws.gov/mammal/manatee.html.

USFWS. 1999b. Roseate terns in North Carolina. http://web.ral.r4.fws.gov/birds/rosetern.html.

USFWS. 1999c. Shortnose sturgeon in North Carolina. http://web.ral.r4.fws.gov/fish/shortst.html.

Van Dolah, R.F., and D.M. Knot. 1984. A biological assessment of beach and nearshore areas along the South Carolina Grand Strand. Final Report, Dept. of the Interior, Fish and Wildlife Service. Marine Resources Div., SCWMR, Charleston, SC.

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levison, W.A. Roumillat. 1992. A physical and biological monitoring study of the Hilton Head Island beach nourishment project. Final Report to Town of Hilton Head Island, South Carolina; SC Wildlife & Marine Resources Div., Charleston, 159 pp.

Weakley, AS. 1986. Summary of Information on Seabeach Amaranth (*Amaranthus pumilus*). NCDHENR, Natural Heritage Program, Raleigh.

Weakley , AS, and MA Bucher. 1992. Status survey of seabeach amaranth (*Amaranthus pumilus* Rafinesque) in North and South Carolina. Report to the North Carolina Plant Conservation Program, and Endangered Species Field Office. 178p.

Wynne, B. 1999. Scoping information to be used in preparing an environmental document for the dredging of Mason Inlet, New Hanover County. North Carolina Wildlife Resources Commission, Raleigh.

APPENDIX A-1 Correspondence

APPENDIX A-2 Permit Application
APPENDIX A-3 6 June 2001 USDA Environmental Assessment
APPENDIX A-4 Revised Biological Monitoring Plan
APPENDIX A-5 USACE Preliminary Compilation

APPENDIX B Magnetometer Report (TAR)

APPENDIX C UNC-IMS Study

APPENDIX D Essential Fish Habitat Assessment

APPENDIX E Geotechnical Data

APPENDIX F – Economics Study

APPENDIX G – Littoral Processes

APPENDIX A

APPENDIX A-1

Correspondence

CORRESPONDENCE INDEX

A. Comments from NC Department of Environment and Natural Resources Departmental Review

1)	Letter	11 May 2000	Doug Huggett (Division of Coastal Management) to JW Forman (Stroud Engineering)
2)	Memorandum	5 May 2000	Melba McGee (Environmental Review Coordinator, NCDENR) to Doug Huggett (Division of Coastal Management)
3)	Memorandum	27 Apr 2000	Franklin T McBride (Wildlife Resources Commission, Division of Inland Fisheries, Habitat Conservation Program) to Melba McGee (Environmental Review Coordinator, NCDENR)
4)	Memorandum	18 Apr 2000	David Taylor and James Patrick Monaghan Jr (Division of Marine Fisheries) to Melba McGee
5)	Memorandum	17 Apr 2000	Milt Rhodes (Division of Water Quality) to Melba McGee (Environmental Review Coordinator, NCDENR)
6)	Memorandum	13 Apr 2000	Stephen Hall (Division of Parks and Recreation, Natural Heritage Program) to Melba McGee (Environmental Review Coordinator, NCDENR)
7)	Memorandum	10 Apr 2000	Shannon Stewart, John Dorney (Division of Water Quality) to Milt Rhodes (Division of Water Quality)
8)	Memorandum	11 Apr 2000	Steve Benton (Division of Coastal Management) to Melba McGee (Environmental Review Coordinator, NCDENR)

B. Responses to NCDENR Agency Comments by Consultants for the Applicant

1)	Letter	13 Sep 2000	JW Forman Jr, PE (Stroud Engineering) to James Patrick Monaghan (Division of Marine Fisheries)
2)	Letter	13 Sep 2000	JW Forman Jr, PE (Stroud Engineering) to Franklin T McBride (NC Wildlife Resources Commission, Division of Inland Fisheries)
3)	Letter	13 Sep 2000	JW Forman Jr, PE (Stroud Engineering) to Milt Rhodes (Division of Water Quality)
4)	Letter	13 Sep 2000	JW Forman Jr, PE (Stroud Engineering) to Stephan Hall (Division of Parks and Recreation)
5)	Letter	13 Sep 2000	JW Forman Jr, PE (Stroud Engineering) to Shannon Stewart (Division of Water Quality, Non-Discharge Branch)

C. Comments by NCDENR Agencies Concerning Applicants Responses to Agency Review Comments

1)	Memorandum	24 Oct 2000	William Wescott, Coastal Coordinator (NC Wildlife Resources Commission, Habitat Conservation Program) to JW Forman (Stroud Engineering)
2)	Letter	6 Oct 2000	Milt Rhodes, SEPA Coordinator (Division of Water Quality) to JW Forman (Stroud Engineering)
3)	Memorandum	2 Oct 2000	Michael D Marshall, James Patrick Monaghan (Division of Marine Fisheries) to Melba McGee, Environmental Review Coordinator (NCDENR)
4)	Memorandum	30 Oct 2000	Stephan Hall (Division of Parks and Recreation) to Melba McGee, Environmental Review Coordinator (NCDENR)

D. Comments from North Carolina State Clearinghouse

1)	Intergovernmental Review Form	2 Feb 2001	North Carolina State Clearinghouse, Department of Administration
2)	Letter	13 Mar 2001	Michelle Duval and Daniel Whittle (Environmental Defense) to Doug Huggett (NCDENR)
3)	Letter	15 Mar 2001	Chrys Baggett (NC Department of Administration) to Doug Huggett (NCDENR)
4)	Letter	15 Mar 2001	Charles Peterson (University of North Carolina at Chapel Hill, Institute of Marine Science) to Doug Huggett (NCDENR)
5)	Letter	20 Mar 2001	Doug Huggett (NCDENR) to Coastal Science & Engineering and Stroud Engineering

E. Responses to Comments from NC Clearinghouse by Consultants for the Applicant

1) Letter	3 Apr 2001	Timothy W Kana, PhD (Coastal Science & Engineering LLC) to Doug Huggett (NCDENR, Division of Coastal Management)
2) Letter	4 Apr 2001	TW Kana, PhD (Coastal Science & Engineering LLC) to Doug Huggett (NCDENR, Division of Coastal Management)

F. Certification – 401 Water Quality

1) Letter	23 Mar 2001	Kerr T Stevens (NCDENR, Division of Water Quality) to Robert Murphy (Carteret County)

G. Comments from Federal Agencies on Permit Application ID 200000362

1) Letter	13 Apr 2001	William L Cox (USEPA) to Col James W DeLony (USACE-Wilmington)
2) Letter	20 Apr 2001	Andreas Mager Jr (NMFS) to Col James W DeLony (USACE-Wilmington)
3) Letter	1 Jun 2001	Garland Pardue (USFWS) to Col James W DeLony (USACE-Wilmington)

H. Responses to Comments from Federal Agencies by Consultants for the Applicants

1) Letter	25 Apr 2001	TW Kana, PhD (Coastal Science & Engineering LLC) to Col James W DeLony (USACE-Wilmington)
2) Letter	30 Apr 2001	TW Kana, PhD (Coastal Science & Engineering LLC) to Col James W DeLony (USACE-Wilmington)
3) Letter	24 May 2001	TW Kana, PhD (Coastal Science & Engineering LLC) to Garland Pardue, PhD (USFWS)

I. Comments from Nongovernmental Organizations and Individuals on Permit Application ID 200000362

1) Letter	17 Apr 2001	Mickey Sugg (USACE-Wilmington) to Pete Allen (Carteret County) recommending response to NGO comments
2) Letter	13 Apr 2001	Charles H Peterson, PhD (UNC-IMS) to Mickey Sugg (USACE-Wilmington)
3) Letter	12 Apr 2001	Jim Stephenson (NC Coastal Federation) to Mickey Sugg (USACE-Wilmington)
4) Letter	12 Apr 2001	Michel Duval (Environmental Defense) to Mickey Sugg (USACE-Wilmington)
5) Letter	10 Apr 2001	Don E Morris (Citizen) to Mickey Sugg (USACE-Wilmington)

J. Responses to Comments from Nongovernmental Organizations and Individuals on Permit Application ID 200000362 by Consultants for the Applicants

1) Letter and Attachment		
	27 Apr 2001	TW Kana, PhD (Coastal Science & Engineering LLC) to Mickey Sugg (USACE-Wilmington) (attachment responds to all correspondents in I)

K. Comments from Consultants to the Applicants to NC Division of Marine Fisheries Regarding Draft Environmental Plan

1) Letter	25 Apr 2001	TW Kana, PhD (Coastal Science & Engineering LLC) to Michael D Marshall (NCDENR, Division of Marine Fisheries)

L. Comments from Applicants to USACE Regarding Requirements under NEPA

1) Letter	8 May 2001	Pete Allen (Carteret County) to Col James W DeLony (USACE-Wilmington)
2) Letter	3 May 2001	C Reese Musgrave, Mayor (Town of Pine Knoll Shores) to Col James W DeLony (USACE-Wilmington)
3) Letter	3 May 2001	William L Fugate, Mayor (Town of Indian Beach) to Col James W Delony (USACE-Wilmington)
4) Fact Sheet	7 Aug 2001	Unsigned response from USACE-Wilmington to applicants on permit application status and time line

M. Additional Comments and Section 7 Endangered Species Consultation from NMFS on Permit Application ID 200000362

1) Letter	25 Jun 2001	Andreas Mager Jr (NMFS-St Petersburg) to Col James W DeLony (USACE-Wilmington)
2) Letter	~26 Jul 2001	Joseph E Powers, PhD (NMFS-St Petersburg) to Col James W DeLony (USACE-Wilmington)

N. Response to Additional Comments from NMFS on Permit Application ID 200000362 by Consultants for the Applicants

1) Letter	17 Aug 2001	JW Forman Jr, PE (Coastal Science & Engineering LLC) to Col James W DeLony (USACE-Wilmington)

O. Correspondence Related to Environmental Monitoring of the Project by the Applicants

1) Letter 18 Jun 2001 TW Kana, PhD (Coastal Science & Engineering LLC) to Mickey Sugg (USACE-Wilmington) with attachments as listed in a-j:
   a) Letter and report (omitting appendices) – UNC to Carteret County dated 10 May 2000
   b) Memo – CSE (Kana) to UNC (Peterson) dated 18 May 2000
   c) Letter – USACE (Harris) to Carteret County dated 28 Feb 2001
   d) Letter – UNC (Peterson) to CSE Baird dated 2 Apr 2001
   e) Proposal – Coastal Science Associates (Florey) to CSE dated 18 Apr 2001
   f) Memo – UNC (Peterson) submitted to NC Division of Marine Fisheries (unattributed) dated 9 May 2001
   g) Revised Proposal – CSA to CSE dated 28 May 2001
   h) Letter – UNC (Peterson) to Mickey Sugg (USACE-Wilmington) dated 3 Jun 2001
   i) Letter – CSE (Kana) to Town of Pine Knoll Shores (Musgrave) dated 8 Jun 2001
2) Letter 11 Jun 2001 Bart J Baca, PhD (CSA) to Kana (CSE)
3) Email Jun 2001 BJ Baca (CSA) to TW Kana (CSE) and revised proposal for environmental monitoring (dated Jul 2001)
4) Letter 17 Jul 2001 Charles H Peterson, PhD (UNC) to Ron Sechler (NMFS)
5) Letter 18 Jul 2001 TW Kana, PhD (CSE) to Ron Sechler (NMFS-Beaufort NC)
6) Letter 5 Aug 2001 Charles H Peterson, PhD (UNC) to Ron Sechler (NMFS-Beaufort NC)

P. Final Comments and Responses from Resource Agencies

1) Letter 20 Sep 2001 Garland Pardue (UFWS) to Col James W DeLony (USACE-Wilmington)
2) Letter 26 Sep 2001 Andreas Mager Jr (NMFS-St Petersburg) to Col James W DeLony (USACE)
3) Letter 27 Sep 2001 James P Monaghan Jr (NC Div Marine Fisheries) to Doug Huggett (NCDCM)

Q. Confirmation of Acceptance of Required Conservation Measures

1) Letter 24 Sep 2001 Reese Musgrave (Town of Pine Knoll Shores) to Col James W DeLony (USACE)
2) Letter 24 Sep 2001 WL Fugate (Town of Indian Beach) to Col James W DeLony (USACE)
3) Letter 24 Sep 2001 Frank Rush (Town of Emerald Isle) to Col James W DeLony (USACE)
4) Letter 21 Sep 2001 Pete Allen (Carteret County) to Col James W DeLony (USACE)
5) Letter 1 Oct 2001 G Wayne Wright (USACE-Wilmington) to Garland Pardue (USFWS)

NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF COASTAL MANAGEMENT

NCDENR

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

DONNA D. MOFFITT
DIRECTOR

May 11, 2000

Bill Foreman
Hestron Plaza Two
151-A Highway 24
Morehead City, NC 28557

Dear Sirs:

Enclosed please find a response from the Departments SEPA coordinator concerning the Bogue Banks beach renourishment Draft Environmental Impact Statement. The SEPA coordinator has indicated that several comments have been received requesting additional information or clarification, and that these issues must be addressed through a revision of the Environmental Document. Therefore, it is requested that you enter into negotiations with the various commenting agencies in an effort to resolve or address these issues. After such negotiations, a revised EIS document should be prepared which addresses the review agency concerns, and twelve (12) copies of the revised document should be submitted to this office, at which time I will transmit the documents to the SEPA coordinator for additional review.

Please feel free to contact me at (919) 733-2293 if you would like to discuss this matter further.

Sincerely,

Doug Huggett

Doug Huggett
Permits and Consistency Unit Head
Division of Coastal Management

cc: Ted Tyndall, DCM - Morehead City

MAILING: 1638 MAIL SERVICE CENTER, RALEIGH, NORTH CAROLINA 27699-1638
PHYSICAL: 2728 CAPITAL BLVD., RALEIGH, NC 27604
PHONE: 919-733-2293 FAX: 919-733-1495

NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

NCDENR

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

RECEIVED
MAY 10 2000
COASTAL MANAGEMENT

MEMORANDUM

TO: Doug Huggett
Division of Coastal Management

FROM: Melba McGee
Environmental Review Coordinator

RE: #1046 Bogue Banks Restoration Plan, DEIS, Carteret County

DATE: May 5, 2000

The proposed project has been circulated and reviewed by our internal divisions.

Our review efforts raised a number of issues that will need to be addressed before this project is released for state review. After revisions have been made, I recommend the revised document be reviewed again internally prior to State Clearinghouse review.

Thank you for the opportunity to respond.

Attachments

State of North Carolina
Department of Environment
and Natural Resources
Division of Marine Fisheries

James B. Hunt, Jr., Governor
Bill Holman, Secretary
Preston P. Pate, Jr., Director

NCDENR
NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

Date April 27, 2000

MEMORANDUM

TO: Melba McGee, Environmental Coordinator
Office of Legislative & Intergovernmental Affairs

FROM: Michael W. Street

SUBJECT: Environmental Assessment
00-E-1046 Bogue Banks Beach Restoration Plan – Carteret County

Attached is the Division's reply for the above referenced project. If you have any questions, please don't hesitate to contact me.

MWS/tn
permits\admin\jpcover.ltr

North Carolina Wildlife Resources Commission

Charles R. Fullwood, Executive Director

MEMORANDUM

TO: Melba McGee
Office of Legislative & Intergovernmental Affairs

FROM: Franklin T. McBride, Manager
Habitat Conservation Program

DATE: April 27, 2000

SUBJECT: Comments for Bogue Banks Beach Restoration Plan, Draft Environmental Impact Study (DEIS), Carteret County. Project # 1046.

Staff biologists with the Wildlife Resources Commission have reviewed the DEIS. Our comments are provided in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et. seq.), the Clean Water Act of 1977 (as amended) and the North Carolina Environmental Policy Act (G.S. 113A-1 et seq., as amended; 1 NCAC-25).

Carteret County is proposing to renourish 16.8 miles of oceanfront beaches in the towns of Pine Knoll Shores, Salter Path, Indian Beach and Emerald Isle. The identified sources of sand for this proposal are located offshore from the project site.

The DEIS indicates that erosion is to blame for loss of beach, dune and maritime forest habitats and a wide range of wildlife resources. If this document seeks to identify causes of lost wildlife resources and habitat then losses attributed to human disturbance, landscape alterations and development should also be included as contributing factors especially since this document indicates that Bogue Banks oceanfront has reached 90% build-out.

Recent studies by C. R. Donoghue "*The Influences of Swash Processes on Donax variablis and Emerita talpoida*" and C. H. Peterson, D. H. M. Hickson, and G. G. Johnson "*Short-term Consequences of Nourishment and Bulldozing on the Dominant Large Invertebrates of the Sandy Beach*" indicate that beach renourishment causes a severe depletion in numbers of macro invertebrates (shorebird food). Population recovery rates of macro invertebrates are dependent on recruitment from pelagic larval stocks and recruitment from neighboring beaches.

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 733-3633 ext. 281 • Fax: (919) 715-7643

State of North Carolina
Department of Environment
and Natural Resources
Division of Water Quality

James B. Hunt, Jr., Governor
Bill Holman, Secretary
T. Kerr Stevens, Director

NCDENR

April 17, 2000

MEMORANDUM

TO: Melba McGee
Department of Environment and Natural Resources

FROM: Milt Rhodes
Division of Water Quality

SUBJECT: Bogue Banks Beach Restoration Plan Environmental Impact Statement Document and FONSI, DENR# 1046, DWQ# 12652

The Division of Water Quality (Division) has reviewed the Draft Environmental Impact Statement document regarding the Restoration of Bogue Banks Beach and offers the following comments.

This document was reviewed by staff in the wetlands unit and planning branch of the Division for consistency with the State Environmental Protection Act. The full comments are attached to this letter, but in summary, these issues should be addressed in the final document.

1. Please supply the Division with a notification of the borrow area selection once it has been made.

2. The project must meet the turbidity standards set forth in the 401 Water Quality Certification for this project during construction.

3. It is desired that work be conducted between the months of November and April to limit the degree and severity of impact to environmental resources.

Thank you for the opportunity to comment. If you have questions regarding these comments, please contact Milt Rhodes at (919) 733-5083 x 366.

TMR: / Bogue Banks Beach Restoration Plan EIS, DENR-1046

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

DIVISION OF PARKS AND RECREATION
NATURAL HERITAGE PROGRAM

April 13, 2000

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

DR. PHILIP K. MCKNELLY
DIRECTOR

MEMORANDUM

TO: Melba McGee

FROM: Stephen Hall SH

SUBJECT: DEIS – Beach Restoration Plan, Bogue Banks

REFERENCE: 1046

The assessment is well-written and appears to be quite thorough. It identifies several potential impacts, however, that are of concern to the Division:

- One of the proposed borrow areas is located within Bogue Inlet. As stated on p. 5-8, if this area is chosen as a source for dredge material, habitat for the piping plover (*Charadrius melodus*), federally and state listed as Threatened, may be lost. We strongly recommend that this area, along with any other areas located within the inlets or on the accreting ends of the banks, be excluded as potential borrow sites.
- Possible impacts to the loggerhead sea turtle (*Caretta caretta*), federally and state listed as Threatened, are also identified (p. 5-8). Impacts may result from the use of inappropriate dredge materials, changes in beach profiles, or from disposal activities taking place within the nesting or hatching periods. The use of nest relocations is proposed to mitigate for some of these impacts, but we regard this as the least desirable form of mitigation. Instead, we recommend that the standard measures supported by the US Fish and Wildlife Service and the US Army Corps of Engineers be followed regarding the (1) the types of sediments that are acceptable for disposal; (2) the beach profile created by renourishment. Beach renourishment should take place strictly in the off-season for sea turtle nesting -- November through April -- not as currently requested (p. 4-10) for the months of October and May.
- Use of the dredge spoils deposited at Brandt Island (p. 4-6) may potentially affect an undescribed butterfly that is currently known to exist only at Fort Macon State Park, Brandt Island, Radio Island, and Bear Island. Use of dredge materials stored in the large pit on Brandt Island would probably cause little impact, but we would be very concerned if any dredge materials are taken from areas of the island that have been stabilized by development of a grass cover.

1615 MAIL SERVICE CENTER, RALEIGH, NORTH CAROLINA 27699-1615
PHONE 919-733-4181 FAX 919-715-3085

State of North Carolina
Department of Environment
and Natural Resources
Division of Water Quality

James B. Hunt, Jr., Governor
Bill Holman, Secretary
Kerr T. Stevens, Director

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

MEMORANDUM

TO:	Milt Rhodes
THROUGH:	John Dorney, DWQ
FROM:	Shannon Stewart, DWQ
DATE:	April 10, 2000
SUBJECT:	Bogue Banks Beach Restoration Plan, Carteret County

Based on a review of the subject EIS, the Division of Water Quality has the following comments:

1. The EIS considers four possible borrow areas for the Bogue Banks Beach Restoration project. In section 3.16.1 of the EIS, it states that borrow area A provides the most promising deposits in terms of beach compatibility and potential yield of beach-quality sediments. Borrow Area A had the lowest R_A value, which indicated that approximately 85% of the deposit would be stable as beach fill in the project area. The other three potential borrow areas (B1, B2, and C) yielded R_A values substantially higher than borrow area A. As noted in the EIS, these areas would therefore require proportionately higher excavation volumes to achieve the same performance as borrow area A. The EIS also states that only a portion of borrow area A will be required to satisfy the nourishment volume requirements of this project – ample beach-quality sediments exist in this location.

   Section 2.3.1 of the EIS lists the selection of borrow areas as an "unresolved issue" at this point in the project. It states that "it will be uncertain until bids are received which combinations of dredge type and borrow area will yield the most cost-efficient project." The Division of Water Quality supports the use borrow area A as the exclusive source for beach-quality sediments for this project. As compared to the other three proposed borrow areas, the use of borrow area A as the sole source for beach sediments would require less material, would improve the durability of the nourishment project, would minimize changes in types and densities of nearshore species, and would reduce the rate of fill loses therefore minimizing turbidity in nearshore waters. Although borrow areas B1 and B2 may result in lower costs related to travel distances, they will have greater impacts on the nearshore environment in and around the project area.

   The Division of Water Quality would also like to request that when a decision is reached on the selection of a borrow area(s) appropriate documentation be provided for comment.

Division of Water Quality • Non-Discharge Branch
1621 Mail Service Center, Raleigh, NC 27699-1621 Telephone 919-733-1786 FAX # 733-9959

http://h2o.enr.state.nc.us/wetlandc.html

NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF COASTAL MANAGEMENT

NCDENR

JAMES B. HUNT JR
GOVERNOR

BILL HOLMAN
SECRETARY

DONNA D. MOFFITT
DIRECTOR

MEMORANDUM

TO: Melba McGee, NC Division of Policy and Development
FROM: Steve Benton, NC Division of Coastal Management
SUBJECT: Review of ~~SCH#~~ 00-1046 DEPT DATE: 4.11.2000

___ A COPY OF ALL COMMENTS RECEIVED BY THE SCH IS REQUESTED

___ REVIEWER COMMENTS ATTACHED

Review Comments:

___ This document is being reviewed for consistency with the NC Coastal Management Program pursuant to federal law and or NC Executive Order 15. Agency comments received by SCH are needed to develop the State's consistency position.

Project Review Number (if different from above) ______________.

A consistencyposition will be developed based upon our review on or before ____________.

___ A Consistency Determination document ___is, or ___may be required for this project pursuant to federal law and or NC Executive Order 15. Applicant should contact Steve Benton or Caroline Bellis in Raleigh, phone (919)733-2293, for information on proper document format and applicable state guidelines and land use plan policies.

___ Proposal is in draft form, a consistency response is inappropriate at this time. A Consistency Determination should be included in the final document.

___ A Consistency Determination Document (pursuant to federal law and/or NC Executive Order 15) is not required.

___ A consistency response has already been issued.
Project Number ___________ Date Issued __________

___ Proposal involves < 20 Acres and or a structure < 60,000 Square Feet and no AEC's or Land Use Plan problems.

___ Proposal is not in the Coastal Area and will have no significant impacts on any land or water use or natural resources of the Coastal Area.

✓ A CAMA Permit ✓ is, or___ may be required for all or part of this project. Applicant should contact ______________ in ________________, phone #_____________, for information.

___ A CAMA Permit ___has already been issued, or___is currently being reviewed under separate circulation. Permit Number____________ Date Issued___________

___ Other (see attached).

State of North Carolina Consistency Position:

___ The proposal is consistent with the NC Coastal Management Program provided that all conditions are adhered to and that all state authorization and/or permit requirements are met prior to implementation of the project.

___ The proposal is inconsistent with the NC Coastal Management Program.

___ Other (see attached)

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Mr. James Patrick Monaghan
North Carolina Department of Environment and Natural Resources
Division of Marina Fisheries
Post Office Box 769
Morehead City, North Carolina 28557

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Mr. Monaghan:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the Division of Marine Fisheries are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff. Also enclosed are revised sections to the Draft EIS. On the revised pages, the replaced text is crossed out, and the revised text is in italics.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (An unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comment: In our review of the scoping document for this project (memorandum dated January 26, 2000) we requested that research be conducted to determine recovery times for benthic populations that are destroyed by pumping and depositing materials. This research has not been fully addressed in the EIS. We realize that sampling needs to continue through early fall for an accurate description of species diversity and species abundance to be completed. We cannot speculate as to what the potential impacts might be from the present EIS. ***We recommend that one complete year of field work be conducted in the offshore borrow areas and the nearshore intertidal deposit areas. Adequate time for data analyses, report preparation, and report review should be allowed and a complete review of these results should be made in the EIS.*** *If possible, data on the benthos should be collected from nearshore and intertidal areas of Fort Macon, Atlantic Beach, and Emerald Isle where pumping has occurred. We* *can provide the research design if requested. We also recommend that the particle size of the existing beach be the size pumped onto the beach since the literature indicates this will lessen recovery times.*

Response: The University of North Carolina, Institute of Marina Sciences, Charles H. (Pete) Peterson have completed the initial phase of the sampling meeting the criteria you have outlined. The results of those studies are provided in the attached report which will replace the preliminary report provided in the draft EIS. Physical and biological impacts and recovery will be monitored systematically following a sampling plan recommended by Dr. Peterson or recognized experts. Your input into that monitoring effort is requested. UNC-IMS has in their possession existing baseline data throughout Bogue Banks. We anticipate using these data when they become available in the published literature to compare construction and post-construction sampling. We requested these data for inclusion in the EIS but were informed that analyses are not available until published. Time is of the essence on this project. The severely eroded condition of the beach means any delay in implementation of a project could lead to higher property damages and losses. Given the existing body of research on impacts to benthic organisms and the natural variability of these systems, we believe that additional pre-nourishment sampling and research will not provide definitive results or allow prediction of impacts more accurate than can be deduced from the experiences in the literature. We believe that the proposed plan will result in reasonably rapid recovery because it will follow the practices discussed below.

There have been numerous studies of recovery of benthic fauna on nourished beaches. Many factors effect the recovery including grain size compatibility of nourishment sand with existing beach sand, seasonal relationship of nourishment to growth period of benthic fauna, depth of sand placed on the beach, levels of turbidity associated with various nourishment sand sources and ability of certain fauna to migrate vertically through the nourished sand. Monitoring of Phase one of the Myrtle Beach Renourishment Project (Jutte, Van Dolah and Levision, March 1999) found that benthic infauna largely recovered after two to three months. The study found that, in some cases, nourishment actually resulted in enhancement of biological assemblages.

The impact of nourishment on beach macro invertebrates has been shown to be highly variable. Virtually all published studies report some initial impact (either confirmed by direct sampling after nourishment, or by inference), However, recovery rates (compared to pre-nourishment densities) have been found the range from days to weeks (e.g. Jutte, et. al. 1999; Gorzelany and Nelson, 1987) to several years (eg. Cutler and Mahadeva, 1982). Studies by Donaghue (1999) at Pea Island (NC) and Peterson et. al.(2000) at Atlantic Beach (NC) quoted by the correspondent generally found longer recovery times the the majority of other researchers, including Van Dolah et/ al (1992) and Baca and Lankford (1987). A fundamental reason for the disparity in results among the various investigators is the extreme natural variability of population densities depending on seasons, variations in sediment compatibility between the natural beach and the nourishment sand, and the frequency of storms. It is generally accepted that the biological populations will recover more slowly if:

Nourished sands do not closely match the native sand grain size distribution,
Nourishment is performed during periods of peak larval recruitment,
The scale of the projects is large relative to the cross-shore dimension, and
Projects are repeated frequently, causing disruption of successive growing cycles.

No study has proven total loss of benthic populations due to nourishment or scraping. The concem is over the rate and scale of recovery compared to natural beaches. The proposed project design seeks to reduce impacts and accelerate recovery in the following ways:

- Selection of borrow area the most closely matches the desirable characteristics for the indigenous benthic fauna. Borrow area A has the best overfill ratios but is slightly coarser and has twice the shell content as the native beach. Borrow areas B1 and B2 have lower percentages of shell and slightly finer mean grain size (yielding moderately higher overfill ratios).Some investigators (eg. Peterson, 2000, personal communications) have suggested that borrow areas may be preferable for recruitment and recovery of beach organisms. Others (eg., Stewart, NCDENR-DWQ, comments) suggest borrow area A will yield sediments that produce fewer overall impacts on the nearshore environment. Regardless of which borrow area is selected, the differences compared to the natural beach, are considered relatively small because of the wide range of sediment sizes that occur between the foredune and inshore zone along Bogue Banks.
- Nourishment will be performed during periods of low biological recruitment periods (eg., late fall, winter and early spring months).
- The scale of the project in the cross-shore dimension is moderate (approximately 50 cy/ft), comparable to nourishment projects that have demonstrated rapid biological recovery such as Myrtle Beach (Baca, et.al, 1987; Jutte et. al, 1999)
- The project will be large enough given the low background erosion rate of the site to avoid frequent repeat nourishment every couple of years so that successive growth cycles are not interrupted as is the case now with frequent beach scraping (bull dozing).

The only means available to verify the impact of the nourishment on the Bogue Banks beach and borrow area fauna is to monitor the impacts through a program that includes characterization of both the physical and biological conditions before, immediately following and for a period sufficient to determine full recovery of the biological resources in the borrow area and on the beaches and to determine the physical performance of the nourishment project.

The Bogue Banks nourishment project will include a program of monitoring of impacts. Specific objectives of the monitoring will be as follows:

1. Document and quantify physical changes in the beach and nearshore zone,
2. Determine the ecological impacts and recovery rates of beach and nearshore biological resources following nourishment, and
3. Document the physical and biological impact and recovery of sand bottom habitats in the borrow area.

Comment: Another primary concern on this project is the time window for dredging. We strongly recommend that the time be shortened from October1 through May 15 to December 1 through March 31. This should reduce effects on recruitment of finfish and minimize effects on traditional beach fisheries.

It appears that, due to funding constraints, the project will have to be constructed in segments as funding becomes available in each of the individual municipalities on Bogue Banks. Construction windows may, therefore, be shortened. However, because of economic considerations and weather contingencies, the applicant wishes to have available the longest possible window for construction. By current state and federal policies, that window runs from November 1 (end of turtle nesting season) to May 15 (beginning of turtle nesting season) in North Carolina.

We believe that the responses provided herein should provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the enclosed information and a response as to the adequacy of the EIS with the revisions indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Franklin T. McBride, Manager
North Carolina Wildlife Resources Commission
Division of Inland Fisheries
1721 Mail Services Center
Raleigh, North Carolina 27699-1721

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Mr. McBride:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the staff biologists with the Wildlife resources Commission are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (An unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comment: The DEIS indicates that erosion is responsible for loss of beach, dune and maritime forest habitats and a wide range of wildlife resources. If this document seeks to identify causes of lost wildlife resources and habitat then losses attributed to human disturbance, landscape alterations and development should also be included as contributing factors especially since this document indicates that Bogue Banks oceanfront has reached 90 percent build-out.

Response: It is not within the scope of the draft EIS to identify causes of lost wildlife resources except for such impacts that might occur as a result of placement of sand on the beach from the designated borrow areas. Significant habitat losses can be attributed solely to erosion of the beach and the subsequent bulldozing of the beach undertaken to protect property from the ocean. With a stable berm fronting the dune as exist along the nourished beach areas of the Town of Atlantic Beach, the need for annual bulldozing of the beachfront would be eliminated allowing vegetation and the macro invertebrates to recolonize the beach, including the berm and dune face, and reestablish habitat that would otherwise be lost indefinitely.

This is illustrated by a survey of Sea Beach Amaranth conducted during August 2000 of the beaches of Bogue Banks from Bogue Inlet to Beaufort inlet. Twenty-three (23) plant individuals were identified along the entire island by the survey. Of those, 20 were located along the beach in portions of the Town of Atlantic Beach that have been nourished in the last ten years. The individual plants were found on the foredune at and above the dune toe. The stable beach that remains as a result of the nourishment projects in Atlantic Beach has created habitat for this endangered plant to flourish. On the remaining beach including Pine Knoll Shores, Salter Path, Indian Beach and Emerald Isle, only three individuals plants were identified. These were located 4 to 5 feet above the dune toe in Salter Path in an area were extensive beach scraping has occurred. It that area the dune is subject to loss because there is no significant berm width fronting the dune. The vegetation, dunes and dry beach areas that make up wildlife habitat on natural beaches require a long term stable beach for protection from the ocean. The nourishment project will provide that stability along the other beaches of Bogue Banks west of Atlantic Beach.

Of the approximately 335 miles of North Carolina's barrier islands from the Virginia border to Little River Inlet, only 143 miles or 43 percent is either developed or subject to development. The remaining 190 miles or 57 percent remains undeveloped and, for the most part, will remain so in perpetuity. A significant portion of the undeveloped barrier islands are accessible only by boat.

In Carteret County the numbers are even more dramatic. The County's barrier islands stretch from Ocracoke Inlet to Bogue Inlet, approximately 81 miles (measured on a County map). The undeveloped portions, from Beaufort Inlet to Ocrackoe inlet, make up 57 miles or approximately 70 percent of the total barrier island length. The developed portion of the County, Bogue Banks (excluding Fort Macon State Park), makes up 24 miles or approximately 30 percent of the County's total barrier island length. The Bogue Banks Project will not alter that distribution. Along the beach of Bogue Banks, the nourishment project will add the following:

Approximately 100 acres of dry beach (i.e., 16.8 miles, 50 feet wide)
Approximately 30 acres of stable dunes that evolve naturally by aeolian processes versus the unnatural bull dozing of coarse grained sand dunes that has occurred each year since 1995.

Comment: The reviewer referred to studies by C. R. Donahue and Peterson et. al. Indicating that beach nourishment causes a severe depletion of in numbers of macro invertebrates (shorebird food). Population recovery rates of macro invertebrates are dependent on recruitment from pelagic larval stocks and recruit from neighboring beaches.

Response: While these studies are important, the nourishment experience in the cases covered in those case studies differs greatly from that which is proposed at Bogue Banks.

Scale: The Pea Island nourishment site is only one mile long but received a total of approximately 500 c.y. / ft over seven years (versus (50 c.y. / ft. for the proposed project).
Frequency of Nourishment: The Pea Island site was nourished eight times between 1991 and 1997.
Sediment Grain size Compatibility: The Pea Island site received sand much finer than the natural beach (m_z=3.67 phi versus native beach 2.33 phi, Peterson, et. al, 2000).
Timing: Both studies involved beach fill placement during the active biological recruitment times in late spring. We anticipate beach fill operations for the Bogue Banks project to be during the optimal environmental windows as directed by the regulatory agencies via permit conditions.

Comment: We are very concerned for foraging shorebirds during all times of the year (breeding season, migration, wintering). North Carolina's coast is nesting habitat for species such as the willet, American oystercatcher, Wilson's plover, and piping plover and we often think of habitet for these as the most important to protect. However, our coast is also serves as very important wintering and migration habitat for many species of shorebirds. Therefore, we are not only concerned about beach renourishment during the breeding season, but throughout the entire year, especially when considering the cumulative impacts of large-scale renourishment projects. We do not believe that the direct and cumulative impacts to intertidal macro invertebrates and shorebirds have been adequately addressed in the DEIS.

Response: The assessment of the benthic invertebrate resources at Bogue Banks conducted by Peterson and Wells has been revised to include (enclosed for your review and inserted into the revised EIS as Appendix C) states that certain macro invertebrates and fish species are present along inshore and offshore areas at Bogue Banks. Therefore, dredging sand from offshore borrow areas and nourishing the shoreline may bury intertidal macrofauna and reduce the available food resource to birds that feed on these organisms. However, direct impacts to macro invertebrates associated with this project will be reduced for several reasons. Dredging and filling activities will occur largely during winter months, avoiding the larval recruitment period of many of these species, including mole crabs (early October) and coquina clams (spring and summer) (Donaghue, 1999). Additionally, studies have shown that intertidal macrofauna can recolonize a nourished area within one or two seasons (Ross and Lancaster, 1996; National Research Council, 1995; Reilly and Bellis, 1978), therefore, impacts will be temporary. Lastly, sand of similar grain size to the existing beach will be used to reduce changes in physical characteristics of the beach that may affect nourishment impacts on invertebrates (Donaghue, 1999; Peterson et al, 1999; Hackney et al, 1996).

Indirect impacts imposed on shorebirds that feed on macro invertebrates will be minimized as well. After impacts to macrofauna have occurred and numbers of these species are depressed, birds that prey upon these invertebrates, including the threatened piping plover, would likely move to adjacent undisturbed beach areas and other suitable feeding areas for the temporary period of population re-establishment. Because macro invertebrates recolonize rapidly, no long term impacts to these organisms or the shorebirds that prey upon them are anticipated with this project.

Comment: The large scale beach nourishment project will bury whole populations of intertidal macro invertebrates may preclude rapid recovery of those populations and does not allow for shorebirds to shift their foraging to nearby sites.

Response: There have been numerous studies of recovery of benthic fauna on nourished beaches. Many factors effect the recovery including grain size compatibility of nourishment sand with existing beach sand, seasonal relationship of nourishment to growth period of benthic fauna, depth of sand placed on the beach, levels of turbidity associated with various nourishment sand sources and ability of certain fauna to migrate vertically through the nourished sand. Monitoring of phase one of the Myrtle Beach Renourishment Project (Jutte, Van Dolah and Levision, March 1999) found that benthic infauna largely recovered after two to three months. The study found that, in some cases, nourishment actually resulted in enhancement of biological assemblages.

The impact of nourishment on beach macro invertebrates has been shown to be highly variable. Virtually all published studies report some initial impact (either confirmed by direct sampling after nourishment, or by inference), However, recovery rates (compared to pre-nourishment densities) have been found the range from days to weeks (e.g. Jutte, et. al. 1999; Gorzelany and Nelson, 1987) to several years (eg. Cutler and Mahadeva, 1982). Studies by Donahue (1999) at Pea Island (NC) and Peterson et. al.(2000) at Atlantic Beach (NC) quoted by the correspondent generally found longer recovery times the the majority of other researchers, including Van Dolah et/ al (1992) and Baca and Lankford (1987). A fundamental reason for the disparity in results among the various investigators is the extreme natural variability of population densities depending on seasons, variations in sediment compatibility between the natural beach and the nourishment sand, and the frequency of storms. It is generally accepted that the biological populations will recover more slowly if:

Nourished sands do not closely match the native sand grain size distribution,
Nourishment is performed during periods of peak larval recruitment,
The scale of the projects is large relative to the cross-shore dimension, and
Project are repeated frequently, causing disruption of successive growing cycles.

No study has proven total loss of benthic populations due to nourishment or scraping. The concern is over the rate and scale of recovery compared to natural beaches. The proposed project design seeks to reduce impacts and accelerate recovery in the following ways:

Selection of borrow area the most closely matches the desirable characteristics for the indigenous benthic fauna. Borrow area A has the best overfill ratios but is slightly coarser and has twice the shell content as the native beach. Borrow areas B1 and B2 have lower percentages of shell and slightly finer mean grain size (yielding moderately higher overfill ratios).Some investigators (eg. Peterson, 2000, personal communications) have suggested that borrow areas may be preferable for recruitment and recovery of beach organisms. Others (eg., Stewart, NCDENR-DWQ, comments) suggest borrow area A will yield sediments that produce fewer overall impacts on the nearshore environment. Regardless of which borrow area is selected, the differences compared to the natural beach, are considered relatively small because of the wide range of sediment sizes that occur between the foredune and inshore zone along

Bogue Banks.

Nourishment will be performed during periods of low biological recruitment periods (eg., winter and early spring months).

The scale of the project in the cross-shore dimension is moderate (approximately 50 c.y./ ft), comparable to nourishment projects that have demonstrated rapid biological recovery such as Myrtle Beach (Baca, et.al, 1987; Jutte et. al, 1999)

The project will be large enough given the low background erosion rate of the site to avoid frequent repeat nourishment every couple of years so that successive growth cycles are not interrupted as is the case now with frequent beach scraping (bull dozing).

The only means available to verify the impact of the nourishment on the Bogue Banks beach and borrow area fauna is to monitor the impacts through a program that includes characterization of both the physical and biological conditions before, immediately following and for a period sufficient to determine full recovery of the biological resources in the borrow area and on the beaches and to determine the physical performance of the nourishment project.

The Bogue Banks nourishment project will include a program of monitoring of impacts. Specific objectives of the monitoring will be as follows:

1. Document and quantify physical changes in the beach and nearshore zone,
2. determine the ecological impacts and recovery rates of beach and nearshore biological resources following nourishment, and
3. document the physical and biological impact and recovery of sand bottom habitats in the borrow area.

Comment: With a total project length (16.8) miles, this is one the longest beach nourishment projects in the last 20 years. The DEIS presents beach nourishment as a "sacrificial shore-protection technique". There are many examples of how beach nourishment provides at best only minimal protection from the encroaching sea and there are examples of the sand from beach nourishment being washed away within weeks of deposition. We question if this is a wise expenditure of public monies considering the cost of the renourishment, potentially short duration of the benefits and the adverse impacts to the fish and wildlife resources dependent on the project area.

Response: Beach nourishment is not a panacea for shore protection and beach management. Each location must be evaluated on its own merits as a candidate site for a successful nourishment project. For beaches with very high background erosion rates of 10 to 50 feet per year, the economics of beach nourishment will be very different from Bogue banks, which has background erosion rates of 1 to 3 feet per year (N.C. Division of Coastal Management, Long Term Average Annual Shoreline Change Rates, Updated through 1992). Carteret County is fortunate to have a beach nourishment project at Atlantic Beach that demonstrates convincingly the Bogue Banks is an excellent location for beach nourishment. The respondents are advised to drive the beach of Bogue Banks from west to east. From the healthy beaches at the west end of Emerald Isle to Atlantic Beach, the berm is narrow (in many places only a low tide beach exist), there is evidence if extensive structural damage to buildings and access decks and walkways, extensive loss of natural dune and adjoining maritime forest and underbrush where present, and evidence that at least 80 percent of the beach has been scraped to provide dune protection since the fall of 1999. The physical change in the beach shape upon entering the town limits of Atlantic Beach is dramatic. There is a wide berm, stable dunes with vegetation and little or no evidence of structural damage to ocean front buildings and decks. The performance of the nourished beach at Atlantic Beach provides physical evidence of a wider dry beach and reduced storm damage throughout the 1990's compared to exposed (non-nourished) beaches in the project area. The reviewer is referred to section 2.2.2 , Physical Impacts, of the draft EIS for a review of the physical factors that make Bogue Banks and excellent site for successful beach nourishment.

We are not aware of any beach nourishment projects constructed in North Carolina where the beaches have washed away in weeks following placement. If such projects do exist, please identify the projects so that the details of the projects can be investigated to determine the reasons for failure.

We believe that the responses provided herein provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the inclosed information and a response as to the adequacy of the EIS with the revision indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Mr. Milt Rhodes
North Carolina Department of Environment and Natural Resources
Division of Water Quality
Post Office Box 29535
Raleigh, North Carolina 27626-0535

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Mr. Rhodes:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the staff of the wetlands unit and the planning branch of the Division are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff. Also enclosed are revised sections of the Draft EIS. On the revised pages, the replaced text is crossed out, and the revised text is in italics.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (an unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comment: Please supply the Division with a notification of the borrow area selection once it has been made.

Response Three borrow areas have been selected for use in the project, areas, A, B1 and B2. These areas are proposed because they contain the beach-compatable sediments. Use of borrow area A will result in the lowest overfill ratios on the beach, the most durable fill, and will be the most cost effective to excavate using a hopper dredge, a technique preferred over others by some regulatory agencies. Borrow areas B1 and B2 contain somewhat finer material and will result in slightly higher overfill ratios. The higher overfill ratios will result in placement of more cubic yards of material to achieve the same adjusted beach profile and project durability. The additional costs associated with the additional sand volumes may be offset by the economies available due to the proximity of borrow areas B1 and B2 to the beaches.

Comment: The project must meet the turbidity standards set forth in the 401 Water Quality Certification for this project:

Response: Turbidity resulting from the disposal activities on the beach is addressed in section 5.9 of the Draft EIS. Results from two studies of turbidity associated with beach nourishment operations showed that, in both studies, turbidity did not exceed 25 ntu's outside the discharge area. Due to the low mud content of the borrow area sediments identified in borrow areas A, B1 and B2 (Appendix E, Table E6 of the Draft EIS), generally less than 4 percent, we believe that the project will be able to meet the requirements of the 401 Water Quality Certification.

Comment: It is desired that work be conducted between the months of November and April to limit the degree and severity of impact to environmental resources.

Response: It appears that, due to funding constraints, the project will have to be constructed in segments as funding becomes available in each of the individual municipalities on Bogue Banks. Construction windows may, therefore, be shortened. However, because of economic considerations and weather contingencies, the applicant wishes to have available the longest possible window for construction. By current state and federal policies, that window runs from November 1 (end of turtle nesting season) to May 15 (beginning of turtle nesting season) in North Carolina.

We believe that the responses provided herein should provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the enclosed information and a response as to the adequacy of the EIS with the revisions indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Stephen Hall
North Carolina Department of Environment and Natural Resources
Division of Parks and Recreation
1615 Mail Service Center
Raleigh, North Carolina 27699-1615

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Mr. Hall:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the Division of Parks and Recreation are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff. Also enclosed are revised sections to the Draft EIS. On the revised pages, the replaced text is crossed out, and the revised text is in italics.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (An unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comment: One of the potential borrow areas is located within Bogue Inlet. As stated on p. 5-8, if this area is chosen as a source for dredge material, habitat for the piping plover (Charadrius melodus), federally and state listed as threatened, may be lost. We strongly recommend that this area, along with other areas located within the inlets or on the accreting ends of the banks, be excluded as potential borrow sites.

Response: The applicant agrees to delete the shoals in and around Bogue inlet as a potential source of borrow material for the beach nourishment project.

Comment: Possible impacts to the loggerhead sea turtle (Caretta caretta), federally and state listed as Threatened, are also identified (p. 5-8). Impacts may result from the use of inappropriate dredge materials, changes in beach profiles, or from disposal activities taking place within the nesting or hatching periods. The use of nest relocations is proposed to mitigate for some of these impacts, but we regard this *as the least desirable form of mitigation. Instead, we recommend that the standard measures supported by the US Fish and Wildlife Service and the US Army Corps of Engineers be followed regarding the (1) the types of sediments that are acceptable for disposal; (2) the beach profile created by renourishment. Beach nourishment should take place strictly in the off-season for sea turtle nesting-- November through April-- not as currently requested (p. 4-10) for the months of October and May.*

Response: To minimize impacts to nesting sea turtles in the project area, standard protocol adopted by the U. S. Fish and Wildlife Service and used in previous beach nourishment projects in North Carolina will be followed. This protocol includes the following guidelines:

1. Only beach quality sand suitable for sea turtle nesting, successful incubation, and hatchling emergence shall be used for beach nourishment on the project site. Furthermore, sand of similar grain size to the existing beach will be used to reduce any changes in physical characteristics of the beach that may affect nest survival.

2. Immediately after completion of the beach nourishment project and prior to the next three nesting seasons, beach compaction shall be monitored and tilling shall be conducted as required to reduce the likelihood of impacting sea turtle nesting and hatching activities.

3. Immediately after completion of this project and prior to the next three nesting seasons, monitoring shall be conducted to determine if escarpments are present and escarpments shall be leveled as required to reduce the likelihood of impacting sea turtle nesting and hatching activities.

4. Carteret County will ensure that contractors doing the beach nourishment and dredging work fully understand sea turtle protection measures.

5. Beach nourishment and dredging activities are planned to begin after November 1 and be completed before May 1. If any filling occurs after May 1, the pipeline will be placed along the landward edge of the berm.

6. If any beach nourishment or dredging activities take place during the period from May 1 through November 15, a standardized nest monitoring and relocation plan will be implemented in addition to the monitoring that already occurs. The plan incorporates monitoring of the beach disposal area each morning from the beginning of the nesting season until all equipment is removed from the beach and the relocation of any nests laid within the project area. Using standard nest relocation techniques, all nests will be located to a suitable nursery beach, agreed to prior to the start of relocation effort by the U.S. Fish and Wildlife Service and the North Carolina Wildlife Resources Commission. Hatching success of relocated nests will be monitored and reported.

7. Immediately after completion of this project and prior to May 1 for three subsequent years, sand compaction will be monitored in the area of restoration in accordance with a protocol agreed to by the Service, the State regulatory agency, and Carteret County. At a minimum, the protocol provided under 7a and 7b below will be followed. If required, the area will be tilled to a depth of 36 inches. All tilling activity must be completed prior to May 1. A report on the results of compaction monitoring will be submitted to the Service prior to any tilling actions being taken. An annual summary of compaction surveys and the actions taken will be submitted to the Service. This condition will be evaluated annually and may be modified if necessary to address sand

compaction problems identified during the previous year.

7a. Compaction sampling stations shall be located at 500-foot intervals along the project area. One station will be at the seaward edge of the dune/berm line (when material is placed in this area); one station will be midway between the dune line and the high water line; and one station will be located just landward of the high water line. At each station, the cone penetrometer shall be pushed to a depth of 6, 12, and 18 inches three times (three replicates). Material may be removed from the hole if necessary to ensure accurate readings of successive levels of sediment. Replicates will be located as close to each other as possible, without interacting with the previous hole and/or disturbed sediments. The three replicate compaction values for each depth will be averaged to produce final values for each depth at each station. Reports will include all 27 values for each transect line, and the final 9 averaged compaction values.

7b. If the average value for any depth exceeds 500 psi for any two or more adjacent stations, then that area will be tilled prior to May 1 of the following year. If values exceeding 500 psi are distributed throughout the project area but in no case do those values exist at two adjacent stations at the same depth, then consultation with the Fish and Wildlife Service will be sought to determine if tilling is required. If a few values exceeding 500 psi are present randomly within the project area, tilling will not occur.

8. Visual surveys for escarpments along the project area shall be made immediately after completion of the beach nourishment project and prior to May 1 for three subsequent years. Results of the surveys will be submitted to the Service prior to any action being taken. Escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet will be leveled to the natural beach contour by May 1. The Service will be contacted immediately if subsequent reformation of escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet occurs during the nesting and hatching season to determine the appropriate action to be taken. If it is determined that escarpment leveling is required during the nesting or hatching season, the Service will provide a brief written authorization that describes methods to be used to reduce the likelihood of impacting existing nests. An annual summary of escarpment surveys and actions taken will be submitted to the Service.

9. From March 1 through April 30 and November 1 through November 15, staging areas for construction equipment will be located off the beach to the maximum extent practicable. Nighttime storage of construction equipment not in use will be off the beach to minimize disturbance to sea turtle nesting and hatching activities. In addition, all construction pipes that are placed on the beach will be located as far landward as possible without compromising the integrity of the dune system. Temporary storage of pipes on the beach will be in such a manner so as to impact the least amount of nesting habitat and shall likewise not compromise the integrity of the dune systems.

These guidelines have been incorporated into the revised EIS in section 3.15. By planning to perform the majority of the project during off-season months, monitoring beach hardness, and relocating nests found in unsuitable habitat if project completion delays occur, impacts to nesting loggerhead sea turtles will be minimized.

Comment Use of dredge spoils deposited at Brandt Island (p. 4-6) may potentially affect an undescribed butterfly that is currently known to exist only at Fort Macon State Park, Brandt Island, Radio Island, and

Bear Island. Use of dredge materials stored in the large pit on Brandt Island would probably cause little impact, but we would be very concerned if any dredge materials are taken from areas of the island that have been stabilized by development of a grass cover.

Response: The applicant agrees to eliminate the dredge spoil islands at Brandt Island as a source of borrow material for the beach nourishment project..

We believe that the responses provided herein should provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the enclosed information and a response as to the adequacy of the EIS with the revisions indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

STROUD ENGINEERING, P.A.
HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

September 13, 2000

Ms. Shannon Stewart
North Carolina Department of Environment and Natural Resources
Division of Water Quality, Non-Discharge Branch
1621 Mail Service Center
Raleigh, North Carolina 27699-1621

Re: Draft Environmental Impact Statement
Bogue Banks Beach restoration Plan
Project # 1046

Dear Ms Stewart:

The comments of your Division on the referenced EIS were greatly appreciated. Responses to the comments of the staff of the Non-discharge Branch of the Division are provided in this letter and the enclosures.

Enclosed with this letter is the "Final Report of The late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." This report will replace the preliminary report included with the Draft EIS reviewed by your staff. Also enclosed are revised sections of the Draft EIS. On the revised pages, the replaced text is crossed out, and the revised text is in italics.

The original schedule for implementation of this project included placement of and on the beach during the coming winter months of years 2000 and 2001. Funding for that County wide project did not materialize as hoped. For that reason the scope of the project has been revised so that the municipalities of Emerald Isle, Pine Knoll Shores, Indian Beach and Salter Path (an unincorporated township of Carteret County) can implement nourishment projects as funding sources are developed. Nourishment projects in each of the communities will be implemented based on the design and constraints outlined in this EIS and any subsequent Major CAMA Permit issued based on this EIS. The Project description, Section 1.4 of the EIS has been revised to reflect this change. A copy of those revisions are included for your review.

Comments: Related to comment concerning impacts associated with selection of borrow areas.

Response: It appears that, due to funding constraints, the project will have to be constructed in segments as funding becomes available in each of the individual municipalities on Bogue Banks. Construction windows may, therefore, be shortened. However, because of economic considerations and weather contingencies, the applicant wishes to have available the longest possible window for construction. By current state and federal policies, that window runs from November 1 (end of turtle nesting season) to May 15 (beginning of turtle nesting season) in North Carolina.

Comment: Comment related to meeting the turbidity standards in the 401 Water Quality Certification for this project.

Response: Turbidity resulting from the disposal activities on the beach is addressed in section 5.9 of the Draft EIS. Results from two studies of turbidity associated with beach nourishment operations showed that, in both studies, turbidity did not exceed 25 ntu's outside the discharge area. Due to the low mud content of the borrow area sediments identified in borrow areas A, B1 and B2 (Appendix E, Table E6 of the Draft EIS), generally less than 4 percent, we believe that the project will be able to meet the requirements of the 401 Water Quality Certification.

Comment: Related to construction schedule:

Response: It appears that, due to funding constraints, the project will have to be constructed in segments as funding becomes available in each of the individual municipalities on Bogue Banks. Construction windows may, therefore, be shortened. However, because of economic considerations and weather contingencies, the applicant wishes to have available the longest possible window for construction. By current state and federal policies, that window runs from November 1 (end of turtle nesting season) to May 15 (beginning of turtle nesting season) in North Carolina.

We believe that the responses provided herein should provide you and your staff with a better understanding of the Bogue Banks Project and the measures to be implemented as part of the project to minimize and to measure the physical and biological impacts of the project.

We would appreciate a timely review of the enclosed information and a response as to the adequacy of the EIS with the revisions indicated. That response should be made to this office to my attention.

If you have questions on any aspect of the project, please feel free to call me.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Enclosures

CC: Robert Murphy, Manager, Carteret County
Doug Huggett, Division of Coastal Management, Raleigh
Ted Tyndall, Division of Coastal Management, Morehead City

STROUD ENGINEERING, P.A.

HESTRON PLAZA TWO
151-A HWY. 24
MOREHEAD CITY, NORTH CAROLINA 28557
(252) 247-7479

October 31, 2000

Ms. Melba McGee
Environmental Review Coordinator
North Carolina Department of Environment and Natural Resources
1601 Mail Service Center
Raleigh, North Carolina, 27699-1601

Re: #1046 Bogue Banks Restoration Plan, Draft EIS, Carteret County

Dear Ms. McGee:

Please find attached letters from the commenting agencies from the initial review of the referenced draft EIS by the Department of Environment and Natural Resources. In all cases the letters indicate that revisions to the DIES and responses provided to each reviewer sufficiently address each reviewers concerns.

Copies of the letters from each reviewer are attached for your information. Also attached are copies of the initial review comments as provided by your office to Doug Huggett and subsequently to this office, and copies of the response letters to each reviewer from this office. All of this correspondence will be attached to the EIS with the index of correspondence.

It is important that review of the EIS proceed on a timely basis. Even though the referendum was voted down by County residents, the Towns of Pine Knoll Shores and Indian Beach are proceeding with preparations to construct a beach nourishment project during the dredging window of years 2001 and 2002. That project will be based on the findings and criteria set out in the referenced EIS.

Doug Huggett has agreed to contact me on the next steps we must take to complete review of the EIS.

If you have any questions concerning the enclosed documents or need additional information, please give me a call.

Sincerely,

STROUD ENGINEERING, P.A.

J. W. Forman, Jr., P.E.
Project Engineer

Attachments

CC Robert Murphy, County Manager, Carteret County
Doug Huggett, DCM, Raleigh
Ted Tyndall, DCM, Morehead City

COMMERCE ST
SUITE B

SUITE A

HESTRON PLAZA TWO

North Carolina Wildlife Resources Commission

Charles R. Fullwood, Executive Director

MEMORANDUM

TO: J.W. Forman
Stroud Engineering

FROM: William Wescott, Coastal Coordinator
Habitat Conservation Program

William Wescott

DATE: October 24, 2000

SUBJECT: Bogue Banks Beach Restoration Plan: Comments regarding consultant responses and the final report of benthic invertebrate and demersal fish resources.

We requested a copy of a USACE study investigating the impacts beach nourishment had on benthic invertebrates. Our Coastal Coordinator in Washington received a copy of the study on October 23, 2000. After reviewing the study and consulting with coastal geologists we are able to respond to your September 13, 2000 letter.

Apparently benthic studies have been diligently undertaken to collect and identify the nearshore and offshore benthic communities that would be impacted by the proposed beach nourishment project. The inclusion of this information in the Final EIS will address our concerns regarding non-specific and incomplete data.

We remain concerned for foraging shorebirds during all times of the year (breeding season, migration, wintering). If beach nourishment occurs then nourishment activities should be scheduled to avoid peak biological activity of invertebrates. We still advocate that a better long-term solution for protecting beachfront development is to establish wider setbacks on all structures as they are rebuilt after being lost to the sea.

Thank you for the opportunity to comment on this project. We look forward to reviewing a complete EIS document. If you need to discuss these comments please call William Wescott at (252) 946-6481.

Cc: Melba McGee, Office of Legislative & Intergovernmental Affairs
Doug Huggett, Division of Coastal Management

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 733-3633 ext. 281 • Fax: (919) 715-7643

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

DIVISION OF WATER QUALITY

NCDENR

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

KERR T. STEVENS
DIRECTOR

October 6, 2000

J.W. Forman
Project Engineer
Stroud Engineering, P.A.
Hestron Plaza Two
151-A Highway 24
Morehead City, NC 28557

Dear Mr. Forman:

The Division of Water Quality (Division) has reviewed the responses to initial comments raised during agency review of the Bogue Banks Beach Restoration Plan Draft Environmental Impact Statement. The responses included in this letter submitted by Stroud Engineering and the modifications to the DEIS adequately address the Division's concerns regarding the project's impact to the surrounding environment. Please be advised that the project should meet the turbidity standard set forth in the 401 Water Quality Certification to be issued by the Division.

Sincerely,

Milt Rhodes
Interim DWQ SEPA Coordinator
SEPA Coordination Team

cc. Melba McGee, DENR NCEPA Coordinator

1617 MAIL SERVICE CENTER, RALEIGH, NORTH CAROLINA 27699-1617
website: h2o.enr.state.nc.us PHONE 919-733-5083 FAX 919-733-9919

State of North Carolina
Department of Environment
and Natural Resources
Division of Marine Fisheries

James B. Hunt, Jr., Governor
Bill Holman, Secretary
Preston P. Pate, Jr., Director

NCDENR
NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

MEMORANDUM

TO: Melba McGee

THROUGH: Michael D. Marshall

FROM: James Patrick Monaghan, Jr. JPMJ.

DATE: October 2, 2000

SUBJECT: 1046 -- Bogue Banks Beach Renourishment

This memo is in response to a letter from J.W. Forman, Jr., P.E., Stroud Engineering, dated September 13, 2000.

We have reviewed the applicant's response to our comments on the EIS. Based upon further review of the EIS and recent literature that has come to our attention we recommend the following:

1. **Continue monitoring the offshore borrow areas and nearshore intertidal deposit areas during the summer of 2001. Also, monitor these areas immediately following renourishment and for a period of time sufficient to determine recovery rates of the fauna.**

2. **A dredging window of November 15 through April 15.**

We appreciate the opportunity to comment on this project.

Cc: W.E. Forman
Ted Tyndall

JAMES B. HUNT JR.
GOVERNOR

BILL HOLMAN
SECRETARY

DR. PHILIP K. MCKNELLY
DIRECTOR

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

DIVISION OF PARKS AND RECREATION

October 30, 2000

MEMORANDUM

TO: Melba McGee

FROM: Stephen Hall

SUBJECT: Response to Comments – DEIS – Beach Restoration Plan, Bogue Banks

REFERENCE: 1046

In our review of the DEIS, we had concerns about the potential for impacts to piping plovers (*Charadrius melodus*) and loggerhead sea turtles (*Caretta caretta*), both federally and state listed as Threatened. We also had concerns about the use of dredge spoil material from Brandt Island, the site of a colony of an undescribed and apparently very rare butterfly. The applicant (letter from J.W. Forman to S.P. Hall, 9/13/00) has addressed each of these concerns to our satisfaction.

1615 MAIL SERVICE CENTER, RALEIGH, NORTH CAROLINA 27699-1615
PHONE 919-733-4181 FAX 919-715-3085

NORTH CAROLINA STATE CLEARINGHOUSE Ref. CO-E-0000-230
DEPARTMENT OF ADMINISTRATION
INTERGOVERNMENTAL REVIEW

STATE NUMBER: 01-E-4300-0357 H0
DATE RECEIVED: 12/11/2000
AGENCY RESPONSE: 02/08/2001
REVIEW CLOSED: 02/13/2001

DEC
HISTORIC PRESERVATION OFFICE

MS RENEE GLEDHILL-EARLEY
CLEARINGHOUSE COORD
DEPT OF CUL RESOURCES
ARCHIVES-HISTORY BLDG - MSC 4617
RALEIGH NC

REVIEW DISTRIBUTION
DENR LEGISLATIVE AFFAIRS
DEPT OF CUL RESOURCES
DEPT OF TRANSPORTATION
EASTERN CAROLINA COUNCIL

PROJECT INFORMATION
APPLICANT: NC Dept of Env & Nat Res
TYPE: State Environmental Policy Act
ERD: Draft Environmental Impact Statement
DESC: Bogue Banks Beach Restoration Plan

multi SM RB 1/3
NC GB 1/231
JCWS 1/29/01

The attached project has been submitted to the N. C. State Clearinghouse for intergovernmental review. Please review and submit your response by the above indicated date. If additional review time is needed, please contact this office at (919)807-2425.

AS A RESULT OF THIS REVIEW THE FOLLOWING IS SUBMITTED:

[X] NO COMMENT

[ ] COMMENTS ATTACHED

SIGNED BY: Renee Gledhill-Earley

DATE: 2/2/01

RECEIVED
FEB - - 2001
N.C. STATE CLEARINGHOUSE

JAN 19 2001

DEC 13 2000

March 13, 2001

Mr. Doug Huggett
CAMA Permit Coordinator
Division of Coastal Management
1638 Mail Service Center
Raleigh, NC 27699-1638
VIA FACSIMILE 919-733-1495

RE: Bogue Banks Beach Restoration Plan – SEPA Draft Environmental Impact Statement

Please accept these comments regarding the proposed project on behalf of Environmental Defense, our 10,000 members in North Carolina and 300,000 members nationwide. In general, we have serious concerns regarding the large-scale, persistent and cumulative effects of this and related beach engineering projects, and the adequacy with which impacts from these projects are addressed. We recognize and acknowledge the efforts of the project sponsor and authors of the draft EIS to address the issues of highest controversy surrounding beach engineering, and offer the following comments regarding those issues for which we have particular concerns:

1) Cumulative and Long Term Impacts: In general, our dominant concern regarding beach engineering projects, particularly ones of such extensive spatial (and potentially temporal) magnitude, is the inadequate assessment of cumulative and long-term impacts to living marine resources and essential fish habitats. Specifically, the impacts of these projects are assessed on a piecemeal, or project-by-project basis, rather than as components of a statewide and regionwide beach engineering effort. We recognize that scientific studies examining the impacts of engineering operations on beach, intertidal and nearshore fauna are ongoing and not yet complete, but enough information exists to warrant a programmatic EIS on *all* of these activities for the North Carolina coast, if not the entire southeast region. We have requested such an evaluation of the Corps of Engineers (see Attachment 1) in a letter dated September 8, 2000. The Corps' response was that such an evaluation was too costly to undertake at the present time.

   Although the current project is proposed to be a one-time placement of sand, designed to "restore the sand deficit and provide for average yearly losses over a decade or so" (DEIS, Section 2.1, p. 2-2), it is clearly stated at the end of the introduction (Section 1.4, p. 1-3) that it is unlikely the entire project could be constructed within the same environmental window. Indeed, it appears that, given the funding needs of the communities, the project will stretch over several environmental windows. We are concerned about the downstream impacts of such discontinuous construction, which, as pointed out in Section 5.4.5 (page 5-2, second paragraph) are not insignificant.

North Carolina Office · 2500 Blue Ridge Road · Suite 330 · Raleigh, NC 27607 · Tel 919 881 2601 · Fax 919 881 2607
New York, NY · Washington, DC · Oakland, CA · Boulder, CO · Austin, TX   Project Offices · Boston, MA · Los Angeles, CA
www.environmentaldefense.org

2) Definition of Project Success: As acknowledged in Section 2.2.2 (p. 2-2) one of the major controversies with respect to beach engineering is the development of criteria, or lack thereof, for defining project success. Given the magnitude of resources required for the proposed project, there ought to be a clearly defined set of criteria by which to measure project success, particularly if state cost-share funds are obtained for any portion of the project as discussed in Section 2.3.3. The DEIS state in Section 2.2.2 that "Success will be defined in relation to how closely the postnourishment volume erosion rate compares with the estimated prenourishment volume erosions rate" (page 2-3), yet fails to identify a range of values which would constitute an acceptable or "successful" erosion rate. Although achievement of a certain rate of erosion may constitute success in an engineering sense, it may not necessarily translate into visible success for the project sponsors (i.e., the communities, and potentially state taxpayers if cost-share funding is obtained). Considering that this project is supposed to serve as "prototype" for future beach maintenance efforts (Section 2.1, page 2-1) and as a basis for determining a "long-range solution" from amongst three alternatives (Section 2.4, page 2-5), development of specific evaluation criteria by the project sponsors, rather than the contracted engineering company, would appear to be critical.

3) Project Purpose: Among the four stated objectives (Section 1.3, page 1-2) of the project is "preservation of the environmental, cultural and aquatic resources of the county". We maintain that this project as designed (mainly due to the extensive geographic scale) protects only the unnatural, i.e., manmade "environmental resources". The three remaining planning objectives are a more realistic statement of purpose. Beach engineering projects are rarely, if ever, consistent with protection of the natural environment, and we are unaware of any such projects that have enhanced the nation's living marine resources. We also disagree with the statement that Bogue Banks serves to draw human activity away from the more pristine shores of Shackleford and Core Banks. Although not accessible by vehicle, there is ample transportation available to these locations via public and private ferries, and certainly the number of privately owned boats anchored in Back and Core Sounds during the summer months does not indicate that the public is dissuaded from visiting these areas.

4) Consideration of Alternatives: The DEIS states that "Property abandonment and relocation at a large scale would leave the beach degraded for many years because it would necessarily become a piece-meal process" (page 1). Yet, as referenced previously, the DEIS indicates that if approved, project construction would itself be piecemealed. A retreat and relocation alternative can be planned to initially target those structures most at risk, and can be implemented gradually, rather than in one massive effort. Indeed, should this project be approved, development of a phased relocation and/or exit strategy should be considered, particularly if cost-share funding is obtained. Given that the community plans to reevaluate the costs and benefits of renourishment after a decade of monitoring (Section 2.2.2), development of such a strategy would be proactive. That being said, having once obtained the necessary approval for a beach engineering project (especially if other funding sources are obtained), it is highly likely that the local communities will naturally expect approval for a second project, at an even greater economic and environmental cost.

Also, under the no-action alternative in Section 4.2, page 4-2 one of the stated, yet unquantified, environmental impacts of this alternative is "chronic impacts to beach fauna". We presume that this would be the result of beach scraping. We disagree with this statement, as it implies that placement of dredged sand on the beach would *not* impact beach fauna and that beach scraping would not occur should the project move forward. Incidentally, we find it interesting that "loss of recreational beach" is listed as a quantifiable environmental impact, considering the subjective and intangible nature of the recreational experience, while no attempt is made to quantify the loss of biota.

5) Monitoring Program/Protocol: We applaud the commitment of the project sponsors to develop a comprehensive pre- and post-construction monitoring plan as outlined in Appendix C, and for initiating pre-project benthic monitoring. We feel that such efforts are absolutely necessary in order to assess project impacts accurately over the proposed 10-year project lifetime. We also feel that a periodic (once every three years), publicly available assessment of impacts should be conducted and the results used to adjust the implementation and maintenance of the project and develop a compensatory mitigation plan if warranted, especially if the communities elect to continue beach engineering as a management option. In light of the fact that environmental impacts are not quantified in the analysis of costs and benefits, we feel very strongly that the project sponsors be responsible for funding the monitoring program.

6) NC Marine Fisheries Commission Policies on Beach Dredge and Fill Activities: The North Carolina Marine Fisheries Commission (MFC) has statutory responsibility for protecting the marine and estuarine resources of North Carolina against impacts from both fishing and non-fishing threats. On November 16, 2000, the MFC approved a new policy for the protection of marine and estuarine resources under its authority from the effects of beach dredge and fill activities and related coastal engineering activities (copy attached). The Habitat and Water Quality Standing Advisory Committee of the NC Marine Fisheries Commission developed the policy in response to increasing number of beach engineering projects being developed and the inadequate consideration of cumulative and long-term impacts of these projects. This policy includes numerous issues that have so far not been adequately addressed in the DEIS.

In addition, the MFC shares responsibility under state law for the development of Coastal Habitat Protection Plans (CHPPs). The statutory goal of these plans is the "net enhancement" of the value to the coastal fishery of each habitat type. The Coastal Ocean CHPP is currently in pre-draft form; it will shortly be issued in public draft. That draft will include a set of policies and procedures to protect the marine and estuarine resources of North Carolina against development activities including beach engineering activities. The CHPP will then be formalized in regulation. The CHPP and its adjunct regulations will become a part of the state's federal coastal zone management plan.

Finally, we would like to explicitly state several requests regarding the Bogue Banks Renourishment DEIS:

- When will a programmatic EIS or comprehensive assessment of beach engineering projects be performed, at least for the state of North Carolina?
- What are the project sponsors' criteria for project success?
- Is there a contract with a research institution to continue the pre-construction benthic monitoring, develop post-project benthic monitoring, as well as develop a pre- and post-construction intertidal monitoring program?
- Should state cost-share monies be obtained, are there plans to proactively develop phased exit strategies in the event that beach engineering is not found to be a viable management alternative?

Until these questions and the other issues we have raised can be sufficiently addressed, we do not feel that the Bogue Banks Renourishment project should move forward. We repeat our request that a programmatic EIS be conducted, including full assessment of cumulative impacts of the multiple projects at various stages of design. We reiterate our willingness to discuss any of the issues that we have raised.

We thank you for the opportunity to comment on this very important project.

Sincerely,

Michelle Duval, Ph.D.
Scientist

Daniel J. Whittle
Senior Attorney

Attachment

cc. Chrys Baggett, State Clearinghouse
NC Marine Fisheries Commission
Tracy Rice, Kevin Moody - USFWS

North Carolina
Department of Administration

Michael F. Easley, Governor Gwynn T. Swinson, Secretary

March 15, 2001

Mr. Doug Huggett
NC Dept of Env & Nat Res
Div of Coastal Mgt
Parker-Lincoln Bldg - 1638 MSC
Raleigh, NC 27699-1638

Dear Mr. Huggett:

Re: SCH File # 01-E-4300-0357; Draft Environmental Impact Statement Bogue Banks Beach Restoration Plan

The above referenced environmental impact information has been reviewed through the State Clearinghouse under the provisions of the North Carolina Environmental Policy Act.

Attached to this letter are comments made by State department(s) in the course of this review. The comment(s) need to be addressed in the Final Environmental Impact Statement. This document should be submitted to the State Clearinghouse upon completion for compliance with the North Carolina Environmental Policy Act.

Best regards.

Sincerely,

Chrys Baggett

Ms. Chrys Baggett
Environmental Policy Act Coordinator

Attachments

cc: Region P
Bill Foreman, Coastal Science & Engineering

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Institute of Marine Sciences
252-726-6841
FAX: 252-726-2426

The University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, North Carolina 28557

15 March 2001

Mr. Doug Huggett
CAMA Permit Coordinator
NC Division of Coastal Management
1638 Mail Service Center
Raleigh, NC
FAX- (919)-733-1495

Re: Bogue Banks Beach Restoration Plan

Dear Mr. Huggett:

I enclose here my comments on the Draft EIS for the Bogue Banks Beach Restoration Plan. I make these comments in my professional capacity as a coastal ecologist with the University of North Carolina at Chapel Hill. These opinions are derived from my 25 years of personal experience in quantitative monitoring of the major beach invertebrates on the beaches of Bogue Banks, my years of experimental analyses of how ecological processes on sand beaches are influenced by the physical character of the sediments, my personal experience with two beach nourishment projects at Fort Macon, my 30+ years of professional reading, research, and experience as a marine ecologist, my two decades of teaching barrier island ecology at Duke University and the University of North Carolina, and my recent experience as a member of the IRC charged with development of CHPPs, including the Coastal Ocean Habitat Protection Plan.

In my professional opinion, the proposed Bogue Banks Beach Restoration Plan is inadequately protective of the important natural resources of the intertidal beach and the coastal ocean, including especially the physical habitat and prey invertebrates required to sustain our recreationally and commercially important fisheries and the valued shorebirds of our beaches. Without (1) scientifically rigorous before-after monitoring of physical character of the sediments, impacts and recovery of the invertebrate prey, and consequences of turbidity and habitat change on the fishes, with required mitigation for any substantive impacts, (2) development of a state plan for assessing cumulative impacts based on results of a programmatic EIS covering all these sand mining and beach deposition projects along the entire coast of the state and beyond, as dictated by the range of the important fishes, (3) a match of sediment grain sizes to the natural sediments of the beach in a way that will protect the habitat value of the beach, and (4) restriction of the project to between Dec 1 and March 31 so as to minimize ecological damage and allow recovery to begin to develop during the ecologically significant spring-summer seasons, this project should not be granted a permit.

(1) Scientifically rigorous before-after monitoring of sediments, benthos, and fishes

The draft EIS is grossly deficient in its commitment to the monitoring that is necessary to evaluate the ecological impacts of the project and thereby allow the agencies to learn how to respond to future requests and how to condition projects to protect adequately the public trust resources. While it is true that monitoring of nourishment projects has been done in the past, this project is unique for its spatial scope, its application to pristine shores, and its context in the midst of potentially hundreds of miles of

similar projects coast-wide. Past beach nourishment projects have been done on short stretches of urbanized shore like Atlantic Beach, Wrightsville Beach, and North Topsail. The application to a pristine beach of such a length as to represent a significant fraction of the functional critical habitat for beach fishes, invertebrates, and shorebirds is unprecedented for North Carolina. Past monitoring projects attached to permit applications are almost uniformly poor scientifically, done merely to satisfy a regulatory burden in a way that typically produces inconclusive results. Monitoring should be designed up-front by and reviewed by professional statisticians so that the agency and the public can have reassurance that the important questions can be answered with adequate power to detect effects of ecological significance. That has not been done here. Here we are told that monitoring will be done by the Carteret County monitoring plan. There is no such plan, no detailed statistical design, and no binding commitment by the county, state, or the responsible party to funding such a project. In fact, the necessary before-project sampling has not even been done. In South Carolina projects, the offshore biology has been monitored before and after such projects in each of the four seasons of the year: this proposal includes pre-project monitoring of benthic invertebrates for only one season (autumn), yet the offshore fishery resources here are arguably even more important than off South Carolina. There are no data included on pre-project monitoring of the beach ecosystem and no design that could be evaluated statistically for its rigor and ability (power) to detect important changes. Granting a permit under such inadequacy is not in the public interest.

There is broad and essentially uniform consensus among the scientific community that the impacts of beach nourishment projects on fisheries through modification of their bottom and water column habitats are poorly understood. The monitoring that has been done for such projects in the past (1) has been too restricted to include all the potentially important impacts on fisheries, (2) has lasted for too short a time period to confidently demonstrate recovery, (3) has failed to meet standards of rigor and high power to detect large impacts, and/or (4) has been done for projects occurring on too small a scale to allow extrapolation to the cumulative effects of permitting many miles of beach nourishment. The impacts of concern include both phases of nourishment projects, the mining of sediments from the shelf and the deposition of sediments on the beach.

A minimally adequate monitoring design for either the mining site or the deposition site would include the following components. First, the monitoring design must begin with quantitative data taken before initiation of the project. Such "Before" observations must be made during each season of importance to the biota that comprise and use the habitat. A single year of such "Before" data is an absolute minimum necessary to make rigorous conclusions and multiple years of "Before" data are required to be completely comfortable in estimating the magnitude of effects with confidence. These "Before" data must include observations made in both the putative "Impact" areas and in "Control" areas that are sufficiently distant not to be affected by the project but sufficiently nearby and similar that they can serve to track conditions that would be expected in the "Impact" area in the absence of the project. The observations made during the "Before" period then need to be replicated in the "After" period in both the putative "Impact" areas and the "Control" areas. This monitoring needs to match the seasonal monitoring done during the "Before" period and needs to extend long enough in time to demonstrate recovery or allow inference of recovery with high statistical confidence. The "Control" area should have replication that involves statistically independent sites. This is preferable for the "Impact" areas too, but sometimes impossible because there may be only one project site. In any event, sufficient subsampling must be done at multiple locations to characterize the habitat and its utilization adequately. This monitoring design must be shown to be likely to have high statistical power to detect any magnitude of impact deemed important to fisheries biologists and managers. This requires an effective statistical design. Perhaps the best model for such rigorous project monitoring comes from the paper on BACI (Before-After-Control-Impact) designs by Stewart-Oaten et al. (1986: Ecology). Most monitoring associated with permits is incapable of statistically demonstrating even large impacts of the project with confidence because of inadequate statistical power in the design. The evaluation of cumulative impacts of beach nourishment on a large scale of tens of miles is a particular challenge, fundable perhaps only by creating a monitoring bank from contributions from multiple projects.

(2) Programmatic EIS for cumulative impacts and appropriate monitoring

Besides the needs to evaluate the impacts of this particular project on Bogue Banks, the responsible permitting authorities have a duty to evaluate the cumulative impacts of all such perturbations to the coastal ocean system. This requires first a programmatic EIS that applies the best scientific judgement, open to public review, analysis, and comment, as to cumulative impacts, especially on fishery populations and shorebirds. For a short stretch of urbanized shoreline, it is readily argued that most fish and shorebirds are mobile enough to move elsewhere to feed when their invertebrate prey resources are killed by beach nourishment. Similarly, when prey resources are mined along with sand from the offshore sand bodies, one can argue that the demersal fishes and crustaceans can feed elsewhere. But when projects are large enough and numerous enough and when projects are repeatedly done over time, then the potential for seriously limiting the production of fishes and birds greatly increases. Furthermore, if the physical sedimentary habitat is permanently altered or modified for the long term, then there is great potential for permanent limitation of the extent of critical fisheries habitat both on continental-shelf sand bodies (a limited habitat already in the southern portion of the state) and on intertidal beaches. Nowhere in this Draft EIS for Bogue Banks is there evidence that the public trust resources will be protected from cumulative spatial and cumulative temporal effects. Until such time that evidence exists, no permit should be granted for this project.

(3) Match of sediment grain sizes to protect habitat value of the beach

The recovery of natural ecological functioning of the beach habitat depends upon closely matching the sediment size distribution to that of the natural undisturbed beach. I have shown in a published paper based on study of a previous beach nourishment project on Bogue Banks (Peterson et al. 2000: Journal of Coastal Research) that the US ACOE requirements for matching sediment sizes are inadequate to allow recovery of function of the beach habitat within the following summer season. Incorporation of either too much shell (coarse material) or too much silt/clay (fine material) inhibits recovery. Too much shell inhibits burrowing by the beach invertebrates, which must burrow into the sediments to feed and avoid erosion and wave-transport off the beach face. Too much shell also prevents many shorebirds from feeding on the invertebrates that are present because coarse particles block the biomechanical ability of bills to extract invertebrate prey (see test in published paper by Quammen 1982: Marine Biology). Too much silt/clay likewise prevents sand burrowers from inhabiting a habitat that now lacks the interstitial spaces among sand grains and the penetrability required for burrowing. In addition, silt/clay is readily suspended causing enhanced turbidity, which clogs the filtration apparatus of these suspension-feeding beach invertebrates (mole crabs, coquina clams, some polychaetes, and amphipods) and inhibits surf fishes like pompano, bluefish, and Spanish mackerel from detecting their prey. We possess feeding data from experiments showing this feeding inhibition on pompano in the presence of elevated turbidity. The Bogue Banks project, as proposed in this Draft EIS, plans use of sediments that are much more dominated by shell fragments than the natural pristine Bogue Banks beaches. This will result in long-term (not just transient) reduction in beach invertebrate populations and thus habitat value for surf fishes and shorebirds. I base this judgement upon knowledge of the physical processes that affect sediments on the beach and upon my lab's survey of the biota of North Carolina beaches as a function of shell content. Silts and clays are gradually winnowed away from beach sediments as they become suspended in the water and make it turbid. Shell fragments, in contrast, are left behind to accumulate on beaches, and thus remain to degrade the beach habitat indefinitely until the next nourishment project is needed. Lower densities of the numerically and functionally important large burrowing invertebrates on shellier beaches are dramatic in our unpublished survey data. Thus, the choice to use shell-rich sediments in the Bogue Banks nourishment project will predictably degrade the critical habitat of the intertidal beach indefinitely. Such a poor match with pristine sediments should not be permitted.

(4) Restriction of the project to Dec 1 through March 31

Because of the seasonality of biological use and activity in both the subtidal sand body habitat and the intertidal beach habitat, sand mining and beach deposition should both be restricted to the colder months to minimize ecological injury and to speed up recovery in the next warm season. The draft EIS for the Bogue Banks project does not constrain the project adequately in light of what is known about biological seasonality to protect the functioning of these habitats. Our monitoring of beach invertebrates on Bogue Banks over a period of 25 years shows that the period of December 1 through March 31 is the proper window during which beach invertebrates like mole crabs and coquina clams have migrated to deeper waters, from which they can initiate recovery through migration and reproduction at the end of the project. Furthermore, our sampling of fish abundance at the sand bodies proposed for mining to conduct this Bogue Banks project demonstrated high abundances and high rates of feeding on bottom invertebrates of the sand bodies on November 29 and again in spring, with low levels in February after clod fronts had reduced water temperatures. The Draft EIS for Bogue Banks does not propose a time frame for the project that will adequately protect either of these habitats from the impacts of the project. A permit should not be granted until the window is narrowed to this Dec 1-March 31 season. Furthermore, the public is entitled to a commitment that such a window will be enforced by DCM: similar restrictions have not been enforced in the past and I have little confidence that they will be in the future, absent some new mechanism of assurance.

I trust that my concerns are clearly and fully enough articulated here. If any comments need further elaboration, please ask. In addition, if you need further information from our files, please ask.

Sincerely,

Charles H. Peterson

Charles H. Peterson
Alumni Distinguished Professor

North Carolina
Department of Environment and Natural Resources
Division of Coastal Management

Michael F. Easley, Governor
William G. Ross Jr., Secretary
Donna D. Moffitt, Director

NCDENR

March 20, 2001

Coastal Science and Engineering, LLC
PO Box 8056
Columbia, SC 29202-8056

and

Stroud Engineering
Hestron Plaza 2(A)
151 Hwy. 24
Morehead City, NC 28557

Dear Sirs:

This letter is in reference to the Bogue Banks Beach Restoration Plan Draft EIS (DEIS). As you may be aware, the DEIS completed its initial State Clearinghouse review on March 15th, 2001. It is my understanding that the State Clearinghouse has provided you with copies of the comments received by that office as of the March 15th deadline. In case this is not correct, I have provided a copy of these comments as well. In addition to these comments, an additional set of DEIS review comments were received in this office on March 16th, 2001. Although these comments were received one day after the official review period ended for the review, after discussion with the State Clearinghouse I have determined that it is appropriate and necessary that these comments be considered and addressed in Final Environmental Impact Statement (FEIS). Therefore, I must ask that you address all of the attached comments in the FEIS, and that 12 copies of the document be submitted to this office so that I may initiate the FEIS review process.

Please let me know if you have any questions concerning this matter. I may be reached at (919) 733-2293 or by e-mail at doug.huggett@ncmail.net.

Sincerely,

Doug Huggett

Doug Huggett
Major Permits Coordinator

cc: Carteret County
DCM – Morehead City
Chrys Baggett, State Clearinghouse

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

April 03, 2001

Mr. Doug Huggett, CAMA Permit Coordinator
NC Division of Coastal Management
1638 Mail Service Center
Raleigh NC 27699-1638 Fax: 919-733-1495

RE: Response to Comments dated 15 March 2001 from Dr. Charles H. Peterson, University of North Carolina Institute of Marine Sciences [Ref: EIS #01–E–0357] Bogue Banks Beach Restoration Plan (2049)

Dear Mr. Huggett:

I am writing on behalf of Carteret County and the Towns of Pine Knoll Shores and Indian Beach, in response to the above-referenced comments on the Bogue Banks nourishment project.

The correspondent has urged your agency to require that four conditions be met before a permit for the Bogue Banks nourishment is granted. I wish to outline herein how the applicant plans to meet certain of these conditions and to explain why others are not possible to achieve in any reasonable time or budget.

Dr. Peterson and his colleagues at UNC-IMS contributed valuable information and data in the development of the draft EIS under contract to Carteret County. They provided the initial biological samplings in November 1999 and February 2000, and prepared a detailed report which is Appendix C of the EIS.

Our project team has actively sought Dr. Peterson's guidance and recommendations for design of the project such that environmental impacts can be minimized. His contributions to the project have been important. We have also sought the advice of other experts [including Dr. Robert Van Dolah (SCDNR) and Dr. Bart Baca (Nova University)] and have reviewed the literature regarding impacts of dredging and beach fills on the fauna of similar project sites.

Early in the county's planning process (fall 1999), we were informed by Dr. Peterson that no quantitative biologic sampling data exist in and around our proposed borrow areas. As a result, the county, at its own initiative, contracted with UNC-IMS for a preproject monitoring that could be used as a baseline for future comparisons. The first of two planned samplings was completed by Dr. Peterson's group in November 1999. Detailed data from this survey are reported in Appendix C of the draft EIS.

UNC-IMS reportedly has completed numerous samplings of benthic organisms along the beach as part of a four-year study of the impacts of beach scraping. We requested relevant data from these samplings so they could be incorporated into the EIS but were informed by Dr. Peterson that they will not be available until one of his students completes a dissertation. As outlined in the draft EIS, we plan to use these data to estimate baseline beach conditions for the project when they become public.

Following are our responses to the four conditions outlined by Dr. Peterson.

Item 1) Rigorous before-after monitoring of sediments, benthos, and fishes.
The draft EIS (Appendix C) outlines the sampling protocols used by Dr. Peterson for his offshore surveys. The applicant proposes to follow up these samplings with additional benthic sampling in spring 2001 (preproject). Postproject sampling will be performed using similar sampling protocols and design in consultation with your agency and other reviewing agencies. Because it now appears that the project will be completed in several discrete segments by three towns and the county over several years, we are requesting guidance from NC DENR and National Marine Fisheries regarding what constitutes an acceptable level of biologic sampling. The Towns of Pine Knoll Shores and Indian Beach do not have unlimited resources to fund research that is more properly performed by universities or government agencies or that is more applicable to global concerns. However, the applicants realize the importance of sampling habitats over which their projects may produce direct and quantifiable impacts. Accordingly, we have recommended that the county and cooperating municipalities sponsor the following:

- A second preproject sampling of benthic organisms in spring 2001 in and around the planned borrow areas following the Peterson sampling design given in Appendix C of the draft EIS.
- Annual postconstruction sampling of benthic organisms in and around the borrow area(s) and beach for up to three years after completion of the Pine Knoll Shores and Indian Beach reaches on a schedule acceptable to state and federal agencies.

The results of Appendix C, as well as research published in the literature, suggest that quantification of impacts to fisheries by the proposed project is not possible by any reasonable amount of sampling of the water column for transient species. Such questions are global in nature and will require a major commitment of time and money to answer in any rigorous sense. We believe that the natural variation in pelagic species passing through and utilizing the borrow area(s) and beach is far too great to quantify impacts or prove cause and effect. This problem is not a straightforward sampling exercise. Therefore, the chance of any sampling schedule offering rigorous, predictive results is negligible.

Item 2) Programmatic EIS for cumulative impacts
The question of cumulative impacts is important and should be addressed in some manner by state and federal agencies. However, this is not a trivial exercise and certainly not one that can be accomplished in a reasonable amount of time. It will take years and millions of dollars to even begin to address this problem in any sort of rigorous way, given the wide range of variables that must be sampled, analyzed, modeled, and integrated. This is a global concern. I believe that years of effort would be required just to develop a scientific sample design or statistical model upon which professionals could agree. The question of cumulative impacts spans the disciplines of oceanography, geology, biology, chemistry,

CSE

water quality, fisheries, primary production, climate, rainfall, runoff, and anthropogenic inputs of man. This is not something that can be answered before the next damaging storm impacts Bogue Banks and, therefore, should not be a prerequisite for granting a permit for the project.

Item 3) Match sediment grain sizes.

The correspondent expressed concern about the shell percentage and advises that "high" shell content should not used. The draft EIS presents data for three borrow areas (A, B1, and B2). Borrow area A contains a deposit having about twice the shell content of the beach. Borrow areas B1 and B2 contain about the same 20 percent shell content as the native beach. As the draft EIS and permit application states in detail, the applicant proposes to use the particular combination of borrow areas that optimizes the match of grain sizes and costs of dredging. The applicant is continuing to collect borings in borrow areas B1 and B2 (beyond those reported in the draft EIS) in response to Dr. Peterson's recommendation to limit the shell percentage. In fact, more care has gone into the search for a good match of sediment types for this project than any previous nourishment along Bogue Banks. Other investigators have noted how poorly prior projects matched the sediments. (Atlantic Beach was too shelly and the Ramada Inn site was too fine.) The applicant believes that there is insufficient monitoring data from these prior projects to make any definite recommendations regarding shell content. If the agencies will provide quantitative criteria for nourishment sediment characteristics (specifically, a particular range of shell percentages) based on previously published studies, the applicant will strive to match them.

Item 4) Restrict the project to December 1 through March 31.

This restriction would be unprecedented, considering the number of nourishment projects that are completed during the biologically productive summer months. We are aware of no data or published reports that state these dates constitute the only acceptable window for dredging. The applicant has chosen to perform the work in cold-water months rather than request a permit for work in summer as other agencies have done. The period from around 1 November to around 1 May has been an accepted standard for construction outside the normal turtle-nesting period in many East Coast states. By shortening the window to only four months, it is highly unlikely that the project can be completed in one season. This means that equipment will have to re-mobilize and re-impact the project areas at considerable extra expense to the applicant.

If quantifiable data exist and state or federal agencies have a justifiable basis for establishing such a restrictive dredging window for the proposed project, the applicant is prepared to adjust the schedule. However, such restrictions should then be applied universally. I believe the schedule for dredging is important. However, to ultimately avoid any sense of arbitrariness, extensive biologic sampling on a monthly basis for many years should be performed by government agencies such that a sound basis for restricting the dredging window can be developed.

Finally, I would like to reiterate that what the applicant is proposing is a one-time project. It will be the first nourishment of Bogue Banks designed to match properly the texture of sediments in the borrow area with those of the native beach. The project will be performed in sections rather than in one complete pass over 16.8 miles such that adjacent areas have time to adjust and recover their biologic populations before the next sections are constructed. It will reduce the need for and frequency of beach scraping, a recurring adverse impact to biota in recent years. And it will allow dunes to build naturally with fine, windblown sediments that facilitate revegetation.

The present beach/dune system of Bogue Banks is not pristine. Its profile has been altered such that it is steeper and more vulnerable than the native beach to severe damage in storms. Coarse sand and pebbles common to the swash zone now reside in the foredunes, inhibiting revegetation. With loss of recreational beach has come a loss of turtle-nesting habitat and diminishment of a vegetative buffer between the ocean and development.

Bogue Banks is eroding, but not fast enough to create economic incentives to relocate. The proposed project, rather than continuing the present cycle of scraping after every storm, has a better chance of restoring the natural character of the beach and reducing the need to scrape. The project scale proposed by the applicant is sufficient to provide recreation and storm-protection benefits for at least one decade.

In closing, I wish to express my firm's commitment to executing the project in as environmentally sensitive a manner as practicable and reasonable. However, I do not believe it is possible for any project to achieve all four conditions recommended by Dr. Peterson. We will be happy to meet with your agency and UNC-IMS representatives at any time to develop an acceptable biological monitoring plan for the project.

Thank you for your consideration.

Yours truly,

Timothy W Kana PhD
Project Director

cc: State Clearinghouse, Chrys Baggett
Carteret County, Frank Rush
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
CSE, Bill Forman

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

April 04, 2001

Mr. Doug Huggett, CAMA Permit Coordinator
NC Division of Coastal Management
1638 Mail Service Center
Raleigh NC 27699-1638 Fax: 919-733-1495

RE: Response to Comments dated 13 March 2001 from Environmental Defense
Bogue Banks Beach Restoration Plan (2049) [SCH File #01-E-4300-0357]

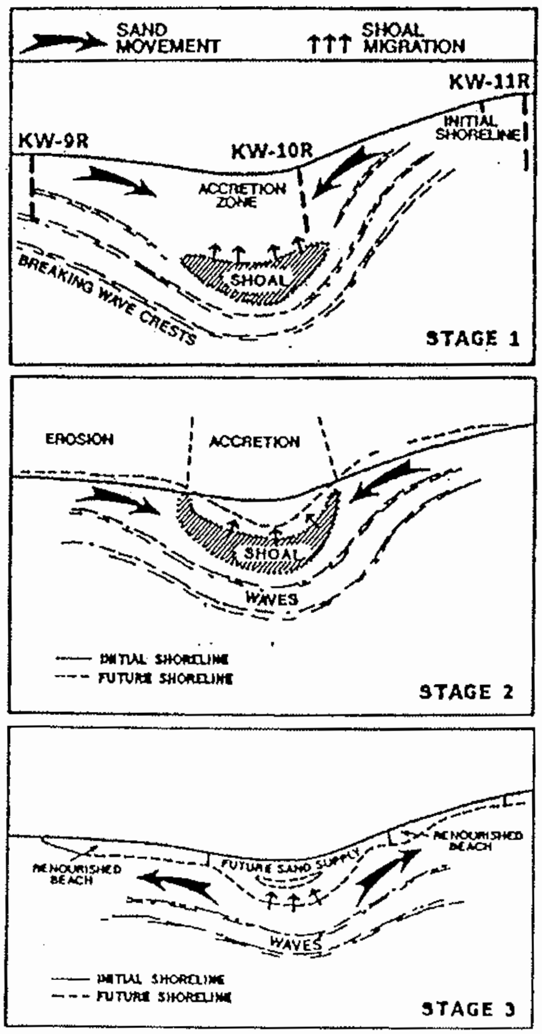
Dear Mr. Huggett:

This letter is in response to Environmental Defense comments dated 13 March 2001 on the above-referenced draft environmental impact statement.

Item 1) Concerns regarding cumulative and long-term impacts and schedule for construction
Response: The question of cumulative impacts is important and should be addressed in some manner by state and federal agencies. However, this is not a trivial exercise and certainly not one that can be accomplished in a reasonable amount of time. It will take millions of dollars to even begin to evaluate this problem in any sort of rigorous way, given the wide range of variables that must be sampled, analyzed, modeled, and integrated. This is a global concern. I believe that years of effort would be required just to develop a scientific sample design or statistical model upon which professionals could agree. The question of cumulative impacts spans the disciplines of oceanography, geology, biology, chemistry, water quality, fisheries, primary production, climate, rainfall, runoff, and anthropogenic inputs of man. This is not something that can be answered before the next damaging storm impacts Bogue Banks.

A growing body of research shows that borrow area dredging and beach nourishment produce short-term, temporary impacts (cf, Van Dolah et al, 1992; Jutte et al, 1999a; 1999b; referenced in the draft EIS, Appendix A). These can be minimized by proper matching of sediments and construction in colder months (as planned for the present project). After the project is complete, there will be nearly the same area of intertidal and offshore habitat available as before the project. It will simply be displaced seaward by the width of the new beach. Environmental studies of similar projects suggest impacted areas will recolonize rapidly. The primary questions for project monitoring are how fast will the borrow area and beach communities recover and how closely will the benthic populations match the native conditions. In theory, these should be easy questions to answer. But in reality, natural populations fluctuate over such wide ranges that there can never be assurance that a change in species numbers or diversity is due to anthropogenic impacts like dredging rather than some global impact such as water temperature change. Recently, South Carolina closed its spring shrimp fishery because the white shrimp larvae count was less than 5 percent of normal for this time of year. The decline was attributed to a prolonged cold snap where water temperatures fell below 45°F for more than 18 days. Such order-of-magnitude declines are common in natural systems and will occur off Bogue Banks as well, whether or not the project is constructed.

The correspondent expresses concern about downstream impacts if the project is performed discontinuously in sections and cites page 5-2 of the draft EIS. The study referenced (Roessler, 1998) relates to the possible effect of an offshore disposal mound near Beaufort Inlet encompassing nearly 30 million cubic yards. This artificial feature built over 30 years in connection with USACE navigation projects may have altered wave/current patterns along Atlantic Beach, although no historical data exist to prove this. The proposed project will not alter the nearshore bottom such that it changes the wave and current patterns to the detriment of downstream communities (cf, Appendix G). The scale of the borrow-area changes for the proposed project are dwarfed by changes around Beaufort Inlet and the offshore mound.



Regarding possible adverse end effects of the project, this will be minimized by tapering of the fill sections as described in the draft EIS and in responses to NCDENR comments in the correspondence section of the draft EIS. Adjacent unnourished areas will tend to benefit rather than suffer from the downstream spread of the beach fill. Many nourishment projects, in fact, are designed as "feeder" beaches whereby sand is placed every few years along an updrift reach in order to flow downcoast and nourish other sections (CERC, 1984). Probably the worst "end effects" occur in <u>natural</u> systems where shoals break free of inlets and bypass to the adjacent beach. As the process occurs, the beach in the lee of the shoal accretes rapidly while the adjacent sections erode. This has been documented in many places (cf, Kana et al, 1985; 1999) and is illustrated schematically in Figure A. The reason that natural shoal bypassing produces adverse end effects is because it tends to concentrate large volumes over short lengths of beach. The proposed project will spread sand relatively thinly and evenly along many miles of shoreline such that perturbations in the shoreline will be minimal.

FIGURE A.

CSE

Item 2) Definition of project success

As engineers for the applicant, my firm is developing quantitative criteria for defining project success. The key variable is the volumetric erosion rate. In our review of prior studies, we found no historical profiles or surveys which could be used as a rigorous basis for predicting this rate. The only data available were linear shoreline change rates (eg, movement of mean high water or vegetation lines) and limited sets of wading depth profiles (not comprehensive for the entire project area). We used these data to extrapolate volumetric changes and estimate approximate beach fill requirements for 5-year, 10-year, and 20-year periods (CSE Stroud, 1999). The applicant has initiated annual surveys of the nearshore and has obtained two sets of 110 profiles spanning the length of Bogue Banks. Each profile extends about 1,000 ft offshore and documents changes to the outer bar.

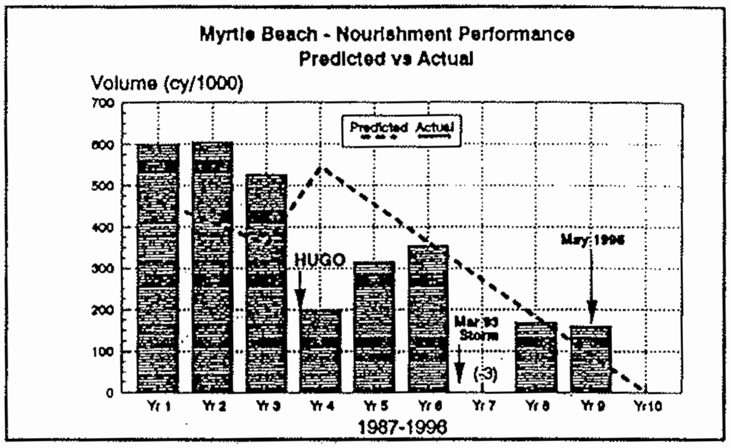
Enclosed is the first beach monitoring report covering the period June 1999 to June 2000. Also contained in the report are about 18 post-*Floyd* profiles from September 1999. The results show a range of erosion and accretion losses and provide more guidance for establishing project erosion rates. However, we consider these data to be insufficient to make any more refined long-term predictions because they only span one year. The applicant plans to resurvey the beach in June 2001 and update these data. As we have represented in the draft EIS, the anticipated volume losses are expected to be of the order 1-5 cy/ft/yr measured to closure depth. The rate will be closer to the high range if borrow areas B1 and B2 (less shelly deposits) are used and closer to the low range if area A (more shelly deposit) is used. Regardless of the rate, the applicant plans to perform annual surveys and quantify the fate of the beach fill such that a more rigorous erosion rate estimate can be developed for Bogue Banks over the next decade.

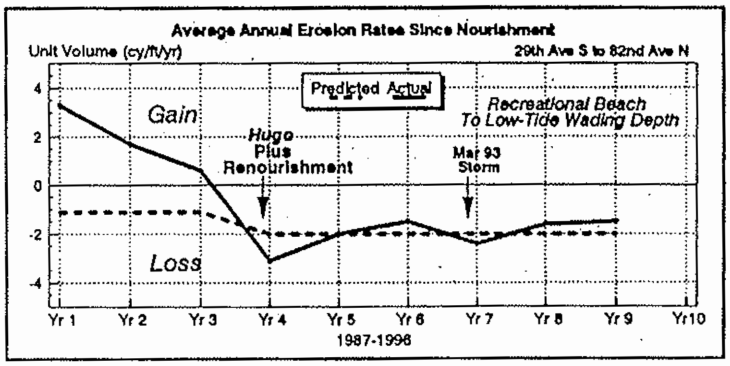
Figure B illustrates similar results for a project in Myrtle Beach (SC). In that particular project, the unit fill volumes were only about one-third the quantities proposed for Bogue Banks. Historical data suggest that Myrtle Beach and Bogue Banks have nearly equal long-term erosion rates.

CSE is in the process of developing "specific evaluation criteria" in consultation with the sponsoring communities. These will be particular to each borrow area(s). In general, the most appropriate criteria are volumetric erosion rates rather than some particular beach width because it is the littoral volume that is important in the long run. Short-term, beach-width fluctuations are poor predictive parameters because they are contour sensitive. For example, Hurricane *Floyd* produced a certain average dune recession (~12 ft) but matched it with seaward movement of mean high water (cf, CSE, 2000 – attached report).

CSE

FIGURE B.





Item 3) The correspondents question one aspect of the project purpose – "preservation of the environmental, cultural and aquatic resources of the county"

We disagree with the correspondent's contention that nourishment projects do not enhance or preserve the nation's living marine resources. It is well established that nourished beaches have restored turtle nesting habitat and vegetated dunes along many coasts that previously were armored with seawalls and had no such habitats (cf, National Academy of Sciences, NRC, 1990; 1995). Nearby Atlantic Beach is one such example. Others include Miami Beach (FL) and Myrtle Beach (SC). Pea Island (NC), a wildlife preserve, has received several inputs of nourishment to counter erosion and maintain protection to valuable back barrier habitats. Considering the biologic value of estuaries and lagoons, any soft solutions like nourishment that maintain the integrity of barrier islands will protect and preserve critical habitats to some degree.

The proposed project will reduce the need for and frequency of sand scraping. This will allow dunes to build gradually with appropriate-sized aeolian sand. Presently, most of the foredunes are composed of medium to coarse sand, pebbles, and shells, an unnatural sediment scraped from the surf zone after recent hurricanes. This is not enhancing the dune habitat.

While undeveloped Core Banks and Shackleford Banks are accessible by boat, only a tiny number of visitors (order of 1-2 percent) go there compared to the numbers visiting Bogue Banks. People want access to the shore. Carteret County strikes a model balance between less accessible beach preserves (~65 percent of shoreline) and accessible recreational beaches (~35 percent). Further, there are no roads through these preserves, unlike the Hatteras National Seashore.

4) Comment on consideration of alternatives regarding abandonment and relocation

The economics of nourishment versus property abandonment can always be refined. However, at present, they are skewed strongly in favor of maintaining the beach as described in detail in the draft EIS. The correspondents assert that the proposed project will be performed piecemeal just as property abandonment would be piecemeal. However, the definition of piecemeal is not the same in this case. Property abandonment would necessarily be done on a lot-by-lot basis with protracted delays and litigation likely. Nourishment, by contrast, is planned for long segments of beach that encompass hundreds of properties. The first segments planned (Pine Knoll Shores and Indian Beach/Salter Path) span over seven miles. This length would be considered a relatively long nourishment project by any standard (CERC, 1984). The Town of Emerald Isle is presently evaluating the feasibility of completing a three-mile project (Reach 3 and part of Reach 2) in 2002-2003. That reach encompasses nearly 200 properties. Each community must make careful decisions in the future regarding whether to continue nourishment or move toward abandonment. The problem now is that there are insufficient historical data to make this determination. The proposed project will offer an opportunity to establish on a site-by-site basis whether nourishment is viable for Bogue Banks. Evidence from the 1986 and 1994 nourishments of Atlantic Beach suggest overwhelmingly that it is viable in this setting. Further, some longtime opponents of coastal development such as Prof. Orrin Pilkey (Duke University) have stated that Bogue Banks is among the best candidate sites for nourishment in North Carolina.

Regarding the concern about beach scraping, the draft EIS makes clear that the proposed project will reduce the need for and frequency of sand scraping. We did not say it would eliminate it because certain contingencies may move property owners to demand scraping after a major storm. However, we expect the political pressure to scrape will be dramatically reduced after the projects just as it has been along Atlantic Beach. A tour of that site confirms that almost no sand scraping was performed after Hurricane *Floyd*, whereas the communities of Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle scraped nearly the entire foredune.

5) Concerns regarding monitoring programs

The applicant is committed to a self-funded monitoring plan which will be developed in consultation with the appropriate regulatory agencies.

6) Concerns regarding proposed North Carolina Marine Fisheries Commission policies on beach dredge and fill activities

To the best of our knowledge, the referenced policies have not yet been certified by the state. The majority of issues raised by these new policies are addressed in the draft EIS. NCDENR has reviewed and approved the draft EIS. The applicants are striving to improve upon existing nourishment practice and work within the present regulatory framework. In fact, it will only be through properly designed and executed projects and long-term monitoring (as planned by the applicant) that state and federal

CSE

agencies can develop realistic and practical policies for protecting marine resources and maintaining the integrity of developed barrier islands via soft engineering solutions. The applicant expects to contribute knowledge regarding impacts after execution of the project such that our regulatory agencies may improve their management of coastal resources.

I hope the above responses adequately address the concerns raised by Environmental Defense. If you need additional clarification, please contact us at the earliest time.

Thank you for your consideration.

Yours truly,

Tim Kana

Timothy W Kana PhD
Project Director

cc: State Clearinghouse, Chrys Baggett
Carteret County, Frank Rush
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
CSE, Bill Forman

Michael F. Easley
Governor

Sherri Evans-Stanton, Acting Secretary
Department of Environment and Natural Resources

Kerr T. Stevens
Division of Water Quality

FILE

JOB 2025
☐ CONTRACTS
☐ INVOICES
☒ CORRESPONDENCE
☐ BIDDING & CONSTR.
☐ WORKING PAPERS

March 23, 2001
Carteret County
DWQ Project # 010324

APPROVAL of 401 Water Quality Certification and ADDITIONAL CONDITIONS

Mr. Robert Murphy
Carteret County Manager
Courthouse Square
Beaufort, NC 28516

Dear Mr. Murphy:

You have our approval, in accordance with the attached conditions and those listed below, to dredge 2.58 square miles of beach front for the purpose of conducting a beach renourishment project along Bogan Banks from Atlantic Beach/Pine Knoll shores to shipwreck Lane is Emerald Isle as described in your application dated March 5, 2001. After reviewing your application, we have decided that this fill is covered by General Water Quality Certification Number 3274. In addition, you should get any other federal, state or local permits before you go ahead with your project including (but not limited to) Sediment and Erosion Control, Coastal Stormwater, Non-Discharge and Water Supply Water shed regulations. **This approval will expire when the accompanying 404 or CAMA permit expires unless otherwise specified in the General Certification.**

This approval is only valid for the purpose and design that you described in your application except as modified below. If you change your project, you must notify us and you may be required to send us a new application. If the property is sold, the new owner must be given a copy of this Certification and approval letter and is thereby responsible for complying with all conditions. If total wetland fills for this project (now or in the future) exceed one acre, compensatory mitigation may be required as described in 15A NCAC 2H .0506 (h) (6) and (7). For this approval to be valid, you must follow the conditions listed in the attached certification and any additional conditions listed below.

1. DWQ staff recommended that the CAMA Permit be conditioned to address all issues raised in the EA or EIS.

If you do not accept any of the conditions of this certification, you may ask for an adjudicatory hearing. You must act within 60 days of the date that you receive this letter. To ask for a hearing, send a written petition, which conforms to Chapter 150B of the North Carolina General Statutes to the Office of Administrative Hearings, P.O. Box 27447, Raleigh, N.C. 27611-7447. This certification and its conditions are final and binding unless you ask for a hearing.

This letter completes the review of the Division of Water Quality under Section 401 of the Clean Water Act. If you have any questions, please telephone John Dorney at 919-733-9646.

Micheal F. Easley
Governor

Sherri Evans-Stanton, Acting Secretary
Department of Environment and Natural Resources

Kerr T. Stevens
Division of Water Quality

Sincerely,

Kerr T. Stevens

Attachment

cc: Corps of Engineers WilmingtonField Office
Wilmington DWQ Regional Office
File copy
Central Files
Doug Huggett, DCM
Dave Clark; Carteret County Engineer

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4

Sam Nunn Atlanta Federal Center
61 Forsyth Street, S.W.
Atlanta, Georgia 30303 - 8960

APR 13 2001

Colonel James W. DeLony
District Engineer
ATTN: Mr. Mickey Sugg
U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, North Carolina 28402-1890

SUBJ: Carteret County: Nourishment of Bogue Banks Beaches
Action I.D. No. 200000362

Dear Colonel DeLony:

This is in reference to the above-listed public notice, dated March 16, 2001, to dredge and discharge approximately 8.0 million cubic yards of sand into wetlands and waters of the U.S. to nourish approximately 16.8 miles of beaches along the eastern shore of Bogue Banks Barrier Island, from Emerald Isle to Pine Knoll Shores, Carteret County, North Carolina. The stated purpose of the project is to restore the shoreline that has been severely damaged within the last five years from hurricanes and winter storms. Individual municipalities are expected to assume responsibility for execution of the nourishment project within a particular reach and to control the timing of implementation, scale, and scope of work, but the County is requesting a permit for the entire project so that the full scope of work can be coordinated.

The U.S. Environmental Protection Agency, Region 4, Wetlands Section (EPA), has reviewed this proposal and the Draft Environmental Impact Statement (DEIS) (dated October 31, 2000) for the project. We note that the preparers of the DEIS have made a commendable effort to address the majority of typical issues with beach nourishment, such as impacts to fauna from nourishment of sand with incompatible grain size, purpose and need, abandonment and relocation options, and impacts to the borrow sites (off-shore). The level of biological studies proposed for pre-project and post-project analysis is significantly better than other nourishment projects we have reviewed (most have no plans to conduct studies at all). However, we still have several concerns with the project as proposed, and with beach nourishment in general. At this time, we cannot recommend authorization of the project. Prior to consideration of project authorization, we recommend that the applicant address the resources agencies' comments on the DEIS and complete the final EIS.

EPA has been equivocal regarding the issue of pumping sand onto an eroding shoreface. Generally, we have not opposed beach nourishment when it provided a disposal site for a nearby, already authorized navigation project. The key factor, however, was whether or not biologically sensitive resources would be adversely affected through the use of this disposal method. As is usually the case, the value of adjacent structures, declining width of the recreational beach, and the perceived need to provide continued economic potential to shorefront property serve as the rationale for beach nourishment. The dollar value assigned to these factors in the benefits/costs calculations are almost always deemed to be greater than any environmental losses.

The DEIS states that the project is "an interim ten-year plan for the community - one that must be monitored carefully and used as a basis for formulating a long-range solution from among three alternatives: (1) no action, (2) abandonment and relocation, or (3) continued renourishment." However, providing wider beaches with no plans to curb shoreline development will only result in greater oceanfront development in ten years. With more development, and the likelihood that property values and tax income from these properties will be much higher in ten years, it appears that the long-range solution will be a foregone conclusion (continued nourishment or perhaps other even more harmful activities such as seawall construction). Because the stated erosion of the shoreline is so low, EPA believes there may be sufficient time *now* to conduct a more detailed analysis to formulate a long-range solution. We believe that a 50-year period may be a more a sensible timeframe to consider for shoreline changes and impacts to oceanfront properties. We believe that this is an appropriate planning period to use, because of the likely impacts from sea-level rise during this timeframe, and also because a long-term plan to abandon and/or relocate homes may be more acceptable when occurring over a 50-year period rather than a ten-year period.

EPA is concerned by the proposal for individual municipalities to complete the project. The public notice states that individual municipalities are expected to assume responsibility for execution of the nourishment project within a particular reach and to control the timing of implementation, scale, and scope of work. However, the EIS and other information presented with the public notice states a relatively specific time frame for construction, and also assumes the use of one dredge for the overall project. EPA believes that the implementation of this large project by as many as four separate entities may provide other challenges which have not been addressed by the EIS, such as coordination of dredging sites to avoid two different municipalities dredging the same area twice, ensuring compliance with the permit by the four additional entities and their contractors, and ensuring that most or all municipalities will complete the project (otherwise, erosion may increase in certain areas, or the longevity of the overall project may suffer). Because the project is being implemented by up to four separate municipalities, with potentially separate project schedules, we believe that it is imperative to prohibit activities during the sea turtle nesting season, and that the specific conditions of any authorization should be exceptionally clear and should reflect a potentially piecemeal completion of the project.

We suggest that a proposal for long-term measures include potential alternative mitigation for project impacts to the near-shore environment. For example, currently untreated nonpoint-source runoff from adjacent developed or hard surface areas could be redirected to some form of treatment within the project reach, prior to discharges to the ocean or sound. In our opinion, lessening the adverse consequences of storm water runoff in this sensitive/important environment could be beneficial. Moreover, water quality improvements would benefit recreational interests. This and other out-of-kind measures could be used for similar nourishment projects which are planned/authorized. Any measures which can lessen the impacts of increasingly pervasive shoreline development need to be examined. We note that the County, although interested in protecting the existing houses on Bogues Banks Island, has made no effort to halt oceanfront development. We recommend that the County and municipalities revise land use plans and improve zoning ordinances, specifically targeting the acquisition and/or preservation of developed and undeveloped lots to prevent future development. These preserved properties could become a network of greenspace and public beach access, enhancing the Bogue Banks experience for tourists and locals alike. Further, we recommend that greater avoidance of hazard areas by development, expanded use of setbacks for structures, and an overall lower development density would significantly reduce storm damage, without necessarily significantly affecting the tax base.

As pointed out by the U.S. Fish and Wildlife Service in their comments to the North Topsail Beach and Surf City nourishment projects (dated March 16, 2001), the addition of sediment from beach fill projects may threaten the sensitive nearshore habitats, particularly hardbottoms which are close to shore. Although the DEIS considers the impacts to hardbottom from dredging of the borrow areas, EPA could find no discussion of the potential impacts to nearshore hardbottom from sedimentation due to sand placement on nearby beaches. EPA recommends that the DEIS fully consider the adverse impacts that sedimentation (due to sand placement) could have on the hardbottom communities offshore, and the fisheries resources that they support.

At this time, EPA cannot recommend authorization, due to potential direct, secondary, and cumulative impacts of the proposed project. We recommend that all agency comments be addressed in the completion of the EIS for the project, prior to project authorization. Thank you for the opportunity to comment on this project. If you have any questions regarding these comments, please contact Kathy Matthews at the above address or by telephone at (404) 562-9373.

Sincerely,

William L. Cox, Chief
Wetlands Section

cc: USFWS, Raleigh
DCM/NCDENR, Raleigh
NMFS, Beaufort
DCM/NCDENR, Morehead City

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1890
WILMINGTON, NORTH CAROLINA 28402-1890

IN REPLY REFER TO April 26, 2001

Regulatory Division

Action ID. 200000362

Mr. Pete Allen, Manager
Carteret County
Courthouse Square
Beaufort, North Carolina 28516

Dear Mr. Allen:

Please reference Carteret County's application for Department of the Army (DA) authorization to conduct beach nourishment along 16.8 miles of Bogue Banks Barrier Island by discharging 8.0 million cubic yards of dredge material into Section 10 Navigable Waters and Section 404 waters of the Atlantic Ocean, in Carteret County, North Carolina.

In response to your proposal, our office has received comments from the National Marine Fisheries Service, by letter dated April 20, 2001 (copy enclosed), recommending against the authorization of your permit request. It is our suggestion that you revise your plans to satisfy the interests of the objecting agency.

It is the policy of the DA to provide an applicant the opportunity to furnish a proposed resolution or rebuttal to all objections from government agencies and other substantive adverse comments before a final decision is made on a proposed project. In this regard, I would appreciate receiving any comments that you have on this matter. If you intend to comment, please give your immediate attention to this matter, so processing of your permit application can be expedited.

If you have questions or comments, please contact me at (910) 251-4811 and I will assist you in coordinating with the review agencies.

Sincerely,

Mickey Sugg
Wilmington Regulatory Field Office

Enclosure

Copy Furnished (with enclosure):

Mr. Bill Forman
804 Arendell Street
Suite 1
Morehead City, North Carolina 28557

Copy Furnished (without enclosures):

Mr. David Rackley
National Marine Fisheries Service
219 Fort Johnson Road
Charleston, South Carolina 29412-9110

Mr. Ron Sechler
National Marine Fisheries Service
101 Pivers Island Road
Beaufort, North Carolina 28516

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive North
St. Petersburg, Florida 33702-2432

April 20, 2001

Colonel James W. DeLony
District Engineer, Wilmington District
Department of the Army, Corps of Engineers
P. O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Mr. Mickey Sugg

Dear Colonel DeLony:

The National Marine Fisheries Service (NMFS) has reviewed **Action ID No. 200000362**, dated March 16, 2001. According to the notice, Carteret County, c/o Mr. Robert Murphy, County Manager, proposes to dredge and discharge approximately 8.0 million cubic yards of predominately sand material for purposes of restoring approximately 16.8 miles of ocean beach between Emerald Isle and Pine Knoll Shores, in Carteret County, North Carolina. The stated purpose of the project is to restore oceanfront shoreline that has undergone erosion within the last five years as a result of hurricanes and winter storms. This letter is provided in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and Part IV.3(a) of the August 11, 1992, Memorandum of Agreement between our agencies. The NMFS hereby advises that components of the proposed work may result in substantial and unacceptable impacts to aquatic resources of national importance, and we provide grounds for determination that issuance of the requested permit must be denied, or the authorized work must be substantially modified, to protect those resources.

The proposed beach nourishment consists of placing dredged material at six locations (reaches). The final project elevation of the beaches would be approximately +8.0 feet mean low water. Approximately half of the dredged material, which would hydraulically excavated from three offshore bottom locations, would be deposited between the low water line and the outer bar located between 500 and 700 feet offshore. The offshore borrow sites (designated as sites A, B1, and B2) are located between 0.5 to 3.0 miles offshore in waters averaging -35 to -45 feet in depth. A hopper dredge or special suction dredge would be used to excavate the upper two to three feet of sediments and hydraulically pump it, via submerged pipeline, directly onto the designated beach area. The material would be deposited between the foredune and a temporary dike located 150-200 feet seaward of the foredune. The deposition area would be designed to allow coarser materials to settle before the fine sediments are washed into the surf zone. Once the material has settled, it would be distributed along the shoreline using equipment such as bulldozers and front-end loaders. Authorization is sought for use of any combination of reaches and borrow sites.

An interagency meeting and inspection of the project area is scheduled for May 11, 2001. An environmental analysis titled "Draft Environmental Impact Statement (DEIS), Bogue Banks Beach Restoration Plan" was sent to us by the applicant; however, normal procedures for review of the document and use of it for decision making have not been implemented. As a result, the NMFS has not formally reviewed or provided comments on the project with regard to procedures that are set forth in Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (NEPA) (40 CFR Parts 1500-1508).

The proposed project is located in an area identified as Essential Fish Habitat (EFH) for adult red drum (*Sciaenops ocellata*) which occur in the water column and surf zone, and larval and adult brown shrimp (*Farfantepenaeus aztecus*) and white shrimp (*Litopenaeus setiferus*) which occur on marine bottoms. Categories of EFH that would be impacted by this work include marine water column, sand bottom, and surf zone. These fishery resources and associated EFH are discussed in detail in documents prepared by the South Atlantic Fishery Management Council (SAFMC). Species under jurisdiction of the Mid-Atlantic Fishery Management Council (MAFMC) also occur in the project area. These species and their associated EFH include larvae, juvenile, and adult summer flounder (*Paralichthys dentatus*), which occur on marine bottom and in the water column and surf zone, and juvenile and adult bluefish (*Pomatomus saltatrix*), which occur in the water column and surf zone.

The project area also provides habitat for other species of commercial, recreational, and ecological importance, including Florida pompano (*Trachinotus carolinus*), southern kingfish (*Menticirrhus americanus*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), Atlantic menhaden (*Brevoortia tyrannus*), and striped mullet (*Mugil cephalus*). Several of these species serve as prey for king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*Scomberomorus maculatus*), and cobia (*Rachycentron canadum*) which are managed by the SAFMC, and for highly migratory species (e.g., billfishes and sharks) that are managed by the NMFS. Detailed information on Federally managed fisheries and their EFH is provided in the 1998 amendments of the Fishery Management Plans of the South and Mid-Atlantic Regions and respectively prepared by the SAFMC and the MAFMC. The amendments were prepared in accordance with the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (P.L. 94-265). In addition, several of the above species are identified as species of "national economic importance" in accordance with Section 906(e)(1) of the Water Resources Development Act of 2986 (PL 99-602).

The NMFS is concerned that the project will adversely affect living marine resources and habitat, including EFH. Over the ten year life of the project, up to eight million cubic yards of material would be excavated from offshore borrow areas and approximately 2.58-square miles of nearshore sand bottom, that is designated as EFH, would be impacted. Notably, physical and biological conditions in these locations may be substantially changed and any return of pre-dredging conditions, including those that associated with ecological and productivity or trophic determinants, could require considerable time and may not occur.

Although a dredging strategy has been designed to encourage recolonization by benthic species, the actual extent of recolonization, and the composition and abundance of species that recolonize the area will not be known unless post-dredging monitoring is implemented. Slow recolonization or undesirable changes in the benthic communities could alter the local marine food web and reduce the overall value of the area as EFH for Federally managed species such as shrimp, red drum, and bluefish. Existing sample data from the project area indicates that it may serve as an important foraging site for species such as spot and Atlantic croaker and others that have significant commercial, recreational, and ecological importance. According to the public notice, sediments in borrow areas A, B1, and B2 have a low percentage of fine materials; however, the composite "overfill ratios" associated with sediments from areas B1 and B2 are 1.97 and 2.19, respectively. Based on this, it is anticipated that a large portion of this material is not expected to remain on the beach and will be redeposited in a 500-700-foot-wide section of the near shore zone. This level of displacement indicates that the material in these borrow areas, in fact, contain large components of fine material, and it is reasonable to conclude that sediment resuspension and greatly elevated levels of turbidity and sedimentation are possible in both the borrow and beach nourishment sites.

Suspended sediments can physically damage respiratory structures of benthic invertebrates and larvae and juvenile fishes. Species that rely on sight for feeding could experience a reduction in feeding efficiency due to poor visibility and they may need to relocate to less desirable habitat where nutritional needs are not met, or only partially fulfilled. While there are no established thresholds regarding the extent of ocean bottom that can be disturbed without modifying or reducing species abundance,[1] the known effects of dredging are such that work involving 2.58 square miles of submerged bottom has potential to be highly and significantly damaging to fishery resources and their habitat, including EFH.

Knowledge regarding impacts to fishery resources is also limited with regard to dredged material placement in the surf zone.[2] Larvae and juveniles of estuarine dependent species such as spot, Atlantic croaker, and summer flounder accumulate in near shore waters prior to passage through ocean inlets en route estuarine nursery areas. Because of the abundance of these species, and in view of the above mentioned concern over effects of suspended sediments and turbidity, potential for significant harm to living marine resources exists. Placement of dredged material in the surf zone also may eliminate or reduce numbers of ecologically important benthic invertebrate species such as donax (*Donax variabilis*) and mole crab (*Emerita talpoidia*).[3,4] These organisms are an important food for

---

[1]Final Feasibility Report and Environmental Impact Statement on Hurricane Protection and Beach and Erosion Control. September 2000. Dare County Beaches (Bodie Island Portion), Dare Co. North Carolina. Vol. 1. U.S. Army Corps of Engineers, Wilmington District.

[2]Hackney, C., M.. Posey, S. Ross, and A. Norris. 1996. A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach nourishment. Report to the U.S. Army Corps of Engineers, Wilmington, N.C. 111p

[3]Donoghue, C. R. 1999. The influence of swash processes on *Donax variabilis* and *Emerita tadpoida*. Ph.D. dissertation: University of Virginia, Department of Environmental Sciences. 197p.

[4]Peterson, C. H., D. H. M. Hickerson, and G. G. Johnson. In press. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of the sandy beach. Journal of Coastal Research.

seasonal resident surf zone species such as Florida pompano and southern kingfish.[5] The alteration of high utilization habitat for surf zone species is particularly significant in this case since up to half of the eight million cubic yards of excavated material would be deposited in this area. The estimated recovery time from beach nourishment activities is in the range of two months to four years for dominant surf zone invertebrates; however, the long-term effect of renourishment activities over a large area of near shore habitat (16.8 miles in this case) is unknown. In North Carolina, the magnitude of this impact may be even greater due to the relatively large number of beach renourishment and protection projects that are either planned or have been authorized. At this time, approximately 58 percent of the state's 320-miles of ocean beaches are subject to beach nourishment and protection activities.[6]

Although beach nourishment projects can be implemented so as to avoid periods of utilization by certain aquatic organisms, species of some fishes, invertebrates, sea turtles, and/or other marine organisms are almost always present and would be at risk. While restricting work to certain seasonal time frames or windows may provide meaningful mitigation in some situations, we note that in connection with this project the applicant seeks approval to work during periods of known high biological activity. Even if work is seasonally restricted, there is a high probability that continuation of dredging and disposal would be sought since high remobilization costs could be avoided and delays due to equipment failure and other problems are inevitable and are likely to necessitate schedule changes.

In connection with the Wilmington Harbor Improvement Project, the Corps of Engineers (COE) is currently funding studies that are aimed at examining the impacts of beach nourishment on early life history stages of fishes. In addition, the COE Engineering Research and Development Center, in cooperation with the National Ocean Service, Center for Coastal Fisheries and Habitat Research (CCFHR), plans to conduct studies at the Ocean Dredged Material Disposal Site near Wilmington and at the CCFHR laboratory in Beaufort, on the effects of various levels of suspended sediments and turbidity on larvae and juvenile fishes. When completed, these studies may help clarify fishery related impacts of dredged material placement in the surf zone and other locations. Unfortunately, these studies will not be completed in time for possible use in determining the level of impacts of the subject project on fishery resources and habitat, including EFH.

The applicant proposes to monitor the environmental impacts of the project; however, details concerning this effort were not provided in the public notice. Based on our experience in such matters, and on results of coordination with CCFHR personnel and Dr. Charles Peterson of the University of North Carolina Institute of Marine Science, it appears that a monitoring plan would only

---

[5]Ross, S.W. and J. E. Lancaster. 1996. Movements of juvenile fishes using surf zone nursery habitats and the relationship of movements to beach nourishment along a North Carolina beach: Pilot Project. National Oceanic and Atmospheric Administration Award No. NA570Z0318. 31p.

[6] Rice, Tracy. US Fish and Wildlife Service. Raleigh, NC. April 12, 2001. Personal communication.

be meaningful if it employs a statistically valid sampling methodology for assessment of impacts and change in faunal composition and abundance.[7] Although the type and level of monitoring proposed at this time is unclear, we do not believe that a detailed statistical analysis is planned.

The high possibility that significant and adverse impacts to living marine resources and their habitat (including EFH) will result from this project, coupled with the relatively undetermined level and duration of those impacts, is of great concern. Based on this, we believe that the Department of the Army has little recourse but to withhold project authorization until a full evaluation of the project has been conducted in accordance with the NEPA and its implementation regulations. Although a draft environmental impact statement has been prepared, no effort has been made to conduct a NEPA review, or to ensure that other needed elements such as development and evaluation of reasonable alternatives; development of sequential mitigation; and opportunity for adequate public review, are adequate.

In view of the preceding, the NMFS recommends that Department of the Army authorization of the project not be granted until such time as the NEPA implementation provisions have been fully met. In fulfilling this requirement, we further recommend that the alternatives analysis include development and evaluation of a phased approach to the project. More specifically, the applicant should consider and evaluate performing a small portion of the desired project, thoroughly evaluating the environmental effects of this work, and then determining the feasibility and prudence of continuing the project. We also note that an EFH assessment, which is required in accordance with 50 CFR 600.920(g), and is specified in our April 17, 2000, "findings"letter to you, has not been received. We must advise that in the absence of this assessment and our response, your authorization of the proposed work would contravene the EFH conservation purposes of the MSFCMA and associated requirements involving coordination between our agencies.

Finally, this project area is within known distribution limits of Federally listed endangered and threatened species that are under purview of the NMFS. Therefore, in accordance with the Endangered Species Act of 1973, as amended, it is the responsibility of the appropriate Federal regulatory agency to review its activities and programs and identify any activity or program that may affect endangered or threatened species or their habitat. Determinations involving species under NMFS jurisdiction should be reported to our Protected Resources Division at the letterhead address. If it is determined that the activities may adversely affect any species listed as endangered or threatened and under NMFS purview, then formal consultation must be initiated.

---

[7]Peterson, Charles H. Alumni Distinguished Professor, University of North Carolina, nstitute of Marine Science, Morehead City, NC. April 13, 2001. Personal communication.

Please direct related comments or questions to the attention of Mr. Ron Sechler at our Beaufort Facility. He can be reached at 101 Pivers Island Rd, Beaufort, North Carolina 28516, or at (252) 728-5090.

Sincerely,

David H. Rackley

for Andreas Mager, Jr.
Assistant Regional Administrator
Habitat Conservation Division

cc: FWS, Raleigh, NC
EPA, ATLA, GA
NCDENR, Raleigh, NC
NCDENR, Morehead City, NC
SAFMC, Charleston, SC
F/HP1 - Susan-Marie Stedman
F/SER4

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

RECEIVED
JUN 06 2001
CSE

CSE - Columbia office

June 1, 2001

Colonel James W. DeLony
District Engineer, Wilmington District
U.S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Attention: Mr. Mickey Sugg

Dear Colonel DeLony:

The U.S. Fish and Wildlife Service (Service) has reviewed March 16, 2001, Public Notice Action ID No. 200000362, the October 2000 draft Environmental Impact Statement (EIS) for the Bogue Banks Beach Restoration Plan received by this office on February 22, 2001, and the draft Supplement to the Final EIS (Supplement) handed out by the applicant at the May 11, 2001, site meeting in Morehead City. Comments are not provided herein on the draft monitoring plan and will be submitted under separate cover. This is the report of the Service submitted pursuant to, and in accordance with, provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and the Endangered Species Act of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.).

The applicant, Carteret County, proposes to dredge sand and shell material and fill 90,000 linear feet of beachfront on Bogue Banks in Carteret County, North Carolina. Up to 8 million cubic yards of fill would be placed 8 feet above mean low water and below, and the sediment would be dredged from up to three sites located 0.5 to 3.0 miles offshore of Bogue Banks in 35 to 45 feet of water. The applicant proposes to construct the project in two phases: the first phase being 7.2 miles of beach fill along Pine Knoll Shores and Indian Beach in the winter of 2001-2002; and the second phase along 9.6 miles of Emerald Isle at an undetermined later date.

Based on the information provided in the application, we recommend the District Engineer not issue a permit for the proposed activities. We believe that the proposed activities, as presently configured, will have unwarranted adverse impacts on the nesting ability of Federally-protected sea turtles and other fish and wildlife resources. In addition, it is our opinion that the applicant has not satisfied the Environmental Protection Agency's 404(b)(1), 40 CFR §230.10(c), and National Environmental Policy Act (NEPA) guidelines as of this time.

The applicant's draft EIS contains a comprehensive economic evaluation of the relocation and rebuilding alternatives, but the document does not adequately address the project's impacts to fish and wildlife resources. Several of the project's details are unclear, sediment compatibility is not fully addressed, and the analysis of impacts to beach invertebrates is not complete. The Service refers the Corps to a recently prepared Environmental Assessment by Applied Technology & Management, Inc., for the Old Sound Creek Dredging Project at Tubbs Inlet (Action I.D. No. 200100552) as a model for an adequate NEPA document for beach fill activities. Get copy.

One facet of the proposed action that is not clear is the project's fill design. Page 4-7 of the draft EIS lists a fill volume of 50 cubic yards (cy) per foot, while page 5-2 states a desired volume of 175 cy/ft. During the May 11, 2001, site meeting Dr. Kana mentioned a 80 to 90 cy/ft volume. The magnitude of the beach fill will, in part, determine the magnitude of impacts to trust resources, and the applicant should better specify the fill volume to be used. Easy to clarify.

The draft EIS does not contain a maintenance plan but alludes to maintenance activities during the ten year project life. The Service recommends that a maintenance plan be prepared and circulated as a supplemental NEPA document for review prior to the issuance of any permit. Information on beach scraping, additional fill, and post-storm activities should be included in such a plan in order for the full scope of the project to be evaluated.

The draft EIS cites the offshore existing environment as containing high turbidity levels and patchy mud or clay areas that impeded visibility for divers. No additional information is described as to whether this condition is pervasive along the entire length of Bogue Banks, at what water depths, or if the hardbottom areas off of Emerald Isle have lower productivity levels (as compared to other hardbottoms in Onslow Bay in similar water depths and locations) because of existing suspended sediment loads in the water column. The EIS should be revised to elaborate on this aspect of the existing environment.

The sedimentation resulting from finer grain material washing off an artificial beach system is similar to, but distinct from, that produced by dredging, or naturally existing in the project area. Turbidity or suspended sediment loads are increased as the mined fill dewaters following placement on the beach, and finer sediments may be suspended and washed off the beach as long as fill material remains on the beach. The latter may lead to deterioration of nearshore habitat quality in the long-term. Studies on Bogue Banks and Wrightsville Beach have shown that nourishment sediment moves offshore artificially filled beaches (Reed and Wells 2000; Thieler et al. 1995). Riggs (1994, p. 17) states that sand placed on Wrightsville Beach has washed off the beach and buried extensive hardbottoms on the inner continental shelf near the federal storm damage reduction project. These hardbottoms were prime fishing locations, but are now significantly degraded due to a covering of two to six inches of sand. Hurme and Pullen (1988) concluded that increased turbidity levels from winnowing of fine sediments in beach fill can extend from a few months to seven years. The currently proposed design includes a high proportion of fine sediments, making this long-term impact a probable occurrence. The applicant states that the hardbottoms off of Bogue Banks are at least 1600 feet from the immediate project area, but provides no supporting evidence that this distance is an adequate buffer from project impacts.

Several beach fill studies had inadequate sampling designs that may have precluded detection of significant alterations in the populations or community parameters measured (Nelson 1991, 1993). The NRC (1995, p. 115) concluded that " . . . efforts should be directed toward obtaining a better understanding of functional changes in the trophic contribution of benthic assemblages to the fish and crustaceans species that rely on the benthos as a major food resource." Dr. Peterson has provided detailed information that would improve the sampling protocol for the proposed project to avoid this pitfall, and the Service reiterates those recommendations.

The effects of high turbidity levels on migrating organisms is unknown, but is potentially adverse. The Cape Lookout region is a migratory pathway for nationally important fish, marine mammals, birds and sea turtles. The placement of fine grained material on the project's beaches will produce an extensive suspended sediment plume in the nearshore waters, extending the indirect impacts of the action beyond the immediate project area and may harm or reduce the habitat quality for these migratory species. Moreover, the Corps noted (USACOE 1973, p. H-15) that it was possible that highly turbid water washing off of a potential project in Brunswick County would enter Lockwoods Folly Inlet during flood tides and create "injurious effects" on oyster-producing areas. Bogue Inlet will be approximately one mile from the project's construction area, and turbidity plumes may affect hardbottoms offshore the inlet as well as aquatic resources in Bogue Sound and the White Oak River estuary. The applicant has provided no detailed description of whether the high proportion of fine-grained sands in borrow areas B1 and B2 will be suspended similar to clay and mud sediments and elevate turbidity levels such that aquatic resources are harmed. The draft EIS states that borrow area B2 in particular has "poor quality material" (p. 3-16), yet as of this time that area is still proposed for use. While the documented mud and silt content for this project of less than 5% is half of the state standard of 10% maximum, recent projects on Oak Island that met that criteria exhibited up to 90 NTUs (nephelometric turbidity units) in field measured turbidity plumes (Ted Wilgis, pers. comm., May 10, 2001). The state water quality standard is 25 NTUs (unless elevated from natural conditions).

The applicant proposes to use all three borrow sites in whatever proportions are most practical in terms of project cost and engineering (p. 2-4 of the draft EIS). The Service cannot concur with this condition, which precludes a full evaluation of environmental impacts to trust resources. The available data indicate that none of the three sites are compatible with the native beach, and any mixture of the three sites will not make the overall fill more compatible.

The Service is highly concerned about the compatibility of the proposed mine material with the existing beach. The Public Notice (PN), draft EIS and Supplement do not provide adequate data on the sediment characteristics of the native beach for a full evaluation of the potential impacts to fish and wildlife resources. Following discussions at the May 11, 2001, site meeting, the applicant collected additional data on the native beach sediments and provided those to the Service on May 25, 2001.

The supplementary information indicates that borrow areas B1 and B2 are too fine and borrow area A has too much carbonate material. Figures E-10 and E-11 in the draft EIS show that site A contains 10-78% carbonate content, but less than 40% of the borrow material exceeds 2 millimeters in grain size. This indicates that roughly half of the carbonate fraction of the fill material is sand-sized or less, and not larger shell fragments. The native beach appears to have 20% carbonate content, and there are no data to show what proportion of this material is sand-sized versus larger shell fragments. Carbonate material breaks down faster than quartz and other inorganic sediments, making it more susceptible to chemical dissolution (USACOE 1995; USACOE 1998). If borrow area A is exclusively used for the project, the carbonate content of the beach would more than double. Carbonate material that is sand-sized or finer will be intermixed with the quartz sediments and not sort out with wave reworking of the fill. Over time this material may break down and/or dissolve, forming a carbonate cement that hardens the beach. Dissolution and cementation of the surface beach sediments has been reported on beach fill projects at Edisto Beach State Park, South Carolina, and Miami Beach, Florida. The Edisto Beach project differed from the native beach sediments by 11-34% (weight percent) in the fraction of sediments greater than 2 mm in size (an approximation for shell hash material) and doubled the percent material in the fine and very fine sand size fraction. The cementation problems in Miami have significantly impaired sea turtle hatchlings' ability to emerge from the nest chamber (Trish Adams, USFWS, pers. comm., 24 January 2001). A higher than background coarse-grained or carbonate fraction also inhibits the burrowing of beach infauna and the foraging of shorebirds (Peterson et al. 2000; Lindquist and Manning 2001; Alexander et al. 1993; Bowman and Dolan 1985).

Incompatible fill materials may adversely affect sea turtle nesting as well as the forage base for colonial waterbirds and migratory shorebirds, including the Federally-listed piping plover (*Charadrius melodus*). The draft EIS does not adequately address these impacts, and should be revised to incorporate information from and compliance with the United States Shorebird Conservation Plan 2000, Executive Order 13186 *Responsibilities of Federal Agencies to Protect Migratory Birds*, and bird census data on the project area's beaches.

The Service is concerned that the project, as currently proposed, will significantly harm the beach invertebrates along 16.8 miles of Bogue Banks. The applicant has not adequately addressed this issue, particularly the impacts of doubling the carbonate content of the beach substrate on beach invertebrates, foraging shorebirds and nesting sea turtles. At the May 11, 2001, site meeting the applicant requested additional information on the impacts of dredge and fill projects on invertebrates from the Service. Appendix A describes the salient research on this environmental impact from major dredge and fill projects.

These populations are a key facet of the coastal food web, and therefore decreased species abundances would reduce the prey base for shorebirds, surf fishes and beach macrofauna. Sediments from borrow areas B1 and B2 are significantly finer than the native sediments (50% losses are anticipated from the initial fill) and borrow area A has double the shell content of the existing beach. The Service is concerned that adverse impacts documented by Peterson et al.

where do they get this?

(2000) may be repeated and extended along 16.8 miles of beachfront. The length of the proposed project may prolong or prevent the recovery of beach invertebrate populations since undisturbed areas may be 3 to 5 miles away. Perpetual beach fill placement has the potential cumulative impact of permanently depressing beach invertebrate populations (Lindquist and Manning 2001).

The applicant proposes to use the natural sand bar offshore as a natural dike to hold the fill material close to the beach. The trough between the swash zone and an offshore bar provides valuable habitat to many benthic and pelagic resources. Figures attached to the state permit application show that this area would be filled with 2 to 10 feet of material, burying and substantially altering the substrate and water depth of the trough habitat. The applicant has not provided any description of the expected impacts to this habitat resulting from the proposed action.

Profile shape will be maintain as long as its a graded deposit

Offshore invertebrates are also impacted by dredge and fill projects. Removal of sand from the offshore borrow areas may permanently alter the physical characteristics of the areas and impact the benthic flora and fauna adapted to existing conditions. The proposed dredging methods are likely to reduce the adverse impacts to the borrow areas due to their shallow depth and intent to leave undisturbed areas between dredging furrows. The applicant has not provided sufficient information to document that the substrate within the furrows will not be changed to mud or rock outcrops, however. The majority of the cores taken in the borrow areas penetrated less than 3 feet of the seafloor, providing the Service with limited data on the strata underlying the borrow furrows.

The Service appreciates that the applicant conducted pre-project benthic surveys, but supports the recommendations of Drs. Peterson and Wells regarding the need to monitor this project for site-specific impacts following the project. The draft EIS states that wave height will be altered by 0.1 feet and the longshore sediment transport energy flux altered by 8-9%. These modifications to the hydrodynamic environment should be monitored to determine the level of resilience of the invertebrate populations, particularly those on the beach.

The timing of the proposed action on Bogue Banks is critical to avoiding and minimizing impacts to fish and wildlife resources. The applicant currently proposes to conduct construction between October 1 and May 15 (draft EIS, p. 4-10), which would impinge on the invertebrate recruitment seasons identified for the island (Reilly and Bellis 1978; Peterson et al. 2000; Lindquist and Manning 2001). The Service recommends that the work be scheduled from December 1 to March 31 instead, minimizing adverse impacts to the beach invertebrate populations, their migratory and resident faunal consumers, and nesting sea turtles and shorebirds.

The Service is concerned about the cumulative impacts that the proposed project might cause on Bogue Bank's coastal ecosystem. Cumulative impacts are not addressed in the applicant's October 2000 draft EIS. Approximately 176 miles of the 320 mile North Carolina shoreline is currently receiving or investigating beach disposal of dredged materials. The applicant recognizes the proximity of the project area to preserved beaches within Carteret County, but does not provide a state-wide contextual analysis. Eight million cubic yards of sediment will be dredged out of the benthic ecosystem and used to bury large portions of the nearshore benthic ecosystem while the applicant pursues a federal, 50 year project to do the same. Several studies have shown that nourishment sediment moves offshore the project beach (Reed and Wells 2000; Thieler et al. 1995), and that over time the need for sediments increases over the life of the project rather than decreases (Trembanis et al. 1998). The cumulative impacts of these dredge and fill projects is the wholesale manipulation of the continental shelf and its associated habitats. The perpetual artificial relocation of hundreds of millions of cubic yards of sediment from one place to another in North Carolina will lead to a long-term, far-reaching degradation of the seafloor and its hardbottom and sandy habitats.

The cumulative effects of the project on offshore fisheries may be the transformation of formerly preferred habitat into unsuitable or unusable habitat. This change could occur as a result of altered substrate characteristics, depth, or other physical parameters. The loss or degradation of this important fish habitat would adversely impact marine birds and marine mammals in addition to harming commercial and recreational fishermen that depend on these resources. The Service recommends that the monitoring plan incorporate detailed surveys of beach and nearshore fishermen to document positive or negative impacts to the local fishing community resulting from the project. Some of the beach seine fishermen on Bogue Banks may keep detailed records of their catches and commercial sales, which could provide data on pre-project conditions. Surveys should be conducted in project areas as well as control areas. North Carolina Division of Marine Fisheries' survey protocols and methodologies should be used by the applicant.

Due to the significant cumulative impacts and adverse environmental impacts, the Service recommends that the current proposed action be modified to avoid, minimize and mitigate anticipated adverse environmental impacts. There is no way to avoid significant impacts to fish and wildlife resources resulting from the proposed action due to the indirect and secondary impacts.

Adverse impacts could be minimized, however, by 1) conducting work during the recommended December 1 to March 31 period; 2) restricting the borrow area to those areas where the carbonate content and grain size more closely matches the native sediments; 3) avoiding construction around all known hardbottoms and site specific Essential Fish Habitat areas; 4) restricting the initial permit to Pine Knoll Shores and Indian Beach (the Emerald Isle phase would be subject to review by resource agencies after considering the monitoring results of phase one); 5) issuing the permit to have a finite life of one construction episode per community and no maintenance requiring new fill material; and, 6) reducing the length of the project to include gaps where beach construction activities would not be conducted and biological resources would find an undisturbed refuge from which to recolonize filled areas.

Finally, for those impacts that cannot be avoided or minimized, the Service recommends compensatory mitigation. Mitigation can be achieved via restoration, enhancement or preservation of similar habitat. For the proposed project, mitigation could be arranged by 1) relocating structures that are chronically and imminently threatened farther inland over time so the need for the proposed activity does not perpetuate indefinitely; 2) setting aside areas that allow overwash and levee/dune gaps (i.e., will not be bulldozed, designing a levee system that better approximates natural geomorphology); 3) not issuing any Corps permits for beach scraping for the ten year life of the project, albeit subject to modification following major storm events (i.e., hurricanes); or 4) purchasing oceanfront conservation easements or tracts at nearby coastal sites.

The applicant has stated that they are not familiar with methodologies allowing the valuation of intangible resources such as fish and wildlife, beach recreation and environmental damages. In order to calculate an appropriate level of compensatory mitigation, such a valuation is needed. The Service refers the Corps to the field of natural resource and environmental economics for valuation methodologies for intangible resources. Kopp and Smith (1993), Freeman (1993), Bergstrom and Cordell (1991), and Walsh et al. (1988) provide meticulous reviews of available methodologies. The Corps regularly uses the Contingent Valuation Method and the unit day value method in evaluating recreational benefits for federal storm damage reduction projects. The Department of Interior uses natural resource damage assessment methodologies to evaluate damages to trust resources. The National Park Service and the U.S. Forest Service utilize various general and specific recreational valuation techniques for visitation and use of their lands. The Center for Environmental and Resource Economics Policy at North Carolina State University, the Institute of Water Resources at the Corps, and the Coastal and Marine Studies Program at East Carolina University all have research and publications on various economic valuations of the North Carolina coastal system in particular. These sources could provide the necessary valuation methods for determining appropriate compensatory mitigation for the proposed action.

An EIS that complies with National Environmental Policy Act (NEPA) guidelines should be prepared as the permit review proceeds. It has become increasingly important to protect the ecological integrity of the barrier island ecosystem, including the intertidal and surf zones, and respond to changes in this environment with less environmentally damaging interventions. Furthermore, we are not likely to concur with the issuance of a permit that would permanently destroy or impair aquatic resources (i.e., the surf zone, water column, hardbottoms, sandy bottoms) designated as Essential Fish Habitat.

In accordance with the procedural requirements of the 1992 404(q) Memorandum of Agreement, Part IV.3(a), between our agencies, we are advising you that the proposed work may result in substantial and unacceptable impacts to aquatic resources of national concern. It is our opinion that the applicant has not satisfied the Environmental Protection Agency's 404(b)(1) nor the 40 CFR §230.10(c) guidelines as of this time. The latter states that "no discharge of dredged or fill material shall be permitted which will cause or contribute to significant degradation" of aquatic ecosystems. The Corps should address compliance with both of these sets of guidelines in the NEPA document.

The Service cannot concur with the project, as proposed, however we look forward to working further with the Corps and the applicant to modify the project to adequately protect fish and wildlife resources. The 16.8 miles of beachfront to be artificially filled would be the longest in North Carolina to date (the Dare County Beaches (Bodie Island Portion) federal project will be 14 miles long). The Corps should therefore use a precautionary approach when evaluating the project's impacts to fish and wildlife resources.

We appreciate the opportunity to provide comments. If you have any questions or comments, please contact Tracy Rice or John Ellis of my staff at (919) 856-4520, extensions 12 and 26 respectively.

Sincerely,

Garland B. Pardue, Ph.D.
Ecological Services Supervisor

References

Alexander, R.R., R.J. Stanton Jr., and J.R. Dodd. 1993. Influence of Sediment Grain Size on the Burrowing of Bivalves: Correlation with Distribution and Stratigraphic Persistence of Selected Neogene Clams. Palaios. 8:289-303.

Bergstrom, J.C., and H.K. Cordell. 1991. An analysis of the demand for and value of outdoor recreation in the United States. Journal of Leisure Research. 23(1).

Bowen, P. R. and G. A. Marsh. 1988. Benthic faunal colonization of an offshore borrow pit in southeastern Florida. Miscellaneous Paper D-88-5. U. S. Army Corps of Engineers, Waterways Experiment Station. Vicksburg, Mississippi.

Bowman, M.L., and R. Dolan. 1985. The Relationship of *Emerita talpoida* to Beach Characteristics. Journal of Coastal Research. 1(2):151-163.

Donoghue, C. 1999. The influence of swash processes on *Donax variabilis* and *Emerita talpoida*. University of Virginia, Department of Environmental Sciences Ph.D. Dissertation. 197 pp.

Freeman, A.M., editor. 1993. *The Measurement of Environmental and Resource Values: Theory and Methods*. Washington, D.C.: Resources of the Future. 516 p.

Gorzelany, J.F. 1983. The effects of beach nourishment on the nearshore benthic macrofauna of Indialantic and Melbourne Beach, Florida, M.S. thesis, Florida Institute of Technology. Melbourne, Florida. 114 pp. (As reported in Stauble and Nelson 1985).

Hurme, A. K. and E. J. Pullen. 1988. Biological effects of marine sand mining and fill placement for beach replenishment: Lessons for other uses. Marine Mining 7:123-136.

Johnson, R. O. and W. G. Nelson. 1985. Biological effects of dredging in an offshore borrow area. Florida Scientist. 48:166-188.

Kopp, R.J. and V.K. Smith, editors. 1993. *Valuing Natural Assets: The Economics of Natural Resource Damage Assessment.* Washington, D.C.: Resources for the Future. 358 p.

Lindquist, N., and L. Manning. 2001. Impacts of beach nourishment and beach scraping on critical habitat and productivity of surf fishes. Final Report to the North Carolina Fisheries Resource Grant Program. 41 pp + figures.

Manning, L. 2001. Personal communication to the author, May 8, 2001. University of North Carolina at Chapel Hill Institute of Marine Sciences, Morehead City, North Carolina.

Minerals Management Service. 1999. Environmental Report. Use of Federal Offshore Sand Resources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware and Virginia. OCS Study MMS 99-0036.

National Research Council. 1995. Beach Nourishment and Protection. National Academy Press. Washington, D.C. 334 pp.

Nelson, W.G. 1991. Methods of biological monitoring of beach restoration projects: problems and solutions in the real world. pp. 263-276. Preserving and Enhancing Our Beach Environment. Proceedings of the 1991 National Conference on Beach Preservation Technology. Florida Shore and Beach Preservation Association, Inc., Tallahassee, Florida.

Nelson, W. G. 1993. Beach restoration in the southeastern US: environmental effects and biological monitoring. Ocean and coastal Management 19:157-182.

Peterson, C.H., D.H.M. Hickerson, and G.G. Johnson. 2000. Short-term Consequences of Nourishment and Bulldozing on the Dominant Large Invertebrates of the Sandy Beach. Journal of Coastal Research. 16(2):368-378.

Rakocinski, C.F., R.W. Heard, S.E. LeCroy, J.A. McLelland, and T. Simons. 1996. Responses by Macrobenthic Assemblages to Extensive Beach Restoration at Perdido Key, Florida, USA. Journal of Coastal Research. 12(1):326-353.

Reed, A.J., and J.T. Wells. 2000. Sediment Distribution Patterns Offshore of a Renourished Beach: Atlantic Beach and Fort Macon, North Carolina. Journal of Coastal Research. 16(1):88-98.

Reilly, F.J. Jr., and V.J. Bellis. 1978. A study of the ecological impact of beach nourishment with dredged materials on the intertidal zone. East Carolina University Institute for Coastal and Marine Resources, Technical Report No. 4., Greenville, North Carolina. 107 pp.

Riggs, S. R. 1994. Nonliving resources. pp. 13-19. in Hart, K. (ed.) Managing the Coastal Ocean for the 21th Century: North Carolina's Role. A proceedings from a conference held May 20-21, 1993, University of North Carolina at Wilmington. N.C. Sea Grant Publication UNC-SG-94-02. 54 pp.

Stauble, D.K. and W.G. Nelson. 1985. Guidelines for beach nourishment: a necessity for project management. *In* Magoon, O.T., H. Converse, D.Miner, D. Clark and L.T. Tobin. (eds). 1985. Coastal Zone '85 Volume I. Proc. of the 4th Symposium on Coastal and Ocean Management. Baltimore, Maryland. 1232 pp.

Thieler, E. R., A. L. Brill, W. J. Cleary, C. H. Hobbs III, and R. A. Gammisch. 1995. Geology of the Wrightsville Beach, North Carolina shoreface: Implications for the concept of shoreface profile of equilibrium. Marine Geology. 126:271-287.

Trembanis, A.C., H.R. Valverde, and O.H. Pilkey. 1998. Comparison of Beach Nourishment Along the U.S. Atlantic, Great Lakes, Gulf of Mexico and New England Shorelines. Journal of Coastal Research. Special Issue #26. Pp. 246-251.

U. S. Army Corps of Engineers. 1973. General Design Memorandum - Phase I. Hurricane-Wave Protection - Beach Erosion Control. Brunswick County, N.C., Beach Projects, Yaupon Beach and Long Beach Segments.

U. S. Army Corps of Engineers. 1995. *Design of Beach Fills*. Engineer Manual EM 1110-2-3301. Washington, D.C.

U. S. Army Corps of Engineers. 1998. *Coastal Engineering Manual, Part III*. Engineer Circular 1110-2-292. Washington, D.C.

Van Dolah, R.F., P. H. Wendt, R. M. Martore, M. V. Levisen, W. A. Roumillat. 1992. A physical and biological monitoring study of the Hilton Head beach nourishment project. Marine Resources Research Institute, South Carolina Marine Resources Division, Charleston, S.C. 159 pp.

Van Dolah, R.F., R. M. Martore, and M.V. Levisen. 1993. A physical and biological monitoring study of the Hilton Head beach nourishment project. Supplemental report prepared by the South Carolina Marine Resources Research Institute for the Town of Hilton Head, South Carolina.

Walsh, R.G., D.M. Johnson and J.R. McKean. 1988. Review of outdoor recreation economic demand studies with non-market benefit estimates, 1968-1988. Colorado Water Resources Research Institute Technical Report No. 54. 131 p.

Wilber, P. and M. Stern. 1992. A re-examination of infaunal studies that accompany beach nourishment projects. pp. 242-257 in New Directions in Beach Management: Proceedings of the 5th Annual National Conference on Beach Preservation Technology. Florida Shore and Beach Preservation Association. Tallahassee, Florida.

cc: NC DCM, Morehead City, NC (Ted Tyndell)
NC DCM, Raleigh, NC (Doug Huggett)
NC DMF, Morehead City, NC (Rick Monaghan)
NC DMF, Morehead City, NC (Mike Street)
NC WRC, Trenton, NC (David Allen)
NC WRC, Kinston, NC (Bennett Wynne)
NC DWQ, Wilmington, NC (Joanne Steenhuis)
NMFS, Beaufort, NC (Ron Sechler)
Coastal Science & Engineering, Morehead City, NC (Bill Forman)
Coastal Science & Engineering, Columbia, SC (Tim Kana)

FWS/R4:TRice:TMR:06/1/01:919/856-4520 extension 12:\200000362-PN.wpd

APPENDIX A. Impacts to Invertebrate Fauna

When a beach is artificially filled, large volumes of sand are placed within the supralittoral and intertidal zones. Beach invertebrate populations are eliminated or greatly reduced. The direct, adverse impacts may be dramatic, but longer-term, indirect impacts related to altered beach characteristics and recruitment of a recovery population may have the greater impact on fish and wildlife resources that depend on beach invertebrates as a food source. Sand placement disturbs the indigenous biota inhabiting the subaerial habitats, which in turn affects the foraging patterns of the species that feed on those organisms (NRC 1995, p. 108).

Donoghue (1999) found the timing of beach fill placement, the time interval between fill placement episodes, the size and type of fill, and the compatibility of the fill material to the native sediments to be critical to the short- and long-term impacts to beach invertebrate populations. Fill placement during the invertebrate reproduction or recruitment periods in early spring and early fall depressed the populations of mole crabs and coquina clams for several months to years; ghost crab populations were similarly decreased as a result of fill placement on the beaches at Pea Island. The alterations to the geomorphology and sediment characteristics of the study beaches appear to be more controlling factors on invertebrate recovery periods than direct burial or mortality.

Peterson et al. (2000) documented beach invertebrate populations following dredge spoil disposal from Bogue Sound on the beaches of Bogue Banks to be reduced by 86-99% (compared to control beaches) 5 to 10 weeks following fill placement. The authors conclude that "Failure of *Emerita* and *Donax* to recover from nourishment by mid summer when they serve as a primary prey base for important surf fishes, ghost crabs, and some shorebirds may be a consequence of the poor match in grain size and high shell content of source sediments and/or extension of the project too far into the warm season" (Peterson et al. 2000, p. 368).

Reilly and Bellis (1978) state that species of beach infauna recruited from pelagic larval stocks, such as mole crabs and coquina clams, will recover if nourishment activity ends before larval recruitment begins in the spring. In the spring, recruitment begins with juveniles and adults approaching the beach. In the Bogue Banks project, nourishment extended from December until June, a time that included the March recruitment period of coquina clams. No increase in coquina clams occurred until approximately two months after cessation of nourishment, and populations failed to reach pre-nourishment numbers found during the winter. At the control site, coquina clams also decreased during the winter as they moved offshore. However, during March, numbers at the control site increased to high levels. The authors conclude that adult coquina clams were probably killed in their offshore wintering environment, and beach nourishment effects, most likely high turbidity, prevented normal pelagic larvae recruitment. The individuals that eventually arrived were post metamorphic adults likely to have diffused from area beaches via littoral drift.

Reilly and Bellis (1978) also found a complete absence of mole crabs within one week of the beginning of the nourishment project at Bogue Banks. Numbers were also reduced at the control site as adults moved offshore to spend the winter. Overwintering adult mole crabs returned to the control site in April, and the young of the year from pelagic larval stocks returned later in the spring. The return of mole crabs at Bogue Banks lagged one month behind that at the control site and then only young of the year mole crabs appeared at the nourished beach. The lack of adults at the nourished beach resulted in drastic reduction in overall biomass of mole crabs.

In addition, beach infauna are indirectly effected by the lack of internal structure in an artificially constructed beach as opposed to a natural beach. The fill material may vary significantly in its mineralogical composition, organic content, grain size distribution and sedimentary characteristics. Over the lifespan of the project, with the continual maintenance of an artificial beach, there will be a semi-permanent to permanent change in the beach, which supports an entire ecosystem.

While species which move on and off the beaches during their life cycle may recolonize the new beach in time, species spending their entire life cycles in the intertidal regions of the beach may be more severely impacted by massive sand placement (Hurme and Pullen 1988). *Haustorius* sp., an amphipod found on many beaches, recovered very slowly after the placement of beach fill on Bogue Banks (Reilly and Bellis 1978) and North Topsail Beach (Lindquist and Manning 2001).

Reilly and Bellis (1978) indicated that numbers of migrating, invertebrate consumers such as the speckled crab (*Arenaeus cribarius*), lady crab (*Ovalipes ocellatus*), ghost crab (*Ocypode quadrata*) and blue crab (*Callinectes sapidus*) were drastically reduced after nourishment activities. The authors conclude that this may be attributable to greater turbidity causing resident populations to move elsewhere, a change in beach slope and offshore bars making approach to the beach difficult, or more likely a reduction in the abundance of prey. Vertebrate consumers, such as fish and shorebirds, may also be adversely affected by a reduction in prey species. Lindquist and Manning (2001) found that Florida pompano (*Trachinotus carolinus*), a visually foraging surf zone fish, experienced a 40.5% decline in feeding on coquina clams and a 30% reduction in feeding on mole crabs during periods of elevated turbidity in a lab setting. Shelly material may also inhibit the foraging of shorebirds due to less efficient beak penetration into the substrate (L. Manning, pers. comm., May 8, 2001).

Coquina clams have been found to be "substrate sensitive" in their grain size preferences (Alexander et al. 1993). If the fill material significantly deviates from the native grain sizes, the ability of *Donax* spp. to burrow can be dramatically impaired. Bowman and Dolan (1985) found that mole crabs increase in abundance in specific grain sizes as well. Recent research on Bogue Banks has found that coquina clams have a decreased ability to burrow in sediment with a high shell content (Lindquist and Manning 2001). An impaired ability to burrow will increase the likelihood of invertebrates being washed out of their habitat and their susceptibility to predation.

Sand flowing onto the lower portion of the beach during the nourishment operation can affect habitat suitability and feeding by beach invertebrates beyond the immediate impact of sediment placement. Rakocinski et al. (1996) found that macrobenthic assemblages in nearshore, sandy-beach environments are less resilient to the impacts of beach construction projects than more diverse offshore assemblages. These nearshore assemblages respond to such projects with "decreased species richness and total density, enhanced fluctuations in those indices, variation in abundances of key indicator taxa, and shifts in macrobenthic assemblage structure" (Rakocinski et al. 1996, p. 326).

The recovery period for benthic communities that are lost to dredging is quite variable, ranging from a few months to several years (NRC 1995, MMS 1999). While the abundance and diversity of benthic fauna may return to pre-dredging values, several studies have documented changes in the species composition of the benthos that lasted more than a year, particularly in areas where bottom sediment composition was altered (Johnson and Nelson 1985, Bowen and Marsh 1988, Van Dolah et al. 1992, 1993, Wilber and Stern 1992). Benthic organisms inhabiting the potential offshore borrow areas serve as food for commercially important species and are essential in marine food chains.

Donoghue (1999) and Bowman and Dolan (1985) found that the dominant invertebrate species (i.e., coquina clams and mole crabs) are also influenced by hydrodynamic parameters. Abundances of coquina clams, for instance, are concentrated on the downdrift sides of beach cusps, and there is evidence that these clams surf from one beach cusp to another on the wave swash (Donoghue 1999). The abundance of these patches of clams decreases with smaller cusps and changes in the hydrodynamic conditions. The ability to maintain burrows and optimize filter feeding appears to be directly related to both grain size and hydrologic parameters, both of which can be drastically altered by an artificial beach fill project.

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

April 25, 2001

Colonel James W. Delony, District Engineer
c/o Mr. Mickey Sugg
US Army Corps of Engineers
PO Box 1890
Wilmington NC 28402

RE: Carteret County – Bogue Banks Beach Nourishment Project
Response to Comments dated 13 April 2001 from US Environmental Protection Agency (W.L. Cox) [SCH File #01-E-4300-0357; USEPA Action IC# 200000362]

Dear Colonel Delony:

I am writing on behalf of the applicants in response to comments dated 13 April 2001 from the US Environmental Protection Agency on the above-referenced project. The comments consist of eight paragraphs in a three-page letter. The following responses apply in order of the original paragraphs.

Paragraph 1
Response: No response needed.

Paragraph 2
Response: Our responses to comments from North Carolina state resource agencies have been incorporated into the final EIS. We will prepare responses to comments from other federal resource agencies as they are received as recommended by the correspondent.

Paragraph 3
Response: Many intangibles (including environmental impacts, recreational enjoyment, and lifestyle) are impacted by beach erosion and nourishment. We did not attempt to place any specific costs or benefits on such intangibles in our review of costs of the project, largely because there is no accepted method for valuing these factors. If the EPA has a particular methodology for assigning dollar values to such items, we will be happy to incorporate them into our analysis. It remains our contention that the cost of the project as quantified in the EIS will be far less than the cost of other alternatives over the next decade.

CSE

Paragraph 4

Response: This paragraph reflects the concern that the proposed project will encourage more oceanfront development over the next ten years. Presently, over 90 percent of the oceanfront is developed, leaving only a small percentage of lots subject to new development. The local communities are actively seeking opportunities to obtain additional oceanfront property for parking and beach access. In any case, relatively little additional oceanfront development is possible. Furthermore, all remaining barrier islands in Carteret County (approximately 55 miles of ocean shoreline) are already set aside as wilderness preserves with no vehicular access.

The applicant has been working for over three years to develop the present plan, obtaining input from representatives of many interests within the community, including environmentalists, developers, academicians, and political leaders. The proposed plan is based on consensus reached after many community forums and careful review of alternatives. A 50-year planning framework and project design life are considered desirable by the community and, in fact, are being evaluated by the US Army Corps of Engineers as part of a recently authorized feasibility study of Bogue Banks. However, the time required between authorization of this feasibility study and construction of a federal project is likely to be at least ten years. The community has determined that a decade is too long to wait for federally sponsored nourishment. Also, given the limited historical database (documented in the EIS), the applicant believes that a ten-year planning time frame is appropriate for this first nourishment. Experience with other communities has proved that a constructed project provides the best means of predicting future performance of larger scale projects such as the one envisioned by the USACE.

Paragraph 5 — Concern regarding multiple jurisdictions performing portions of the project without coordination

Response: The lead applicant (Carteret County) will coordinate production of plans and specifications such that environmental construction windows as prescribed in the permits are honored. The proposed borrow areas will be dredged once under the present project with later reaches avoiding the already dredged areas. Such coordination will be prescribed in contract documents. Copies of early construction plans (for the first reaches completed) will be shared with later contractors. As-built surveys will locate excavation areas used in each nourishment. Engineering reports will be prepared for each reach outlining the anticipated design life of that particular reach in the absence of other reaches being nourished or in conjunction with already nourished reaches, as applicable. Further, the county and local communities are committed to detailed monitoring and performance evaluation of each beach fill.

Paragraph 6 — Comment concerns nonpoint-source runoff and land planning

Response: The topography of barrier islands such as Bogue Banks forces most drainage toward the lagoon (Bogue Sound). Unlike mainland beaches such as Myrtle Beach, there is relatively little drainage toward the ocean. Furthermore, paved surfaces make up a small fraction of the land cover on Bogue

Banks. The sandy sediments that dominate the island have high percolation rates, aiding natural drainage.

The applicants are actively seeking opportunities to acquire additional oceanfront parcels for use as public access or conservation easements. Oceanfront development, which is nearly 90 percent built out, is subject to state setback regulations based on 30-year to 60-year erosion projections, depending on the type of building. With so much of the land already developed, the communities have chosen nourishment as the most viable alternative for (1) increasing separation between existing buildings and the sea, (2) reducing damages to properties due to storms and surges, (3) reducing the pressure for yearly beach scraping, (4) protecting and preserving existing barrier island habitats, and (5) providing improved recreational beach area for everyone. The project is attempting to apply best-management practices and a totally soft solution to coastal erosion as recommended by the National Academy of Sciences [NRC (1995) *Beach Nourishment and Protection*]. No other alternative provides comparable benefits commensurate with the project costs.

Paragraph 7 — Comment concerns potential impacts to hard-bottom communities
Response: The draft EIS addresses this concern in detail. Borrow areas will be situated at least 7,500 feet (ft) from the nearest hard bottom habitat (see Figure E1 of the EIS). Based on our analysis of profile closure depth and confirmed hard-bottom exposures, we believe the project will not produce a measurable increase in turbidity or exchange of sediment between the fill and offshore hard-bottom areas. The published reports of hard bottom (Hine and Snyder, 1985) and our preliminary borrow investigation (CSE Stroud, 1999) show hard bottom close to shore only around the westernmost project reach off Emerald Isle. The Hine and Snyder (1985) geologic map suggest the possible presence of hard bottom within 1,500 ft of the project shoreline between transects 10 and 28 (western Emerald Isle). If so, this would place hard bottom in less than 30-ft water depths just seaward of the outer bar. However, none of our cores in water depths less than 40 ft detected hard bottom (CSE Stroud, 1999).

The Hine and Snyder (1985) map is based on broad extrapolations from relatively sparse seismic and ground-truth data. No cores were obtained by them inside the 10-meter contour. (See Figure E2 of the EIS.) Based on our direct scuba observations of 140 sites off the project area, we believe a thin sand veneer occurs over the entire lower shoreface off Bogue Banks between the beach and the ~35-ft contour. The hard bottom confirmed at stations C18a1 and C18a2 (see Figure E5 of the EIS) is situated in water depths >40 ft about 4,500 ft offshore of transect 29 (see Annex E1, Table E1-D). This is believed to represent the most proximal outcrop of hard bottom off the project area. Because of its presence and the poor quality of sediments near it, the proposed borrow area B2 is terminated over two miles east of the Emerald Isle-West reach. In general, there is more sand and less hard bottom offshore of Bogue Banks compared to Topsail Beach or Surf City, based on reports available to date.

CSE

Paragraph 8 — Comment concludes with opposition to the project based on "potential direct, secondary, and cumulative impacts"

Response: The correspondent has not provided any quantitative analysis or reference to other nourishment projects demonstrating specific, permanent adverse impacts. If quantitative standards exist for certain concerns expressed by the correspondent, the applicants are prepared to modify the design and seek to achieve those standards.

I hope that the above-listed responses adequately address the US EPA's comments regarding the project. Please contact me if you need further information about any aspect of the project. Thank you for your consideration.

Yours truly,

Timothy W Kana PhD
Project Director

cc: Carteret County, Frank Rush
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
Town of Emerald Isle, Mayor Barbara Harris
State Clearinghouse, Chrys Baggett
CSE, Bill Forman
NCDENR, Doug Huggett

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

April 30, 2001

Mr. Mickey T. Sugg
Regulatory Field Office
USACE, Wilmington District
PO Box 1890
Wilmington NC 28402-1890

RE: Carteret County – Bogue Banks Beach Restoration Project – USACE Action ID# 200000362]
Response to Comments dated 20 April 2001 from Andreas Mager, Jr. (NMFS)

Dear Mr. Sugg:

I am writing on behalf of the applicant in response to comments (dated 20 April 2001 from the National Marine Fisheries Service, Andreas Mager, Jr.) on the above-referenced project. Some of the concerns raised by NMFS match those of other agencies. Therefore, we direct you to our responses to comments from:

1) North Carolina Division of Marine Fisheries (18 April 2000 and 2 October 2000 comments; 13 September 2000 responses).
2) NCDENR-Wildlife Resources Commission (27 April 2000 and 24 October 2000 comments; 13 September 2000 responses).
3) University of North Carolina-Institute of Marine Sciences (15 March 2001 and 13 April 2001 comments; 3 April 2001 responses).
4) Environmental Defense (13 March 2001 and 12 April 2001 comments; 4 April 2001 responses).

Copies of these letters and responses are contained in the SEPA final EIS for the project, a copy of which has been delivered to your office. We believe the final EIS addresses all salient issues and presents a comprehensive evaluation of the project.

RE: Concerns Regarding Essential Fish Habitat
We have discussed the review required of essential fish habitats (EFHs) with NMFS representatives in Morehead City and St. Petersburg (FL). We are in the process of preparing the document and will submit it as required under NEPA. The habitats that are applicable include areas of offshore sand bottom, surf zone, and water column.

NMFS expresses concern that "physical and biological conditions in (the offsbore borrow areas) may be substantially changed . . .". The applicant is also concerned and has endeavored to design a project that will:

CSE

1) Only minimally change the bottom topography with shallow cuts of the order 2-3 feet.
2) Leave similar underlying sediments as are presently exposed at the surface.
3) Leave undisturbed "furrows" adjacent to the cuts from which recruitment can occur.
4) Match as closely as possible the grain size of the fill material with that of the beach.
5) Avoid dredging deposits containing >5 percent mud.
6) Perform work during colder months when biological productivity is lowest.

We are not aware of any nourishment project in the Southeast that followed the above protocols <u>and</u> produced long-term adverse impacts to essential fish habitat.

RE: Concerns Regarding Biological Monitoring
See previously referenced responses.

RE: Sediment Resuspension and Turbidity
Persistent turbidity results when discrete clay-sized particles are in suspension. Silt and fine sand has settling velocities orders of magnitude faster than clay. The "fines" referenced by the correspondent and reflected in overfill ratios consist mainly of sand-sized sediment. Clay-sized material will be a fraction of the "mud" fraction which will total no more than 5 percent of the borrow material.

Such concentrations of mud are ubiquitous in the nearshore zone and account for the chronic resuspension during storms and large seas. Species common to the area of Bogue Banks are adapted to order-of-magnitude variations in turbidity in the foreshore. The proposed project will not produce permanent elevated turbidity levels because the amount of clay-sized material that will be mobilized by dredging a 2.58-square-mile area is dwarfed by the volume of free mud on the ocean floor over other sections of the inner shelf in this setting. In fact, the applicant has chosen the borrow areas so as to avoid areas off Bogue Banks that have higher concentrations of mud on the sea floor.

RE: Potential Reductions in Important Surf Zone Species
The correspondent references two studies that indicate nourishment reduced populations of Donax and Emerita. These studies (Donaghue, 1999, and Peterson et al, 2000) describe impacts resulting from cases quite different than the proposed project. Donaghue observed declines at Pea Island on a beach that was nourished almost yearly over a seven-year period, leaving little time for recovery before the next fill in a one-mile reach. The Peterson et al study at Bogue Banks examined the impacts from placement on the beach of noncompatible, muddy sediments from Bogue Sound. Mean grain size was 3.67ϕ, which is nearly in the silt range and nearly an order of magnitude finer than the mean grain size in the project area. A review of the literature shows that where borrow sediments closely match the native beach and projects follow the six protocols listed previously in this letter, biologic and turbidity impacts tend to be exceedingly short-lived. References to other pertinent literature are given in Appendix A of the SEPA EIS for the project.

CSE

RE: Numbers of Nourishment Projects
We question the correspondents estimate of 58 percent of North Carolina beaches being considered for nourishment when only about 43 percent are developed. Further, Bogue Banks is the only developed barrier island for 52 miles to the east/north and for 21 miles to the west. In other words, the Cape Lookout region is not likely to experience chronic impacts of repeated nourishment activities.

RE: Schedule of Construction
The applicant has requested a November to April construction window to minimize the number of dredge mobilizations. The project will be performed in at least two phases with reaches 4, 5, and 6 (Indian Beach, Salter Path, and Pine Knoll Shores) scheduled for 2000-2001. Penalties will be imposed on the contractor if construction is incomplete prior to the end of the environmental window, assuming the applicants are granted permits with reasonable time conditions. We expect to work closely with NMFS to coordinate activities at the beginning and end of the construction window so as to avoid any commercial fishing activities in the surf zone in November or turtle nesting in April

RE: Proposed COE Turbidity Impact Studies
We encourage NMFS to review the historical literature on turbidity impacts on larvae and juvenile fishes. The Chesapeake Bay Institute of The Johns Hopkins University completed a series of controlled experiments in the 1970s investigating the question of turbidity impacts on fish egg-hatching success and fish larvae. We recall that these experiments showed no significant effects for the natural ranges of turbidity in the upper Chesapeake Bay (much higher suspended sediment levels than offshore Bogue Banks). Only the most extreme concentrations (above worst storm levels) showed some initiation of lethal effects (cf, Auld and Schubel, 1974; Schubel, 1977, p. 409; Sherk et al, 1974). These studies were funded by NSF, NMFS, and the State of Maryland.

References

Auld, AH, and JR Schubel. 1974. Effects of suspended sediment on fish eggs and larvae. Spec. Rept. 40, Chesapeake Bay Institute, The Johns Hopkins Univ., Baltimore, MD.

Schubel, JR. 1977. Sediment and quality of the estuarine environment: some observations. In IH Suffett (ed), *Fate of Pollutants in the Air and Water Environments*, Part I, Vol. 8, John Wiley & Sons, New York, NY, pp 399-423.

Sherk, JA, JM O'Connor, DA Newman, RD Prince, and KV Wood. 1974. Effects of suspended and deposited sediments on estuarine organisms. Ref. 74-20, Natural Resources Institute, University of Maryland, College Park.

RE: Proposed Monitoring
See response to Peterson letter and draft monitoring plan dated 25 April 2001 which we submitted to your office. Our proposed statistical analysis exceeds that which was initiated by Dr. Peterson as part of the applicant's SEPA EIS.

CSE

RE: "High Possibility" of Adverse Impacts
We disagree with this qualified statement and question its basis. In our opinion, the comment reflects a selective rather than comprehensive review of the literature, as noted above. Again, we believe that there are no known instances of prolonged adverse impacts of nourishment to indigenous organisms for projects that followed the six protocols previously listed. If such cases exist, we would like to obtain copies of any reports or documentation so that we may improve future projects.

In conclusion, we appreciate the correspondent's comments and concerns and have sought to address them by applying best-management practices to the design. In my opinion, the comments greatly overstate the potential for biological impacts based on a selective reading of the literature. Further, without quantitative standards and guidelines, the comments do not provide sufficient rationale for denying permits. Instead, more would be learned by proceeding with the initial reaches and carefully monitoring the physical and biological impacts of the project, as we are proposing. The applicant has no desire or motivation to degrade the shoreline or fishery on which the economy of Carteret County depends.

Thank you for your consideration.

Yours truly,

Tim Kana

Timothy W Kana PhD
Project Director

cc: NMFS, Morehead City, Ron Sechler
Carteret County, Frank Rush
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
Town of Emerald Isle, Mayor Barbara Harris
CSE, Bill Forman

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

May 24, 2001

Mr. Garland Pardue
US Fish & Wildlife Service
551-F Pylon Drive
Raleigh NC 27606

Tel: 919-856-4520
Fax: 919-856-4556

RE: Carteret County – Bogue Banks Beach Restoration Project – Federal Action ID# 200000362]
Supplementary Information Requested by USFWS on 11 May 2001 (interagency meeting)

Dear Mr. Pardue:

I am writing on behalf of Carteret County and the Towns of Pine Knoll Shores, Indian Beach, and Emerald Isle in regard to the permit application for the above-referenced project. Representatives from your agency, Ms. Tracy Rice and Mr. John Ellis, attended an interagency meeting in Morehead City on 11 May 2001 and provided comments and requests for additional information. This letter and its attachments provide the information requested. These data are intended to supplement the information contained in the permit application and final EIS approved under the SEPA review process.

Work Accomplished

At the request of your agency, the Towns of Pine Knoll Shores and Indian Beach funded additional beach sediment collection and analyses as follows:

- 64 surficial sediment samples from Bogue Banks transect 48 (Emerald Isle) through transect 78 (Atlantic Beach). Sixteen, even-numbered transects were sampled along the dune face, top of berm, beach face, and low-tide terrace at low tide on 15 May 2001.

- 32 samples were analyzed in the laboratory by combining physical pairs from adjacent transects (eg, dune samples from transects 48 and 50 were combined physically, mixed completely, and a representative ~100-gram sample was tested for sediment properties). Samples were labeled B4850a for dune samples at transects 48 and 50, B4850b for berm samples, etc.

CSE

- Laboratory analysis of each sample consisted of:
  - Mechanical sieving at 0.25ϕ intervals.
  - Computation of grain-size distribution (GSD) parameters (mean, standard deviation, skewness, percent coarser than 2 mm, etc.).
  - Chemical analysis of the calcium carbonate fraction via acid reduction (dilute HCl) using a representative 20-gram sample.
  - Physical separation of the mud fraction (sizes passing the 230 ASTM sieve; ie, <0.0625 mm diameter) to determine the mud percent.
  - Size parameters were calculated by the Method of Moments and via graphic techniques of Inman (1952) and Folk and Ward (1957).

- Groups of samples were combined statistically using the raw weight percentages of each size fraction to calculate "composite" GSDs. Composites included:
  - CDUNE8 – composite of the eight dune tests (representing 16 physical samples).
  - CDUNE4 – composite of four of the dune tests (representing transects less altered by scraping).
  - CBERM8 – composite of the eight berm tests (representing 16 berm samples).
  - CBF8 – composite of the eight beach face tests, etc.
  - CLTT8 – composite of the eight low-tide terrace tests, etc.

- Overall beach composites were computed for all 32 tests ("COMP32") and 28 tests ("Comp28" which omits four of the dune samples).

- The composites from the 15 May 2001 sampling were compared with the June 1999 results. All new beach sediment data have been added to Table E3-Revised (EIS) and are attached to this letter. The 1999 "Native Beach" composite is compared with the 2001 composites at the bottom of Table E3.

- The "Native Beach" GSD was revised by averaging the results from the June 1999 and the May 2001 survey as follows (see Table E3 for additional details):
  - 1999 beach composite (20 samples) – mean = 0.302 mm
  - 2001 beach composite (28 samples) – mean = 0.298 mm
  - Revised native composite – mean = 0.300 mm

- Overfill ratios (RAs) for individual samples in three offshore borrow areas were recomputed using the revised native composite GSDs. These are given in Table E5-Revised. The typical change in RAs after this revision was ~0.01, or about 1 percent.

- Sediment characteristic maps of various textural parameters were updated for the three borrow areas. These include data from additional borings obtained between November 2000 and March 2001, which were in processing at the time of the interagency meeting.
  - Area A – ~76 cores
  - Area B1 – ~46 cores
  - Area B2 – ~42 cores

  Additional core data are given in Annex E1-Table E1-F (Appendix E to EIS).

- Results of the supplementary individual and composite GSDs (sample split weights, frequency, cumulative frequency, and statistics) are enclosed with this letter.

Borrow Area Delineation

As part of the final design for the Pine Knoll Shores and Indian Beach projects, we will optimize borrow areas A, B1, and B2 to effect a close match between the borrow sediments and the revised native beach sediments. This is an iterative process because of the number of variables involved and the natural variability of Bogue Banks' beach and offshore area. However, final decisions regarding exactly which portions of the borrow areas will be used cannot be made until all variables are known. These include the capabilities of each dredge of the winning construction bidder and the unit-volume bid price. (For example, if bid prices are lower than expected, more sand may be dredged, up to the maximum permitted volume.)

The final design will identify the optimal areas for excavations and will provide statistical composites for applicable groups of samples from borrow areas A, B1, and B2.

We anticipate collecting additional borings prior to any nourishment along Emerald Isle. The present data are focused in anticipation of construction along Pine Knoll Shores and Indian Beach reaches between November 2001 and April 2002. We request that your agency review these data in the context of the Pine Knoll Shores and Indian Beach reaches.

CSE

Supplement to the Biological Assessment

Also enclosed herein is a supplement to the biological assessment given in the EIS. Additional site visits and surveys have been performed since the EIS was prepared. The most recent survey was 14-15 May. The majority of Pine Knoll Shores and Indian Beach lacks any dry beach. Property owners are continuing to scrape the beach and rebuild the foredune. There are escarpments up to 8 feet high in some newly scraped dunes (see photo 1.4) and continued undercutting and mass wasting of vegetated dunes. In addition to the reduction of viable turtle nesting and seabeach amaranth habitat (see photos), even more habitable structures are imminently threatened than was reported in the EIS. We encourage you and your staff to visit the site and see the continued loss of dune and dry beach habitat. This is particularly noticeable upon leaving Pine Knoll Shores and traveling east along the beach into the Town of Atlantic Beach (which was nourished in 1986 and 1994 prior to five landfall hurricanes, see photo 1.6).

We appreciate the comments from your agency and hope you find the enclosed information responsive. Time is of the essence, and it is critical that we obtain your review of the project at the earliest time. Our project team and representatives of the county and towns would like to meet with you any time in the next two weeks and discuss these results in detail. Thank you for your consideration.

Yours truly,

Tim Kana

Timothy W Kana PhD
Project Director

cc: USACE, c/o Mickey Sugg
NMFS, Morehead City, Ron Sechler
NC CAMA, Doug Huggett
Carteret County, Pete Allen
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
Town of Emerald Isle, Mayor Barbara Harris
CSE, Bill Forman

Attachments

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1890
WILMINGTON, NORTH CAROLINA 28402-1890

IN REPLY REFER TO April 17, 2001

Regulatory Division

Action ID. 200000362

Mr. Pete Allen, Manager
Carteret County
Courthouse Square
Beaufort, North Carolina 28516

Dear Mr. Allen:

Please reference Carteret County's application for Department of the Army (DA) authorization to conduct beach nourishment along 16.8 miles of Bogue Banks Barrier Island by discharging 8.0 million cubic yards of dredge material into Section 10 Navigable Waters and Section 404 waters of the Atlantic Ocean, in Carteret County, North Carolina.

In response to your proposal, our office has received comments by letter (copies enclosed) from private organizations and individuals recommending against the authorization of your permit request. It is our suggestion that you revise your plans to satisfy the interests of the objecting individuals and organizations.

It is the policy of the DA to provide an applicant the opportunity to furnish a proposed resolution or rebuttal to all objections from government agencies and other substantive adverse comments before a final decision is made on a proposed project. In this regard, I would appreciate receiving any comments that you have on this matter. If you intend to comment, please give your immediate attention to this matter, so processing of your permit application can be expedited.

If you have questions or comments, please contact me at (910) 251-4811 and I will assist you in coordinating with the review agencies.

Sincerely,

Mickey Sugg
Wilmington Regulatory Field Office

Enclosures

Copy Furnished (with enclosures)

Mr. Bill Forman
804 Arendell Street
Suite 1
Morehead City, North Carolina 28557

Copies Furnished (without enclosures):

Mr. Charles Peterson
The University of North Carolina
at Chapel Hill
Institute of Marine Sciences
3431 Arendell Street
Morehead City, North Carolina 28557

Ms. Michelle Duval and Mr. Daniel Whittle
Environment Defense
2500 Blue Ridge Road, Suite 330
Raleigh, North Carolina 27607

Mr. Jim Stephenson
North Carolina Coastal Federation
3609 Highway 24 (Ocean)
Newport, North Carolina 28570

Mr. Don Morris
511 Broad Creek Loop Road
Newport, North Carolina 28570

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Institute of Marine Sciences
252-726-6841
FAX: 252-726-2426

The University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, North Carolina 28557

13 April 2001

Mickey T. Sugg
US Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402-1890
FAX- (910)-251-4025

Re: Bogue Banks Beach Restoration Plan

Dear Mr. Sugg:

I enclose here my comments on the Draft EIS for the Bogue Banks Beach Restoration Plan. I make these comments in my professional capacity as a coastal ecologist with the University of North Carolina at Chapel Hill. These opinions are derived from my 25 years of personal experience in quantitative monitoring of the major beach invertebrates on the beaches of Bogue Banks, my years of experimental analyses of how ecological processes on sand beaches are influenced by the physical character of the sediments, my personal experience with two beach nourishment projects at Fort Macon, my 30+ years of professional reading, research, and experience as a marine ecologist, my two decades of teaching barrier island ecology at Duke University and the University of North Carolina, and my recent experience as a member of the IRC charged with development of CHPPs, including the Coastal Ocean Habitat Protection Plan.

In my professional opinion, the proposed Bogue Banks Beach Restoration Plan is inadequately protective of the important natural resources of the intertidal beach and the coastal ocean, including especially the physical habitat and prey invertebrates required to sustain our recreationally and commercially important fisheries and the valued shorebirds of our beaches. Without (1) scientifically rigorous before-after monitoring of physical character of the sediments, impacts and recovery of the invertebrate prey, and consequences of turbidity and habitat change on the fishes, with required mitigation for any substantive impacts, (2) development of a federal or state plan for assessing cumulative impacts based on results of a programmatic EIS covering all these sand mining and beach deposition projects along the entire coast of the state and beyond, as dictated by the range of the important fishes, (3) a match of sediment grain sizes to the natural sediments of the beach in a way that will protect the habitat value of the beach, and (4) restriction of the project to between Dec 1 and March 31 so as to minimize ecological damage and allow recovery to begin to develop during the ecologically significant spring-summer seasons, this project should not be granted a permit.

(1) Scientifically rigorous before-after monitoring of sediments, benthos, and fishes

The draft EIS is grossly deficient in its commitment to the monitoring that is necessary to evaluate the ecological impacts of the project and thereby allow the agencies to learn how to respond to future requests and how to condition projects to protect adequately the public trust resources. While it is true that monitoring of nourishment projects has been done in the past, this project is unique for its spatial scope, its application to pristine shores, and its context in the midst of potentially hundreds of miles of

similar projects coast-wide. Past beach nourishment projects have been done on short stretches of urbanized shore like Atlantic Beach, Wrightsville Beach, and North Topsail. The application to a pristine beach of such a length as to represent a significant fraction of the functional critical habitat for beach fishes, invertebrates, and shorebirds is unprecedented for North Carolina. Past monitoring projects attached to permit applications are almost uniformly poor scientifically, done merely to satisfy a regulatory burden in a way that typically produces inconclusive results. Monitoring should be designed up-front by and reviewed by professional statisticians so that the agency and the public can have reassurance that the important questions can be answered with adequate power to detect effects of ecological significance. That has not been done here. Here we are told that monitoring will be done by the Carteret County monitoring plan. There is no such plan, no detailed statistical design, and no binding commitment by the county, state, or the responsible party to funding such a project. In fact, the necessary before-project sampling has not even been done. In South Carolina projects, the offshore biology has been monitored before and after such projects in each of the four seasons of the year: this proposal includes pre-project monitoring of benthic invertebrates for only one season (autumn), yet the offshore fishery resources here are arguably even more important than off South Carolina. Yet, for Bogue Banks, there has been sampling in the offshore mining areas only in one season. There are no data included on pre-project monitoring of the beach ecosystem and no design that could be evaluated statistically for its rigor and ability (power) to detect important changes. No monitoring of the surf fish abundance and gut contents/fullness is even mentioned or contracted. Granting a permit under such inadequacy is not in the public interest.

There is broad and essentially uniform consensus among the scientific community that the impacts of beach nourishment projects on fisheries through modification of their bottom and water column habitats are poorly understood. The monitoring that has been done for such projects in the past (1) has been too restricted to include all the potentially important impacts on fisheries, (2) has lasted for too short a time period to confidently demonstrate recovery, (3) has failed to meet standards of rigor and high power to detect large impacts, and/or (4) has been done for projects occurring on too small a scale to allow extrapolation to the cumulative effects of permitting many miles of beach nourishment. The impacts of concern include both phases of nourishment projects, the mining of sediments from the shelf and the deposition of sediments on the beach.

A minimally adequate monitoring design for either the mining site or the deposition site would include the following components. First, the monitoring design must begin with quantitative data taken before initiation of the project. Such "Before" observations must be made during each season of importance to the biota that comprise and use the habitat. A single year of such "Before" data is an absolute minimum necessary to make rigorous conclusions and multiple years of "Before" data are required to be completely comfortable in estimating the magnitude of effects with confidence. These "Before" data must include observations made in both the putative "Impact" areas and in "Control" areas that are sufficiently distant not to be affected by the project but sufficiently nearby and similar that they can serve to track conditions that would be expected in the "Impact" area in the absence of the project. The observations made during the "Before" period then need to be replicated in the "After" period in both the putative "Impact" areas and the "Control" areas. This monitoring needs to match the seasonal monitoring done during the "Before" period and needs to extend long enough in time to demonstrate recovery or allow inference of recovery with high statistical confidence. The "Control" area should have replication that involves statistically independent sites. This is preferable for the "Impact" areas too, but sometimes impossible because there may be only one project site. In any event, sufficient subsampling must be done at multiple locations to characterize the habitat and its utilization adequately. This monitoring design must be shown to be likely to have high statistical power to detect any magnitude of impact deemed important to fisheries biologists and managers. This requires an effective statistical design. Perhaps the best model for such rigorous project monitoring comes from the paper on BACI (Before-After-Control-Impact) designs by Stewart-Oaten et al. (1986: Ecology). Most monitoring associated with permits is incapable of statistically demonstrating even large impacts of the project with confidence because of inadequate statistical power in the design. The evaluation of cumulative impacts of beach nourishment on a large scale of tens of miles is a particular challenge, fundable perhaps only by creating a monitoring bank from contributions from multiple projects.

(2) Programmatic EIS for cumulative impacts and appropriate monitoring

Besides the needs to evaluate the impacts of this particular project on Bogue Banks, the responsible permitting authorities have a duty to evaluate the cumulative impacts of all such perturbations to the coastal ocean system. This requires first a programmatic EIS that applies the best scientific judgement, open to public review, analysis, and comment, as to cumulative impacts, especially on fishery populations and shorebirds. For a short stretch of urbanized shoreline, it is readily argued that most fish and shorebirds are mobile enough to move elsewhere to feed when their invertebrate prey resources are killed by beach nourishment. Similarly, when prey resources are mined along with sand from the offshore sand bodies, one can argue that the demersal fishes and crustaceans can feed elsewhere. But when projects are large enough and numerous enough and when projects are repeatedly done over time, then the potential for seriously limiting the production of fishes and birds greatly increases. Furthermore, if the physical sedimentary habitat is permanently altered or modified for the long term, then there is great potential for permanent limitation of the extent of critical fisheries habitat both on continental-shelf sand bodies (a limited habitat already in the southern portion of the state) and on intertidal beaches. Nowhere in this Draft EIS for Bogue Banks is there evidence that the public trust resources will be protected from cumulative spatial and cumulative temporal effects. Until such time that evidence exists, no permit should be granted for this project.

(3) **Match of sediment grain sizes to protect habitat value of the beach**

The recovery of natural ecological functioning of the beach habitat depends upon closely matching the sediment size distribution to that of the natural undisturbed beach. I have shown in a published paper based on study of a previous beach nourishment project on Bogue Banks (Peterson et al. 2000: Journal of Coastal Research) that the US ACOE requirements for matching sediment sizes are inadequate to allow recovery of function of the beach habitat within the following summer season. Incorporation of either too much shell (coarse material) or too much silt/clay (fine material) inhibits recovery. Too much shell inhibits burrowing by the beach invertebrates, which must burrow into the sediments to feed and avoid erosion and wave-transport off the beach face. Too much shell also prevents many shorebirds from feeding on the invertebrates that are present because coarse particles block the biomechanical ability of bills to extract invertebrate prey (see test in published paper by Quammen 1982: Marine Biology). Too much silt/clay likewise prevents sand burrowers from inhabiting a habitat that now lacks the interstitial spaces among sand grains and the penetrability required for burrowing. In addition, silt/clay is readily suspended causing enhanced turbidity, which clogs the filtration apparatus of these suspension-feeding beach invertebrates (mole crabs, coquina clams, some polychaetes, and amphipods) and inhibits surf fishes like pompano, bluefish, and Spanish mackerel from detecting their prey. We possess feeding data from experiments showing this feeding inhibition on pompano in the presence of elevated turbidity. No matter which sediment source is chosen from those surveyed off Bogue Banks, turbidity in the surf zone will result and will likely degrade fisheries through further loss of prey organisms and inhibition of feeding by visually oriented fishes. The Bogue Banks project, as proposed in this Draft EIS, plans use of sediments that are much more dominated by shell fragments than the natural pristine Bogue Banks beaches. This will result in long-term (not just transient) reduction in beach invertebrate populations and thus habitat value for surf fishes and shorebirds. I base this judgement upon knowledge of the physical processes that affect sediments on the beach and upon my lab's survey of the biota of North Carolina beaches as a function of shell content. Silts and clays are gradually winnowed away from beach sediments as they become suspended in the water and make it turbid. Shell fragments, in contrast, are left behind to accumulate on beaches, and thus remain to degrade the beach habitat indefinitely until the next nourishment project is needed. Lower densities of the numerically and functionally important large burrowing invertebrates on shellier beaches are dramatic in our unpublished survey data. Thus, the choice to use shell-rich sediments in the Bogue Banks nourishment project will predictably degrade the critical habitat of the intertidal beach indefinitely. Such a poor match with pristine sediments should not be permitted.

(4) Restriction of the project to Dec 1 through March 31

Because of the seasonality of biological use and activity in both the subtidal sand body habitat and the intertidal beach habitat, sand mining and beach deposition should both be restricted to the colder months to minimize ecological injury and to speed up recovery in the next warm season. The draft EIS for the Bogue Banks project does not constrain the project adequately in light of what is known about biological seasonality to protect the functioning of these habitats. Our monitoring of beach invertebrates on Bogue Banks over a period of 25 years shows that the period of December 1 through March 31 is the proper window during which beach invertebrates like mole crabs and coquina clams have migrated to deeper waters, from which they can initiate recovery through migration and reproduction at the end of the project. Furthermore, our sampling of fish abundance at the sand bodies proposed for mining to conduct this Bogue Banks project demonstrated high abundances and high rates of feeding on bottom invertebrates of the sand bodies on November 29 and again in spring, with low levels in February after clod fronts had reduced water temperatures. The Draft EIS for Bogue Banks does not propose a time frame for the project that will adequately protect either of these habitats from the impacts of the project. A permit should not be granted until the window is narrowed to this Dec 1-March 31 season. Furthermore, the public is entitled to a commitment that such a window will be enforced: similar restrictions have not been enforced in the past and I have little confidence that they will be in the future, absent some new mechanism of assurance.

I trust that my concerns are clearly and fully enough articulated here. If any comments need further elaboration, please ask. In addition, if you need further information from our files, please ask.

Sincerely,

Charles H. Peterson

Charles H. Peterson
Alumni Distinguished Professor

NORTH CAROLINA
COASTAL
FEDERATION

3609 HWY 24 (OCEAN) • NEWPORT, NORTH CAROLINA 28570 • (252) 393-8185 • Fax (252) 393-7508

RECEIVED
APR 23 2001

April 12, 2001

Mickey T. Sugg
Department of the Army
Wilmington District, Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402-1890

RE: Bogue Banks Beach Nourishment – Action ID No. 200000362

Dear Mr. Sugg:

The following represents the comments of the North Carolina Coastal Federation (NCCF) on the permit request by Carteret County to dredge and discharge approximately 8 million cubic yards of material into Section 10 navigable waters and Section 404 waters to nourish approximately 16.8 miles of beaches along the eastern section of Bogue Banks barrier island from Emerald Isle to Pine Knoll Shores, in Carteret County, NC.

NCCF represents approximately 6,000 members across coastal North Carolina and participates actively in all facets of regulatory and environmental protection activities affecting the state's coast. NCCF has a long history of environmental advocacy regarding the beachfront of the Outer Banks and other segments of the North Carolina coastline, and appreciates the opportunity to submit these comments.

For the past couple of years, NCCF has publicized our Beach Renourishment Policy through our newsletters to its members and the general public, and comment letters to government agencies. This seven point policy (attached) outline the criteria we are committed to use to evaluate beach renourishment proposals. Comments submitted in this letter are based upon this policy.

First and foremost, we are requesting that the Corps of Engineers require Carteret County to prepare an Environmental Impact Statement (EIS) pursuant to the National Environmental Policy Act (NEPA) for this project. The nourishment of 16.8 contiguous miles of beaches is unprecedented on the North Carolina coast and would make it one of the longest stretches on the east coast. Due to its length, the project could have very significant primary, secondary and cumulative impacts upon biological resources that must be fully examined through a NEPA EIS before action on this permit can be taken. The preparation of an EIS under the NC Environmental Policy Act in no way eliminates the need for an EIS under NEPA. NEPA may serve as a substitute for SEPA; but SEPA

E-Mail: nccf@nccoast.org
www.nccoast.org

is not a substitute for NEPA. Inasmuch as the applicant has prepared a SEPA document, it should reduce the time necessary to prepare an EIS that meets NEPA requirements.

The permit application requests permit authority for ten years, which would allow maintenance and potential renourishment with this period. Irregardless of the model that projects the nourishment project will last ten years, it is likely that Bogue Banks would be renourished one or more times after severe storms during the ten year duration of the permit utilizing disaster relief funds provided by the Federal Emergency Management Agency. As a result, it will be necessary for the applicant to determine the environmental impacts of the project by projecting a worst-case scenario of severe storms and multiple reconstructions of the project necessary to maintain its ten-year lifespan. An alternative would be to grant a permit for a shorter duration of time, i.e. three years; or to condition the permit in such a way that prohibits renourishment within the ten-year period.

Second, we are requesting that a public hearing be held on the permit and on the Environmental Impact Statement required under NEPA. The public in Carteret County expressed their opposition to the expenditure of County funds on beach nourishment. In March 2000, Carteret County citizens rejected a county-wide referendum by a 73% to 27% margin that would have allowed the County to issue bonds to construct a beach nourishment project that is identical to the one described in this permit application. In this same referendum, the Town of Emerald Isle and the unincorporated area of Salter Path also voted against the bond issue. Both Emerald Isle and Salter Path are areas that could be nourished through this permit. Given this history, the Corps is faced with compelling circumstances that necessitate a public hearing in order to fully assess "the needs and welfare of the people" of Carteret County.

INADEQUATE CONSIDERATION OF ALTERNATIVES

The EIS submitted by the applicant as part of the SEPA process fails to adequately consider alternatives to the proposed project. This constrained view of alternatives is, in part, the result of the applicant's reliance upon inaccurate and unjustified assumptions. These assumptions also result in the benefits of the project being overstated and the costs being understated.

The applicant unjustifiably dismisses non-structural alternatives. The applicant concludes, without analysis or thoughtful discussion, that the only non-structural alternative is to relocate all the oceanfront structures, an endeavor the applicant estimates would cost almost $111 million. A non-structural alternative, however, does not necessarily entail relocation of all of the structures. No assessment is made of the alternative of a moderated retreat in which temporary, small-scale nourishment is used to reduce storm damage hazards in the short term while threatened structures are removed and either relocated or demolished. Further, Pine Knoll Shores, Indian Beach, Salter Path and Emerald Isle are distinctly different communities with unique development histories and patterns. As a result, a non-structural alternative must be evaluated on a community-by-community basis to determine its relative feasibility and cost, before folding these analyses in to an overall formula.

Prevailing public policy, and the law of the State of North Carolina, establish a policy of retreat from eroding shorelines through building relocation, building setbacks, development restrictions, and land use planning. 15 N.C.A.C. § 7H.0202(b), 7H.0306, 7H.0308. The primary purpose of the project is storm damage prevention and hazard reduction, not saving or relocating all existing structures. A genuine and open-minded analysis of alternatives must evaluate thoroughly the costs and benefits of a range of combinations of selective relocation, demolition, and temporary nourishment.

The applicant should be required to identify threatened structures that were grand fathered by the Coastal Area Management Act setback rule, i.e. were not in compliance with the rule when it was passed, and as a result could not be expected to survive long-term erosion rates on the oceanfront. The applicant also grossly exaggerates the cost of the retreat/relocation alternative by inflating the value of land beneath threatened structures as if the land was not threatened as well.

Because the applicant has not examined combinations of non-structural strategies of retreat, relocation, demolition. and temporary. short-term beach nourishment. the applicant has failed to comply with its duties under NEPA to give the project a "hard look" and to examine carefully all practicable alternatives.

ENVIRONMENTAL WINDOW UNACCEPTABLE

The environmental window requested by the applicant is unacceptable based on available monitoring data supplied by the applicant. If the applicant wishes to proceed with a window that extends from 1 November to 15 May, then it will be necessary for the applicant to conduct preconstruction monitoring during 2001-2002 to demonstrate that the environmental impact is not significant. Existing marine monitoring data of the borrow areas and invertebrate monitoring data from UNC Institute of Marine Sciences demonstrates that the environmental window for construction should be no wider than 1 December to 31 March.

The reason cited by the applicant for the wider window is to accommodate the completion of the project during two seasons. The applicant has divided the 16.8 mile project in to six stretches and has proposed constructing three stretches during each season. The Corps should require the applicant to consider constructing the project over three seasons in order to decrease the impact on marine and terrestrial fauna. In the Corps' "Projected Cost for Shore protection in North Carolina Over the Next 30 Years" (March 2000), the Corps wrote:

"Projects along Bogue Banks would be constructed in 3 phases with the first phase covering Pine Knoll Shores, the second phase covering all of Salter Path, Indian

Beach, and the eastern end of Emerald Isle. The third phase would cover the remaining portion of Emerald Isle."

One of the reasons the project should be segmented in to three or more sections is prevent harmful economic impacts on Carteret Counties sportfishing industry, which is second only to Dare County. The SEPA EIS correctly states, "The health of those activities (fishing, boat building, and outfitting and supply) is dependent on the health of the marine environment." The SEPA EIS does not quantify the impact of the sportsfishing industry in Carteret County nor does it adjust the economic impact of the project for the damage that would be done to this industry by expanding the environmental window. 5

MONITORING DATA AND PLAN INADEQUATE

The plan for monitoring the impact on environmental resources is incomplete and inadequate. The applicant did conduct some monitoring of fish abundance at the proposed borrow sites during the 1999-2000 season. The monitoring results demonstrated "high abundances and high rates of feeding on bottom invertebrates of the sand bodies on November 29 and again in the spring, with low levels in February after clod fronts had reduced water temperatures," according to Dr. Charles H. Peterson, who conducted the survey for the applicant. During the 2000-2001 season, the applicant conducted no monitoring of benthic invertebrates and fish abundance. At no time has the applicant conducted any monitoring of biological use and activity in the intertidal beach habitat.

The applicant has not produced a monitoring protocol, except to promise that a Carteret County monitoring plan will be utilized. No monitoring plan was included in the SEPA EIS. The Corp must require in its scoping meeting with the applicant that the Carteret County monitoring plan must accompany the draft NEPA EIS. It is insufficient and ineffective to simply establish a permit condition that monitoring will be conducted. The protocol and schedule for monitoring must be determined as part of the NEPA EIS process.

Preconstruction monitoring of marine and invertebrate activity is a necessity to establish a baseline on which to determine project impacts. The applicant missed an important opportunity in 2000-2001 to gather the necessary data to develop a baseline. It is unclear how the project can proceed during the 2001-2002 season without adequate and reliable baseline data. 10.

IMPACT TO MARINE RESOURCES

The Habitat and Water Quality Committee of the NC Marine Fisheries Commission approved a document entitled "Policies for the Protection and Restoration of Marine and Estuarine Resources from Beach Dredging and Filling in Large-Scale Coastal Engineering" in November 2000. (Attached) These policies were later adopted by the

NC Marine Fisheries Commission, which has statutory authority for protecting marine and estuarine resources. The document establishes seven policies related to large-scale beach dredge-and-fill and related projects. The SEPA EIS fails to adequately address and in most cases fails to address at all the seven policies. The seven policies must be addressed through the NEPA EIS that examines the potential impact of the project on Essential Fish Habitat as required by the Magnuson-Stevens Act.

MORE STUDY OF SAND SUITABILTY NEEDED

The applicant has selected three potential sand sources or borrow sites (A, B1 & B2). The applicant also requests flexibility in reach and borrow areas, with a clear preference towards maximizing the use of borrow area A. Borrow areas B1 and B2 have overfill ratios of 1.97 to 2.19 in order to retain sufficient sand on the beach. Borrow area A is a significantly courser grain size than borrow areas B1 and B2 and has an overfill ratio of 1.16. At the same time, borrow area A contains 44 percent carbonate material compared to 15 to 20 percent on the native beach. Mud percentage in borrow area A averaged about 4 percent in the upper 2.3 feet of the section. The mean grain size at borrow area A (0.51 mm) is significantly larger than the native beach (0.302 mm). The percent of sediment larger than 2 mm at borrow site A is 20.5 percent compared to about 5 percent on the native beach.

If the question is whether the sediment from borrow site A will stay on the beach, it is more likely to than borrow areas B1 and B2. However, the characteristics of borrow area A in terms of coarseness, large shell fragments, as well as mud composition should not qualify borrow site A as a suitable match for Bogue Banks beaches. Further study of borrow site A must be conducted to determine if the sand source could be made compatible with the native beach with the addition of a screening mechanism to sort out the largest particles and shell fragments and a filter mechanism to lower the mud content. Unless additional mechanisms are employed, it is premature to conclude that borrow site A is a suitable sand source.

Borrow area B2 appears to be the closest match to the native beach, although it too contained a relatively high percentage of mud (4.1 percent) and should be combined with a filtering mechanism to reduce turbidity. Borrow area B1 contained less mud, but its grain size was finer than the native beach which could reduce the project's longevity.

There are two unresolved regulatory issues that must be addressed before this project proceeds. First, based upon the mud and silt contents in the borrow sites, there is a serious question about whether the project can comply with the turbidity standard of the North Carolina Environmental Management Commission. The turbidity standard apples to dredging activities at the borrow areas as well as at the discharge site at the surf zone. NCCF recently has photographed large turbidity plumes associated with dredging activities at the Oak Island beach "sea turtle" project in Brunswick County currently being carried out the the Corps. Steps must be taken to prevent this type of impact from future projects. There also appears to be a real question about whether beach renourishment projects are in fact mining, and should be authorized by a Mining Permit from the NC Department of Environment and Natural Resources. This issue should be resolved to assure compliance with applicable mining standards.

FAILURE TO CONSIDER CUMULATIVE IMPACTS

The applicant's SEPA document gives inadequate attention to cumulative impacts. NEPA requires that the cumulative effects of this project be analyzed along with the effects of existing and potential projects. Cumulative impacts "can result from individually minor but collectively significant actions taking place over a period of time." 40 C.F.R. § 1508.7.

To conduct a valid cumulative impacts analysis, the applicant must look at not only the ongoing and potential projects listed in Table 6-1 of the Dare County EIS (attached), but at all other North Carolina beachfront sand disposal activities. In its 30-year economic forecast, the Corps includes three more proposed major nourishment projects not counted in the cumulative impacts figures: Topsail Beach, Surf City, and North Topsail Beach. Combined predicted shoreline lengths for these projects would add another 20.5 miles to the length of impacted beach.

Other current and proposed projects which need to be considered by the Corps in addition to the projects in Table 6-1 are:

PROJECT	AGENCY	TYPE OF PROJECT	STATUS	LENGTH
Topsail Beach	Corps of Engineers	Nourishment	Proposed	5.5 miles
Bogue Banks (three phases)	Corps of Engineers	Nourishment	Proposed	17 miles
Surf City	Corps of Engineers	Nourishment	Proposed	5 miles
North Topsail Beach	Corps of Engineers	Nourishment	Proposed	10 miles
Wilmington Harbor -- Bald Head Island	Corps of Engineers	Spoil disposal	Current	1 additional mile
Wilmington Harbor -- Caswell Beach/Oak Island	Corps of Engineers	Spoil disposal	Current	9.6 miles
Wilmington Harbor – Holden Beach	Corps of Engineers	Spoil disposal	Current	2 miles
Atlantic Intracoastal Waterway	Corps of Engineers	Expanded channel dredging with spoil disposal	Proposed	from Virginia to South Carolina state line
Drum Inlet/Core Banks	Corps of Engineers	Spoil disposal	Unscheduled	2 miles
Onslow Beach	Marine Corps at	Nourishment	Proposed	1 mile

(partially in the CBR System)	Camp Lejeune			
Mason Inlet Relocation --Figure Eight Island	New Hanover County	Spoil disposal	Proposed	2 miles
Figure Eight Island	Private	Nourishment	Current	2 miles
Long Beach Sea Turtle Restoration Project	Corps of Engineers	Nourishment	Proposed	2.3 miles
Lockwoods Folly River Environmental Restoration	Corps of Engineers	Possible dredging and disposal	Proposed	Unknown
			TOTAL	**59.4 miles known**

Adding these figures to those listed in Table 6.1 of the Dare County EIS yields an estimated total of 136 miles of shoreline slated for sand disposal, almost double the 76.7 miles in Table 6-1. The total is now close to 43% of the entire North Carolina coastline. It is important to note also that this total does not include the new Atlantic Intracoastal Waterway project length, which may place new sand disposal on numerous beaches up and down the entire length of the coast, according to an August 3, 2000 public notice.

In the absence of a programmatic EIS for the North Carolina coast, it is incumbent upon the applicant to conduct an analysis of the cumulative impact of its beach renourishment project on marine and terrestrial flora and fauna in conjunction with all other beach nourishment projects on the North Carolina coast that are underway or planned within the ten-year lifespan of the project.

In conclusion, we strongly recommend that the Corps fully review the environmental impacts of the Bogue Banks project by conducting a thorough Environmental Impact Statement (EIS) as required by NEPA and holding public hearings to gain input from citizens.

Sincerely,

Jim Stephenson
Program Analyst

Attachments

(A)

NCCF Beach Renourishment Policy

NCCF will not object to a beach renourishment project if:

✓ (1) There is acceptable and adequate sources of sand available;
✓ (2) Project is properly planned, timed, and executed;
✓ (3) Habitat monitoring is done to evaluate the effects on fisheries habitat;
✓ (4) Project planners are completely forthcoming about the long-term financial costs of renourishment,
✓ (5) Financing arrangements place the burden on the people who benefit,
✓ (6) There is adequate public access (including parking) if county, state or federal funds are spent, and
✓ (7) Long-term planning is undertaken to address future beach protection when renourishment projects are no longer feasible either due to insufficient sand supplies or funding.

NORTH CAROLINA MARINE FISHERIES COMMISSION
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

(B)

NORTH CAROLINA MARINE FISHERIES COMMISSION

POLICIES FOR THE PROTECTION AND RESTORATION OF MARINE AND ESTUARINE RESOURCES FROM BEACH DREDGING AND FILLING AND LARGE-SCALE COASTAL ENGINEERING

NORTH CAROLINA MARINE FISHERIES COMMISSION HABITAT AND WATER QUALITY STANDING ADVISORY COMMITTEE: NOVEMBER 6, 2000
NORTH CAROLINA MARINE FISHERIES COMMISSION: NOVEMBER 16, 2000

Policy Context

This document establishes the policies of the North Carolina Marine Fisheries Commission (Commission) regarding protection and restoration of the state's marine and estuarine resources associated with beach dredge and fill activities, and related large-scale coastal engineering projects. The policies are designed to be consistent with the overall habitat protection policies of the Commission, adopted April 13, 1999, as amended February 17-18, 2000, as follows:

> It shall be the policy of the North Carolina Marine Fisheries Commission that the overall goal of its marine and estuarine resource protection and restoration programs is the long-term enhancement of the extent, functioning and understanding of those resources.
>
> Toward that end, in implementing the Commission's permit commenting authority pursuant to N.C.G.S. §143B-289.52(a)(9), the Chairs of the Habitat and Water Quality Standing Advisory Committee, in consultation with the Commission Chair, shall, to the fullest extent possible, ensure that state or federal permits for human activities that potentially threaten North Carolina marine and estuarine resources:
>
> (1) are conditioned on (a) the permittee's avoidance of adverse impacts to marine and estuarine resources to the maximum extent practicable; (b) the permittee's minimization of adverse impacts to those resources where avoidance is impracticable; and (c) the permittee's provision of compensatory mitigation for all reasonably foreseeable impacts to marine and estuarine resources in the form of both informational mitigation (the gathering of base-line resource data and/or prospective resource monitoring) and resource mitigation (in kind, local replacement, restoration or enhancement of impacted fish stocks or habitats); and
>
> (2) result, at a minimum, in no net loss to coastal fisheries stocks, nor functional loss to marine and

estuarine habitats and ecosystems.

The findings presented below assess the marine and estuarine resources of North Carolina which are potentially threatened by activities related to the large-scale movement of sand in the coastal ocean and adjacent habitats, and the processes whereby those resources are placed at risk. The policies established in this document are designed to avoid, minimize and offset damage caused by these activities, in accordance with the laws of the state and the general habitat policies of this Commission.

Marine and Estuarine Resources At Risk from Beach Dredge and Fill Activities

The Commission finds:

1. In general, the array of large-scale and long-term beach alteration projects currently being considered for North Carolina together constitute a real and significant threat to the marine and estuarine resources of the United States and North Carolina.

2. The cumulative effects of these projects have not been adequately assessed, including impacts on public trust marine and estuarine resources, use of public trust beaches, public access, state and federally protected species, state critical habitats and federal essential fish habitats.

3. Individual beach dredge-and-fill projects and related large-scale coastal engineering activities rarely provide adequate assessment or consideration of potential damage to fishery resources under state and federal management. Historically, emphasis has been placed on the logistics of sand procurement and movement, and economics, with environmental considerations dominated by compliance with limitations imparted by the Endangered Species Act for sea turtles, piping plovers and other listed organisms.

4. Opportunities to avoid and minimize impacts of beach dredge-and-fill activities on fishery resources, and offsets for unavoidable impacts have rarely been proposed or implemented.

5. Large-scale beach dredge and fill activities have the potential to cause impacts in four types of habitats:

a. waters and benthic habitats near the dredging sites;
b. waters between dredging and filling sites;
c. waters and benthic habitats near the fill sites; and
d. waters and benthic habitats potentially affected as sediments move subsequent to deposition in fill areas.

6) Certain nearshore habitats are particularly important to the long-term viability of North

Carolina's commercial and recreational fisheries and potentially threatened by large-scale, long-term or frequent disturbance of sediments:

a. inlets;
b. the swash and surf zones and beach-associated bars; and
c. underwater soft-sediment topographic features, both onshore and offshore underwater hard-substrate topographic features.

7) Large sections of North Carolina waters potentially affected by these projects, both individually and collectively, have been identified as Essential Fish Habitats (EFH) by the South Atlantic Fishery Management Council (SAFMC) and the Mid-Atlantic Fishery Management Council (MAFMC). Affected species under federal management include:

a. summer flounder (various nearshore waters, including the surf zone and inlets; certain offshore waters);
b. bluefish (various nearshore waters, including the surf zone and inlets);
c. red drum (ocean high-salinity surf zones and unconsolidated bottoms to a depth of 50 meters);
d. several snapper and grouper species (live hard bottom from shore to 600 feet, and -- for estuarine-dependent species [e.g., gag grouper and gray snapper] -- unconsolidated bottoms and live hard bottoms to the 100 foot contour);
e. spiny dogfish (various coastal waters from the surf zone to 200 miles);
f. black sea bass (various nearshore waters, including unconsolidated bottom and live hard bottom to 100 feet, and hard bottoms to 600 feet);
g. penaeid shrimps (offshore habitats used for spawning and growth to maturity, and waters connecting to inshore nursery areas, including the surf zone and inlets);
h. coastal migratory pelagics (sandy shoals of capes and bars, barrier island and ocean-side waters from the surf zone to the shelf break inshore of the Gulf Stream; all coastal inlets);
i. corals of various types (hard substrates and muddy, silty bottoms from the subtidal to the shelf break);
j. calico scallops (unconsolidated bottoms northeast and southwest of Cape Lookout in 62-102 feet);
k. sargassum (wherever it occurs out to 200 miles);
l. many large and small coastal sharks, managed by the Secretary of the Department of Commerce (inlets and nearshore waters, including pupping and nursery grounds).

8) Beach dredge and fill projects also potentially threaten important fish habitats for anadromous species under federal, interstate and state management (in particular, inlets and offshore overwintering grounds), as well as essential overwintering grounds and other critical habitats for weakfish and other species managed by the Atlantic States Marine Fisheries Commission and the State of North Carolina. The SAFMC identified for anadromous and catadromous

species those habitats that have been EFH if there had been a council plan (inlets and nearshore waters).

9) Many of the habitats potentially affected by these projects have been identified as Habitat Areas of Particular Concern by the SAFMC. The specific fishery management plan is provided in parentheses:

a. all nearshore hard bottom areas (SAFMC, snapper-grouper);
b. all coastal inlets (SAFMC, penaeid shrimps, red drum, and snapper-grouper);
c. near-shore spawning sites (SAFMC, penaeid shrimps, and red drum)
d. well-known seafloor features, including the Point, Ten Fathom Ledge and Big Rock (SAFMC, snapper-grouper, coastal migratory pelagics, and corals);
e. pelagic and benthic sargassum (SAFMC, snapper-grouper);
f. sandy shoals of Cape Lookout, Cape Fear, and Cape Hatteras (SAFMC, coastal migratory pelagics) and;
g. Bogue Sound and New River Estuary (SAFMC, coastal migratory pelagics).

10) Habitats likely to be affected by beach dredge and fill projects include many being recognized in North Carolina Fishery Management Plans as important for state-managed species. Many of these habitats are in the process of being recognized as Critical Habitat Areas by the Commission, in either FMPs or in Coastal Habitat Protection Plans. Examples include:

a. inlets (Blue Crab FMP, Red Drum FMP, River Herring FMP);
b. oceanic nearshore waters (Blue Crab FMP, Red Drum FMP); and
c. many others as FMPs and CHPPs are adopted over the coming years.

11) Recent work by scientists in east Florida has documented exceptionally important habitat values for nearshore, hard-bottom habitats often buried by beach dredging projects, including use by over 500 species of fishes and invertebrates, and juveniles of many reef fishes. Equivalent scientific work is just beginning off North Carolina, but life histories suggest that similar habitat use patterns will be found.

Threats to Marine and Estuarine Resources from Beach Dredge and Fill Activities

The Commission finds that beach dredge-and-fill activities and related large-scale coastal engineering projects (including inlet alteration projects) threaten the marine and estuarine resources of North Carolina through the following mechanisms:

1. Direct mortality and displacement of organisms at and near sediment dredging sites;
2. Alteration of seafloor topography and associated current and waves patterns and magnitudes at dredging areas;

3. Alteration of seafloor sediment size-frequency distributions at dredging sites, with secondary effects on benthos at those sites;
4. Elevated turbidity and deposition of fine sediments down-current from dredging sites;
5. Direct mortality and displacement of organisms at initial sediment fill sites;
6. Elevated turbidity in and near initial fill sites, especially in the surf zone, and deposition of fine sediment down-current from initial fill sites;
7. Alteration of near-shore topography and current and waves patterns and magnitudes associated with fill;
8. Movement of deposited sediment away from initial fill sites, especially onto hard bottoms;
9. Alteration of large-scale sediment budgets, sediment movement patterns and feeding and other ecological relationships, including the potential for cascading disturbance effects;
10. Alteration of large-scale movement patterns of water, with secondary effects on water quality and biota;
11. Alteration of movement patterns and successful inlet passage for larvae, post-larvae, juveniles and adults of marine and estuarine organisms;
12. Alteration of long-term shoreline migration patterns (inducing further ecological cascades with consequences that are difficult to predict); and
13. Exacerbation of transport and/or biological uptake of toxicants and other pollutants released at either dredge or fill sites.

Commission Policies for Beach Dredge and Fill Projects and Related Large Coastal Engineering Projects

The Commission establishes the following general policies related to large-scale beach dredge-and-fill and related projects, to clarify and augment the general policies already adopted on April 13, 1999:

1. Projects should fulfill the Commission's general habitat policy by avoiding, minimizing and offsetting damage to the marine and estuarine resources of North Carolina;

2. Projects should provide detailed analyses of possible impacts to each type of Essential Fish Habitat (EFH), with careful and detailed analyses of possible impacts to Habitat Areas of Particular Concern (HAPC) and Critical Habitat Areas (CHA), including short and long term, and population and ecosystem scale effects;

3. Projects should provide a full range of alternatives, along with assessments of the relative impacts of each on each type of EFH, HAPC and CHA;

4. Projects should avoid impacts on EFH, HAPCs and CHAs that are shown to be avoidable through the alternatives analysis, and minimize impacts that are not;

5. Projects should include assessments of potential unavoidable damage to marine resources,

using conservative assumptions;

6. Projects should be conditioned on the avoidance of avoidable impacts, and should include compensatory mitigation for all reasonably predictable impacts to the marine and estuarine resources of North Carolina, taking into account uncertainty about these effects. Mitigation should be local, up-front and in-kind wherever possible;

1. Projects should include baseline and project-related monitoring adequate to document pre-project conditions and impacts of the projects on the marine and estuarine resources of North Carolina;

2. All assessments should be based upon the best available science, and be appropriately conservative so as to be prudent and precautionary; and

3. All assessments should take into account the cumulative impacts associated with other beach dredge-and-fill projects in North Carolina and adjacent states, and other large-scale coastal engineering projects that are ecologically related.

References

Butler IV, M. J., J. H. Hunt, W. F. Herrnkind, M. J. Childress, R. Bertelsen, W. Sharp, T. Matthews, J. M. Field, and H. G. Marshall. 1995. Cascading disturbances in Florida Bay, U.S.A.: cyanobacteria blooms, sponge mortality, and implications for juvenile spiny lobsters Panulirus argus. Mar. Ecol. Prog. Ser. 129:119-125.

Dodge, R. E., R. C. Aller and J. Thomson. 1974. Coral growth related to resuspension of bottom sediments. Nature 247: 574-576.

Gilmore, R. G., Jr. 1977. Fishes of the Indian River Lagoon and adjacent waters, Florida. Bull. Fl. St. Mus. Bio. Sci. 22(3), 147 p.

Gilmore, R. G., Jr. 1992. Striped croaker, Bairdiella sanctaeluciae, pp. 218-222. In C. R. Gilbert, ed. Rare and endangered biota of Florida. II. Fishes. Univ. Press of Florida, Gainesville, FL, 242 p.

Hackney, C.T., M. Posey, S. Ross and A. Norris. 1996. A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach renourishment. Report to the U.S. Army Corps of Engineers, Wilmington District.

Kirtley, D. W. and W. F. Tanner. 1968. Sabellariid worms: builders of a major reef type. J. Sed.

Kirtley, D. W. and W. F. Tanner. 1968. Sabellariid worms: builders of a major reef type. J. Sed. Petrol. 38(1):73-78.

Lindeman, K. C. 1997. Comparative management of beach systems of Florida and the Antilles: applications using ecological assessment and decision support procedures. pp.134-164. In: G. Cambers, ed. Managing beach resources in the smaller Caribbean islands. UNESCO Coastal Region & Small Island Papers # 1, 269 p.

Lindeman, K.C. and D.B. Snyder. 1999. Nearshore hardbottom fishes of southeast Florida and effects of habitat burial caused by dredging. Fish. Bull. 97(3):508-525.

Nelson, W. G. 1989. Beach nourishment and hard bottom habitats: the case for caution. pp. 109-116. In: S. Tait, ed. Proc. 1989 National Conf. Beach Preserv. Technol. Fl. Shore and Beach Preserv. Assoc., Tallahassee, FL, 236 p.

Nelson, W. G. and L. Demetriades. 1992. Peracariids associated with sabellariid worm rock (Phragmatopoma lapidosa Kinberg) at Sebastian Inlet, Florida, U.S.A. J. Crust. Bio. 12(4):647-654.

Odum, W. E. 1982. Environmental degradation and the tyranny of small decisions. BioScience 32(9):728-29.

Pandolfi, J., D. R. Robertson, and D. R. Kirtley. 1998. Sabellariid worms: builders of a major reef type. Coral Reefs 17:120.

Peterson, C.H., D.H.M. Hickerson and G.G. Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. J. Coastal Res. 16(2): 368-378.

Sedberry, G. R. and R. F. Van Dolah. 1984. Demersal fish assemblages associated with hard-bottom habitat in the South Atlantic Bight of the U. S. A. Environ. Biol. Fishes 11(4):241-258.

South Atlantic Fishery Management Council. 1998. Final habitat plan for the South Atlantic region: Essential Fish Habitat requirements for fishery management plans of the South Atlantic Fishery Management Council. 457 pp plus appendices.

Telesnicki, G.J. and W.M. Goldberg. 1995. Effects of turbidity on the photosynthesis and respiration of two South Florida reef coral species. Bull. Mar. Sci. 57(2):527-539.

Wilber, P. and M. Stern. 1992. A re-examination of infaunal studies that accompany beach nourishment projects. Proc. 1992 Natl. Conf. Beach Preserv. Tech. pp: 242-256.

C

Table 6-1: **Cumulative analysis of existing, proposed and potential miles of NC beaches affected by sand disposal.**

Existing, Proposed, and Potential Beach Disposal & Nourishment Projects	Average Miles per year	Percent of total NC Beaches Affected per Year	Total Miles of Beach Affected	Percent of total NC Beaches*
Existing Beach Disposal from Maintenance Dredging				
Disposal Cycle 1yr	4.5	1.4%	4.5	1.4%
Disposal Cycle 2yr	1.7	0.5%	3.7	1.2%
Disposal Cycle 4yr	0.2	0.1%	1.0	0.3%
Disposal Cycle 5yr	0.2	0.1%	1.0	0.3%
Disposal Cycle 6yr	0.3	0.1%	2.2	0.7%
Disposal Cycle 8yr	0.3	0.1%	5.4	1.7%
Existing Beach Nourishment				
Carolina Beach	2.3	0.7%	6.8	2.1%
Wrightsville Beach	1.0	0.3%	3.0	0.9%
Proposed Project				
Dare Co. NED Plan	**5.0**	**1.6%**	**14.8**	**4.6%**
Subtotal	15.3	4.8%	42.4	13.3%
**Other Potential Project				
Ocean Isle	1.8	0.4%	5.3	1.7%
Oak Island	4.0	0.8%	12.0	3.8%
Holden Beach	2.3	0.4%	7.0	2.2%
Dare Co. Beaches (Hatteras and Ocracoke Islands Portion).	3.3	1.0%	10.0	3.1%
Total	26.7	8.3%	76.7	20.8%

Notes:
* Based on 320 miles of North Carolina ocean beach
**Ongoing Corps Studies in various stages of completion. Numbers are speculative and subject to change. Potential project sizes may vary and any given project may or may not be built

6.01.3 Nearshore Ocean. Two borrow areas (S1 and N1) will be excavated in the nearshore ocean. Excavation will directly impact an area of about 7 square miles when completely utilized (year 50). Initial construction will impact a total area of about 1 square mile of sandy ocean bottom. Multiple dredging areas within a given borrow site may be used to reduce material transport and/or allow for concurrent operation of more than one dredge in a given area. A typical borrow section is shown in figure 6-1. Existing depths at the proposed borrow sites range from 30' to 60'. The depth of cut will

e

ENVIRONMENTAL DEFENSE

finding the ways that work

North Carolina Office
2500 Blue Ridge Road, Suite 330
Raleigh, NC 27607
919/881-2601 919/881-2607 fax

Date: April 12, 2001

To: Mickey Sugg

From: Michelle Duval and Dan Whittle

# of pages: 18 (including cover)

Re: Comments Action ID No. 200000362 – Permit to Dredge and Discharge Material to Nourish Eastern Section of Bogue Banks

e

ENVIRONMENTAL DEFENSE

finding the ways that work

April 12, 2001

Mickey T. Sugg
Department of the Army
Wilmington District, Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402-1890
VIA FACSIMILE: 910-251-4025

RE: Action ID No. 200000362 - **Permit to Dredge and Discharge Material to Nourish Eastern Section of Bogue Banks**

Dear Mr. Sugg:

Please accept the following comments regarding the above-referenced matter on behalf of Environmental Defense, our 10,000 members in North Carolina and our 300,000 members nationwide. We have previously submitted comments on the Bogue Banks Beach Restoration Plan (attached) to the NC Division of Coastal Management and the NC State Clearinghouse and incorporate those comments by reference.

In general, we feel very strongly that the Corps' Wilmington District has an obligation under the National Environmental Policy Act (NEPA) to perform a new, comprehensive Environmental Impact Statement (EIS) for this project, particularly in light of the fact that a programmatic EIS has not been performed for the suite of beach engineering projects that is being proposed for the North Carolina coast. These projects and their impacts to coastal habitats and species do not exist in isolation from one another, yet that is precisely how the environmental impacts are evaluated. Given the number of such projects being proposed within the state, and the value of North Carolina's coastal habitats to commercially and recreationally important fish species all along the Atlantic seaboard, the NC Marine Fisheries Commission developed a policy for and a set of criteria by which beach engineering projects should be assessed (see attached). This policy also details the threats to marine and estuarine resources from dredge and fill activities.

We continue to maintain the need for thorough, scientifically defensible cumulative impacts analyses for this and all ongoing and proposed beach engineering projects. We have yet to see an analysis that adequately considers the long-term, cumulative impacts upon the coastal ocean ecosystem. Ideally, a statewide plan for assessing cumulative impacts should be implemented based upon the results of a programmatic EIS as described above. It should be designed in consultation with ecologists and biostatisticians to ensure that it has the proper statistical power to answer questions of biological relevance both spatially and temporally. Until such a plan can be designed, this project should not be permitted.

North Carolina Office · 2500 Blue Ridge Road · Suite 330 · Raleigh, NC 27607 · Tel 919 881 2601 · Fax 919 881 2607
New York, NY · Washington, DC · Oakland, CA · Boulder, CO · Austin, TX · Project Offices · Boston, MA · Los Angeles, CA
www.environmentaldefense.org

Finally, although we expressed our support of the applicant's stated intent to conduct a monitoring program as indicated in the draft EIS, we have learned through Dr. Charles Peterson of the University of North Carolina's Institute of Marine Sciences that indeed, there is no Carteret County monitoring plan; furthermore, that there is no commitment by any party—state, county or sponsor—to fund this critical portion of the project. The habitats, water column and marine organisms are all public trust resources and must be treated as such. The local project sponsors do not have the unmitigated right to impact these resources without sufficient documentation of such impacts simply because the residents have requested the project. Both the spatial and temporal extent of the Bogue Banks project warrant a statistically valid monitoring plan. Until a contract is in place to perform this monitoring, we strongly opposed permitting this project.

Thank you for the opportunity to comment on this important issue and for your consideration of our views.

Sincerely,

Michelle Duval, Ph.D.
Scientist

Daniel Whittle
Senior Attorney

Attachments (3)

ENVIRONMENTAL DEFENSE

finding the ways that work

March 13, 2001

Mr. Doug Huggett
CAMA Permit Coordinator
Division of Coastal Management
1638 Mail Service Center
Raleigh, NC 27699-1638
VIA FACSIMILE 919-733-1495

RE: Bogue Banks Beach Restoration Plan – SEPA Draft Environmental Impact Statement

Please accept these comments regarding the proposed project on behalf of Environmental Defense, our 10,000 members in North Carolina and 300,000 members nationwide. In general, we have serious concerns regarding the large-scale, persistent and cumulative effects of this and related beach engineering projects, and the adequacy with which impacts from these projects are addressed. We recognize and acknowledge the efforts of the project sponsor and authors of the draft EIS to address the issues of highest controversy surrounding beach engineering, and offer the following comments regarding those issues for which we have particular concerns:

1) Cumulative and Long Term Impacts: In general, our dominant concern regarding beach engineering projects, particularly ones of such extensive spatial (and potentially temporal) magnitude, is the inadequate assessment of cumulative and long-term impacts to living marine resources and essential fish habitats. Specifically, the impacts of these projects are assessed on a piecemeal, or project-by-project basis, rather than as components of a statewide and regionwide beach engineering effort. We recognize that scientific studies examining the impacts of engineering operations on beach, intertidal and nearshore fauna are ongoing and not yet complete, but enough information exists to warrant a programmatic EIS on *all* of these activities for the North Carolina coast, if not the entire southeast region. We have requested such an evaluation of the Corps of Engineers (see Attachment 1) in a letter dated September 8, 2000. The Corps' response was that such an evaluation was too costly to undertake at the present time.

   Although the current project is proposed to be a one-time placement of sand, designed to "restore the sand deficit and provide for average yearly losses over a decade or so" (DEIS, Section 2.1, p. 2-2), it is clearly stated at the end of the introduction (Section 1.4, p. 1-3) that it is unlikely the entire project could be constructed within the same environmental window. Indeed, it appears that, given the funding needs of the communities, the project will stretch over several environmental windows. We are concerned about the downstream impacts of such discontinuous construction, which, as pointed out in Section 5.4.5 (page 5-2, second paragraph) are not insignificant.

North Carolina Office · 2500 Blue Ridge Road · Suite [illegible] · Raleigh, NC 27607 · Tel 919 881 2601 · Fax 919 881 2607
New York, NY · Washington, DC · Oakland, CA · Boulder, CO · Austin, TX · Project Offices · Boston, MA · Los Angeles, CA
www.environmentaldefense.org

2) Definition of Project Success: As acknowledged in Section 2.2.2 (p. 2-2) one of the major controversies with respect to beach engineering is the development of criteria, or lack thereof, for defining project success. Given the magnitude of resources required for the proposed project, there ought to be a clearly defined set of criteria by which to measure project success, particularly if state cost-share funds are obtained for any portion of the project as discussed in Section 2.3.3. The DEIS state in Section 2.2.2 that "Success will be defined in relation to how closely the postnourishment volume erosion rate compares with the estimated prenourishment volume erosions rate" (page 2-3), yet fails to identify a range of values which would constitute an acceptable or "successful" erosion rate. Although achievement of a certain rate of erosion may constitute success in an engineering sense, it may not necessarily translate into visible success for the project sponsors (i.e., the communities, and potentially state taxpayers if cost-share funding is obtained). Considering that this project is supposed to serve as "prototype" for future beach mainrenance efforts (Section 2.1, page 2-1) and as a basis for determining a "long-range solution" from amongst three alternatives (Section 2.4, page 2-5), development of specific evaluation criteria by the project sponsors, rather than the contracted engineering company, would appear to be critical.

3) Project Purpose: Among the four stated objectives (Section 1.3, page 1-2) of the project is "preservation of the environmental, cultural and aquatic resources of the county". We maintain that this project as designed (mainly due to the extensive geographic scale) protects only the unnatural, i.e., manmade "environmental resources". The three remaining planning objectives are a more realistic statement of purpose. Beach engineering projects are rarely, if ever, consistent with protection of the natural environment, and we are unaware of any such projects that have enhanced the nation's living marine resources. We also disagree with the statement that Bogue Banks serves to draw human activity away from the more pristine shores of Shackleford and Core Banks. Although not accessible by vehicle, there is ample transportation available to these locations via public and private ferries, and certainly the number of privately owned boats anchored in Back and Core Sounds during the summer months does not indicate that the public is dissuaded from visiting these areas.

4) Consideration of Alternatives: The DEIS states that "Property abandonment and relocation at a large scale would leave the beach degraded for many years because it would necessarily become a piece-meal process" (page 1). Yet, as referenced previously, the DEIS indicates that if approved, project construction would itself be piecemealed. A retreat and relocation alternative can be planned to initially target those structures most at risk, and can be implemented gradually, rather than in one massive effort. Indeed, should this project be approved, development of a phased relocation and/or exit strategy should be considered, particularly if cost-share funding is obtained. Given that the community plans to reevaluate the costs and benefits of renourishment after a decade of monitoring (Section 2.2.2), development of such a strategy would be proactive. That being said, having once obtained the necessary approval for a beach engineering project (especially if other funding sources are obtained), it is highly likely that the local communities will naturally expect approval for a second project, at an even greater economic and environmental cost.

Also, under the no-action alternative in Section 4.2, page 4-2 one of the stated, yet unquantified, environmental impacts of this alternative is "chronic impacts to beach fauna". We presume that this would be the result of beach scraping. We disagree with this statement, as it implies that placement of dredged sand on the beach would *not* impact beach fauna and that beach scraping would not occur should the project move forward. Incidentally, we find it interesting that "loss of recreational beach" is listed as a quantifiable environmental impact, considering the subjective and intangible nature of the recreational experience, while no attempt is made to quantify the loss of biota.

5) Monitoring Program/Protocol: We applaud the commitment of the project sponsors to develop a comprehensive pre- and post-construction monitoring plan as outlined in Appendix C, and for initiating pre-project benthic monitoring. We feel that such efforts are absolutely necessary in order to assess project impacts accurately over the proposed 10-year project lifetime. We also feel that a periodic (once every three years), publicly available assessment of impacts should be conducted and the results used to adjust the implementation and maintenance of the project and develop a compensatory mitigation plan if warranted, especially if the communities elect to continue beach engineering as a management option. In light of the fact that environmental impacts are not quantified in the analysis of costs and benefits, we feel very strongly that the project sponsors be responsible for funding the monitoring program.

6) NC Marine Fisheries Commission Policies on Beach Dredge and Fill Activities: The North Carolina Marine Fisheries Commission (MFC) has statutory responsibility for protecting the marine and estuarine resources of North Carolina against impacts from both fishing and non-fishing threats. On November 16, 2000, the MFC approved a new policy for the protection of marine and estuarine resources under its authority from the effects of beach dredge and fill activities and related coastal engineering activities (copy attached). The Habitat and Water Quality Standing Advisory Committee of the NC Marine Fisheries Commission developed the policy in response to increasing number of beach engineering projects being developed and the inadequate consideration of cumulative and long-term impacts of these projects. This policy includes numerous issues that have so far not been adequately addressed in the DEIS.

In addition, the MFC shares responsibility under state law for the development of Coastal Habitat Protection Plans (CHPPs). The statutory goal of these plans is the "net enhancement" of the value to the coastal fishery of each habitat type. The Coastal Ocean CHPP is currently in pre-draft form; it will shortly be issued in public draft. That draft will include a set of policies and procedures to protect the marine and estuarine resources of North Carolina against development activities including beach engineering activities. The CHPP will then be formalized in regulation. The CHPP and its adjunct regulations will become a part of the state's federal coastal zone management plan.

Finally, we would like to explicitly state several requests regarding the Bogue Banks Renourishment DEIS:

- When will a programmatic EIS or comprehensive assessment of beach engineering projects be performed, at least for the state of North Carolina?
- What are the project sponsors' criteria for project success?
- Is there a contract with a research institution to continue the pre-construction benthic monitoring, develop post-project benthic monitoring, as well as develop a pre- and post-construction intertidal monitoring program?
- Should state cost-share monies be obtained, are there plans to proactively develop phased exit strategies in the event that beach engineering is not found to be a viable management alternative?

Until these questions and the other issues we have raised can be sufficiently addressed, we do not feel that the Bogue Banks Renourishment project should move forward. We repeat our request that a programmatic EIS be conducted, including full assessment of cumulative impacts of the multiple projects at various stages of design. We reiterate our willingness to discuss any of the issues that we have raised.

We thank you for the opportunity to comment on this very important project.

Sincerely,

Michelle Duval
Michelle Duval, Ph.D.
Scientist

Daniel Whittle (KP)
Daniel J. Whittle
Senior Attorney

Attachment

cc. Chrys Baggett, State Clearinghouse
NC Marine Fisheries Commission
Tracy Rice, Kevin Moody - USFWS

NORTH CAROLINA MARINE FISHERIES COMMISSION
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

NORTH CAROLINA MARINE FISHERIES COMMISSION

POLICIES FOR THE PROTECTION AND RESTORATION OF MARINE AND ESTUARINE RESOURCES FROM BEACH DREDGING AND FILLING AND LARGE-SCALE COASTAL ENGINEERING

NORTH CAROLINA MARINE FISHERIES COMMISSION HABITAT AND WATER QUALITY STANDING ADVISORY COMMITTEE: NOVEMBER 6, 2000
NORTH CAROLINA MARINE FISHERIES COMMISSION:

Policy Context

This document establishes the policies of the North Carolina Marine Fisheries Commission (Commission) regarding protection and restoration of the state's marine and estuarine resources associated with beach dredge and fill activities, and related large-scale coastal engineering projects. The policies are designed to be consistent with the overall habitat protection policies of the Commission, adopted April 13, 1999, as amended February 17-18, 2000, as follows:

> It shall be the policy of the North Carolina Marine Fisheries Commission that the overall goal of its marine and estuarine resource protection and restoration programs is the long-term enhancement of the extent, functioning and understanding of those resources.
>
> Toward that end, in implementing the Commission's permit commenting authority pursuant to N.C.G.S. §143B-289.52(a)(9), the Chairs of the Habitat and Water Quality Standing Advisory Committee, in consultation with the Commission Chair, shall, to the fullest extent possible, ensure that state or federal permits for human activities that potentially threaten North Carolina marine and estuarine resources:
>
> (1) are conditioned on (a) the permittee's avoidance of adverse impacts to marine and estuarine resources to the maximum extent practicable; (b) the permittee's minimization of adverse impacts to those resources where avoidance is impracticable; and (c) the permittee's provision of compensatory mitigation for all reasonably foreseeable impacts to marine and estuarine resources in the form of both informational mitigation (the gathering of base-line resource data and/or prospective resource monitoring) and resource mitigation (in kind, local replacement, restoration or enhancement of impacted fish stocks or habitats); and
>
> (2) result, at a minimum, in no net loss to coastal fisheries stocks, nor functional loss to marine and estuarine habitats and ecosystems.

The findings presented below assess the marine and estuarine resources of North Carolina which are potentially threatened by activities related to the large-scale movement of sand in the coastal ocean and adjacent habitats, and the processes whereby those resources are placed at risk. The policies established in this document are designed to avoid, minimize and offset damage caused by these activities, in accordance with the laws of the state and the general habitat policies of this Commission.

Marine and Estuarine Resources At Risk from Beach Dredge and Fill Activities

The Commission finds:

1) In general, the array of large-scale and long-term beach alteration projects currently being considered for North Carolina together constitute a real and significant threat to the marine and estuarine resources of the United States and North Carolina.

2) The cumulative effects of these projects have not been adequately assessed, including impacts on public trust marine and estuarine resources, use of public trust beaches, public access, state and federally protected species, state critical habitats and federal essential fish habitats.

3) Individual beach dredge-and-fill projects and related large-scale coastal engineering activities rarely provide adequate assessment or consideration of potential damage to fishery resources under state and federal management. Historically, emphasis has been placed on the logistics of sand procurement and movement, and economics, with environmental considerations dominated by compliance with limitations imparted by the Endangered Species Act for sea turtles, piping plovers and other listed organisms.

4) Opportunities to avoid and minimize impacts of beach dredge-and-fill activities on fishery resources, and offsets for unavoidable impacts have rarely been proposed or implemented.

5) Large-scale beach dredge and fill activities have the potential to cause impacts in four types of habitats:

    a) waters and benthic habitats near the dredging sites;
    b) waters between dredging and filling sites;
    c) waters and benthic habitats near the fill sites; and
    d) waters and benthic habitats potentially affected as sediments move subsequent to deposition in fill areas.

6) Certain nearshore habitats are particularly important to the long-term viability of North Carolina's commercial and recreational fisheries and potentially threatened by large-scale, long-term or frequent disturbance of sediments:

    a) inlets;
    b) the swash and surf zones and beach-associated bars; and

c) underwater soft-sediment topographic features, both onshore and offshore underwater hard-substrate topographic features.

7) Large sections of North Carolina waters potentially affected by these projects, both individually and collectively, have been identified as Essential Fish Habitats (EFH) by the South Atlantic Fishery Management Council (SAFMC) and the Mid-Atlantic Fishery Management Council (MAFMC). Affected species under federal management include:

a) summer flounder (various nearshore waters, including the surf zone and inlets; certain offshore waters);
b) bluefish (various nearshore waters, including the surf zone and inlets);
c) red drum (ocean high-salinity surf zones and unconsolidated bottoms to a depth of 50 meters);
d) several snapper and grouper species (live hard bottom from shore to 600 feet, and – for estuarine-dependent species [e.g., gag grouper and gray snapper] – unconsolidated bottoms and live hard bottoms to the 100 foot contour);
e) spiny dogfish (various coastal waters from the surf zone to 200 miles);
f) black sea bass (various nearshore waters, including unconsolidated bottom and live hard bottom to 100 feet, and hard bottoms to 600 feet);
g) penaeid shrimps (offshore habitats used for spawning and growth to maturity, and waters connecting to inshore nursery areas, including the surf zone and inlets);
h) coastal migratory pelagics (sandy shoals of capes and bars, barrier island and ocean-side waters from the surf zone to the shelf break inshore of the Gulf Stream; all coastal inlets);
i) corals of various types (hard substrates and muddy, silty bottoms from the subtidal to the shelf break);
j) calico scallops (unconsolidated bottoms northeast and southwest of Cape Lookout in 62-102 feet);
k) sargassum (wherever it occurs out to 200 miles);
l) many large and small coastal sharks, managed by the Secretary of the Department of Commerce (inlets and nearshore waters, including pupping and nursery grounds).

8) Beach dredge and fill projects also potentially threaten important fish habitats for anadromous species under federal, interstate and state management (in particular, inlets and offshore overwintering grounds), as well as essential overwintering grounds and other critical habitats for weakfish and other species managed by the Atlantic States Marine Fisheries Commission and the State of North Carolina. The SAFMC identified for anadromous and catadromous species those habitats that have been EFH if there had been a council plan (inlets and nearshore waters).

9) Many of the habitats potentially affected by these projects have been identified as Habitat Areas of Particular Concern by the SAFMC. The specific fishery management plan is provided in parentheses:

a) all nearshore hard bottom areas (SAFMC, snapper-grouper);
b) all coastal inlets (SAFMC, penaeid shrimps, red drum, and snapper-grouper);
c) near-shore spawning sites (SAFMC, penaeid shrimps, and red drum)

d) well-known seafloor features, including the Point, Ten Fathom Ledge and Big Rock (SAFMC, snapper-grouper, coastal migratory pelagics, and corals);
e) pelagic and benthic sargassum (SAFMC, snapper-grouper);
f) sandy shoals of Cape Lookout, Cape Fear, and Cape Hatteras (SAFMC, coastal migratory pelagics) and;
g) Bogue Sound and New River Estuary (SAFMC, coastal migratory pelagics).

10) Habitats likely to be affected by beach dredge and fill projects include many being recognized in North Carolina Fishery Management Plans as important for state-managed species. Many of these habitats are in the process of being recognized as Critical Habitat Areas by the Commission, in either FMPs or in Coastal Habitat Protection Plans. Examples include:

a) inlets (Blue Crab FMP, Red Drum FMP, River Herring FMP);
b) oceanic nearshore waters (Blue Crab FMP, Red Drum FMP); and
c) many others as FMPs and CHPPs are adopted over the coming years.

11) Recent work by scientists in east Florida has documented exceptionally important habitat values for nearshore, hard-bottom habitats often buried by beach dredging projects, including use by over 500 species of fishes and invertebrates, and juveniles of many reef fishes. Equivalent scientific work is just beginning off North Carolina, but life histories suggest that similar habitat use patterns will be found.

Threats to Marine and Estuarine Resources from Beach Dredge and Fill Activities

The Commission finds that beach dredge-and-fill activities and related large-scale coastal engineering projects (including inlet alteration projects) threaten the marine and estuarine resources of North Carolina through the following mechanisms:

1) Direct mortality and displacement of organisms at and near sediment dredging sites;
2) Alteration of seafloor topography and associated current and waves patterns and magnitudes at dredging areas;
3) Alteration of seafloor sediment size-frequency distributions at dredging sites, with secondary effects on benthos at those sites;
4) Elevated turbidity and deposition of fine sediments down-current from dredging sites;
5) Direct mortality and displacement of organisms at initial sediment fill sites;
6) Elevated turbidity in and near initial fill sites, especially in the surf zone, and deposition of fine sediment down-current from initial fill sites;
7) Alteration of near-shore topography and current and waves patterns and magnitudes associated with fill;
8) Movement of deposited sediment away from initial fill sites, especially onto hard bottoms;
9) Alteration of large-scale sediment budgets, sediment movement patterns and feeding and other ecological relationships, including the potential for cascading disturbance effects;
) Alteration of large-scale movement patterns of water, with secondary effects on water quality and biota;
11) Alteration of movement patterns and successful inlet passage for larvae, post-larvae, juveniles and adults of marine and estuarine organisms;

12) Alteration of long-term shoreline migration patterns (inducing further ecological cascades with consequences that are difficult to predict); and
13) Exacerbation of transport and/or biological uptake of toxicants and other pollutants released at either dredge or fill sites.

Commission Policies for Beach Dredge and Fill Projects and Related Large Coastal Engineering Projects

The Commission establishes the following general policies related to large-scale beach dredge-and-fill and related projects, to clarify and augment the general policies already adopted on April 13, 1999:

1) Projects should fulfill the Commission's general habitat policy by avoiding, minimizing and offsetting damage to the marine and estuarine resources of North Carolina;

2) Projects should provide detailed analyses of possible impacts to each type of Essential Fish Habitat (EFH), with careful and detailed analyses of possible impacts to Habitat Areas of Particular Concern (HAPC) and Critical Habitat Areas (CHA), including short and long term, and population and ecosystem scale effects;

3) Projects should provide a full range of alternatives, along with assessments of the relative impacts of each on each type of EFH, HAPC and CHA;

4) Projects should avoid impacts on EFH, HAPCs and CHAs that are shown to be avoidable through the alternatives analysis, and minimize impacts that are not;

5) Projects should include assessments of potential unavoidable damage to marine resources, using conservative assumptions;

6) Projects should be conditioned on the avoidance of avoidable impacts, and should include compensatory mitigation for all reasonably predictable impacts to the marine and estuarine resources of North Carolina, taking into account uncertainty about these effects. Mitigation should be local, up-front and in-kind wherever possible;

7) Projects should include baseline and project-related monitoring adequate to document pre-project conditions and impacts of the projects on the marine and estuarine resources of North Carolina;

8) All assessments should be based upon the best available science, and be appropriately conservative so as to be prudent and precautionary; and

9) All assessments should take into account the cumulative impacts associated with other beach dredge-and-fill projects in North Carolina and adjacent states, and other large-scale coastal engineering projects that are ecologically related.

12) Alteration of long-term shoreline migration patterns (inducing further ecological cascades with consequences that are difficult to predict); and
13) Exacerbation of transport and/or biological uptake of toxicants and other pollutants released at either dredge or fill sites.

Commission Policies for Beach Dredge and Fill Projects and Related Large Coastal Engineering Projects

The Commission establishes the following general policies related to large-scale beach dredge-and-fill and related projects, to clarify and augment the general policies already adopted on April 13, 1999:

1) Projects should fulfill the Commission's general habitat policy by avoiding, minimizing and offsetting damage to the marine and estuarine resources of North Carolina;

2) Projects should provide detailed analyses of possible impacts to each type of Essential Fish Habitat (EFH), with careful and detailed analyses of possible impacts to Habitat Areas of Particular Concern (HAPC) and Critical Habitat Areas (CHA), including short and long term, and population and ecosystem scale effects;

3) Projects should provide a full range of alternatives, along with assessments of the relative impacts of each on each type of EFH, HAPC and CHA;

4) Projects should avoid impacts on EFH, HAPCs and CHAs that are shown to be avoidable through the alternatives analysis, and minimize impacts that are not;

5) Projects should include assessments of potential unavoidable damage to marine resources, using conservative assumptions;

6) Projects should be conditioned on the avoidance of avoidable impacts, and should include compensatory mitigation for all reasonably predictable impacts to the marine and estuarine resources of North Carolina, taking into account uncertainty about these effects. Mitigation should be local, up-front and in-kind wherever possible;

7) Projects should include baseline and project-related monitoring adequate to document pre-project conditions and impacts of the projects on the marine and estuarine resources of North Carolina;

8) All assessments should be based upon the best available science, and be appropriately conservative so as to be prudent and precautionary; and

9) All assessments should take into account the cumulative impacts associated with other beach dredge-and-fill projects in North Carolina and adjacent states, and other large-scale coastal engineering projects that are ecologically related.

References

Butler IV, M. J., J. H. Hunt, W. F. Herrnkind, M. J. Childress, R. Bertelsen, W. Sharp, T. Matthews, J. M. Field, and H. G. Marshall. 1995. Cascading disturbances in Florida Bay, U.S.A.: cyanobacteria blooms, sponge mortality, and implications for juvenile spiny lobsters Panulirus argus. Mar. Ecol. Prog. Ser. 129:119-125.

Dodge, R. E., R. C. Aller and J. Thomson. 1974. Coral growth related to resuspension of bottom sediments. Nature 247: 574-576.

Gilmore, R. G., Jr. 1977. Fishes of the Indian River Lagoon and adjacent waters, Florida. Bull. Fl. St. Mus. Bio. Sci. 22(3), 147 p.

Gilmore, R. G., Jr. 1992. Striped croaker, Bairdiella sanctaeluciae. pp. 218-222. In C. R. Gilbert, ed. Rare and endangered biota of Florida. II. Fishes. Univ. Press of Florida, Gainesville, FL, 242 p.

Hackney, C.T., M. Posey, S. Ross and A. Norris. 1996. A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach renourishment. Report to the U.S. Army Corps of Engineers, Wilmington District.

Kirtley, D. W. and W. F. Tanner. 1968. Sabellariid worms: builders of a major reef type. J. Sed. Petrol. 38(1):73-78.

Lindeman, K. C. 1997. Comparative management of beach systems of Florida and the Antilles: applications using ecological assessment and decision support procedures. pp.134-164. In: G. Cambers, ed. Managing beach resources in the smaller Caribbean islands. UNESCO Coastal Region & Small Island Papers # 1, 269 p.

Lindeman, K.C. and D.B. Snyder. 1999. Nearshore hardbottom fishes of southeast Florida and effects of habitat burial caused by dredging. Fish. Bull. 97(3):508-525.

Nelson, W. G. 1989. Beach nourishment and hard bottom habitats: the case for caution. pp. 109-116. In: S. Tait, ed. Proc. 1989 National Conf. Beach Preserv. Technol. Fl. Shore and Beach Preserv. Assoc., Tallahassee, FL, 236 p.

Nelson, W. G. and L. Demetriades. 1992. Peracariids associated with sabellariid worm rock (Phragmatopoma lapidosa Kinberg) at Sebastian Inlet, Florida, U.S.A. J. Crust. Bio. 12(4):647-654.

Odum, W. E. 1982. Environmental degradation and the tyranny of small decisions. BioScience 32(9):728-29.

ındolfi, J., D. R. Robertson, and D. R. Kirtley. 1998. Sabellariid worms: builders of a major reef type. Coral Reefs 17:120.

Peterson, C.H., D.H.M. Hickerson and G.G. Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. J. Coastal Res. 16(2): 368-378.

Sedberry, G. R. and R. F. Van Dolah. 1984. Demersal fish assemblages associated with hard-bottom habitat in the South Atlantic Bight of the U. S. A. Environ. Biol. Fishes 11(4):241-258.

South Atlantic Fishery Management Council. 1998. Final habitat plan for the South Atlantic region: Essential Fish Habitat requirements for fishery management plans of the South Atlantic Fishery Management Council. 457 pp plus appendices.

Telesnicki, G.J. and W.M. Goldberg. 1995. Effects of turbidity on the photosynthesis and respiration of two South Florida reef coral species. Bull. Mar. Sci. 57(2):527-539.

Wilber, P. and M. Stern. 1992. A re-examination of infaunal studies that accompany beach nourishment projects. Proc. 1992 Natl. Conf. Beach Preserv. Tech. pp: 242-256.

ENVIRONMENTAL DEFENSE
NATURAL RESOURCES DEFENSE COUNCIL

September 8, 2000

Colonel James W. DeLony
District Engineer, CESAW
U.S. Department of the Army, Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Re: Continuous Beach Dredging and a Programmatic EIS for the Wilmington District

Dear Colonel DeLony:

We respectfully request that the U.S. Army Corps of Engineers prepare a programmatic Environmental Impact Statement (EIS) in connection with all beach dredging projects ("restorations," "renourishments," "beach erosion control," "beach disposal" and related projects) under the authority of the Wilmington District. The programmatic EIS should include an analysis of those currently undergoing review under the National Environmental Policy Act (NEPA) or under development for the district's area of responsibility. The analyses should also reflect the wide array of current projects for which adequate cumulative impacts analysis has not yet been conducted.

The current array of large-scale and long-term projects in this district is unprecedented. Projects are proposed for almost every developed beach area in the state. Major projects are proposed for Dare County beaches (a 13-foot dune and 50-foot beach berm along 14.8 miles of beach over fifty years with "renourishment" every three years involving up to 80 million cubic yards of sand), the "Highway 12" section of Dare County (Pea Island, Hatteras Island and Ocracoke Island), Brunswick County (details not yet available, but even more extensive beach "renourishment" over as much as 20 miles), Carteret County (16.8 miles of beach modification for which almost $30 million in public funding is being sought), and elsewhere. On-beach "disposal" is also proposed in connection with a variety of other projects, including the Wilmington Harbor deepening project.

These and related projects overlap significantly in their geographic and ecological contexts, and are very likely to cause serious and diverse cumulative impacts to both offshore and near-shore resources that could best be analyzed holistically. Practical alternatives that could reduce these and future cumulative impacts can most effectively be evaluated programmatically. Piecemeal analysis of environmental effects is almost certain to underestimate the degree of threat to publicly held marine and estuarine resources.

Artificial beach enhancement projects interact not only with other projects in terms of sand source areas, deposition areas and ultimate transport areas, but also collectively on the fishes and other organisms which use those habitats. Moreover, the impacts associated with the alteration of sand distribution and movement patterns also interact with other large-scale coastal engineering projects, including inlet modification projects like those at Oregon Inlet and Mason's Inlet, and various beach, harbor and channel maintenance activities. None of these can be appropriately assessed in isolation.

Furthermore, these projects together constitute a real and significant threat to the marine and estuarine resources of the United States and North Carolina. Large sections of the waters potentially affected by the projects, both individually and collectively, have been identified as Essential Fish Habitats (EFH) by the South Atlantic Fishery Management Council (SAFMC) and the Mid-Atlantic Fishery Management Council (MAFMC). Affected resources potentially include overfished species that are beginning to rebuild (e.g., summer flounder and bluefish), many species that are still in significant trouble (e.g., red drum, some snappers and groupers, spiny dogfish and black sea bass) and others which are fully fished and not able to stand further environmental stress (e.g., penaeid shrimps, coastal migratory pelagics, among others). The projects also stand to affect Essential Fish Habitats which have yet to be formally identified for anadromous species under federal management (but which clearly include inlets), as well as essential overwintering grounds and other critical habitats for striped bass, weakfish and other species managed by the Atlantic States Marine Fisheries Commission and the State of North Carolina.

Many of the habitats potentially effected by these projects have been identified as Habitat Areas of Particular Concern by the relevant federal fishery management councils: all near-shore hard bottom areas (SAFMC for snapper-grouper); all coastal inlets (SAFMC for penaeid shrimps, red drum, and snapper-grouper); near-shore spawning sites (SAFMC for penaeid shrimps, and red drum), the Point, Ten Fathom Ledge and Big Rock (SAFMC for snapper-grouper, coastal migratory pelagics, and corals); pelagic and benthic sargassum (SAFMC for snapper-grouper); sandy shoals of Cape Lookout, Cape Fear, and Cape Hatteras (SAFMC for coastal migratory pelagics); and Bogue Sound and New River Estuary (SAFMC for coastal migratory pelagics).

In 1998, administrative rules mandated by the 1996 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act designated all near-shore hardbottom and coral reefs of the southeast U.S., and the other habitats listed in the paragraph above, as Habitat Areas of Particular Concern, the highest level of Essential Fish Habitat. Under the Corps' current process, multiple large dredging and filling events will occur in these ssential Fish Habitat/Habitat Areas of Particular Concern without adequate study of short or long term impacts.

In a letter to the North Carolina Clearinghouse dated August 24, 2000 (attached hereto), the North Carolina Marine Fisheries Commission (MFC) concluded that the Dare County program constitutes a significant threat to state-managed marine and estuarine resources, and that its impacts cannot be adequately analyzed without a comprehensive assessment of impacts from the larger variety of such programs under development. The MFC is particularly concerned about cumulative impacts on surf-dwellers, on overwintering fish concentrations, and on the large suite of larval fishes which interact with the surf zone and inlets during their journeys into nurseries in the sounds. The SAFMC has expressed similar concerns about other projects in the region, and recently discussed the problem in detail at its Habitat and Environmental Protection Advisory Panel meeting in Charleston, SC. The MAFMC has expressed its concerns related to similar projects off New Jersey, and will be taking this matter up at Habitat Committee and Advisory Panel meetings in the near future.

In addition, the Jacksonville District COE received a letter dated June 27, 2000, signed by 70 Ph.D. scientists expressing concern over the continuing absence of detailed cumulative impact analyses in Corps EAs and EISs, despite more than 50 large offshore dredge and nearshore fill projects on the continental shelf of southeast and central Florida in the last 40 years. Over 500 marine species are known to use the nearshore reefs that can be buried by these projects, frequently as nursery areas. In addition, offshore dredge sites are often near reefs, and chronically elevated turbidity can have direct and indirect effects upon productivity across the shelf. Dozens of species are subject to diverse effects across the shelf areas affected by these massive dredge and fill projects. Fifteen North Carolina Ph.D. scientists signed that letter. Similar concerns exist with respect to impacts of large-scale and near-continuous dredging off North Carolina.

No other set of human activities comes close to posing the degree of threat to near-shore essential fish habitats as that posed by the activities under your management. Past NEPA assessments have not fully assessed the function of offshore and nearshore habitats affected by dredge and fill operations, the short-term impacts on the vast majority of species which utilize these habitats, nor the potential cumulative impacts across the affected shelf areas. Although some information related to these issues is newly available, several key references from the 1980's and early 1990's that expressed concern or questioned simplistic assumptions about effects have not been cited. A programmatic EIS focused on the North Carolina coast would provide the Corps with the opportunity to look systematically at past, present, and future effects of these large, semi-continuous dredging projects.

We recognize that beach management involves a complex mixture of many scientific disciplines and economic and political interests. However, the technical information is available and the administrative momentum is clear: a detailed, ecosystem-scale examination of cumulative impacts is necessary and will aid future project planning.

For these and additional reasons, a programmatic EIS on current and planned beach dredging projects along the North Carolina coast is urgently needed. The thorough development of such an EIS would provide all interested parties -- federal, state and local agencies, the scientific community, and national and state environmental organizations -- with a structured forum for proactively addressing the many environmental aspects of semi-continuous dredge and fill operations on the North Carolina coast and practical alternatives that would minimize impacts.

We would welcome the opportunity to further discuss the rationale for a programmatic EIS and its possible scope. We are therefore available to meet at the Wilmington District Office to discuss any aspect of this set of issues. We look forward to discussing these issues in further detail.

Yours truly,

Daniel J. Whittle
Senior Attorney
Environmental Defense
2500 Blue Ridge Road
Suite 330
Raleigh, N.C. 27607
919-881-2601

Michelle A. Duval, Ph.D.
Staff Scientist
Environmental Defense
2500 Blue Ridge Road
Suite 330
Raleigh, N.C. 27607
919-881-2601

Sarah Chasis
Senior Attorney
Natural Resources Defense
40 West 20th Street
New York, N.Y. 10011
212-727-4507

Bradford H. Sewell
Senior Project Attorney
Natural Resources Defense Council
40 West 20th Street
New York, N.Y. 10011
212-727-4507

Attachment

April 10,2001

RECEIVED
APR 23 2001

RECEIVE
APR 13 2001
REGULATORY
WILMINGTON FIELD OFFICE

Department of the Army
Corps of Engineers
Mr. Mickey T. Sugg

Your office is in receipt of an application from Carteret County, c/o of Robert Murphy, county Manager to nourish 16.8 miles of the Bogue Banks beaches. I wish to comment on that application.

The requirements of your office that all permits and comments from governing agencies be submitted before your agency will issue the permit have not been fulfilled. I submit the following observations.

1. The draft EIS statement has not been completed and presented for a public hearing as required. Enclosed is a copy of comments I submitted to the Division of Coastal Management on February 6, 2001 pertaining to the draft EIS. I specifically requested a public hearing on the document along with other proposals. I have received no communication from DCM.
2. I have not seen a public notice advertised in the local newspapers by CAMA regarding public comment or a public hearing as required by their procedures.
3. The issue of public Beach access to ACE standards has not been accomplished. The town of Pine Knoll Shores has only two public access points and parking is very limited. Emerald Isle has several public access points but very little parking. There is almost no public parking from the recently purchased regional facility west to the point. Most of the beachfront is blocked off by private gated communities.
   All issues of public access should be addressed before the permit is issued.
4. The County application proposes biological monitoring on board each dredge except January and February. The monitoring should take place at all times of operation.
   I request you consider my comments on SEC 5.18 of the attached Copy of comments to Mr. Doug Huggett of DCM . All monitors Must be highly qualified and paid by the State to avoid a conflict Of interest.

February 6, 2001

Mr. Doug Huggett
Division of Coastal Management

RE: EIS study. Proposed Bogue Banks Beach Nourishment.

I was able to perform a cursory layman's review of the above mentioned study to day after a legal notice was finally posted in the local paper January 24, 2001. The document was made available at four locations throughout Carteret county after I called the county managers office and then your office several times requesting information. As a layman I am not qualified to comment on the technical and scientific data that was in the report. I do feel I can comment on the common sense aspects of the document.

According to NCAC 25.06.04 the coastal agency may hold public hearings to increase public awareness, clarify issues, and gather additional public comment. The document was not adequately advertised for public display. Therefore I request your agency to withhold approval until such time that public hearings are held and the public has had ample time to view and comment on it.

Sec:2.0 page 21 states that bulldozing is detrimental to the beach environment. If the beach nourishment project is allowed to proceed will beach scraping be permitted in the years between applications of dredged sand?

Sec.2.2.1 page 21 states that funding for this project will be 64% local and 36% from other sources. What is the source of the 36% portion of the funding? Why is it not disclosed in this EIS? The citizens of Carteret County voted by a large majority that they were not in favor of using local funds to fund beach nourishment.

SEC.3.4.5 notes that the net long shore transport rates of sand are low. 3.4.6 states that erosion is due to storm events. No mention is made of the fact that most scientists attribute the increased erosion to an increased rate of sea level rise. The sea level rise in turn causes the beaches to move naturally in response. Why was this aspect of the issue not addressed? At best the nourishment will be short lived and the damage to the environment will have already been done.

SEC 3.15.3 notes that endangered Loggerhead and Green turtles are the two most common types found in this area. Although their presence is mostly in the warm months; they are present at times in the winter

I request your consideration of the above statement and assurance that all the requirements of your agency have been met before issuing the permit to proceed. I also request a public hearing be conducted in Carteret County.

Sincerely yours,

Don E. Morris
511 Broad Creek Loop Rd.
Newport NC 28570

ph: 252-727-0315

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

April 27, 2001

Mr. Mickey T. Sugg
Regulatory Field Office
USACE, Wilmington District
PO Box 1890
Wilmington NC 28402-1890

RE: Carteret County – Bogue Banks Beach Restoration Project
Response to Comments – USACE Action ID# 200000362]

Dear Mr. Sugg:

I am writing on behalf of Carteret County and the Towns of Pine Knoll Shores, Indian Beach, and Emerald Isle in response to comments on the above-referenced project from:

1) Don E. Morris (dated 10 April 2001)
2) Environmental Defense (Michelle Duval and Daniel Whittle) (dated 12 April 2001)
3) NC Coastal Federation (Jim Stephenson) (dated 12 April 2001)
4) University of North Carolina-Institute of Marine Sciences (Charles Peterson) (dated 13 April 2001)

We appreciate the opportunity to address the correspondents' concerns in the attachments to this letter. In some cases, the comments duplicate those submitted to NC CAMA in the course of the SEPA review process. Therefore, the present response references certain earlier responses we have made and incorporated into the final EIS. We will be happy to meet with any of the correspondents and discuss their concerns in more detail.

Thank you for your consideration.

Yours truly,

D E White for TWK

Timothy W Kana PhD
Project Director

cc: Carteret County, Frank Rush
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
Town of Emerald Isle, Mayor Barbara Harris
NC CAMA, Doug Huggett
CSE, Bill Forman

ATTACHMENT
Response to Comments — USACE Action ID# 200000362

1) Response to Morris Letter

The draft EIS has been reviewed, commented upon, revised, and finalized by all required state agencies. To the best of our knowledge, the reviews have followed all state requirements with respect to public notices and requests for comments. Further, the proposed project has been presented to the community in essentially the same form as given in the EIS during at least ten community forums since fall 1999. Widely publicized, public forums were held at four sites around Carteret County prior to the county referendum in March 2000 and at county council meetings and town council meetings at the affected towns. Also, several workshops were conducted over the past two years involving representatives of state and federal resource agencies in which the Bogue Banks project was discussed in detail. In addition, there has been extensive press coverage and explanation of the project in connection with council meetings and the bond referendums.

The proposed project will be funded locally with no federal contribution. The applicant (county and towns) is actively seeking to comply with all ACE standards as if this were a federally funded project. To this end, the Town of Pine Knoll Shores recently acquired centrally located oceanfront property with space to accommodate 100 vehicles.

The applicant expects to comply with all conditions placed on the permits including schedules and requirements for on-board biological monitoring.

Regarding comments in an associated letter dated 6 February 2001 from Mr. Morris to Doug Huggett (CAMA), these are addressed in the draft and final EIS. It is now likely that nearly 100 percent of the project will be funded by the applicant towns through special tax districts.

2) Response to Environmental Defense Letter

Attached is a copy of our response to Environmental Defense's 13 March 2001 comments (which accompanied the 12 April letter) on the SEPA draft EIS for the project.

Because the NEPA and SEPA requirements are essentially the same, we believe the existing EIS addresses all salient concerns. Only one item is incomplete under NEPA requirements – preparation of the EFH report, which is in preparation and will be submitted in May to NMFS and USACE. We wish to reiterate that assessment of cumulative impacts for all pending North Carolina projects is not a trivial exercise. An appropriate place to start, however, may be to look at the experience in other states. South Carolina, for example, has nourished approximately 60 miles of its coast (30 percent) since 1980. South Carolina Department of Natural Resources has worked closely with the US Army Corps of Engineers and South Carolina Coastal Council (now SCDHEC-OCRM) to evaluate environmental impacts of many of these projects. A general conclusion of these studies, according to Dr. Robert F. Van Dolah (SCDNR) is that the impacts to flora and fauna are short-lived on the beach with recovery typically occurring in weeks to months. Borrow area recovery rates are much more variable (as is the physical nature of the areas) and may require up to several years, although some recovered in one season.

There are no documented cases that we are aware of in the Southeast where dredging for nourishment produced a permanent or even short-lived biologic desert. The question is, rather, when and how similar are benthic populations on the beach and in borrow areas after nourishment. The evidence from states that have nourished high percentages of their coast indicate biologic recovery is relatively rapid (order of the life cycle for individual species), and the ensuing species diversity is similar to predredging conditions. Dredging does not directly impact pelagic species because they are mobile and can avoid dredges, so it is reasonable to assume that if benthic populations recover rapidly, the local fishery will not be adversely impacted. This is why other states tend to focus nourishment impact monitoring on the benthic species. We are aware of no statistically valid methods of quantifying impacts to fisheries due to nourishment projects. If there is a way to quantify the effect of dredging and distinguish it from such direct impacts to fisheries as commercial trawling and recreational fishing, we would appreciate a reference in the literature from the correspondent.

The Towns of Pine Knoll Shores and Indian Beach anticipate funding environmental monitoring surveys as a condition of the permits for the first reaches scheduled for

CSE

construction. They are working closely with the resource agencies to design a program that will provide meaningful, quantitative results.

Carteret County initiated and is continuing to fund the first island-wide physical monitoring surveys of Bogue Banks. Data collected in June 1999, September 1999 after Hurricane *Floyd*, and June 2000 provide the most comprehensive measure of sand losses to date. Data such as these are critical for evaluating the feasibility of nourishment and developing correlations with biologic impacts. It is through such monitoring that the project sponsors have determined that nourishment is feasible and will result in fewer adverse impacts to existing dune and turtle nesting habitats (than the present policy of doing nothing or sand scraping after every storm) and fewer adverse impacts to the local tax base than property abandonment, relocation, or condemnation. The applicant has demonstrated in the EIS/permit application a commitment to completing the project based on sound, scientific study and careful site-specific monitoring. Included in this effort was baseline biologic monitoring by Dr. Peterson at UNC-IMS (Appendix C of the EIS).

3) **Response to NC Coastal Federal Letter**

Speaking on behalf of the applicant, we believe that the SEPA EIS exceeds existing practice for locally funded nourishment projects and is as comprehensive as necessary for a project of this scope. The EIS has been thoroughly reviewed and approved by all state resource and clearinghouse agencies. Further, it introduces substantial new geotechnical, survey, and environmental data for the site, obtained at the applicant's expense. The EIS, in other words, is not simply a recitation of existing data and information.

We cannot predict the renourishment cycle because many intangibles would affect it. However, the correspondent greatly overstates the concern about multiple nourishments being required. It is true that the applicant may seek reimbursement in the event of a major storm, but for such funds to be forthcoming, two basic criteria would have to be met:

CSE

1) Beach damage is so severe that buildings remain imminently threatened.
   and
2) Reimbursement would only apply to the portion of the nourishment sand lost during the storm.

Without the project, the communities may seek emergency dune restoration, relocation, and rebuilding funds from FEMA after major storms. With the project, the level of damages is likely to be reduced and less funds required to restore sand volume losses than to rebuild or relocate structures. Atlantic Beach's experience during the past five years demonstrates how nourishment reduces property damages and, therefore, the outlay for storm disaster relief. Further, the applicant's post-storm surveys after Hurricane *Floyd* (see attached report entitled "Survey Report 2000 – Bogue Banks, North Carolina"; CSE, 2000) show that *Floyd* caused volumetric erosion to the upper beach and dunes within the project area that was a small fraction of the planned nourishment volume. Therefore, the scale and cost of renourishment after major storms over a ten-year period are likely to be much smaller than the initial nourishment cost. After small storms, the nourished beach will be left to rebuild naturally and no remedial measures are anticipated. Nourishment will reduce the pressure to scrape the dunes back into place after storms in the project area, just as it has done along Atlantic Beach.

Three referendums have been held for the project. The county-wide referendum in March 2000 failed. The Pine Knoll Shores and Indian Beach referendums in March 2001 and April 2001 (respectively) passed by a greater than 2:1 margin. The EIS outlines in detail the substantial financial contribution that Bogue Banks makes to Carteret County.

RE: Consideration of Alternatives — We disagree with the correspondent. While many different nonstructural scenarios are possible, the one suggested by the Coastal Federation is infeasible. It contradicts a most fundamental tenet of shore protection, which is consistency and uniformity of protection whether the choice is to armor, to nourish, to construct groin fields, or to set back buildings. The applicant has chosen a soft solution–nourishment– based on sufficient data which demonstrate this to the most viable alternative. Nourishment longevity is proportional to the square of the project length. Therefore, if only short reaches are nourished, the fill will not provide much more protection than sand scraping provides at present (because the pockets of fill will quickly spread alongshore). To restore a sand deficit of a certain volume, one has to add that volume, not a fraction of it.

Carteret County is a model for coastal zone management in North Carolina. Less than 33 percent of its ocean shoreline is developed and accessible by car. The rest is held in trust as part of the Cape Lookout National Seashore. Bogue Banks is the only generally accessible beach in the county. There are 53 miles of undeveloped barrier islands to the east and north, and 21 miles of undeveloped barrier islands to the west. Bogue Banks has low erosion rates, making it (in the words of Prof. Orrin Pilkey, Duke University) among North Carolina's best candidate sites for nourishment. Further, the proposed project will be locally, not federally, funded. Nourishment of Atlantic Beach demonstrates, on a site-specific basis, the feasibility and likely longevity of a project of the scale proposed. That reach also proves that future property damage will likely be reduced significantly by nourishment.

RE: Environmental Window — The correspondent requests an environmental window of 1 December to 31 March based on the opinion of one expert, Dr. Peterson. Please see our response to this concern in our letter dated 3 April 2001 regarding Dr. Peterson's comments. On behalf of the applicant, we met with NC Division of Marine Fisheries and Dr. Peterson on 5 April 2001 and discussed the concern regarding this issue. We understand the concern regarding November construction relates principally to the fall finger mullet fishery. Apparently, this fishery involves setting nets at access points near the Atlantic Beach/Pine Knoll Shores town line and catching fish migrating east to west from Beaufort Inlet. The applicant is willing to begin the first reach (Pine Knoll Shores) at the central or western end so as to stay several miles away from the commercial fishermen in November.

At present, about 40 percent of the project (Pine Knoll Shores East and West, and Indian Beach/Salter Path) is slated for construction between November 2001 and April 2002. The second phase would most likely involve Emerald Isle East and portions of Emerald Isle Central at least one year later. In short, it appears likely that the project will be constructed in two or more phases as recommended by the correspondent.

CSE

RE: Monitoring Data and Plan — The applicant is working closely with the resource agencies to develop a rigorous environmental monitoring plan following recommendations by Dr. Peterson, experts at SCDNR, Dr. Bart Baca (CSA), and standard practice in other southeast states. A copy of the draft plan was forwarded to USACE on 25 April. We disagree with Dr. Peterson's opinion that identification of samples to the "family" level is sufficient and instead have proposed identification to "species" level so that scientifically defensible statistics may be produced. Because the initial reaches funded for nourishment represent only 42 percent of the total project length, we have proposed monitoring before and after construction of 50 percent of the stations established by UNC. We anticipate that future reaches will involve monitoring of additional stations around the time of their funding and construction. The draft monitoring plan for the PKS-IB-SP reaches represents a financial commitment of >1 percent of total project costs added to what the applicant has already spent for baseline biological studies.

RE: Impact to Marine Resources — The applicant addresses this concern in our letter dated 4 April 2001 to Environmental Defense. We are also in the process of preparing a report on potential impacts to essential fish habitat (EFH) and have discussed this requirement with NMFS representatives in Morehead City and St. Petersburg (Florida)

RE: Sand Suitability Studies — The applicant has obtained over 140 borings in and around the proposed borrow areas. Approximately 25 of these were obtained as recently as February 2001 and are not yet reported in documents. However, the EIS provides detailed data from 90 borings in or immediately adjacent to borrow areas A, B1, and B2. We believe that the density of borings presented in the EIS far exceeds other geotechnical studies to date for nourishment projects in North Carolina. When our additional borings obtained recently are added, the average density of cores will be approximately 25 per square mile. We are using these data to further refine the borrow areas such that the closest possible match with the native beach is obtained. Presently, it appears some mix of sediments from borrow areas B1, B2, and A will yield the optimum size distribution.

CSE

We disagree with the correspondent's contention that the coarse, shelly material in borrow area A should be screened off before placement of the remaining sediment on the beach. We are aware of no documentation that confirms sediments with 40-45 percent shell material will be detrimental to beach organisms. North Carolina beaches contain a wide range of sediment sizes and textures in the cross-shore dimension, as well as regionally varying mean grain sizes and sediment textures. The mix of sediments in the proposed borrow areas will sort naturally upon placement, just as the native sediments do.

Concerns about high shell percentage were expressed by Dr. Peterson (see our response to his comments), and we suspect that the Coastal Federation is basing their comment on Peterson's opinion. Whether or not high shell percentages (order of 40-45 percent of the material) are lethal to organisms or result in lower densities of organisms in the surf zone has not been proved by rigorous studies. Peterson's limited observations (derived from cursory investigations at Atlantic Beach) are insufficient to prove cause and effect. If the resource agencies have specific standards for shell content, grain size, and mud percentages that must be met, we will strive to meet them. In the meantime, we will continue to refine the borrow areas such that mud percentage is minimized, shell content falls within the natural range for North Carolina beaches, and the overfill ratios are a low as possible. The applicant has no desire to place high percentages of mud on the beach. (A defacto standard in many jurisdictions is 15 percent clay-silt.) Our first choice for dredging equipment is self-loading hopper dredges because a portion of the fines will be decanted back to the water column near the borrow area before placement on the beach.

The EIS addresses potential turbidity and sediment transport in Appendix G and in Sections 3.14, 3.16, and 5.16. Construction activities will cause temporary elevation of turbidity levels immediately around the dredge and at the discharge points on the beach. These elevated levels will not persist and will fall within the natural range of turbidity for the area. For "large" plumes to persist, there has to be exceedingly high percentages of disaggregated clay in the sediments. Dredging in fluff mud in estuaries is commonly associated with long-duration, large-scale plumes. Such conditions, however, do not exist around the proposed borrow areas.

CSE

RE: Cumulative Impacts — We have addressed this issue in responses to the Peterson comments and Environmental Defense comments.

RE: NCCF Beach Renourishment Policy — The applicant comes as close to satisfying all seven policies of the NCCF as any nourishment project ever attempted in North Carolina.

1) Borrow areas defined in detail and continuing to be optimized by a dense network of borings.

2) Project is being scheduled for cold weather months, and our project planning team has extensive project experience.

3) Habitat monitoring was initiated by the applicant during early planning and will continue as the project is constructed.

4) The applicant has discussed costs openly in numerous community forums and has presented details in the EIS.

5) The project will be locally funded with the largest burden (>50 percent) placed on oceanfront owners.

6) All communities involved maintain public access to their beaches and are actively seeking opportunities to increase access.

7) The EIS details the planning that has gone into the project and will be required after ten years to reevaluate whether to continue. Further, the USACE has initiated a long-term study for beach restoration of Bogue Banks.

Finally, the applicant (at its own initiative) established the first systematic monitoring of the beach and inshore zone to quantify erosion rates. This latter effort is ultimately the most important determinant of costs of projects and whether or not future projects will be feasible and economic.

4) **Response to University of North Carolina Letter**
See attached response dated 3 April 2001.

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

April 25, 2001

Mr. Michael D. Marshall
Division of Marine Fisheries
NC Department of Environment and Natural Resources
PO Box 769
Morehead City NC 28557-0769

RE: Pine Knoll Shores and Indian Beach Nourishment Projects
Draft Environmental Plan

Dear Mike:

As we discussed with you, Rick Monaghan, and Dr. Peterson on 5 April at your office, we have prepared a "strawman" environmental monitoring plan for the above-referenced projects. I would like for you to review the plan with your staff, Dr. Petersen, and others of your choosing, and let us know what changes if any may be required.

The specific scope of work is based on several factors, as follows:

- Recommendations by Dr. Peterson in Appendix C of the final EIS for the Bogue Banks nourishment project.
- Recommendations by Dr. Bart J. Baca (president of Coastal Science Associates, Jacksonville, FL, and Columbia, SC) with whom we plan to contract and perform the study.
- Recommendations and standard practice of South Carolina Department of Natural Resources (care of Dr. Robert F. Van Dolah).
- Authorizations by town officials to fund the indicated scope of work up to four times (ie, four samplings and analyses) to be scheduled at your office's discretion.
- The fact that the anticipated projects for Pine Knoll Shores and Indian Beach represent less than 50 percent of the entire Bogue Banks project area.

The scope of work entails quantitative sampling of the borrow areas and beach using a representative suite of stations established by UNC-IMS. The consensus recommendation for schedule appears to be a spring and fall preproject sampling and a spring and fall postproject sampling. Four monitoring periods will entail a major financial commitment by the community commensurate with overall project costs. Further, I believe what we are proposing

CSE

in this plan greatly exceeds the environmental monitoring that has been performed in connection with other locally funded projects in North Carolina.

If you have any questions about our proposed scope of work or need information on CSA's qualifications, I will be happy to forward them. In the meantime, thank you for your consideration.

Yours truly,

Tim Kana

Timothy W Kana PhD
Project Director

cc: NC Division of Coastal Management, Mr. Doug Huggett
National Marine Fisheries, Mr. Ron Sechler
US Army Corps of Engineers, Mr. Mickey Sugg

DRAFT

Environmental Monitoring Plan

Town of Pine Knoll Shores and Town of Indian Beach
Beach Nourishment Project

The following draft plan was prepared by Coastal Science Associates, Inc (CSA*i*) (c/o Dr. Bart J. Baca and Mr. Stephen R. Florey) based on their understanding of the general requirements of North Carolina's Division of Marine Fisheries and prior experience with similar projects.

Background

The intent of the proposed ecological study is to assess the existing biological conditions of the of benthic invertebrates at the proposed offshore borrow areas for the Bogue Banks beach nourishment project located in Carteret County, North Carolina.

The ecological study will include benthic sampling and analysis from offshore borrow areas and near by controls. CSA*i* proposes to use 50 percent of the stations previously sampled by UNC's Institute of Marine Sciences (UNC-IMS). Benthic sampling will be conducted at the beaches that have been proposed to be nourished. Benthic samples will also be collected on one of the adjacent unnourished beaches to act as a control.

CSA*i* recommends that four sampling events be performed to assess the recovery of the borrow sites and beach nourishment activities. Two sampling events (spring-fall) should be conducted prior to the dredging event, and two sampling events (spring-fall) should be conducted after the nourishment activities have been completed. Based on the information provided, CSA*i* proposes the following scope of services.

Task 1. Field Collection of Benthic Samples

The proposed borrow area to be sampled is located approximately 2 miles south of Salter Path/Indian Beach, Carteret County, North Carolina. The depths in the sampling area range from 35 feet (ft) at the inshore areas to 47-49 ft in the offshore areas.

The proposed sampling will produce a total of 100 core samples (50 percent of the stations originally sampled by UNC-IMS in fall 1999) from both the offshore borrow areas and control areas. Cores will be collected by divers using a cylindrical corer (9.9 cm in internal diameter). All station locations will be selected from the previous study performed by UNC-IMS. All stations will be located by Differential Global Positioning System (DGPS). All benthic samples collected will be sieved in the field through a 0.5-mm stainless steel sieve bucket. All sediment and organisms retained in the bucket will be preserved in 10 percent buffered formalin with Rose Bengal stain.

In addition, four stations will be sampled on the proposed beach to be nourished. Two stations will be sampled within the project area, and two will be sampled outside the project area to act as controls. A total of 12 cores will be collected along the beach. Every attempt will be made to perform the sampling at the same station locations as the Lisa Manning report (NC Sea Grant, April 2000).

Task 2. Laboratory Methods

Once samples have been transported to the laboratory, core sediment samples will be carefully re-sieved through a 0.5-mm stainless steel sieve bucket and screen. This sediment reduction will expedite the sorting process. The remaining sediments and organisms will be placed in labeled, double-ziplock bags and initially preserved in 10 percent buffered formalin solution with Rose Bengal stain. Organisms will be allowed to harden for 48 hours and then will be transferred to 80 percent ethanol alcohol. After the hardening period, the organisms will be placed in sorting trays and submersed/ diluted in de-ionized water to minimize any volatile alcohol vapor production during identification.

Organisms will then be sorted and enumerated in the laboratory and identified to the lowest possible taxon (species level in most cases) with the aid of a variable power dissecting microscope (Bausch & Lomb) and/or a compound microscope (Swift or Bristol). Organisms will be identified by an experienced biologist utilizing various identification keys for organisms expected to be collected (eg, Abbott, 1974; Bousfield, 1965; Bynum and Fox, 1977; Dover, 1979; Fauchald, 1977; Fox and Bynum, 1975; Gosner, 1978; Heard, 1982; Kaplan, 1988; Morris, 1975; Ruppert and Fox, 1988;

Uebelacker and Johnson, 1984; Williams, 1984). Species identified for each station will then recorded on a laboratory bench sheet (per EPA, 1989).

Task 3. Data Analysis

Benthic data from the borrow area and control site will be statistically compared to evaluate changes in faunal abundance and number of species present among sites and over time. Analysis will include variance testing (ANOVA) or the nonparametric Kruskai-Wallis test, as necessary. Comparison among specific treatment groups will be completed using the Student-Newman-Keuls test (parametric and unparametric designs). Diversity indices will be computed for each area (all samples combined) using Shannon's diversity index (H), species richness (SR) and evenness (J). Changes in overall community composition among sites and seasons can be evaluated using a proportional similarity coefficient (Bray-Curtis) with flexible sorting strategy and a cluster intensity (ß) of -0.25.

Task 4. Reporting

A report for each of up to four (4) sampling events (including details of field data collection, data presentation, analysis, and conclusions/results) will be submitted to North Carolina Division of Marine Fisheries within 120 days following completion of the fieldwork.

Board of Commissioners
Doug Brady, Chairman
Jonathan Robinson, Vice-Chairman
Bettie Bell
David Wheatly
Jimmy LaShan
Sam Stell
Mac Wells

County Manager
Pete Allen
Tel: (252) 728-8450
Fax: (252) 728-2092
petea@co.carteret.nc.us
www.co.carteret.nc.us

May 8, 2001

Colonel James W. DeLony, District Engineer
U. S. Army Engineer District, Wilmington
Post Office Box 1890
Wilmington, North Carolina 28402

Re: Bogue Banks SEPA Final EIS
Carteret County/Pine Knoll Shores Nourishment Project
Action ID# 200000362

Dear Colonel DeLony:

It is very troubling to hear that your office may require a full NEPA review of the referenced project. If this review is required, the Towns of Pine Knoll Shores and Indian Beach, and the unincorporated community of Salter Path, will not be able to construct their planned beach nourishment projects as scheduled during the winter of years 2001 and 2002.

The most troubling aspect of this news is that compliance with the SEPA process with the State of North Carolina is nearly complete and the State is nearing a point of being ready to issue permits for the project. Since the State SEPA process is as mandated by NEPA, we fail to see the justification for this second tier of redundant review. We fail to see how an additional level of procedural review will expose or cause to be investigated any additional environmental impacts not identified under the federally mandated SEPA process.

The Towns of Pine Knoll Shores and Indian Beach and Carteret County (for the unincorporated Salter Path area) are prepared to implement beach nourishment projects in their respective communities with dredging to begin in November of this year. These communities are justifying the nourishment project based on threats to the valuable oceanfront properties and recreational resources that currently exist. Additional delays could further endanger property and could represent significant financial impacts to the economy of this County and these communities.

It is our understanding that the Corps has the authority to limit or not invoke the NEPA process for the project. We would question what federal interests are involved in the project that would invoke a full NEPA review of the project. This question is especially relevant since the SEPA process has been fully complied with. The Bogue Banks project is a local project with locally justified benefits funded entirely with local funds.

Our consultants advise me that there are three federal agencies with jurisdictional authority over the environmental aspects of the project: EPA, U. S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS). The jurisdiction of these agencies involves wetlands, endangered species, and fisheries coordination. We are currently working to complete the Essential Fish Habitat Assessment required by NMF. The biological assessment required by FWS for endangered species coordination is included in the SEPA EIS. Additionally, the plan for monitoring impacts to fisheries and benthic resources in the borrow and deposition areas is currently being reviewed by the Division of Marine Fisheries and NMFS. We anticipate finalizing that plan in the next two weeks.

We request that you make a full assessment of the work done to date and permit the project based on the SEPA EIS and any additional coordination with the three federal agencies that is required. We are confident that we can complete the required agency coordination in a time period that will permit construction to begin during November of this year.

Please do not invoke what seems to be a purely procedural NEPA process of redundant reviews that will cause delays to this very important project.

I look forward to your response.

Sincerely,

Pete Allen,
County Manager

THE TOWN OF PINE KNOLL SHORES

100 Municipal Circle, Pine Knoll Shores, North Carolina 28512

(252) 247-4353 • Fax (252) 247-4355

May 3, 2001

Colonel James W. Delony, District Engineer
c/o Mr. Mickey Sugg
US Army Corps of Engineers
PO Box 1890
Wilmington NC 28402

RE: Bogue Banks SEPA Final EIS
Carteret County/Pine Knoll Shores Nourishment Project
[Action ID# 200000362]

Dear Colonel Delony:

I am disturbed to learn at this late date that your office may require a full NEPA review on our project in response to comments from the National Marine Fisheries Service. If this review is required, we cannot construct our project next winter, and we will lose one year. Properties will remain imminently threatened in Pine Knoll Shores.

I believe that I made it clear in my last correspondence to you that time is of the essence. It disturbs me that we are just now learning of this possibility three months after submitting our permit application to your office. Our consultants also requested guidance from your office and CAMA regarding these procedures more than 1½ years ago in December 1999.

As you are aware, we have completed the SEPA review and have submitted the final EIS to your office. We followed the regulatory procedures and permitting path that your office and the state advised us to follow in December 1999. This included preparing an EIS rather than an EA on the project. There are no significant issues remaining, and all state agencies have accepted our EIS.

As I understand it, there are no extraordinary problems associated with our project which might elevate the review requirements to the full NEPA process. We are not impacting endangered species or permanently changing air or water quality. The only outstanding federal requirement not contained in the SEPA EIS, I am told, is a brief report on Essential Fish Habitat (EFH). Our consultants are completing this and will submit it to your office this month as per instruction from NMFS.

I have been told that most beach nourishment projects are performed without an EIS. I find it incredulous that the SEPA EIS would be considered insufficient in this case. I am told that the state is ready to move forward with our permits so that we have sufficient time to secure a contractor for this winter. If it is your intent to delay a decision on our project until fall, tell me now so we will not waste any more time in trying to initiate a project in November.

Our community is solidly behind this project, and we are not asking the federal government for any assistance with funding. I am at a loss to know what agency needs more time to review and comment on this project after the extensive local and regional press it has received.

Please let me hear from you on this matter.

Yours truly,

C. Reese Musgrave, Mayor

TOWN OF INDIAN BEACH
Post Office Box 306
Salter Path, North Carolina 28575
(252) 247-3344

May 03, 2001

Colonel James W. Delony, District Engineer
c/o Mr. Mickey Sugg
US Army Corps of Engineers
PO Box 1890
Wilmington, North Carolina 28402

Re: Bogue Banks SEPA Final EIS
Carteret County/Indian Beach Nourishment Project
(Action ID# 200000362)

Dear Colonel Delony:

The county informed me this week that your office is considering requiring full NEPA review of our nourishment project. I do not understand why this is necessary after we have gone through the SEPA process and have submitted a complete EIS on the project. If NEPA review is required, why were we not informed of this in February when our permit application was submitted?

This concerns me because we cannot build our project next winter if we have to wait for another comment period. We are solidly behind the project and do not feel we have the time to wait any longer. We expect to get new sand and have our properties protected next year. We are not asking for federal money.

We have tried to work with the Corps and have waited patiently for your Section 111 study. If you require full NEPA review, we will suffer another unnecessary delay. I am having trouble understanding why you need another comment period after every agency has already commented.

The state is ready to make their decision. We are ready to protect our homes. If you plan to deny our permit, tell us now so that we may pursue other remedies.

Sincerely,

W. L. Fugate

William L. Fugate, Mayor

1100 Salter Path Road • Indian Beach, North Carolina • Fax (252) 247-0513

Regulatory
Prepared by USACE - Wilmington
Hand delivered to Town of Pine Knoll Shores

(to go with N&O article 8/6/01)

Fact Sheet
Carteret County Beach Renourishment Permit Application

Date: August 7, 2001

Subject: Summary on the permit status for the Carteret County 16.8 mile Bogue Banks Beach nourishment permit application, Action ID 200000362.

1) On February 5, 2001, our office received a copy of the permit application, dated January 29, 2001, to dredge and pump approximately 8.0 million cubic yards of sand along 16.8 miles of Bogue Banks Beaches, starting at Pine Knoll Shores and terminating in Emerald Isle, Carteret County, NC.

2) The permit application was considered incomplete because of uncertainty as to who was the applicant, the county or the towns or both. After clarification from the towns and county, the application was considered complete on March 14, 2001. A Public Notice was issued on March 16, and responses were received from all Federal agencies as well as environmental organizations and a few citizens. The comments were mailed (April 17 and April 26) to the County to provide them an opportunity for rebuttal comments.

3) Telephone calls were made to Frank Rush, Assistant County Manager; Mayor Reese Musgrave, Pine Knoll Shores, and Bill Forman, applicant's consultant, on May 1, to explain the Federal NEPA process and potential requirements. The differences between the SEPA and NEPA processes were discussed and explained. In addition we explained that the "State EIS" document does not meet our Federal EIS requirements and there was no coordination of the "State EIS" with us or the other Federal review agencies. At the initial scoping meeting in October of 1999, we had requested that the "State EIS" be circulated to the Federal agencies for review. This never occurred.

4) A scoping meeting was held May 11, 2001 with all the applicants, National Marine Fisheries Service (NMFS), US Fish and Wildlife Service (USFWS), and other interested parties to discuss the proposal and the "State EIS". Issues of discussion were the following: cumulative impacts of beach (re)nourishment along the NC coast, Essential Fish Habitat (EFH), sand compatibility sampling- concerns with too much carbonate material, the need for additional beach sampling transects, the monitoring report, cost of additional sampling and monitoring, and Threatened and Endangered species- the need to include a detailed comparison of current habitat for turtles and sea beach amaranth vs the post-construction habitat, and the value of using data from Atlantic Beach. We discussed the NEPA process and how the Federal agencies did not receive the "State EIS" until the permit application was made.

5) Essential Fish Habitat consultation was initiated on March 16 via Public Notice. The consultant provided a copy of the EFH assessment and proposed monitoring report. On

May 21, a letter was sent to NFMS requesting comments on the applicant's EFH assessment, the EIS, and the proposed monitoring report.

6) A copy of the Threatened and Endangered Species Biological Assessment (BA) was mailed to USF&W Service on April 25. The BA was also included in the "State EIS" that was sent to them in March. On May 18, a letter was sent to the Service initiating formal consultation.

7) We determined that the economics and the sand compatibility results should be reviewed in house to verify study methodology and to ensure their accuracy. A copy of the sand compatibility study was given Geo-Tech on April 27, and the economic analysis was given to our economist on May 14. The economic analysis has been confirmed. We are awaiting information on the sand compatibility from Geo-tech.

8) On June 14, a meeting was held to discuss U.S. Fish & Wildlife Service's concerns with the project and the submitted Biological Assessment (BA). Comments from USFWS were discussed. The consultants brought data and samples from 60 additional sand borings and discussed their findings. USFWS disagrees with the compatibility of the material-too much shell content. We were told that the BA is incomplete and formal consultation would not begin until completed document is submitted (Disclosed in their June 12 letter- received in our office on the 19th).

9) Also on 14 June, letters were sent to Mr. Pete Allen, County Manager: a) informing him of our NEPA responsibilities and that we would be determining if an EA or EIS will be required w/in the next 60 days, and b) furnishing the USFWS comments on their proposal.

10) On June 20, a meeting was held at NMFS's office. NMFS expressed concerns that the project boundaries (in relationship to the borrow sites & which site will he used w/ which reach) were not well defined, and the exact amount of material needs to be included. Also, there is a need to identify the dredging technique. This information was discussed by the county representatives. The monitoring plan was discussed.

11) On July 16, a follow-up meeting was held at NMFS's office to discuss the monitoring plan. A copy of the NMFS June 25 letter that expresses their concerns regarding NEPA requirements, sand compatibility results, monitoring plan, and EFH (w/ EFH recommendations) was distributed and discussed. CSE (the county's consultant) distributed copies of the revised monitoring plan. The county needs to identify goals in the monitoring plan and describe the plan in detail.

12) The updated BA was sent, by CSE, to NMFS in St. Petersburg, Florida and to USFWS on July 13. NMFS has sent us a letter (dated July 26-Biological Opinion (BO)) stating that formal consultation is not necessary provided hopper dredge guidelines are implemented. The NMFS letter was faxed to the County and Mr. Forman.

13) On August 6, we decided that an EA would be sufficient at the present time to satisfy our NEPA requirements. This decision was relayed to the County and the consultants on August 7.

14) On August 7, I spoke with USFWS regarding the timeframe for submitting their BO. They stated that they could produce it by mid-September. It doesn't appear that there will be any outstanding issues involved with endangered species. We asked that a copy of any mitigation recommendations be sent so that we can forward them to the applicant. This will help them get started on implementing the recommendations.

15) We are awaiting information from Geo-tech and Environmental Branch regarding the sand compatibility study. Environmental has stated that they would draft a report.

16) To date needed information from the applicant: a) a completed EA, b) updated and approved monitoring plan, and c) response to NMFS concerns with EFH consultation, d) a Section 401 Water Quality Certification from the State, and e) a CAMA permit. With USFWS BO (projected in mid-September) and this information, the projected time frame for the issuance of a permit could be mid to late October.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive North
St. Petersburg, Florida 33702-2432

June 25, 2001

Colonel James W. DeLony
District Engineer, Wilmington District
Department of the Army, Corps of Engineers
P. O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Mr. Mickey Sugg

Dear Colonel DeLony:

This responds to your May 21, 2001, request for additional comments concerning plans by Carteret County, c/o Mr. Robert Murphy, County Manager, to renourish beaches located on Bogue Banks in Carteret County, North Carolina (**Action ID No. 2000003620**). You specifically ask for comments concerning the Draft Environmental Impact Statement (DEIS); the May 31, 2001, revised monitoring plan for pelagic fish and invertebrates; and the May 15, 2001, Essential Fish Habitat (EFH) Assessment. The project involves dredging of up to 2.58 square miles of ocean bottom and deposition of up to 8 million cubic yards of dredged material on ocean beaches. Approximately 1,400 acres of intertidal and subtidal beach habitat along 16.8 miles of ocean beach between Emerald Island and Pine Knoll Shores, in Carteret County, North Carolina would be altered by the project.

By letter dated April 20, 2001, the National Marine Fisheries Service (NMFS) commented on anticipated impacts of the project on living marine resources, including EFH. In that letter we recommended against project implementation due the severity of anticipated impacts. Subsequent to that, we participated in a May 11, 2001, interagency meeting with the applicant to discuss our concerns. Many of the issues raised in our April letter remain unresolved.

DRAFT ENVIRONMENTAL IMPACT STATEMENT

The status of the Corps of Engineers' (COE) determination regarding compliance with procedural requirements of the National Environmental Policy Act (NEPA)(40 CFR Parts 1500-1508) needs to be resolved. It appears that granting Department of the Authorization in this case would constitute a major Federal action due to subsequent effects on the human environment. We also believe that the project is not consistent with NEPA requirements which require sequential mitigation of impacts. As pointed out in earlier reports, less damaging alternatives and impact reduction opportunities exist.

At the May 11 meeting, Coastal Science and Engineering, LLC (CSE), the applicant's consultant, provided a copy of the Draft Supplement to Bogue Banks Beach Nourishment Plan, Final Environmental Impact Statement (FEIS). The document is dated May 8, 2001, and responds to our April 20, 2001, letter. Considering that issues related to compliance with the NEPA implementation regulations are uncertain, submission of the FEIS seems premature. We also note that material provided in the FEIS does not resolve concerns raised in our initial report on the project. Although a line-by-line review of the DEIS has not been prepared, the following issues need to be addressed:

1. Sediment compatibility between the proposed borrow sites and Bogue Banks beaches was discussed at the May 11 meeting and additional sediment analysis data, as requested by the U.S. Fish and Wildlife Service (FWS), were provided. Based on coordination with the FWS, and on information provided in their letter dated June 1, 2001, the suitability of the excavated sand for beach use remains questionable. Sediments in borrow Sites B1 and B2 are exceptionally fine grained and material at borrow Site A has excessive carbonate levels. Excessive amounts of carbonates can form a carbonate cement and may harden the beach to a point where use by burrowing invertebrates may be limited. Although we agree that deposition of compatible material during winter months would allow reestablishment of invertebrate populations, the DEIS gives no assurance that these conditions will be met. Lacking either an acceptable plan of action or reasonable evidence of only minor effects we remain concerned that the project could adversely effect 16.8 miles of intertidal habitat and fauna that supports commercially and recreationally important fishery resources. We also note that Appendix A of the FWS' letter contains and excellent overview of research related to the impacts of dredging and filling associated with beach nourishment. This information should be incorporated into the environmental documents for the project.

2. The DEIS and other information provided by the applicant is confusing in terms of the amount of material that would be placed on the beach and the length of beach to be nourished. For example, the DEIS indicates that a fill volume of 50-cubic yards of material per liner foot is planned. At the May 11 meeting 80 to 90-cubic yards per linear foot of beach was mentioned. Accurate volumetric and linear amounts of material to be deposited on the beach need to be provided.

3. The DEIS notes that maintenance work may be required during the ten year life of the project, but a plan for maintaining the project is not provided. The frequency and magnitude of anticipated maintenance should be addressed in the FEIS and if project maintenance is anticipated, details concerning this work should be developed and provided for agency review prior to granting Federal authorization of the project.

4. Borrow sites B1 and B2 contain sediments with high levels of fine grain material that is subject to protracted resuspension during dredging and disposal activities. If plans to use these sites are retained then possible effects on subadult fish and invertebrates, EFH, and other living marine resources should be identified in the FEIS.

5. The DEIS states that up to 50 percent of the material placed on the beach will end up offshore, but the document does not adequately address the potential for, and effects of, long-term resuspension and transport of material to offshore areas that support hardbottom habitat. The DEIS

concludes that since hardbottoms are located no closer than 1600 feet from work sites on Bogue Banks no impacts are anticipated. No basis is given for the conclusion that this distance is sufficient to preclude project related impacts.

6. It is unclear whether coordination with our Protected Resources Division has been conducted. As presently proposed, use of a hopper dredge could occur in areas that support sea turtles. As noted in our April 20, 2001 letter, determinations involving species under NMFS jurisdiction should be reported to our Protected Resources Division. If the proposed activities may adversely affect any species listed as endangered or threatened, then formal consultation must be initiated.

REVISED MONITORING PLAN

Previously identified deficiencies in the original monitoring plan were discussed in considerable detail at the May 11 meeting. The revised monitoring plan titled, "Revised Environmental Services Proposal: Bogue Banks Beach Restoration Project, Bogue Banks , North Carolina," addresses some of our concerns. Coordination with staff at the NOAA Center for Coastal Fisheries and Habitat Research (CCFHR) and Dr. Charles Peterson of the University of North Carolina, Institute of Marine Science indicates that the revised plan still would not provide the statistical analysis needed to adequately evaluate project related impacts on living marine resources. The enclosed letter, dated June 3, 2001, from Dr. Peterson to Mr. Mickey Sugg of your Regulatory Division, outlines our concerns. Development of an acceptable monitoring plan is a key element of the proposed project and authorization of the should be withheld pending fulfillment of this need.

EFH ASSESSMENT

The applicant prepared EFH Assessment, dated May 10, 2001, provides an adequate description of Federally managed species and EFH found in the project area. The NMFS does not agree, however, with the applicant's determination that the proposed dredging and disposal of dredged material in EFH will minimally impact these species and habitats. Consequently, the issues and concerns identified in our April 20, 2001, letter remain valid. As currently proposed, the applicant would have almost unlimited flexibility regarding the use of borrow sites, nourishment locations, and dredging techniques. This flexibility could preclude the use of more environmentally prudent actions that would reduce levels of adverse impact to EFH. Other potential impacts to EFH include:

Marine Water Column EFH

The range of potential impacts of off shore dredging and disposal on Bogue Banks beaches are not adequately described in the EFH Assessment. In our comments on the DEIS we noted that use of hopper dredges in areas having fine sediments (e.g., borrow sites B1 and B2) could be problematic due to high suspension rates of this material. Regardless of the dredging technique used, exceptionally high levels of suspended sediments could damage or kill early life history stages of Federally managed species.

Surf Zone EFH

Discharging material dredged from borrow sites B1 and B2 on to Bogue Banks beaches would result in elevated turbidity levels. Related effects of this are largely undetermined with regard to subadult fish and invertebrates, including federally managed species, but could be significant and adverse. The FEIS states that the NMFS selectively reviewed data concerning impacts of turbidity and suspended sediments on fishery resources. This is not accurate and the concerns we identified regarding the uncertain status of the impacts of beach nourishment on fishery resources found in the surf zone are well supported. Although we continue to have significant concerns regarding possible impacts on EFH and associated fishery resources, we believe that the project could be modified to address those concerns. Changes regarding dredging techniques (e.g., specified use of a hydraulic dredge), identification and use of specific locations within the borrow sites where compatible sand exists, and setting limits on beach locations that would be impacted during dredging cycles would reduce the level of our concerns.

Hardbottom EFH

The EFH Assessment notes that the various borrow and disposal sites are located between 1600 and 6500-feet from the nearest hard bottom habitat and that mechanisms for natural transport of fine sediments to these sites are do not exist. Studies perfomed on Bogue Banks and Wrightsville Beach have shown that sediment from nourished beaches has moved offshore and buried hardbottom habitat. Unless the applicant's conclusion regarding this issue can be substantiated, we continue to believe that hardbottom habitat could be adversely affected by the project.

Seasonal Restrictions on Dredging

Seasonal restrictions on dredging can reduce project specific and cumulative impact of dredging and beach disposal of dredged material. However, the dredging window (November 1 - April 15) proposed by the applicant is unacceptable because it impinges on recruitment seasons for surf zone dwelling invertebrates and estuarine dependent species which begins as early as January. While some species are at risk during any season, the proposed dredging window does not sufficiently reduce impacts to fishery resources.

Monitoring Plan

The EFH Assessment states that the proposed monitoring plan will address the project's impacts on Federally managed species. We disagree and refer to our May 31, 2001, comments concerning the adequacy of the revised monitoring plan. The physical and biological conditions and construction techniques that would allow beach nourishment to take place with only minimal impact to EFH must be demonstrated. A properly designed and implemented monitoring plan is also needed for determination of the role of this project in connection with other similar activities.

The NMFS strongly believes that a phased approach to this project would allow impact measurement and would provide opportunities for inclusion of modifications that are needed to preclude significant harm to living marine resources and EFH. If performed in phases, Phase I could include the work on Pine Knoll Shores and Indian Beach (7.2-miles) and would include impact monitoring. Authorization of subsequent work would be contingent upon successful completion of the initial phase in compliance with permit conditions and based on the outcome of environmental monitoring. The monitoring results would be used to develop a plan for Phase II which would include the Pine Knoll Shores portion of the project.

In view of the preceding, the NMFS recommends that Department of the Army authorization of the project not be granted unless it is in accord with the following EFH recommendations:

EFH Conservation Recommendations

1. The timing of the proposed action is critical to protecting EFH and associated fishery resources. Therefore, in order to avoid and minimize potential adverse impacts all dredging and disposal activities for beach nourishment shall be limited to the period between November 15 and March 1 of any year.

2. Adverse impacts to EFH can be avoided and minimized if sand sources have low levels of fine grained materials and carbonates and are otherwise compatible with existing sediment on the beach that is to be nourished. Therefore, criteria shall be established to ensure that material placed on beaches is compatible with that which currently exits on the beach.

3. The monitoring plan for this project should utilize statistically valid sampling procedures. The proposed monitoring shall be modified to include such procedures and shall be subject to review and approval by the COE and review agencies prior to project start up.

4. In order to avoid and minimize adverse impacts to EFH and associated fishery resources the project plans should be revised to identify a the exact location for extraction of borrow material, the specific type of dredging equipment to be used, and exact location of beach segment where the material will be deposited. Based on the information provided, adjustments will be developed as needed to preclude significant harm to living marine resources and EFH.

5. In recognition of this being the largest beach nourishment project ever proposed in North Carolina a phased construction approach and monitoring of fishery resources and habitat is needed. Therefore, phased construction and monitoring shall be required and implementation of subsequent work phases shall be contingent upon successful demonstration that significant environmental harm has not occurred and adequate monitoring, as needed for determination of individual work related and cumulative effects on living marine resources and EFH are determined.

Pursuant to Part IV.3(a) of the 1992 404(q) Memorandum of Agreement (MOA) between our agencies, we advised by letter dated April 13, 2001, that the proposed work will substantially and unacceptably impact nationally important aquatic resources. The information provided herein supplements our earlier report and is provided in accordance with, and in continuance of the cited MOA provisions. We further note that provisions concerning your responsibilities pursuant to Section 305(b)(4)(B) of the Magnuson-Stevens Fishery Conservation and Management Act requires your office to provide a written response to this letter within 30 days of its receipt and at least 10 days prior to final approval of the action. A preliminary response is acceptable if final action cannot be completed within 30 days. Your final response must include a description of measures to be required to avoid, mitigate, or offset the adverse impacts of the activity. If your response is inconsistent with our EFH Conservation Recommendations, you must provide an explanation of the reasons for not implementing those recommendations [50 CFR Section 600.920(j)].

Please direct related comments or questions to the attention of Mr. Ron Sechler at our Beaufort Facility. He can be reached at 101 Pivers Island Rd, Beaufort, North Carolina 28516, or at (252) 728-5090.

Sincerely,

for Andreas Mager, Jr.
Assistant Regional Administrator
Habitat Conservation Division

Enclosure

cc: FWS, Raleigh, NC
EPA, ATLA, GA
NCDENR, Raleigh, NC
NCDENR, Morehead City, NC
SAFMC, Charleston, SC
F/HP1 - Susan-Marie Stedman
F/SER4

3433

Routed: 01 Aug 01
Action: PM
CF: DE
DD
DP
DX
TS
OP
RG

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive North
St. Petersburg, FL 33702
(727) 570-5312, FAX 570-5517
http://caldera.sero.nmfs.gov

JUL 26 2001

F/SER3:EGH:mdh

RECEIVED
AUG 2 2001
COASTAL SCIENCE & ENGINEERING, PLLC.

RECEIVED
AUG 0 1 2001
REGULATORY
WILMINGTON FIELD OFFICE

Colonel James W. DeLony
District Engineer
Wilmington District
Army Corps of Engineers
Department of the Army
P.O. Box 1890
Wilmington, NC 28402-1890

Dear Colonel DeLony:

This responds to your July 5, 2001, letter and July 2001 Environmental Assessment (EA) on the Bogue Banks Beach Renourishment Project, Carteret County, North Carolina (Corps of Engineers permit application number 200000362), submitted to the National Marine Fisheries Service (NMFS), Habitat Conservation Division, Beaufort, North Carolina, by Dr. Timothy W. Kana of Coastal Science and Engineering LLC (preparers of the EA) and forwarded to NMFS Southeast Regional Office, Protected Resources Division. Our comments are rendered pursuant to the interagency consultation requirements of section 7 of the Endangered Species Act (ESA) on the potential project impacts to federally-listed species under NMFS purview, of proposed beach renourishment activities in Carteret County. We have assigned number I/SER/2001/00783 to this consultation; please refer to it in future correspondence on this activity.

The applicants (Carteret County, and the towns of Pine Knoll Shores, Indian Beach, and Emerald Isle) propose to excavate by hydraulic dredge up to 6.7 million cubic yards of beach-quality sediment from ocean borrow areas situated 0.5 to 3.0 miles offshore of Bogue Banks to renourish approximately 16.9 miles of Carteret County beaches between the towns of Pine Knoll Shores and Emerald Isle. A hopper-type dredge (or dredges) would be the most likely method employed for sand excavation from the offshore sites. Construction activities are planned to occur between November and April. Federally-listed sea turtles, whales, and shortnose sturgeon may be present in the action area.

A hopper dredge is likely to be used for most of the proposed activity; therefore, NMFS concurs with the conclusions of the EA that the project may affect listed species under NMFS purview that may be present. Hopper dredges are known to occasionally take sea turtles and sturgeon, and pose a collision risk to whales. Construction during November through April will minimize dredge interactions with migratory and nesting sea turtles by avoiding the peak period of sea turtle abundance in the action area. Observers aboard the hopper dredges will minimize the chances of dredge collisions with migrating whales. Because of foraging habits, it is unlikely that shortnose sturgeon will occur at the offshore dredging sites.

The potential for adverse effects to listed species from hopper dredging of offshore sand borrow areas for beach renourishment activities proposed to be permitted by the Corps for this project is covered by an existing NMFS biological opinion to the Corps. On September 25, 1997, NMFS issued a Regional Biological Opinion to the Corps' South Atlantic Division on the continued hopper dredging of channels and borrow areas in the southeastern United States, including offshore borrows areas off North Carolina. That opinion analyzed hopper dredging effects on sea turtles, whales, and shortnose sturgeon, and included non-discretionary reasonable and prudent measures, and implementing terms and conditions, to minimize potential interactions with these federally-listed marine species.

Since the Wilmington District will require NMFS-approved endangered species observer coverage aboard the hopper dredge (to watch for whales, sea turtles, and sturgeon) and must abide by all the other terms and conditions, including incidental take limits, established in the 1997 Regional Biological Opinion, NMFS believes that any adverse effects to listed species have been adequately considered and minimized, and no further consultation is necessary.

This concludes consultation responsibilities under section 7 of the ESA for the proposed action. Consultation should be reinitiated if new information reveals impacts of the identified activity that may affect listed species or their critical habitat, a new species is listed, the identified activity is subsequently modified or critical habitat determined that may be affected by the identified activity.

We appreciate the opportunity to comment and work with the Corps of Engineers, Wilmington District. Please contact Eric Hawk, fishery biologist, at (727) 570-5312, or by e-mail at eric.hawk@noaa.gov, if you have any questions or if we may be of further assistance.

Sincerely,

Joseph E. Powers, Ph.D.
Acting Regional Administrator

cc: F/SER4 - Andy Mager
F/SEC7 - Ron Sechler
F/PR3

o:\section7\informal\bogue.wil
File: 1514-22 f.1. NC

HOP297

R. L. VanAntwerp
Brigadier General, U.S. Army
Division Engineer
South Atlantic Division, Corps of Engineers
Room 313, 77 Forshyth St., S.W.
Atlanta, Georgia 30355-6801

Dear Brigadier General VanAntwerp;

Enclosed is the regional biological opinion concerning the use of hopper dredges in channels and borrow areas along the Southeast U.S. Atlantic coast. This biological opinion amends the regional opinion conducted in 1995, and supersedes the interim biological opinion issued on April 9, 1997. The opinion recognizes the efforts of the Corps of Engineer's (COE) South Atlantic Division (SAD) to minimize sea turtle takes through application of new technology such as draghead deflectors, seasonal dredging windows, termination of projects in which high rates of turtle takes are observed, and elevated staff effort to identify and resolve site-specific problems. Despite these major efforts and continuing plans by the COE to improve the effectiveness of the rigid draghead deflector and to resolve dredging schedules to reduce the likelihood of sea turtle interactions, NMFS believes that further sea turtle takes are likely in future years. However, we believe that these takes are not likely to jeopardize the continued existence of any species. An annual incidental take, by injury or mortality of 35 loggerheads 7 Kemp's ridleys, 7 green turtles, 2 hawksbills, and 5 shortnose sturgeon is listed in the incidental take statement appended to the enclosed opinion. This annual take level can be monitored over fiscal years to be consistent with project contracts.

I appreciate your continued commitment to reduce sea turtle takes associated with dredging in your Division. COE Division and District staff have facilitated the excellent working relationship that exists between our offices within the SAD. We look forward to continuing these cooperative efforts in sea turtle conservation.

Sincerely,

Hilda Diaz-Soltero
Office Director
Office of Protected Resources

Endangered Species Act - Section 7 Consultation

Biological Opinion

Agency: U.S. Army Corps of Engineers, South Atlantic Division

Activity: The continued hopper dredging of channels and borrow areas in the southeastern United States

Consultation Conducted By: National Marine Fisheries Service, Southeast Regional Office

Date Issued: ____________

Background

Hopper dredging in channels and borrow areas along the southeastern coast of the United States during the spring of 1997 resulted in an unanticipated high rate of loggerhead turtle take. The number of takes quickly approached the incidental take level established in the regional biological opinion (BO) issued to the Army Corps of Engineers (COE) on August 25, 1995. A formal consultation considering the take rates as well as the dredging locations and conditions was conducted and an interim biological opinion (IBO) was issued on April 9, 1997 and is incorporated herein by reference. The IBO concluded that continued hopper dredging during the 1997 fiscal year was likely to take additional sea turtles but was not likely to jeopardize the continued existence of any species. The incidental take, by injury or mortality, of seven (7) documented Kemp's ridleys, seven (7) green turtles, two (2) hawksbills, sixteen (16) loggerhead turtles, and five (5) shortnose sturgeon was set pursuant in the IBO. This modification added 15 loggerheads to the annual incidental take level, bringing the 1997 fiscal year total incidental take level to 35 loggerheads.

The history of Endangered Species Act (ESA) Section 7 consultations on the deployment of hopper dredges to maintain the depths of southeastern channels is discussed in the August 25, 1995 BO and is incorporated herein by reference. Although no endangered sea turtles have been taken in any channel dredging projects during the 1997 fiscal year, 28 loggerheads have been taken, including 9 loggerheads taken subsequent to the issuance of the IBO (Table 1).

During 1997, the COE responded to high rates of sea turtle takes by assessing each dredging project, modifying draghead deflectors when apparently necessary, conducting relative abundance surveys and relocation trawling, and ultimately ending a number of projects prior to completion (Kings Bay, Brunswick Harbor, Savannah Harbor, Morehead City).

1991 Biological Opinion

Two hundred twenty-five sea turtle takes, including 22 live turtles, were documented between 1980 and 1990 in the Southeast channels despite limited observer coverage in most channels throughout most of that decade (Table 2a.). Seventy-one of these turtles were taken in four months of dredging in the Canaveral ship channel in 1980, the first year in which observers were required. Twenty-one were observed in over two years of dredging in the Kings Bay Channel in 1987–1989, after observers were first deployed on dredges in that channel. Observers were required on most hopper dredges after 1989. Documented takes of turtles on dredges in Brunswick and other Southeast U.S. channels indicated that sea turtles were vulnerable to hopper dredges in all southeastern channels during warmer months. These observations resulted in the Section 7 consultation that concluded with a BO issued on November 25, 1991.

The November 1991 BO was the first cumulative area consultation between NMFS and COE's South Atlantic Division (SAD) regarding hopper dredging. The BO considered hopper dredging in channels from the Canaveral in Florida through Oregon Inlet, North Carolina. The 1991 BO concluded that continued unrestricted hopper dredging in Southeast U.S. channels could jeopardize the continued existence of listed sea turtles. The Opinion established a reasonable and prudent alternative to unrestricted hopper dredging which prohibited the use of a hopper dredge in the Canaveral ship channel, and from April 1 through November 30 in other southeastern channels north of Canaveral. An incidental take level was established based on assumptions that takes would be significantly reduced due to limited dredging windows, but that water temperatures in some years would result in turtle presence in channels during December and March. Observers were required on dredges equipped with outflow and/or inflow screening in March and December. The presence or absence of turtles in December would determine the further need for observer coverage into January. The documented incidental take of a total of five (5) Kemp's ridley, green, hawksbill or leatherback turtle mortalities in any combination of which no more than two (2) are Kemp's ridley, or fifty (50) loggerhead turtle mortalities was set. The Opinion anticipated that seasonal restrictions on hopper dredging would be adjusted on a channel-by-channel basis as better information on turtle occurrence was collected. Additionally, the development and testing of a draghead deflector was promoted.

1995 Biological Opinion

Between 1992 and 1995, only 16 sea turtle takes were documented (Table 2b.), including three that were alive when collected during dredging operations in the SAD under the dredging windows established in the November 1991 BO (see above). During that period COE developed a rigid draghead deflector that appeared to be effective during videotaped dredging trials using mock turtles, as well as during experimental dredging associated with trawling in the Canaveral Channel. COE also completed a study of six Southeast channels to determine seasonal abundance and spatial distribution of these turtles. A discussion of the findings can be found in the COE report entitled "Assessment of Sea Turtle Abundance in Six South Atlantic U.S. Channels" (Dickerson et al. 1994), summarized in the 1995 BO. Based on the new information, COE requested expanded dredging windows and observer requirements. NMFS considered their request and developed alternative dredging windows and observer requirements and added requirements for the use of hopper dredges in borrow areas along the east coast.

After 1995, COE districts within the SAD generally required observers in some channels, such as Kings Bay, throughout the winter, beyond the new monitoring windows. SAD hopper dredge projects were initially conducted in the middle of the dredging windows, when nearshore waters were cool. During 1996, only nine sea turtle takes, including one green turtle and eight loggerheads, were documented (Table 2c.). No more than three takes occurred in any project. The new dredging windows and draghead deflector requirements appeared to provide good protection to sea turtles.

Hopper dredging operations contracted for the 1997 fiscal year were planned for early in the calendar year, however a number of operations were not begun until late winter. Beginning on March 2, 1997, loggerhead takes occurred in Kings Bay at rates higher than previously observed. Six turtles were taken in four days of dredging. While consulting with NMFS regarding this unprecedented rate of loggerhead takes, a COE specialist from the Waterways Experiment Station proposed some modifications to the draghead with the potential to reduce sea turtle takes. Relocation trawling was also initiated, beginning March 9,1997; however, as can be seen on Table 2, these efforts did not preclude further sea turtle takes in Kings Bay. Dredging was terminated on March 12, 1997, with only 53 percent of the project completed.

Table 1 lists the sea turtle takes observed in hopper dredges throughout the SAD during 1997, as well as the steps taken by COE to reduce the likelihood of takes. Deflector dragheads were re-engineered to fit specific dredges wherever possible and relocation trawling was initiated. Dredging was terminated prior to completion of projects in Kings Bay, Brunswick Harbor, Savannah Harbor and Charleston Harbor. Consultation was reinitiated to consider the effects of the remaining hopper dredging projects anticipated for the 1997 fiscal year. In addition to those specific projects listed in the resulting April 1997 IBO, dredging at Reach II of the Myrtle Beach dredge disposal area is likely to begin before the fiscal year ends. Despite ongoing dredging at the Oregon Inlet, no sea turtle takes have been documented since May 15.

Proposed Activity

This consultation addresses the use of hopper dredges in channels and borrow areas along the Atlantic portion of COE's SAD within the existing dredging windows (Table 3). Channels dredged by hopper dredges include: Oregon Inlet, Morehead and Wilmington Harbors, Charleston, Port Royal and Savannah harbors, Brunswick, Kings Bay, Jacksonville, St. Augustine and Ponce de Leon inlets, West Palm Beach, Miami and Key west channels. Borrow areas that may be dredged by hopper dredges include areas off of Dade County Florida and Myrtle Beach South Carolina.

Draghead deflectors will be used on all projects and observers will be required at least during those periods identified in Table 3. Year-round observer coverage will likely be required by the COE for most channels, particularly those with histories of high sea turtle catch rates such as Kings Bay. Within the South Atlantic Division, the COE will try to schedule dredging of the highest risk areas (Canaveral, Brunswick, Savannah, and Kings Bay) during periods when nearshore waters are coolest -- after December 15 but well before March. Priority for winter dredging will also be given to areas that have substrates that reduce the efficiency of the deflector (Wilmington Harbor channel, Reach 1 of Myrtle Beach). Completion of all projects during the cold-water months will be attempted when possible.

Listed Species and Critical Habitat

Listed species under the jurisdiction of the NMFS that may occur in channels along the southeastern United States and which may be affected by dredging include:

Threatened:

(1) the threatened loggerhead turtle - Caretta caretta

Endangered:

(1) the endangered right whale - Eubalaena glacialis
(2) the humpback whale - Megaptera novaeangliae
(3) the endangered/threatened green turtle - Chelonia mydas
(4) the endangered Kemp's ridley turtle - Lepidochelys kempii
(5) the endangered hawksbill turtle - Eretmochelys imbricata
(6) the endangered shortnose sturgeon - Acipenser brevirostrum

Green turtles in U.S. waters are listed as threatened, except for the Florida breeding population which is listed as endangered.

Additional endangered species which are known to occur along the Atlantic coast include the finback (Balaenoptera physalus), the sei (Balaenoptera borealis), and sperm (Physeter macrocephalus) whales and the leatherback sea turtle (Dermochelys coriacea). NMFS has determined that these species are unlikely to be adversely affected by hopper dredging activities.

Information on the biology and distribution of sea turtles can be found in the 1991 and 1995 BOs, which are incorporated by reference. Channel specific information has been collected by COE for channels at Morehead City, Charleston, Savannah, Brunswick, Fernandina and Canaveral, and is presented in detail in COE summary report entitled "Assessment of Sea Turtle Abundance in Six South Atlantic US Channels" (Dickerson et al., 1994) and in the COE Biological Assessment.

There is no significant new information regarding the status of these species that has not been discussed in the BOs that have been incorporated by reference (March 12, 1997 and August 25, 1995).

Assessment of Impacts

The Biological Opinion issued in 1991 contained strict dredging windows that appeared to be very effective at limiting the number of sea turtles taken by hopper dredges during channel maintenance dredging in the Southeast U.S. along the Atlantic coast. Between 1991 and 1995, no more than 8 turtles were taken in any year, and many of those taken were released alive. Studies conducted by the COE (Dickerson et al., 1994) documented turtle distribution and abundance in six channels that suggesting the existing windows were accurate. However, the COE requested expansion of existing windows to lessen the burden of maintenance dredging while testing and further developing a rigid draghead deflector design. The deflector was effective at pushing aside mock turtles when tested during 1994, and preliminary field trials in the Canaveral shipping channel had encouraging results. NMFS considered this new information, presented by the COE in a biological assessment forwarded to NMFS in November 1994. The resulting BO, issued August 25 1995 expanded dredging windows and modified observer requirements.

Only 9 sea turtle takes were documented in 1996, suggesting that the expanded dredging windows and the deflector requirements provided protection to sea turtles that was similar to the previously more-restrictive windows. However, the COE's internal policy resulted in conduct of most of the hopper dredging projects during months when coastal waters were still cold, consistent with the previous dredging. The increased rate of take observed during 1997 and discussed below suggests that the restriction of hopper dredging to months when nearshore waters are cold remains the best method for minimizing sea turtle takes.
Unfortunately, a number of dredging projects contracted for early 1997 in the SAD but not restricted to mid-winter months, were delayed into the Spring. This delay coincided with a unseasonably warm winter, when the waters of Kings Bay reached 60°F in early March. The incidental take of nine loggerheads in Kings Bay over only 11 days of dredging indicated that the nearshore abundance of loggerheads was high, apparently higher than during the late 1980's when observers were first deployed on hopper dredges in Kings Bay.

There were other indicators of high nearshore sea turtle abundance along the Southeast U.S. Atlantic coast during 1997. Commercial shrimp trawling conducted without the use of turtle excluder devices (TEDs) offshore of South Carolina and Georgia between May 15 and July 15 resulted in sea turtle catch rates higher than previously documented. Sixty nine sea turtles were taken in 29 days of shrimping off of South Carolina, including 65 loggerheads, 3 ridleys and 1 leatherback. Forty-six sea turtles were taken in 17 days of towing off of Georgia. The sea turtle catch per unit effort (CPUE) for this operation is about 0.35 turtles per hour of trawling, standardized to 100 feet (30.5 m) of total headrope length fished. The CPUE (same units) for commercial shrimp trawling in the 1970s and 1980s reported by Henwood and Stuntz (1987a) was only 0.0487. Loggerhead turtles were the predominant species reported by Henwood and Stuntz and have also been predominantly observed in this study. They account for most of the increase in overall CPUE. The CPUE for loggerheads alone has been greater than 0.30 turtles per hour, while the value reported in Henwood and Stuntz was 0.0456 turtles per hour. The rates of taking for leatherback and Kemp's ridley turtles in the Atlantic study area have also been higher than anticipated.

The high relative density of sea turtles during 1997 may be due to an unseasonably warm winter or other factors contributing to annual variations in abundance, due to an actual increase in the abundance of benthic immature sea turtles in the loggerhead population, or due to a combination of these factors. Trends in the status of loggerheads are generally identified at the nesting beach, when the most accessible life stage, adult nesting females, can be counted. Because they mature at 20 to 30 years of age, increases or decreases in the abundance of benthic immature loggerheads as determined by incidental captures in nearshore waters would not be observed for decades. While nesting beach surveys suggest that the South Florida population of loggerheads increased and now appears to be stable, increases have not been apparent on nesting beaches of Georgia and South Carolina. Further work on the development of multi-year in-water sampling sites is needed to identify trends in multiple age-classes of the loggerhead population.

The COE noted that 14 of the 28 takes that occurred during 1997 were on the same dredge, the Eagle. The high rate of takes, particularly on this dredge, suggested that the deflecting draghead was not installed properly or was not being operated properly. Takes occurred in a number of the 1997 dredge projects during clean-up. Ridges left behind after the initial dredging are leveled during clean-up, but the draghead passes over troughs. Takes occurring during clean-up may be difficult to avoid since the draghead deflector must remain hard on the bottom to be effective.

The COE has been conducting meetings between districts within the SAD to discuss the results of assessments of channel conditions and dredge inspections. They have determined that the draghead deflector has not been working properly due to poor education of the dredge operators on its proper use, and due to poor tailoring of the deflector to specific dragheads. Increased efforts to educate dredge operators are planned. Additionally, since fewer than 10 private hopper dredges operate within SAD, engineers that have designed the conceptual deflector will be sent to the dredges to insure that the deflectors are adapted to each draghead and that the operators understand how to use the deflector effectively.

Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal actions, that are reasonably certain to occur within the action area of the Federal action subject to consultation. These are discussed in detail in the biological opinions incorporated by reference.

Conclusion
NMFS believes that the elevated rate of observed sea turtle takes by dredges in the southeastern United States during March of 1997 was likely due to increased abundance of loggerheads in nearshore waters due to an unseasonably warm winter. There is no way to predict whether similar conditions will be encountered in upcoming seasons. Over the past six years, the COE's SAD has continuously expressed a commitment to minimize sea turtle takes, and has conducted research and taken repeated steps to further this goal. Repeated termination of dredging operations due to high sea turtle takes during 1997 confirms their commitment to avoid sea turtle takes. Further efforts to educate the dredging industry and recruit their interest and involvement in avoiding sea turtle takes are necessary and are planned by the COE. Additionally, the COE has committed to additional efforts to improve the effectiveness of the deflecting draghead. The sea turtle deflector should be tailored to each hopper dredge draghead and the dredge operators should be fully trained in the operation of the draghead to ensure proper use and improve effectiveness. Improvements in operator and deflector performance are necessary prior to reliance on the draghead as a mechanism for reducing sea turtle takes.

NMFS anticipates that the COE's interest in improving the performance of the deflector, their commitment to limit the use of hopper dredges in channels of high sea turtle abundance during periods when nearshore waters are likely to be cold, and their overall goal of further reducing sea turtle takes during hopper dredge activities will minimize the interactions of hopper dredges with sea turtles. However, annual variation in the abundance of sea turtles in some channels and borrow areas make it likely that sea turtle takes will still occur. Additionally, overall increases in loggerhead and Kemp's ridley populations are anticipated due to TED requirements that have reduced the mortality rates of benthic lifestages of these species. Lastly, in some years high levels of hopper dredging activity may be necessary. For example, termination of projects prior to completion during FY 1997 may result in an increase in the number and length of hopper dredging projects necessary for channel maintenance during FY 1998. Therefore, NMFS believes that up to 35 loggerheads may be taken by injury or mortality, as well as 7 Kemp's ridleys, 7 green turtles, 2 hawksbills, and 5 shortnose sturgeon. These takes are not likely to jeopardize the continued existence of these species and the ongoing commitment by the COE to further minimize takes may reduce the likelihood of sea turtle takes in the future even if nearshore sea turtle abundances increase.

Conservation Recommendations
Pursuant to section 7(a)(1) of the ESA, conservation recommendations are made to assist COE in reducing or eliminating adverse impacts to loggerhead, green, and Kemp's ridley turtles that result from hopper dredging in the southeastern United States. The recommendations made in the 1995 BO are pertinent to this consultation as well, and therefore remain valid. Further recommendations are given below.

- Because of the possibility of annual variation in water temperatures, sea turtle abundance, and hopper dredging demand, NMFS has retained the dredging windows established in the 1995 BO. However, the COE has expressed a commitment to deploy hopper dredges during cold-water periods in channels with high sea turtle abundance or with substrates that render the deflector ineffective. NMFS appreciates the COE's commitment to do this, and recommends that the SAD priority list be finalized and distributed to the Districts and NMFS prior to the initiation of dredging during FY 1998.

- The COE should work with the dredging industry to insure their understanding of the importance of sea turtle conservation and to increase the industry's interest in minimizing sea turtle takes.

- Greater than 50% of the loggerheads taken in North Carolina may be from the northern nesting assemblage of loggerheads. While recent loggerhead nesting beach surveys did not identify a decline in the number of nesting females on beaches north of Cape Canaveral, increases observed in the south Florida nesting assemblage have not been noted. High sea turtle catch rates during only the early weeks of the wood debris clean-up conducted by COE off Cape Fear during 1997, as well as preliminary work conducted in North Carolina, suggest that turtles may be abundant in North Carolina channels primarily during migration into and emigration out of North Carolina inshore waters. The COE should work with the NMFS Beaufort Laboratory and the North Carolina Division of Marine Fisheries to document the movements of sea turtles off North Carolina during spring and fall months. Results from these studies may provide insights into further safe dredging windows to minimize the likelihood of takes of loggerheads from the more vulnerable northern nesting assemblage. Summer windows would reduce the pressure to complete all SAD hopper dredging during cold-water periods.

- The COE should investigate further modifications of the draghead to minimize the need for clean-up. Some method to level the peaks and valleys created by dredging would reduce the amount of time dragheads are removed from the bottom sediments.

Incidental Take Statement

Section 7(b)(4) of the Endangered Species Act (ESA) requires that when a proposed agency action is found to be consistent with section 7(a)(2) of the ESA, and the proposed action may incidentally take individuals of listed species, NMFS will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. It also states that reasonable and prudent measures, and terms and conditions to implement the measures, be provided that are necessary to minimize such impacts. Only incidental taking resulting from the agency action, including incidental takings caused by activities approved by the agency, that are identified in this statement and that comply with the specified reasonable end prudent alternatives, and terms and conditions, are exempt from the takings prohibition of section 9(a), pursuant to section 7 of the ESA.

Based on the high rate of sea turtle takes observed during of 1997, increases in the Kemp's ridley population, possible increases in the benthic lifestages of loggerhead populations, annual variation in nearshore abundance of sea turtles and hopper dredge demands, the NMFS anticipates that hopper dredging in the Southeast U.S. Atlantic area of the SAD may result in the injury or mortality of sea turtles and shortnose sturgeon. Therefore, a low level of incidental take, and terms and conditions necessary to minimize and monitor takes, are established. The annual (by fiscal year) documented incidental take, by injury or mortality, of seven (7) Kemp's ridleys, seven (7) green turtles, two (2) hawksbills, thirty-five (35) loggerhead turtles, and five (5) shortnose sturgeon is set pursuant to section 7(b)(4) of the ESA.

To ensure that the specified levels of take are not exceeded early in any project, COE should reinitiate consultation for any project in which more than one turtle is taken within 24 hours, or once five or more turtles are taken. The Southeast Region, NMFS, will cooperate with COE in the review of such incidents to determine the need for developing further mitigation measures or to terminate the remaining dredging activity.

Section 7(b)(4)(c) of the ESA specifies that in order to provide an incidental take statement for an endangered or threatened species of marine mammal, the taking must be authorized under section 101(a)(5) of the Marine Mammal Protection Act of 1972 (MMPA). Since no incidental take in the Atlantic Region has been authorized under section 101(a)(5) of the MMPA, no statement on incidental take of endangered right whales is provided.

The reasonable and prudent measures that the NMFS believes are necessary to minimize the impact of hopper dredging in channels and borrow areas in the southeastern United States have been discussed with COE. The following terms and conditions are established, in addition to those identified in the 1995 BO, to implement these measures and to document the incidental take should such take occur.

1. The COE's draghead deflector engineer that assistant in this design design should inspect the rigid draghead deflector annually to ensure that the deflector has been tailored appropriately to each draghead. Additionally, the inspector should assess whether the dredge operator appears to be familiar with the operation of the draghead deflector and provide necessary training where appropriate.

2. If the rigid draghead deflector appears to be ineffective in Wilmington Harbor and slows the dredging project such that the amount of time the hopper dredge will be deployed is increased, the deflector should be removed from the draghead for that channel.

3. The COE should develop an educational/training program for dredge operators to increase their understanding of how the draghead deflector works and why it is necessary.

SOUTH ATLANTIC COAST HOPPER DREDGING (Calendar Year 97)					
Project	Dredge Period	Approximate Amount of Work Completed	Turtle Takes	Mitigative Measures Taken	Remarks
Kings Bay	3/1/97 to 3/12/97	Removed 437,000 out of 821,000 cy Approximately 53% completed.	L 3/2/97 L 3/4/97 L 3/5/97 L 3/6/97 L 3/6/97 L 3/6/97 L 3/8/97 L 3/8/97 L 3/12/97	Sea turtle deflecting draghead used. Jacksonville Dist. specialist inspected deflector on 3/6/97. Relocation trawling started 3/9/97. Extensive, ongoing consultation with NMFS as takes occurred. All work terminated 3/12/97 due to high take levels even though relocation trawling had become operational.	Water temp. 57 to 58 F. Dredge Eagle 1. Two takes in one batch on 3/6/97 and 3/8/97. Contract required removal of relatively small veneer of material. Most takes occurred through starboard dragarm. Rapidity of takes was a surprise to all concerned.
Brunswick Harbor	2/6/97 to 3/19/97	Removed 975,400 cy Work stopped at 50% completion	L 3/9/97	Sea turtle deflecting draghead used. Sea turtle abundance, based on visual observations, prompted termination of work because of potential for unacceptable levels of entrainment.	Water temp 63 F. Dredge RN Weeks. Historic abundance of sea turtles and high levels of entrainment in 1991 was part of the reason for termination of work.
Savannah Harbor	3/4/97 to 3/22/97	Removed about 545,500 cy, or about 52% of what could have been dredged	L 3/14/97 L 3/22/97 L 3/22/97	Sea turtle deflecting draghead used. Dredging terminated so as not to take any more sea turtles.	Water temp. 63 F. Numerous sea turtles sighted. Dredge Ouachita was 'skimming' high areas to bring depth to acceptable levels quickly before leaving for urgent work in Mississippi River.
Charleston Harbor	3/14/97 to 3/26/97	Bid qty 900,000 cy Req. qty 408,000 cy Removed qty 350,000 cy About 39% completed	L 3/19/97 L 3/20/97 L 3/21/97 L 3/25/97 L 3/26/97	WES expert / developer of sea turtle deflecting draghead system, conducted onboard Inspection and made recommendations. Some changes to draghead and dredging operation made. Relocation trawling performed.	Water temp. 61 F. Dredge Eagle 1.
Myrtle Beach borrow area (Phase 1)	9/15/96 to 5/13/97	Bid qty 2.5 million cy Work completed	L 4/15/97 L 5/04/97 L 5/09/97	Sea turtle deflecting draghead used. Relative abundance trawling on 3/28-29/97, with 12 hours of "nets in water", yielded one loggerhead. Trawling on 5/8 thru 5/13/97 yielded no sea turtles.	This is one of 3 phases / reaches of total project. Part of work in all phases is by pipeline dredge. Total quantity of material to be dredged is about 6 million CY
Morehead City Harbor	4/25/97 to 5/16/97)	About 120,000 cy removed out of about 1,720,000 cy About 7% of work completed	L 4/27/97 L 4/30/97 L 5/01/97 L 5/02/97 L 5/15/97 L 5/15/97	Sea turtle deflecting draghead. Relocation trawling began 5/8/97 and continued until termination of dredging. One loggerhead captured on 5/9/97. Nighttime trawling performed 5/10 & 5/11 with no turtles captured. Because of concern over extensive takes, dredging terminated with only 7 % of work done.	Dredge Manhatten Island

Wilmington Harbor (interior Channels)	2/14/97 to 3/13/97	About 217,300 cy removed Work completed	No takes		Dredge McFarland
MOTSU	3/14/97 to 4/3/97	About 60,000 cy removed Work completed	No takes		Dredge McFarland
Wilmington Harbor (Ocean Bar)	4/3/97 to 4/30/97	About 300,000 cy Work completed	L 4/07/97	Sea turtle deflecting draghead.	Dredge RN Weeks
Dade County Beach (Miami Reach)	3/30/97 7/20/97 (estimate)	About 380,00 of 475,000 cy completed as of 6/6/97	No takes	Based on past dredging and anecdotal information about sea turtlesin area, takes are not anticipated.	

L = Loggerhead cy = cubic yards

TABLE 2a. Sea turtle takes (includes live, injured and killed) observed on hopper dredges prior to the regional consultation. Observers were not required on all projects until 1989, after which extensive monitoring was required.

Year	Project	Turtle Takes
1980 Total = 71	Canaveral	50 Cc, 3 Cm, 18 Unidentified
1981 Total = 6	Canaveral	3 Cc, 1 Cm, 2 Unidentified
1984/1985 Total = 12	Canaveral	1 Cc, 11 Unidentified
1986 Total = 9	Canaveral	5 Cc
	Kings Bay	1 Cc, 3 Cm
1987 Total = 5	Kings Bay	3 Cc, 1 Cm, 1 Unidentified
1988 Total = 46	Brunswick	1 Cc
	Canaveral	13 Cc, 3 Cm, 18 Unidentified
	Kings Bay	6 Cc, 3 Lk, 2 Cm
1989 Total = 21	Canaveral	9 Cm, 2 Unidentified
	Kings Bay	8 Cc, 1 Cm
	Savannah	1 Cc
1990 Total = 12	Canaveral	3 Cc, 5 Cm
	Kings Bay	4 Cc
1991 Total = 43	Brunswick	20 Cc, 1 Lk, 1 Unidentified
	Charleston	3 Cc
	Kings Bay	1 Cc
	Savannah	17 Cc

Cc = *Caretta caretta*, Loggerhead
Cm = *Chelonia mydas*, Green turtle
Lk = *Lepidochelys kempi*, Kemp's ridley turtle

TABLE 2b. Sea turtle takes (includes live, injured and killed) observed on hopper dredges between the November 1991 and the August 1995 Regional Biological Opinion

Year	Project	Turtle Takes
1992 Total = 2	Port Royal, SC	2 Cc
1994 Total = 8	Canaveral	1 Cm
	Morehead City	1 Cc
	Kings Bay	2 Cc
	Savannah	3 Cc, 1 Lk
1995 Total = 6	Canaveral	1 Cc
	Palm Beach	3 Cc, 2 Cm

Cc = *Caretta caretta*, Loggerhead
Cm = *Chelonia mydas*, Green turtle
Lk = *Lepidochelys kempi*, Kemp's ridley turtle

TABLE 2c. Sea turtle takes (includes live, injured and killed) observed on hopper dredges after the August 25, 1995 Biological Opinion

Year	Project	Turtle Takes
1996 Total = 9	Morehead City Harbor	1 Cc
	Myrtle Beach (Borrow Area Reach I)	2 Cc
	Kings Bay	1 Cc
	Palm Beach	1 Cc, 1 Cm
	Wilmington Harbor	3 Cc
1997 Total = 28	Brunswick Harbor	1 Cc
	Charleston Harbor	5 Cc
	Kings Bay	9 Cc
	Morehead City Harbor	6 Cc
	Myrtle Beach (Borrow Area Reach 1)	3 Cc
	Savannah Harbor	3 Cc
	Wilmington Harbor (Ocean Bar)	1 Cc

Cc = *Caretta caretta*, Loggerhead
Cm = *Chelonia mydas*, Green turtle
Lk = *Lepidochelys kempi*, Kemp's ridley turtle

TABLE 3. Current requirements for dredging windows, observer requirements and use of hopper dredges in borrow areas along the east coast established in the August 1995 BO.

AREA		SEA TURTLE MONITORING: NAVIGATION CHANNELS		SEA TURTLE MONITORING: BORROW AREAS	
	WHALE MONITORING	WINDOWS	MONITORING	WINDOWS	MONITORING
North Carolina to Pawleys Island, SC (includes channels at Oregon Inlet, Morehead City and Wilmington)	One observer (daytime coverage) between 1 Dec and 31 Mar. Monitoring by dredge operator and sea turtle observer between 1 Apr and 30 Nov.	Year Round	Two observers (100% monitoring) 1 Apr - 30 Nov	Year Round	One observer (50% monitoring) 1 Apr - 30 Nov
Pawleys Island, SC to Tybee Island, GA (includes channels at Charleston, Port Royal and Savannah)	One observer (daytime coverage) between 1 Dec and 31 Mar. Monitoring by dredge operator and sea turtle observer between 1 Apr and 30 Nov.	1 Nov - 31 May	Two observers (100% monitoring) 1 Nov - 30 Nov and 1 Apr - 31 May	Year Round	One observer (50% monitoring) 1 Apr - 30 Nov
Tybee Island, GA to Titusville, FL (includes channels at Brunswick, Kings Bay, Jacksonville, St. Augustine, and Ponce de Leon Inlet)	Aerial surveys in right whale critical habitat, 1 Dec thru 31 Mar. One observer (daytime coverage) between 1 Dec and 31 Mar.	1 Dec - 15 Apr	Two observers (100% monitoring) 1 Apr - 15 Apr	Year Round	One observer (50% monitoring) 1 Apr - 15 Dec
Titusville, FL to Key West, FL (includes channels at West Palm Beach, Miami and Key West)	Whale observations are not necessary beyond those conducted between monitoring of dredge spoil.	Year Round	Two observers (100% monitoring) year round	Year Round	One observer (50% monitoring) year round

CSE
COASTAL SCIENCE & ENGINEERING PLLC
804 ARENDELL STREET • SUITE I • MOREHEAD CITY NORTH CAROLINA 28557 • TEL 252-222-0976 • FAX 252-222-0967

August 17, 2001

Colonel James W. Delaney, District Engineer
U. S. Army Engineer District, Wilmington
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Attention: Mr. Mickey Sugg

Re: Bogue Banks Beach Restoration Project
Responses to National Marine Fisheries Service letter of June 25, 2001

Dear Colonel Deloney:

This letter is in response to comments in the June 25, 2001 letter to your office from Southeast Regional Office of National Marine Fisheries Service concerning plans to nourish 16.8 miles of ocean shoreline located in Carteret County, North Carolina (Action ID No. 2000003620). This letter addresses specific comments in the referenced letter.

In reference to the last sentence of the first page of the referenced letter, if the agencies know of less damaging alternatives and impact reduction opportunities that do not significantly alter the scope and costs of the project and are supported by quantitative research data, we request that those opportunities be revealed as soon as possible. Additionally, the Corps of Engineers has been implementing beach nourishment projects in North Carolina for over fifty years. We would expect to be held to the same standards of environmental protection in project implementation as applied to Corps of Engineers' projects.

Item 1. Sediment Compatibility:

We continue to disagree with the position of U. S. Fish and Wildlife Service that the sands proposed as beach fill material are not compatible. The Geotechnical Engineering Branch of the Corps of Engineers, Wilmington District, is currently reviewing the sand compatibility data. We expect that their review will be in agreement with our assessment of the borrow area sediments. It is an error to state that borrow sediments in borrow area B1 and B2 are exceptionally fine grained. As shown by the records of borings taken in the borrow areas and summarized in figures E8a, E8b and E9a (CSE, July 2001) mean grain size for composite samples from the borrow area A was 0.51 to 0.54 mm (coarse sand), 0.28 mm (medium sand) for borrow area B1 and 0.31 mm (medium sand) for borrow area B2. This compares with mean grain sizes for the native beach material composite samples of 0.30 mm (see table 5, Biological Assessment, July, 2001).

Percent mud for sand samples from borrow areas B1, B2 and A proposed for use does not exceed 4 percent. The standard the Corps of Engineers uses for beach compatible sand is 10 percent mud content (percent passing the No. 200 sieve).

The accepted standard for quantifying compatibility is the overfill factor, R_A (CERC 1984). This is a measure of how similar a borrow sediment is to the native beach. Section 3 of the Biological Assessment reports R_A=s for individual borrow samples ranging from <1.02 to >10.0 with means of about 1.15 in revised borrow area A, 1.58 in revised borrow area B1, and 1.50 in revised borrow area B2. As shown in Section 4 of the Biological Assessment, by combining sediments from borrow area A with those in borrow areas B1 and B2 in proportions of approximately 1:2, a composite R_A of about 1.3-1.35 results. Shell content for an example composite of 62 borings is approximately 32 percent (see Biological

Assessment, Table 5 and Appendix A). A further advantage of the borrow areas chosen is the slightly broader size distribution than the native sediment. This is important from an engineering standpoint because it means the borrow sediment will be more stable and last longer, a primary goal of the project. Borrow areas with narrow size distributions will generally not perform as well even if the mean grain size matches the native sediment (USACE 1995a).

The example composite size distribution of 62 borings from borrow areas A, B1, and B2 is expected to be modified favorably after placement on the beach because of the following factors:

- Construction by hopper dredge (the 95 percent most probable dredging method) will eliminate nearly all mud before pump-out onto the beach (D. Hussin, Great Lakes Dredge & Dock, pers. comm., April 2001), thus shifting the mean grain size to a slightly coarser value.

- Shell material in the cores contains high proportions of friable thin shell (eg, *Donax* sp.) which will be broken into smaller shell hash fragments in the swash zone, narrowing the size distribution.

- Natural sorting in the littoral zone of a broad distribution of sediments will maintain the distinct difference between the offshore bar (fine sand), beach face (medium to coarse sand and shell), and dune (fine sand). Presently, there are portions of the profile such as the horns of beach cusps containing >70 percent shell material.

The proposed borrow areas have been selected to provide sediments that are compatible with the native beach. The borrow materials identified for this project are more compatible than sands placed on Atlantic Beach or Pine Knoll Shores by the Corps of Engineers as part of past nourishment projects. This project meets a higher standard, but at the same time, should not be held to a higher standard than Corps of Engineers projects.

With reference to the calcium carbonate content of the sediments, none of the sediments to be dredged and placed on the beach are highly reactive. While calcium carbonate material breaks down much faster than quartz and feldspar, the process is not rapid. Shell fragments from the borrow area would require many decades to centuries to break down completely and dissipate from the beach as well as an overburden to provide pressure to consolidate the sand. Cementation is not likely to occur, because the fill will be placed within the active surf zone and will not contain high proportions of muddy material. Hydraulic fills have the advantage of producing a slurry that runs down the profile during construction. Fine-grained material is selectively sorted and winnowed in the surf during placement. The natural flooding of the beach by different wave and storm events provides a periodic washing of the sand that flushes the calcium carbonate from the sands. Reports of sites (eg, Edisto Beach, SC) where cementation may have occurred generally involved placement of unwashed sediments above the spring swash line where the periodic flushing does not occur.

With regard to re-establishment of beach organisms essential to health of recreational and commercial fish species, There have been numerous studies of environmental impacts of beach nourishment projects over the past 20 years. The majority of beach nourishment projects have had no long-term environmental effects when compatible, low silt/clay materials are used, when borrow sites are properly selected, and when proper timing is adhered to.

Lankford and Baca (1989) and Baca et al (1991) published two articles summarizing the findings of available literature relative to the severity of impacts from various forms of beach nourishment. They found that impacts to beach sites were few and short-lived but that impacts to borrow sites were more long-lived (Table 9).

TABLE 9. Impacts to various communities as a result of different types of beach nourishment methods. (H = high impacts M = medium impacts L= low impacts)

IMPACTS	TO BEACH OR BORROW SITE	OFFSHORE DREDGING	NEARSHORE DREDGING	SHOAL SCRAPING
Benthic macro-invertebrates	Borrow	M	H	M
Reefs and hardbottoms	Borrow	M	M	L
Fisheries	Borrow	M	M	L
Turtle nesting	Beach	L	L	L
Bird nesting	Beach	L	L	L
Diversity/richness	Borrow	M	H	L
Commercial/recreational value	Borrow	M	H	L

Macro-invertebrates, diversities, and commercial/recreational values were impacted by nearshore dredging. Importantly, however, "high" is relative as these impacts were not significant or long-lived in most cases (reviewed in Lankford and Baca 1989). In a recent South Carolina study comparing predredging (CSA 1999) and postdredging impacts (CSA 2000) on offshore areas, although impacts were noticeable, they had virtually disappeared after one year.

Most of the monitoring studies of beach nourishment projects in the southeastern United States show that macro-invertebrate community recovery is rapid once dredging and filling have ceased (Saloman 1974, Cutler and Mahadevan 1982, Naqvi and Pullen 1982, Gorzelany 1983, Reilly and Bellis 1983, Gorzelany and Nelson 1987, Hurme and Pullen 1988). Within the caveate of proper borrow-site selection and compatible, low silt/clay material, there is no research which contradicts this statement. Recent experience with Florida and New Jersey projects also supports these findings.

In recent years, there have been a few papers published which suggest possible long-term and/or significant impacts to certain species (eg, Donaghue 1999, Peterson et al 2000). These papers have been selectively referenced by the agencies as evidence of unacceptable impacts to biological resources due to nourished beaches. Some clarification of the exact nature of the nourishment projects upon which these studies were based is appropriate. These studies (Donaghue, 1999, and Peterson et al, 2000) describe impacts to populations of *Donax* and *Emerita* for nourishment cases quite different than the proposed project. Donaghue observed declines at Pea Island on a beach that was nourished almost yearly over a seven-year period, leaving little time for recovery before the next fill in a one-mile reach. The Peterson et al study at Bogue Banks examined the impacts from placement on the beach of highly non-compatible, muddy sediments from dredging of the Atlantic Intracoastal Waterway on the north side of Bogue Sound. Mean grain size of the fill was 3.67φ, 0.070 mm (very fine sand), which is nearly in the silt range and nearly five times finer than the mean grain size proposed for this Bogue Banks project.

These papers do illustrate practices to be avoided in the implementation of a beach nourishment project that results in the minimum impacts to biological resources, i.e., frequent re-nourishment and nourishment with non-compatible fine sediments.

Item 2. Clarification of the Project Schedule and Nourishment Quantities:

The proposed project consists of excavating by hydraulic dredge up to 6.7 million cubic yards of beach-quality sediment from ocean borrow areas situated 0.5 to 3.0 miles offshore of the project area. Sediment would be pumped onto the beach between the toe of the existing dune and the low water line and shaped by bulldozers into a profile that closely matches the natural beach. Approximately 50 percent of the excavations would be deposited by run-out from the discharge point between mean low water and the outer bar (~500 ft offshore). Typical fill sections would add ~44 to 113 cubic yards per linear foot (cy/ft) of beach and advance the shoreline 50 to 125 ft. The work would be performed in phases covering all or portions of each of six designated reaches according to the following schedule (subject to local funding availability).

- ***Phase I*** (funding approved) - Reaches 4, 5, and 6 - Towns of Pine Knoll Shores and Indian Beach - 7.2 miles - up to 3.1 million cubic yards* - November 2001 to April 2002.

- ***Phase II*** (subject to funding) - Reach 3 and eastern half of Reach 2 - Town of Emerald Isle - 3.0 miles - up to 1.7 million cubic yards* - November 2002 to April 2003.

- ***Phase III*** (subject to funding) - Reach 1 and western half of Reach 2 - Town of Emerald Isle - 6.7 miles - up to 1.9 million cubic yards* - November 2003 to April 2004 (or later environmental window).

As described above, the proposed project has been revised in anticipation of phased construction over at least three years (i.e., three environmental windows). Three borrow areas (A, B1, and B2) will be used, but excavations will be limited to specific areas within A, B1, and B2 (shown on Figs 26-27 of the Biological Assessment). Fill sections will involve up to the indicated volumes given in the permit application but may be less depending on final construction bids because the project funding is fixed. Representative fill sections are given in the permit application. The fill sections shown in the permit application indicate a base fill volume (based on the ~4.5 million cubic yard volume deficit) and an additional "overfill" volume representing the additional quantity needed to match the performance of the native beach. The final project volume and section volumes cannot be known with certainty until bids are received and compared with the budget available for each phase. Based on best-available information, the proposed project will be executed as follows.

Phase I - Reaches 4, 5, and 6 - Towns of Pine Knoll Shores and Indian Beach (transects 48-77). See sheets 3d, 3e, 3f, 7, 8, and 9 of the permit application.

Dates of Construction: 1 November 2001 through 30 April 2002.

Borrow areas: B1, B2, and A within the revised areas and sections shown in Figures 26-30 of the Biological Assessment. Approximately 65 percent of the fill will be obtained from B1 and B2 and 35 percent will be obtained from A.

Estimated Phase I volumes:

	Initial Base Volume (cy)	Advance Nourishment Plus Overfill Volume (cy)	Total Volume (cy)
Reach 4	550,000	440,000	990,000
Reach 5	480,000	240,000	720,000

Reach 6	905,000	445,000	1,350,000
Phase I Total			3,060,000

Phase I dimensions:

	Depth of Cut (ft)	Volume Cubic Yards (%)	Areas (acres / sq. miles)
Borrow area A	~2	1,071,000 (35)	332 / 0.52
Borrow areas B1 and B2	~3	1,989,000 (65)	411 / 0.64
Phase I Total		3,060,000 (100)	743 / 1.16

Beach Area	Length (ft)	Avg. Unit Volume (cy/ft)	Estimated Added Dry Beach Width (ft)	Estimated Added Dry Beach (acres)
Reach 4	13,400	73.9	82	25.2
Reach 5	8,800	81.8	91	18.4
Reach 6	15,400	87.7	97	34.3
Phase I Total	35,600(~7.1 miles)			77.9

Inshore (Surf Zone) Areas	Average Width Impacted by Direct Filling (ft)	Area (acres)
Reach 4	525	161
Reach 5	510	103
Reach 6	525	186
Phase I Total		450

Time required for construction: ~153 days (at 20,000 cubic yards per day average)

Average production per day: ~250 ft

Fill sequence (anticipated):

Begin Phase I in Reach 5 - Pine Knoll Shores West to avoid November surf fishery in Atlantic Beach
Fill Reach 5 @ ~1,800 ft per week (impacted areas)
Fill Reach 6 - Pine Knoll Shores East
Fill Reach 4 - Indian Beach
End Phase I

Type of equipment and construction sequence: Hydraulic dredge

There are an estimated 20 self-propelled hopper dredges and one shallow-cut suction dredge certified to perform work of this type in the U.S. Therefore, there is a 95 percent probability that the type of equipment used will by a self-propelled hopper dredge. Hopper dredges excavate borrow areas, then travel to an inshore site about 1,000 ft offshore where they connect to a temporary pipeline. From there, slurry of sediment and water is pumped to shore and distributed in sections along the beach. Sediment is discharged parallel to the shore and semi-contained by low berms. The slurry runs alongshore and down-profile, carrying finer grained sediments into the surf where it is mixed and sorted by waves. Clay-sized particles dissipate beyond the surf zone and silts and very fine sands tend to settle beyond the outer bar. The balance settles in the trough or in the new berm. After completion of ~1-2 miles, the landing pipe from offshore is moved to a new locality. The area just filled is graded to the final slopes (matching the natural beach elevation and slopes above high water) and then left to adjust naturally. Typically, a given 1-2 mile reach is only impacted by construction activities for approximately one month, and then the operation moves to another reach.

Phase II - Reach 3 and portions of Reach 2 - Emerald Isle East and Emerald Isle Central (ie, Indian Beach/Emerald Isle town line at transect 48 to ~30th Street at transect 34). See sheets 3b, 3c, 5, and 6 of the permit application.

Anticipated dates for construction: 1 November 2002 through 30 April 2003.

Borrow areas: B1, B2, and A within the revised areas and sections shown in Figures 26-30 of the Biological Assessment. Approximately 65 percent of the fill will be obtained from B1 and B2 and 35 percent will be obtained from A.

Estimated Phase II volumes:

	Initial Base Volume (cy)	Advance Nourishment Plus Overfill Volume (cy)	Total Volume (cy)
Reach 3	970,000	485,000	1,455,000
Reach 2 (east part)	150,000	75,000	225,000
Phase II Total	1,120,000	560,0000	1,680,000

Phase II dimensions:

	Depth of Cut (ft)	Volume Cubic Yards (%)	Areas (acres / sq. miles)
Borrow area A	~2	588,000 (35)	182 / 0.285
Borrow areas B2 and B1	~3	1,092,000 (65)	226 / 0.353
Phase II Total		1,680,000 (100)	408 / 0.638

Beach Area	Length (ft)	Avg. Unit Volume (cy/ft)	Estimated Added Dry Beach Width (ft)	Estimated Added Dry Beach (acres)
Reach 3	12,900	112.8	125	37.0
Reach 2 (east part)	2,800	80.4	89	5.7
Phase II Total	15,700(3.0 miles)			42.7

Inshore (Surf Zone) Areas	Average Width Impacted by Direct Filling (ft)	Area (acres)
Reach 3	575	~170
Reach 2 (east part)	475	~30
Phase II Total		200

Time required for construction: ~112 days (at 15,000 cubic yards per day average)

Average production per day: ~140 ft

Fill sequence (anticipated):

Begin Phase II at east end of Reach 3 (Indian Beach/Emerald Isle town line at transect 48)
Fill Reach 3
Fill eastern 2,800 ft of Reach 2 ending at 30th Street (~transect 34)
End Phase II

Type of equipment: Hydraulic dredge

Phase II (Reach 3 and part of Reach 2) represents 17.9 percent of the total project length and 25.1 percent of the total project volume.

Phase III - Remainder of Reach 2 from 30th Street (transect 34) to Ebb Tide Drive (transect 25) and all or portions of Reach 1 (Ebb Tide Drive to Shipwreck Lane, transect 8) - Central and Western Emerald Isle.

Anticipated dates for construction: 1 November 2003 through 30 April 2004.

Borrow areas: B1, B2, and A within the revised areas and sections shown in Figures 26-30. Approximately 65 percent of the fill will be obtained from B1 and B2 and 35 percent will be obtained from A.

Estimated Phase III volumes:

	Initial Base Volume (cy)	Advance Nourishment Plus Overfill Volume (cy)	Total Volume (cy)
Reach 2 (west part)	617,000	308,000	925,000
Reach 1	753,000	282,000	1,035,000
Phase III Total	1,370,000	590,000	1,960,000

Phase III dimensions:

	Depth of Cut (ft)	Volume Cubic Yards (%)	Areas (acres / sq. miles)
Borrow area A	~2	686,000 (35)	212 / 0.33
Borrow areas B2 and B1	~3	1,274,000 (65)	263 / 0.41
Phase III Total		1,960,000 (100)	475 / 0.74

Beach Area	Length (ft)	Avg. Unit Volume (cy/ft)	Estimated Added Dry Beach Width (ft)	Estimated Added Dry Beach (acres)
Reach 2 (west part)	11,700	79.1	88	23.6
Reach 1	23,700	43.7	49	26.7
Phase III Total	35,400(6.7 miles)			50.3

Inshore (Surf Zone) Areas	Average Width Impacted by Direct Filling (ft)	Area (acres)
Reach 2 (west part)	425	114
Reach 1	425	231
Phase III Total		345

Time required for construction: ~130 days

Average production per day: 270 ft

Fill sequence: To be determined upon review of conditions around time of construction

Type of equipment: Hydraulic dredge

Phase III (Reach 1 and the west part of Reach 2) represents 39.9 percent of the total project length and 29.3 percent of the total project volume.

Summary

Phase I: Reaches 4, 5, and 6 - 3,060,000 cy - Nov 2001 - Apr 2002
Transects 48 to 77 (Pine Knoll Shores and Indian Beach town limits)
37,600 linear feet (7.1 miles)

Phase II: Reach 3 and 2,800 ft of Reach 2 - 1,680,000 cy - Nov 2002 - Apr 2003
Transects 34 to 48 (eastern Emerald Isle, 1st Street to 30th Street)
15,700 linear feet (3.0 miles)

Phase III: Reach 1 and remainder of Reach 2 - 1,960,000 cy - Future
Transects 8 to 34 (western and central Emerald Isle, Shipwreck Lane to 30th Street)
35,400 linear feet (6.7 miles)

Totals: Reaches 1 through 6 - 6,700,000 cy
Transects 8 to 77 [Shipwreck Lane (Emerald Isle) to Atlantic Beach town line)
88,700 linear feet (16.8 miles)

See Appendix B of the Biological Assessment, the Permit Application, for detailed maps and cross-sections of the proposed project.

Item 3. Maintenance Work to the Project During Its Ten year Life:

The frequency and magnitude of the maintenance work that might be required to the project is dependent solely upon the frequency of Hurricane and extreme storm events with winds and waves that cause significant damage to the project. Naturally, the frequency and magnitude of these events cannot be predicted. If maintenance dredging and beach filling are required, it would be done under the guidelines established in the state and federal permits for the proposed project. The time of year, borrow area location, and other criteria set forth in the permits would be followed. The Corps of Engineers and the N.C. Division of Coastal Management would also have to approve any maintenance work because it would represent a deviation from the three phased implementation plan for the project.

Item 4. Fine Grained Materials in Borrow Areas B1 and B2:

It is an error to identify materials in borrow areas B1 and B2 as having high levels of fine grained materials. Fine-grained materials that produce elevated turbidity levels are those sediments with very low settling velocities (i.e., clays and silts). As previously stated in the SEPA EIS and Biological Assessment, the proposed borrow area tests an average of less than 4 percent mud (percent passing the No. 200 sieve). Fine and very fine sand in the borrow areas produce short term increases in suspended sediment and is generally not considered to result in adverse impacts to biota given settling times that are much shorter than the silt and clay sediments.

In the New Jersey Study (USACE, 2001) turbidity measurements indicated that the effects of beach fill operations on short-term turbidity appeared to be limited to a relatively narrow swash of beach front (less than 500 m). Borrow sediments in the New Jersey project contained a silt and clay fraction generally less than 10 percent by weight. The clay/silt fraction in the sediments proposed for nourishment of Bogue banks is 4 percent or less.

Another finding in the New Jersey study was that measurements of turbidity at stations located far from the filling operations showed that maximum NTU values measured near the fill operations did not appear to be outside the range that organisms would be exposed to during periods of high wave energies. This agrees with the EIS that turbidity associated with the nourishment operations will probably not exceed background levels during periods of high wave energy at the beach.

Van Dolah et al. (1992) assessed turbidity conditions associated with a beach nourishment project at Hilton Head, South Carolina. They concluded that elevated turbidity was restricted to a small area near the discharge point during periods of active nourishment operations. Van Dolah et al. (1994) reached similar conclusions for a study of beach nourishment effects at Folly Beach, South Carolina. The spatial extent of the turbid plume in this study, as determined by measurements of NTUs, extended approximately 1,000 m (~3,300 feet) in the direction of longshore current a distance of 15m (~49 feet) from shore, and 500 m (~1,650 feet) at a distance of 30 m (~98 feet) from shore. Turbidity levels varied depending on local wind and wave conditions. During periods of calm winds and seas, turbidities of about

100 NTUs were measured near the discharge. With strong winds and turbulent waves, turbidities increased to 200 NTUs within 300 m (~984 feet) of the discharge. Van Dolah et al. (1994) stated that background turbidities approached 100 NTUs during episodes of storm generated turbulence. They concluded that, "Although dredge effluent does increase turbidity levels in the immediate vicinity of the outfall, there are many other factors such as local weather and wave energy that will also produce this effect. The turbidity levels found at Folly Beach during nourishment and the dispersal of the sediment plume were not considered unusual or severe relative to normal fluctuations of background levels."(USACE, 2001).

Item 5. Offshore Movement of Fill Sediments:

The shape and slope of beach profiles evolves in relation to wave energy and sediment grain size (Bascom 1951; Komar 1976). Tide range also plays an important role because it controls the elevations over which waves act on the profile. Where sediments are uniform across the foreshore, there tends to be less topography, particularly in the fine to very fine sand ranges. But in settings like Bogue Banks where there is a relatively broad range of sediment grain sizes, profiles have more complex morphology. Bars and troughs are more common and berms tend to be more mobile (Hayes 1976). By using a graded deposit of similar-sized sediments from borrow areas A, B1, and B2, waves will adjust the nourished profile to a morphology similar to the existing beach. Nourishment will displace the profile seaward (including the offshore bar and trough) and not simply infill the trough as depicted on reference cross-sections in the permit application.

If a narrow, borrow size distribution were used, the resulting profile would be more uniform. The profile illustrations in the permit application are idealized to show the relative scale of the fill sections. These are easier to visualize than a complex profile that will develop across the littoral zone to closure depth (approximately -30 ft NGVD).

Hardbottom impacts are addressed below.

CSE has collected sediment cores over a grid offshore of the project area covering some 16 miles along shore and 2.5 miles offshore of the project area (See figure 5, EIS, Appendix E). In only two locations was exposed hard bottom discovered, at the location of cores C20a1 and C20a2, offshore of Emerald Isle, reach 2. These locations are 4000 and 13,000 feet from the beach respectively, well outside the littoral zone. There is no research to support the claim of NMFS that fine sediments from the nourished beach will bury and adversely impact the hard bottom habitats. The contrary may be true based on findings of the New Jersey study. The New Jersey study (USACE, 2001) found that the turbid plume from the nourishment operations area extended less than 500 m (1,640 feet) in the direction of longshore transport in the swash zone and dispersed rapidly across the surf zone. The proposed fill materials contain such a small percentage of clay and silt sized sediment that relocation of these sediments from the offshore zone to the littoral zone should not result in an increase in the rate of change of movement of fine sediments in the offshore area.

Item 6. Coordination with NMFS Protected Resource Division:

Endangered species coordination with the Protected Resource Division was completed on July 26, 2001 with a letter from Joseph E. Powers, Acting Regional Administrator, National Marine Fisheries Service, St. Petersburg, Florida, to Colonel James W. Deloney, District Engineer, Wilmington District.

Hardbottom EFH Impacts:

With regard to hardbottom impacts, the closure depth, the depth that defines the seaward limit of sediment transport in the littoral zone, has been estimated at –30 feet, NGVD. The bottom seaward of the closure depth remains dynamic but to a much lesser degree than the littoral zone. There is ongoing redistribution of muddy surficial sediments in the offshore areas associated with suspension and settling related to waves and local currents. Exposed hardbottom areas are, more than likely, ephemeral, subject to periodic burial and exposure by free mud layers that are known to exist and move around over sandy and hard bottoms in deeper water well beyond the depth of closure (i.e. the cross-shore advection limit of the fill).

Seasonal Restrictions on Dredging:

It is proposed that the Bogue Banks project honor existing protocols outlined in the regional Biological Opinion of 1997 between the NMFS and the Corps of Engineers for the Southeastern coast of the United States. From the standpoint of NMFS, hopper dredging would be permitted year round as long as the dredge intakes are equipped with turtle exclusionary devices and monitors are stationed on the dredges. NMFS imposes no seasonal restrictions on hydraulic dredge operations. Even though these operational criteria are valid for the offshore, or intake, portions of the project, restrictions on the upland work are more restrictive. The protocol for the upland, beach, work will require that dredging be based on the protocol agreement between the Corps of Engineers and the U. S. Fish and Wildlife Service. These restrictions require that no work be performed on the beach after May 1 due to the potential for nesting sea turtles, and after April 1 in areas where there is a potential for nesting piping plovers. It is upon these restrictions and upon negotiations with the N. C. Division of Marine Fisheries during preparation of the SEPA EIS, that the proposed window of November 1 to April 30 was based. We feel that, as long as the criteria outlined in the Regional Biological Assessments are met, the proposed dredging window remains valid.

Monitoring Plan:

The Monitoring plan is in the process of being revised in accordance with the comments from the meeting at NMFS at Pivers Island on July 16, 2001. The results of the June sampling of beach and borrow area resources are being evaluated in order that design of the study can be modified so the results will be statistically significant. The comments provided by Charles H. (Pete) Peterson in his letter of 3 June, 2001 will be addressed in the Monitoring Plan to be submitted following this letter. We are insisting that the final plan provide specific details of the plan that will enable the plan to be used for compliance purposes by the Corps of Engineers.

The applicants agree to a phased implementation of the project as described under item 2 above. The applicants will not agree to make the implementation of phases 2 and 3 contingent upon the outcome of the environmental monitoring of phase 1. This is an unreasonable requirement without precedent on Corps of Engineers projects. This requirement subjects the co-applicant municipality, Emerald Isle, to the possibility that their project cannot be performed while Pine Knoll Shores and Indian Beach gain the benefits of a protective beach. Further, in keeping with best management practices, the applicants have defined the entire scope of the work instead of submitting piece meal applications for various reaches. The criteria and need for nourishment is uniform and rational for the six reaches. There is no basis, in our opinion, to hold one or more reaches to a different standard than others.

EFH Conservation Requirements:

1. Timing of Dredging and Filling: This is addressed above under Seasonal Restrictions on Dredging.

2. Sand Compatibility: We feel that there has been adequate evidence provided to the federal agencies that the borrow material proposed for use is compatible. The monitoring plan will include sampling of post dredging beach sediment samples to verify that this criteria is being met. We also feel that a review of the sand compatibility by the Corps of Engineers will confirm the evidence presented to date.

3. Monitoring Plan Statistical Validity: The Monitoring plan in preparation will include analyses of data from the June Sampling event and a plan design based on statistical analyses of that data that will ensure that results are statistically significant.

4. The exact locations of the borrow areas to be used is addressed in item 2 above.

5. The Bogue Banks project is a large project and will have impacts on aquatic resources. We feel that adequate evidence has been presented to the federal agencies that the project will be implemented in such a manner as to minimize the impacts and to quantify impacts to some important resources. Additionally, we feel that sufficient information has been referenced on the results of the studies of others on the biological impacts of beach nourishment to provide a level of confidence that the proposed project is being implemented using "Best Management Practices" developed as a result of those studies. Finally, the project is being implemented based on existing dredging protocols developed based on regional Biological Opinions of the NMFS and USFWS in conjunction with the Corps of Engineers.

As indicated above, the applicants prefer a phased implementation of the project as described under item 2 above. The applicants will not agree to make the implementation of phases 2 and 3 contingent upon the outcome of the environmental monitoring of phase 1. This is an unreasonable requirement without precedent on Corps of Engineers projects or other projects that we are aware of.

This response was prepared by Coastal Science and Engineering, Morehead City. Comments related to this response should be directed to CSE at the address shown above.

Sincerely,

COASTAL SCIENCE & ENGINEERING, PLLC

J. W. Forman, Jr., P.E.
Senior Engineer

CC: Reese Musgrave, Town of Pine Knoll Shores
Pete Allen, County of Carteret
Buck Fugate, Town of Indian Beach
Ron Sechlor, NMFS, Beaufort, NC
Tracey Rice, USFWS, Raleigh, NC
Frank Rush, Town of Emerald Isle

Final TWK

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

June 18, 2001

Mr. Mickey T. Sugg
Regulatory Field Office
USACE, Wilmington District
PO Box 1890
Wilmington NC 28402-1890

RE: Carteret County – Bogue Banks Beach Restoration Project – USACE Action ID# 200000362]
Biological Monitoring

Dear Mickey:

I am writing to update you on the status of our plans for biological monitoring of the above-referenced project. Following is a chronology of events in this regard and copies* of relevant correspondence and reports. The purpose of this file is to document for your agency the efforts that the applicants have made to initiate biological monitoring of the project.

October 1999	– Carteret County contracted with UNC-IMS (Dr. Peterson) to design a monitoring program and perform initial offshore sampling. Beach sampling not contracted because of ongoing but incomplete study by IMS student.
November 1999	– Fall borrow area sampling by IMS.
February 2000	– Supplementary fish samplings by IMS.
6 March 2000	– Draft SEPA EIS submitted to NCDENR
21 March 2000	– County funding referendum fails – limited funds available to continue with EIS/permitting.
* 6 April 2000	– (received by CSE 5 April 2001) Beach sampling study: "Effectiveness of Beach Bulldozing Against Shoreline Erosion and the Impacts of Bulldozing on Biological Resources" by Peterson, Wells, Manning, and Conaway.
* 10 May 2000	– Draft IMS report on initial fall-winter samplings (7 pp + appendices).
* 18 May 2000	– CSE comments on draft IMS report (6 pp).
11 September 2000	– Revised IMS biological monitoring report submitted (13 pp + appendices) incorporated into EIS as Appendix C.

CSE

16 October 2000 – CSE contracted by Town of Pine Knoll Shores for final design of reaches 5 and 6 of county plan.

31 October 2000 – Second draft EIS submitted incorporating comments and responses to NCDENR reviews.

29 December 2000 – CSE contracted by Town of Indian Beach for final design of reach 4 of county plan.

24 January 2001 – Permit application for county project (six reaches, 16.8 miles) submitted to CAMA and USACE.

* 28 February 2001 – USACE informs Carteret County that the permit application should include individual municipalities as co-applicants.

16 March 2001 – Public notice issued by USACE on Bogue Banks permit application (Action ID 200000362).

* 2 April 2001 – Dr. Peterson informs CSE that he can no longer be engaged in the environmental monitoring of Bogue Banks.

4 April 2001 – Final SEPA EIS incorporating comments and responses from all state agencies.

10 April 2001 – Town of Pine Knoll Shores establishes a budget NTE $150,000 for biological monitoring in connection with reaches 5 and 6.

* 18 April 2001 – Coastal Science Associates Inc (CSA) (Dr. Bart Baca) submits draft proposal for pre and postmonitoring within budget parameters established by Pine Knoll Shores.

* 9 May 2001 – (received by CSE and CSA on 18 May) Dr. Peterson's comments on draft CSA monitoring plan submitted to NC Division of Marine Fisheries.

11 May 2001 – Interagency meeting with USACE, USFWS, NMFS, applicants, CSE, CSA, and Dr. Peterson.

* 28 May 2001 – Revised CSA biological monitoring proposal received by CSE.

* 3 June 2001 – Dr. Peterson's comments on revised CSA monitoring proposal.

* 8 June 2001 – CSE letter to Pine Knoll Shores recommending authorization of initial spring sampling immediately.

CSE

11 June 2001 – Pine Knoll Shores authorizes initial spring sampling following CSA's revised proposal plus modifications as outlined in 8 June letter by CSE.

16 June 2001 – CSA initiates offshore and beach sampling as outlined in their revised proposal and CSE's 8 June letter.

CSA representatives will be available this week to meet with NMFS in Morehead City and discuss the specific sampling and analysis plan. The work that we are initiating this month will follow standard methodology and accepted protocols for statistical design.

CSA has completed environmental monitoring projects for many nourishment projects (eg, Myrtle Beach, Pawleys Island, Seabrook Island, and Hunting Island) and has had to comply with requirements of the States of Florida and South Carolina, as well as other jurisdictions in regard to sampling design and analyses. I am asking that your agency advise us as soon as possible on any specific sampling requirements of the federal government for the proposed project so that we can develop an appropriate scope of work and budget. We anticipate accomplishing a significant level of monitoring commensurate with the overall scope of the project.

Thank you for your consideration.

Yours truly,

Timothy W Kana PhD
Project Director

Enclosures

cc: USFWS, Raleigh
NMFS, Morehead City, Ron Sechler
NC Division of Marine Fisheries, Mike Marshall
Carreret County, Frank Rush
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
Town of Emerald Isle, Mayor Barbara Harris
CSE, Bill Forman

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Institute of Marine Sciences
252-726-6841
FAX: 252-726-2426

The University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, North Carolina 28557

10 May 2000

Mr. Robert Murphy
County Manager
Carteret County
Courthouse
Beaufort, NC 28516

And

Dr. Tim Kana
CSE-Baird
P.O. Box 8056
Columbia, SC 29202-8036

Dear Bob and Tim:

Please find enclosed our Final Report on the "Bogue Banks beach renourishment project: Late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining." We have included Appendices with all the raw data to allow any future recalculations or analyses. Because no subsequent spring sampling has taken place, the report is quite descriptive and does not involve any analysis of impacts. The assessment should serve well as a late fall baseline for assessing impacts of any future mining of sediments at the proposed borrow areas.

Please direct any questions to us if clarifications are necessary.

Sincerely,

Pete

Charles H. Peterson
Alumni Distinguished Professor

John Wells
Professor and Director

FINAL REPORT

Bogue Banks beach renourishment project: Late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining

Prepared for

Carteret County and CSE Baird, Inc.

By

Charles H. Peterson & John T. Wells
Institute of Marine Sciences
University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, NC 28557

May 10, 2000

Charles H. Peterson

John T. Wells

1. Background

There are several environmental issues relating to the benthic habitat and biological resources that arise in considering a beach renourishment project for Bogue Banks. The most significant include: (1) impacts to and recovery of the benthic invertebrate community at the borrow areas; (2) potential impacts to commercially or recreationally important demersal fishes and crustaceans in part because of these effects on their benthic invertebrate prey; (3) impacts to and recovery of the benthic invertebrate community on the intertidal and shallow subtidal beach; and (4) potential impacts to commercially and recreationally important fishes in the surf zone and/or shorebirds in large part because of these effects on their benthic invertebrate prey and because of enhanced turbidity along the shoreline.

Each of these issues deserves evaluation and requires some field monitoring before and after renourishment to evaluate the resulting impacts. Because the benthic invertebrate community at the offshore borrow sites changes across the seasons, it is appropriate to sample in multiple seasons (fall and spring) both before and after the renourishment project to assess impacts and recovery. Because renourishment was originally planned for winter 2000-2001, an initial set of samples was collected in the late fall of 1999 to provide fall baseline data to characterize the benthic invertebrate community at the prospective offshore borrow sites and at nearby control sites that were not planned to be mined prior to any disturbance from the renourishment project. This report includes a description of results from an analysis of the fall 1999 samples. We also include here a complete analysis of composition of surface sediment samples in each of the borrow sites and control sites so as to characterize the sedimentary habitat in which the invertebrates live. Sedimentary habitat is the prime factor that controls abundance and composition of soft-bottom invertebrate communities. The invertebrate sampling needs to be repeated in a spring prior to any sand mining, and then possibly in fall and spring of each year after mining until sufficient recovery has been documented. Sediment sampling must also be repeated after the mining has occurred to evaluate potential impacts on the sedimentary habitat and subsequent recovery, but an annual frequency should suffice for monitoring of sediment character.

The test of the impact of removing sand from the three "Borrow Areas" A, B1, and B2 (Fig, 1) requires the use of a BACI (Before-After-Control-Impact) experimental design. Samples from impact (Borrow) areas will be compared with those from control (undisturbed) areas both before and after the sand is removed. (Control areas would have no sand removed but would otherwise be affected by all other impacts, i.e. storms, shrimping, etc., that affect the impact area.) These samples taken before the removal of the sand can be compared with identically conducted samplings made after sand mining to evaluate impacts. In addition, the design also calls for spring sampling both before and after the removal of sand to assess the seasonal component, for a minimum of 4 sampling periods to complete the assessment of impacts. This report describes only the first of those samplings. The study does not include any spring sampling of the Borrow Areas or any sampling of the intertidal beaches.

Assessment of the significance of the offshore mining of sands for the renourishment also involves evaluation of potential impacts on demersal fishes and crustaceans at the borrow site. Impacts could occur directly during sand mining and indirectly through modification of the prey community. This effect on prey could last for some unknown time. The fish and crustacean community also changes seasonally so sampling is needed to document presence and relative abundance of demersal fish and crustaceans and to describe their utilization of benthic invertebrate prey. Trawl sampling was first conducted in late fall 1999, coincident with the sampling of the benthos. We conducted one additional trawl sampling in early February 2000 to document over-winter use of the Borrow Areas by fishes. This should be repeated in one or more springs to document the date of seasonal return of fishes to the site. Our analysis includes not only the information on fish and crustacean abundances on the two dates but also a description of their diet from gut contents in the late fall 1999 collection.

No sampling has yet taken place to serve as the before-renourishment monitoring data for the intertidal invertebrates of Bogue Banks beaches or for sea turtles. The invertebrate community of the intertidal beaches is › strongly seasonal and dynamic within the warm season that sampling to provide baseline information should occur throughout the warm season, with subsequent identically designed sampling to assess potential impacts and recovery but after the project has been completed. The complete design for such beach monitoring would include "before and after" sampling of control beaches where no renourishment occurs.

2. Description of Sampling and Analytic Methodologies

A. Benthic Prey Resources

Two hundred core samples were collected during late fall of 1999 (12-22 November) to characterize the invertebrate macrofauna at all three prospective borrow sites and at control sites near each borrow site (Fig. 1). Ten replicate core samples were taken at each of six sites in Borrow Area A and at each of two sites from Borrow Area B-1 and Borrow Area B-2. Ten replicate cores were also taken at each of ten control sites: six around Borrow Area A and two near each Borrow Area B site. Exact locations of each site were determined using a handheld GPS with differential receiver (Table 1). Water depths ranged from 35 feet at the inshore sites and 47-49 feet at the offshore sites. Cores were taken by divers using a cylindrical corer 9.9 cm in internal diameter (each covering a surface area of 76.4 cm^2) with 500-µm mesh across the top to prevent loss of surface animals. Replicates were haphazardly positioned at each systematically distributed (see Fig. 1) sample station within a 3-m^2 area. All core samples were taken to a depth of 10 cm. After being transported to the boat, the contents were emptied from the core tubes into plastic bags, labeled, and sealed. Immediately upon returning to the lab, the material from the cores was sieved through a 500-µm mesh. Material retained on the sieve was preserved in a 5% aqueous solution of buffered formalin. Rose Bengal vital stain was added to the samples to facilitate sorting. After a week, the formalin was drained off through a 500-µm sieve and replaced with 70% ethanol. Subsequently, animals were separated from detritus by hand picking and identified to family. Several benthic impact studies including especially those by Warwick (1988) of IMER in Plymouth, England have demonstrated that analysis of response at the level of family preserves all the information about community patterns without the high costs of proceeding to species-level.

At the same time that the macrofaunal cores were taken, divers collected three 2.65cm-diameter cores to a depth of 2 cm at each site to sample the meiofauna (fauna smaller than 0.5mm and greater than 0.063mm). These samples were iced onboard ship, preserved in the lab with a 5% aqueous solution of formalin, and archived for possible analysis, if required.

Benthic sled sampling was used to collect belt transect samples of larger, more sparsely distributed animals such as hermit crabs and sand dollars. The sled has matching steel blades on both the top and the bottom so that it functions properly no matter how it lands on the bottom. To produce a belt transect, the sled (25 cm tall with a 63 cm wide blade) was towed 15.8 m along the bottom by a line extending to the boat and sampled the top 6 cm of sediment. Sediment passes through the 6 mm mesh and larger organism are retained. A taut-line buoy attached to the sled allowed for accurate positioning along the marked course. We sampled only on a flat-calm day (9 December 1999) at sea to prevent the sled from bouncing and to control its positioning. Using this sled, we took 40 belt transect samples of 10 m^2 each. This design yielded two replicate belt transect samples at each of the 20 sampling sites (Fig. 1). Animals found in the sled samples were identified, counted, and recorded. Species not immediately identifiable in the field were collected and returned to the lab for identification.

B. Demersal Fish and Crustaceans

In order to provide a semi-quantitative characterization of demersal fishes and crustaceans, including commercially or recreationally important species, that occupy the potential borrow areas and may conceivably be impacted directly by dredging operations or indirectly by loss of their benthic invertebrate prey, we sampled the demersal species of the three borrow areas. Replicate trawl samples were taken on 29 November 1999 and again on 4 February 2000 from the R/V Capricorn using timed 20-minute otter-trawl tows at 4.02k/hr with a 12.3-m otter trawl. Thus the trawl would cover 16,492 m^2 of bottom area if there were no currents. The actual bottom area covered varied according to wind and tidal currents during any specific tow, which is why tows were standardized by time and speed rather than distance covered. These trawl samples were distributed as follows: 4 in Borrow

Area A and 2 in each of Borrow Areas B-1 and B-2. The contents of each tow were identified to species, counted, and recorded. In addition, stomachs of up to 20 replicate individual fish of the most abundant species were removed, and preserved by formalin injection onboard ship during. Stomach contents for up to twenty of the eight most common fish species from the November trawl survey were identified (when possible) and divided into major taxonomic group (e.g. polychaete, decapod, bivalve, etc.). Fish guts were examined from both inshore areas and offshore areas when possible. The divided categories were then weighed to the nearest 0.0001 g. Detailed inspection of some of the diet remains allowed identification to the family, genus or species level of some of the gut contents.

C. Sediments

At each site where macrofaunal cores were collected, divers also took core samples for grain-size analysis of sediments. Composite bottom samples were obtained at each of the ten Borrow Area sites and each of the ten control sites. Using PVC sampling tubes (16.5 cm [6.5 in] long and 2.5 cm [1 in] wide), divers collected 3 replicate samples of the upper 2 cm of the bottom within a 3-m^2 area at each of the twenty sites. Sample tubes were tightly capped, then brought to the surface and returned to the laboratory for analysis. Loss of fine-grained material, which can occur with conventional grab samplers, is minimized by using diver collections. Samples were assumed to be representative of the surficial material in which most of the macrofauna live.

In the laboratory, the replicate sediment samples were combined in a single container, then washed three times to remove salts and placed in a drying oven. After recording the bulk sample weight, a Calgon dispersant was added and the fine-grained (mud) component (by definition less than 0.063 mm diameter) was rinsed through a #230 mesh wet sieve. The remaining material (sand + gravel/coarse shell) was reweighed and prepared for sieve analysis. Prior to sieving the sand-sized fraction, the gravel/coarse shell fraction (by definition more than 2 mm in diameter) was removed with a #10 mesh sieve and weighed. A Tyler mechanical splitter was used to obtain a 25 g subsample of the remaining material (sand) which was then sieved at ¼ phi intervals (Carver 1971).

Each sieve stack was placed in a mechanical ro-tap for 20 minutes. Individual sieve fractions were weighed and recorded. Small amounts of fine-grained sediment that had not previously washed through the wet sieve were collected in a pan at the bottom of the sieve stack and, for computational purposes, were included with the wet-sieved material. Percentages of gravel/coarse shell, sand, and fine-grained sediment were computed from the bulk sample weights, and percentages of each size fraction in the sand range were computed from the 25 g splits that were sieved. Mean and standard deviation were computed using Excel software and mean phi values were converted to millimeters using the standard conversion, phi = $-\log_2(\text{mm})$, where mm corresponds to the intermediate diameter in mm (Folk 1974).

3. Results

A. Benthic Invertebrate Resources

Table 2 (2a for per-core results and 2b normalized to per square meter) presents the results of analyses of the 200 core samples taken to describe the benthic macrofauna at the three Borrow Areas and the surrounding Controls for each. Total macrofaunal densities were slightly greater at the offshore sites (14.1 invertebrates per core at Borrow Area A and 9.3 per core averaged over nearby Control sites) than at the inshore sites (9.7 invertebrates per core averaged over Borrow Areas B-1 and B-2 and 6.6 per core averaged over nearby Control sites. Results suggest slightly higher macrofaunal abundances in the Borrow Areas than in their respective Control Areas (Fig. 2). The polychaetes accounted for 65 % to 75 % of the total macrofauna in these late-fall 1999 samples. Other common groups in order of abundance were bivalve molluscs, nemerteans, small crustaceans, and echinoderms (see Appendix for all raw data).

Table 3 (3a for per-belt transect results and 3b normalized to per square meter) describes the results of analysis of all 40 belt transects for larger benthic invertebrates. The inshore sites revealed higher numbers of these larger invertebrates than the offshore sites. Borrow Area A contained 3.1 larger invertebrates per $10m^2$ belt transect and its nearby Control sites averaged 2.8, as compared to the average of Borrow Areas B-1 and B-2, which was 0.7 and their nearby control sites of 1.2 (Table 3). No consistent difference appeared between Borrow and Control Areas in this data set (Fig. 3). Gastropods were the most common taxon represented in these samples.

B. Demersal Fish and Crustaceans

Trawl sampling detected relatively large number of demersal fish occupying the seafloor habitat during late fall, declining by early February (Table 4 presents the results of trawling for fishes and crustaceans on 29 November 1999 and Table 5 presents the 4 February 2000 results). In November, offshore areas were dominated by spot, which accounted for more than 50% of total catch and was sufficiently abundant there to create a pattern of slightly higher fish densities offshore than inshore. In addition to spot, pinfish, pigfish, and croaker were the most common species offshore. Inshore fishes were dominated by croaker, silver perch, silversides, pinfish, and sea mullet.

The abundance of most fish species had decreased by 4 February. This February sampling took place after a 3-week cold spell, the first prolonged cold weather of the winter of 1999-2000. The contents of these February 2000 samples (Table 5a,b) contrasted with those of November 1999 (Table 4a,b), showing an average reduction in catch by 81.3%. Catch in February from inshore stations was 41.3% and of offshore stations 3.7% of the corresponding catches in November. The abundances of two commercially and recreationally important species, spot and croaker, which made up 50.8% of the fall catch, dropped by 98.9% and 99.8% respectively. In February, pinfish, menhaden, and silversides made up 96.4% of the total catch. Spot, croaker, pigfish, sea mullet, and silver perch all showed large declines from November to February in both inshore and offshore areas. Pinfish catch in offshore areas was greatly reduced in February compared to November; however, inshore catches of pinfish were similar across dates. Two species of fish, menhaden and southern flounder (both found only in the inshore area), were more abundant in February than in November.

Examination of the stomach contents of the eight most abundant fish (croaker, gray trout, pinfish, pigfish, sea mullet, silver perch, silversides, and spot) demonstrated that many of the benthic invertebrates found in core samples and belt transects were major diet items of these fish (Table 6). Only about half of all stomachs examined were empty, with some variation among species. Major prey species for croaker and pinfish included polychaete worms, bivalves, and occasionally small shrimp (primarily grass shrimp, *Palaemonetes* sp.) and crabs (primarily pinnotherid crabs). Shrimp (both *Palaemonetes* sp. and penaeids) and to a lesser degree portunid crabs were the primary prey species found in the stomachs of gray trout. Sea mullet prey items were dominated by pinnotherid and portunid crabs and large polychaete worms. Small grass shrimp and other bottom-dwelling crustaceans (amphipods and isopods) were the dominant prey found in silver perch stomachs. Pigfish stomachs contained primarily polychaetes with an occasional grass shrimp present. Some polychaetes and small crustaceans (isopods, cumaceans, and amphipods) were found in the stomachs of spot, but stomachs were relatively empty compared to other species. Finally, silversides fed primarily on harpacticoid (benthic dwelling) and calanoid (planktonic) copepods.

Comparisons between stomach contents of fish collected from inshore and offshore locations were possible for six of the eight species that were caught in abundance in both areas (croaker, gray trout, pinfish, silver perch, silversides, and spot). Examination of the data revealed no consistent pattern in either the proportion of empty stomachs or major prey items between the two areas.

C. Sediments

Data are summarized in Table 7; individual size frequency curves and histograms are provided in Figure 4. With the exception of two treatment sites in Borrow Area A, sands comprised at least 90% of the bottom sediment by weight. In all cases, muds comprised less than 4% of the sediment by weight. Visual inspection of the samples revealed that the coarse fraction, typically less than 8% by weight, was comprised primarily of coarse shell fragments. Using the Wentworth size scale (Folk 1974), mean grain size in 80% of the samples was classified as fine sand and 20% as either medium or coarse sand. Values for standard deviation showed that 85% of the samples were moderately or moderately well sorted. Reed and Wells (2000) found similar sediment distribution patterns off Fort Macon, Atlantic Beach and Pine Knoll Shores, NC, in samples taken at 36 locations during each of two sampling periods, fall 1996 and spring 1997. Their samples showed muddier sediments occurring in the offshore areas but no significant seasonal variations in mean size or sorting.

4. Discussion

The benthic invertebrates occupying the bottom in both the inshore and offshore Borrow Areas represent species that are indeed being consumed by demersal fishes, such as spot, croaker, pinfish, pigfish, and sea mullets. Our gut examinations revealed that feeding was active and intense on the benthos in late November. Compared to other gut data, the percentages of empty stomachs in this data set are quite low. The densities of benthic invertebrates (6-16 individuals per 76.4-cm^2 core) are similar to those found occupying sandy bottoms in the Beaufort Inlet in December 1994 (Peterson et al. 1999), which were around 10 individuals per 76.4 cm^2 core (the same used in this study). The Beaufort Inlet samples were taken at a depth of 26-36 feet, similar to the inshore sites sampled in this study. Both surveys showed a general dominance by polychaetes. No other sampling of benthic invertebrates is truly comparable to these because of differences in sieve mesh size, water depth, reef proximity, geography, or sedimentology. Nevertheless, we present some benthic macrofauna data in Tables 8 (total macrofauna) and 9 (major taxa) from these other studies for contrast. Densities of benthic infauna in cores at the Borrow Areas in late November during our sampling period and in the earlier Beaufort Inlet study are lower than those observed near hard-bottom reefs off Wrightville Beach (Posey and Ambrose 1994) and those observed by Van Dolah (1994) in finer sediments off Hilton Head, South Carolina (Table 8). For those taxa reported in Posey and Ambrose (1994), bivalves, gastropods, scaphopods, amphipods, isopods, polychaetes, and echinoderms, densities were higher than in our sampling of the Borrow Areas (Table 9).

Belt transects for larger invertebrates revealed a similar dominance by gastropod molluscs in our new data set from the Borrow Areas and in our earlier Beaufort Inlet study. These larger invertebrates were slightly more common in the Beaufort Inlet than in the study areas sampled here (Table 10). Greater echinoderm (sand dollar) densities occurred in the vicinity of the Beaufort Inlet. The only other analogous data set on larger invertebrates comes from Dahlgren et al. (1994), although they report only some taxa from belt transects near hard-bottom reefs off Wrightsville Beach. Dahlgren et al. (1994) reported belt transect data (Table 10) for several classes of echinoderms near the same reefs studies by Posey and Ambrose (1994). Dahlgren et al. (1994) observed higher densities of holothuroids (sea cucumbers) than we document in the Borrow Areas but similar densities of echinoids (sand dollars) and stelleroids (sea stars) (Table 10). The difference in sea cucumber densities is likely also a consequence of the finer sediments in the site studied by Dahlgren et al. (1994).

Our fish sampling revealed high densities of many fishes, dominated by species of substantial value to commercial and recreational fisheries of North Carolina and neighboring states. These fishes were actively feeding on the benthic macrofauna. Shrimp catches were low, although commercial shrimp trawling was being conducted in the immediate vicinity of all the Borrow Areas at the time of our sampling in late fall 1999. Many species of demersal fish of the estuaries of North Carolina and the Southeast generally are known to exit the sounds and estuaries in the fall on route to offshore sites for overwintering. The precise locations of these overwintering sites are not completely described, but our sampling indicates that this area off Bogue Banks is utilized in abundance during late fall by spot, croaker, pigfish, pinfish, silver perch, and sea mullet. Subsequent sampling during early February revealed emigration of these fishes to unknown locations as the weather became cooler. We have been unable to find any comparable semi-quantitative data on demersal fish abundances in shallow shelf habitats off the Carolinas; however, the densities observed in late November 1999 were judged by our boat captain, who has operated this trawl routinely for 25 years, to be similar to densities in spring, summer, and fall around Beaufort Inlet (J. Purifoy, pers. com.).

Our sampling is appropriately designed to serve as the fall baseline data set for the Borrow Areas in contemplation of a monitoring scheme to assess impacts of and recovery from the sand mining for beach renourishment. This includes not only the benthic macrofauna and demersal fishes but also the sediments on the sea floor. Because the macrofauna is so closely tied to sediment character, the evaluation of any changes in surface sediment character after mining is critical to interpreting the impacts on and recovery of benthic invertebrates and probably also fishes. The monitoring of the offshore Borrow Areas that we anticipate includes another analogous sampling in a spring season to provide baseline data for that season of the year. The standard deviations in our initial data set on infauna at the Borrow Areas suggest that we will have sufficient statistical power to detect about a 20% change in total infaunal density. Analyses of densities of individual families will be less powerful, but an ordination analysis on the entire community data set will have power similar to that of the test of total infaunal density.

In addition, baseline sampling of the nourishment sites and control sites on the beach itself would also need to be conducted prior to sand mining, but during the warm months when the intertidal beach is used by macrofauna. We already possess a substantial amount of data on abundances of intertidal beach invertebrates from all along Bogue Banks from 1997-1999 from studies conducted by L. Manning (unpubl.: see Table 11 for an example data set). This information can be incorporated into an assessment design to evaluate the potential consequences of the renourishment on the beach system, allowing contrasts between the multiple summers before renourishment and the summer or summers afterwards as one means of assessing impact and rate of recovery. In addition, sampling should be conducted at control sites that do not receive sand from the project to allow detection of interannual change unrelated to the project, but the design for this assessment will need to be finalized after the scope and timing of the project is defined.

5. Literature Cited

Carver, R.E., 1971. Procedures in Sedimentary Petrology. Wiley-Interscience, New York. pp. 49-127.

Dahlgren, C.P., M.H. Posey, and A.W. Hulbert. 1999. The effects of bioturbation on the infaunal community adjacent to an offshore hardbottom reef. Bull. Mar. Sci. 64:21-34.

Day, J.H., J.G. Field, and M.P. Montgomery. 1971. The use of numerical methods to determine the distribution of the benthic fauna across the continental shelf of North Carolina. J. Anim. Ecol. 40:93-125.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill, Austin, TX.

Peterson, C.H., H.C. Summerson, H.S. Lenihan, J. Grabowski, S.P. Powers, and G.W. Safrit, Jr. 1999. Beaufort Inlet Benthic Resources Survey. Report to the U.S. Army Corps of Engineers, Wilmington District Office, NC.

Posey, M.H. and W.G Ambrose, Jr. 1994. Effects of proximity to an offshore hard-bottom reef on infaunal abundances. Mar. Biol. 118:745-753.

Reed, A.J. and J.T. Wells. 2000. Sediment distribution patterns offshore of a renourished beach: Atlantic Beach and Fort Macon, North Carolina. Journal of Coastal Research (in press).

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levinsen, and W.A. Roumillat. 1992. A physical and biological monitoring study of the Hilton Head beach nourishment project. Report to the Town of Hilton Head Island, Hilton Head Island, SC, and the South Carolina Coastal Council, Charleston, SC. pp 159.

Warwick, R.M. 1988. The level of taxonomic discrimination required to detect pollution effects on marine benthic communities. Mar. Poll. Bull. 19:259-268.

Figures

Figure 1. Schematic representation of sampling sites (see Table 1 for precise coordinates of each site).

Figure 2. Mean (+standard deviation) abundances of macrofauna from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

Figure 3. Mean (+standard deviation) abundances of epibenthic fauna from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average two10 m^2 belt transects per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

Figure 4. Size frequency curves and histograms of composite bottom samples taken at treatment and control sites in Borrow Areas A, B-1, and B-2.

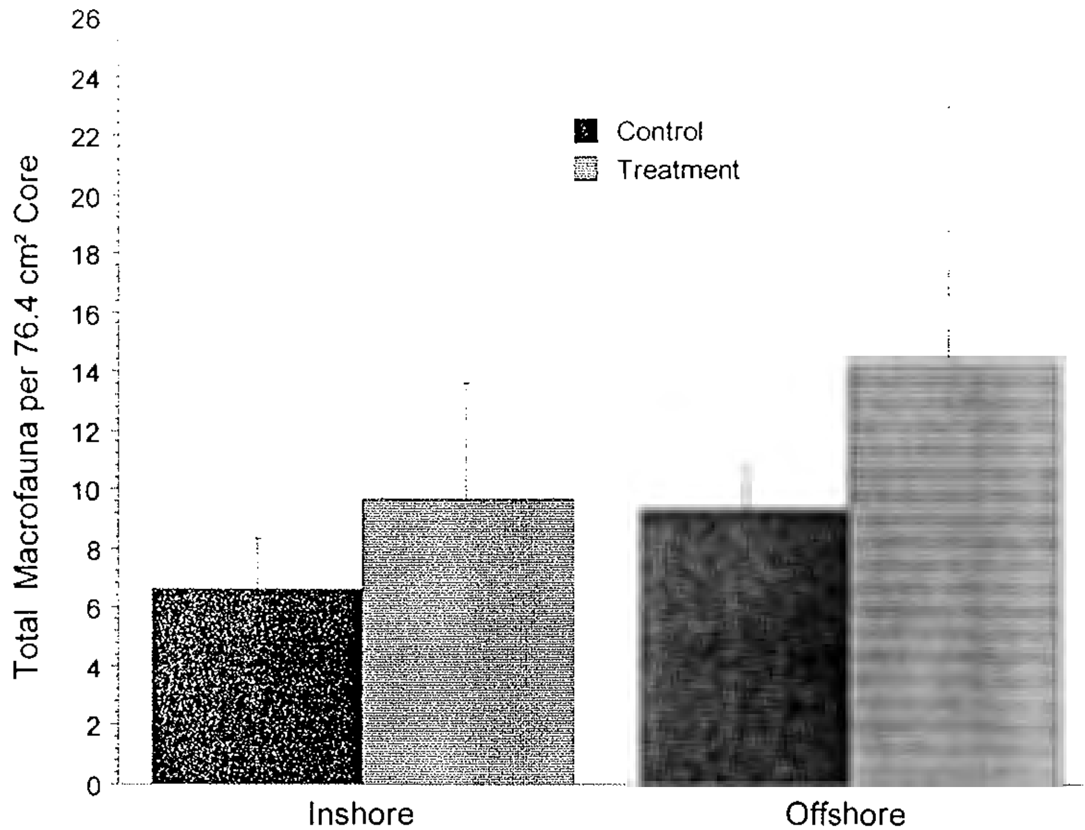


Figure 2. Mean (+standard deviation) abundances of macrofauna from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

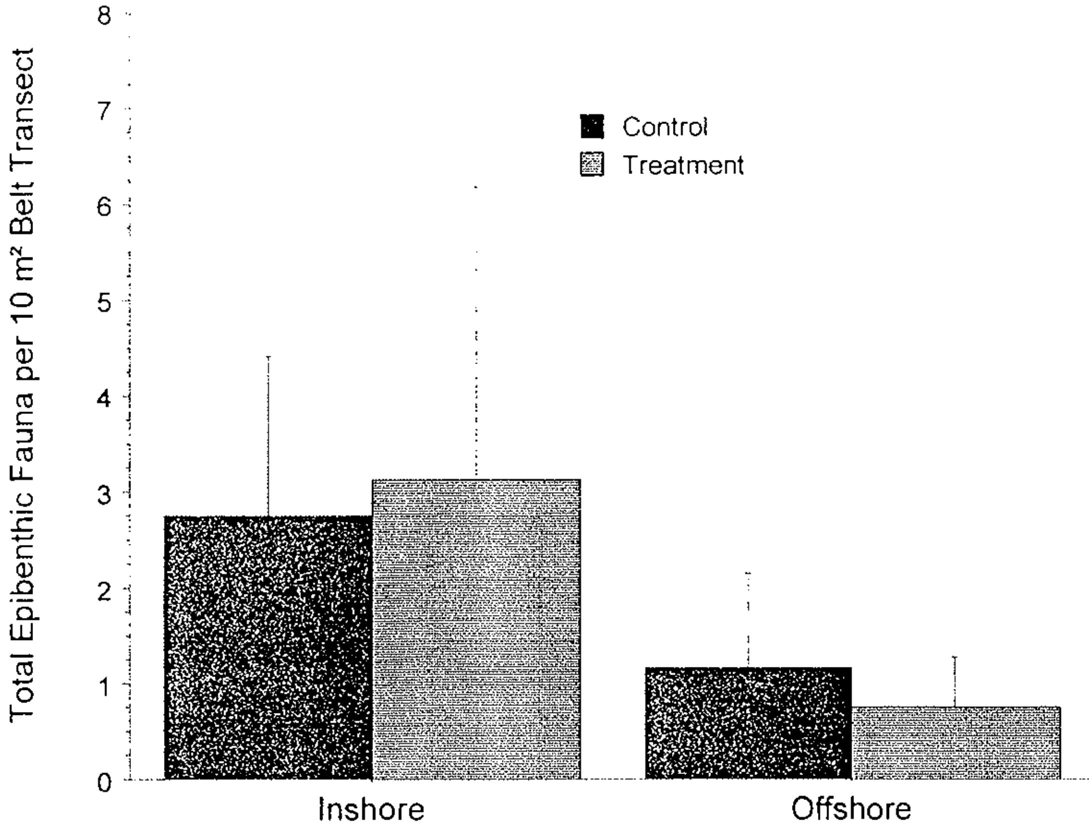
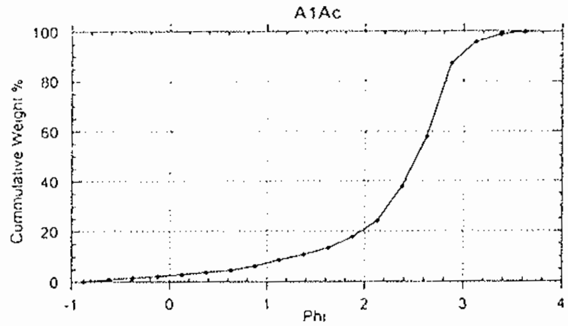
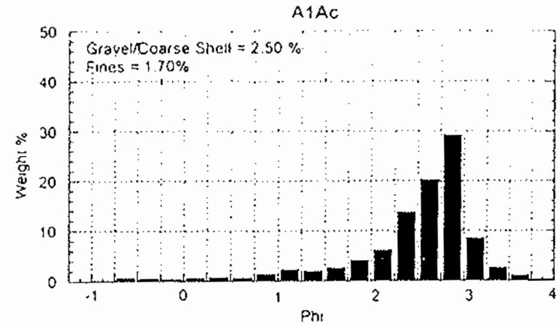
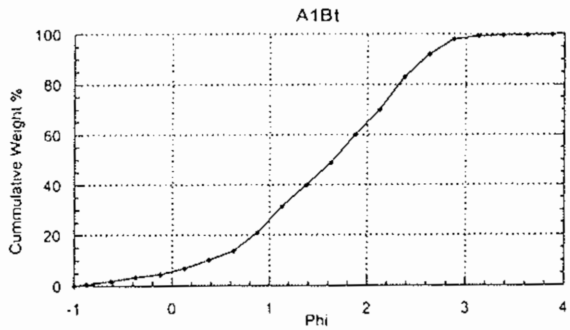


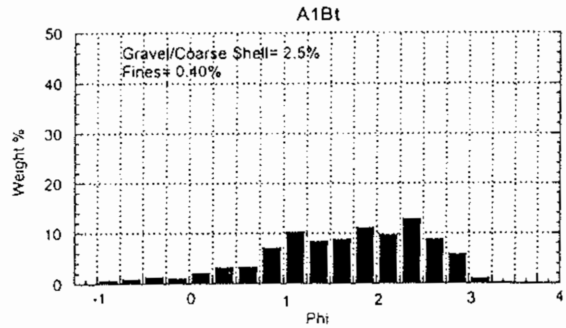
Figure 3. Mean (+standard deviation) abundances of epibenthic fauna from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average two10 m^2 belt transects per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

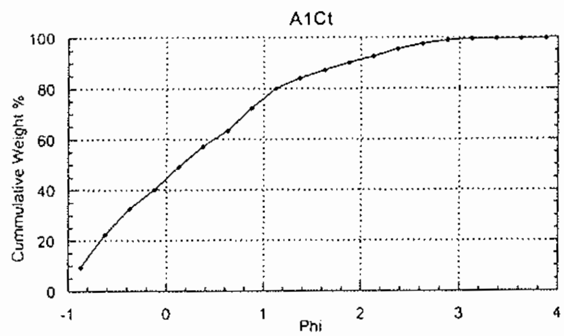
Figure 4. Size frequency curves and histograms of composite bottom samples taken at treatment and control sites in Borrow Areas A, B-1, and B-2.

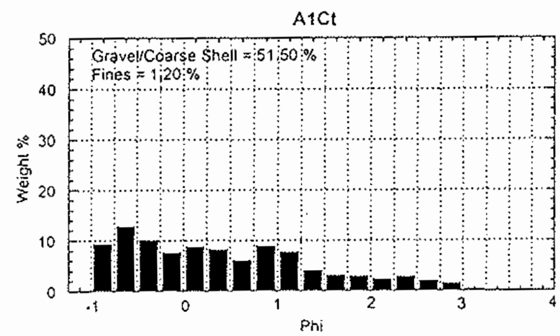

A1Ac
Cummulative Weight %
Phi

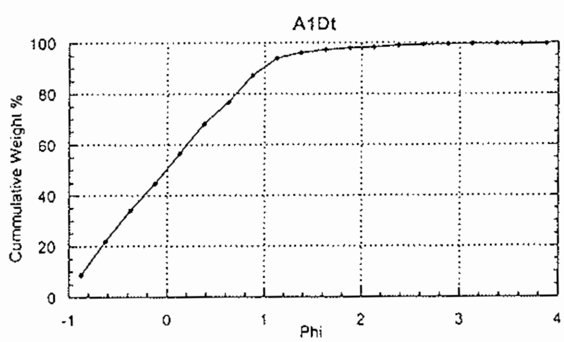

A1Ac
Gravel/Coarse Shell = 2.50 %
Fines = 1.70%
Weight %
Phi

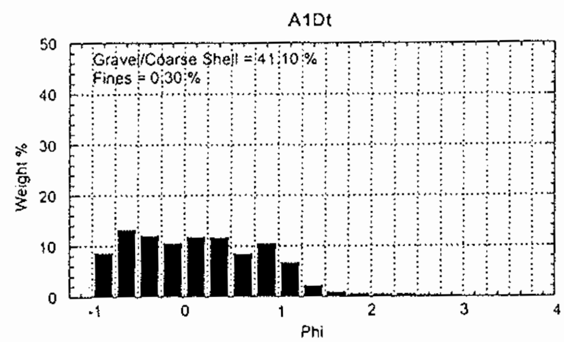

A1Bt
Cummulative Weight %
Phi

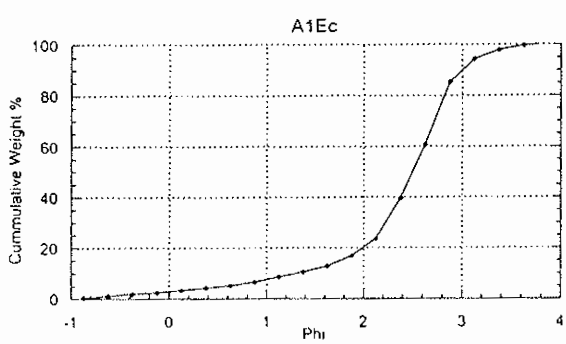

A1Bt
Gravel/Coarse Shell= 2.5%
Fines= 0.40%
Weight %
Phi

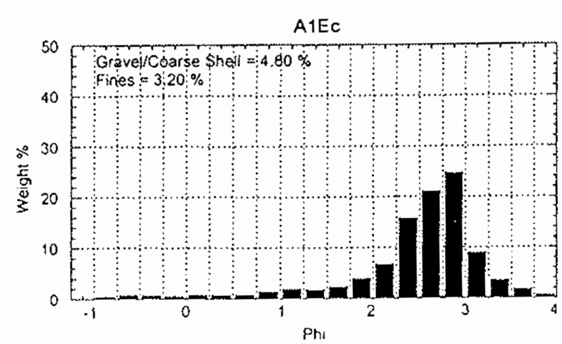

A1Ct
Cummulative Weight %
Phi

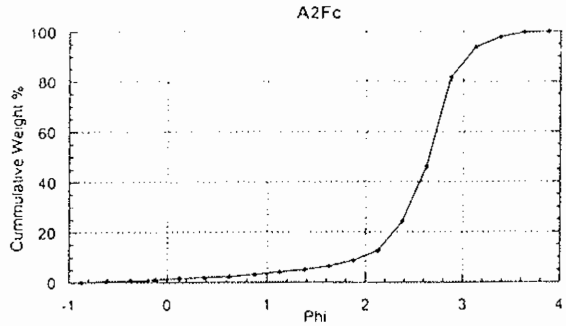

A1Ct
Gravel/Coarse Shell = 51.50 %
Fines = 1.20 %
Weight %
Phi

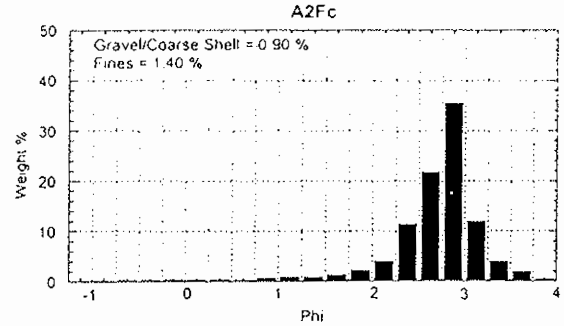

A1Dt
Cummulative Weight %
Phi

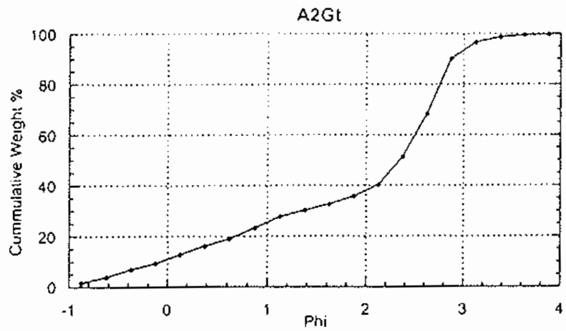

A1Dt
Gravel/Coarse Shell = 41.10 %
Fines = 0.30 %
Weight %
Phi

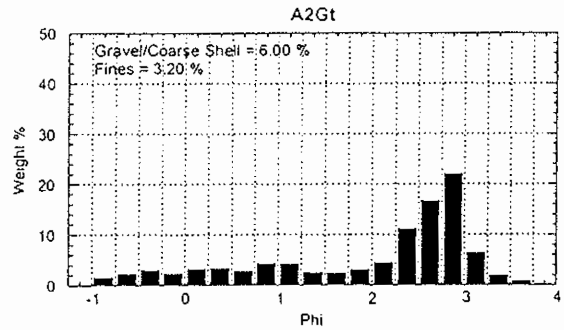

A1Ec
Cummulative Weight %
Phi

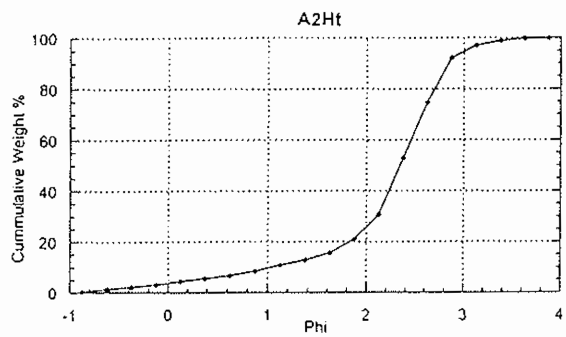

A1Ec
Gravel/Coarse Shell = 4.80 %
Fines = 3.20 %
Weight %
Phi

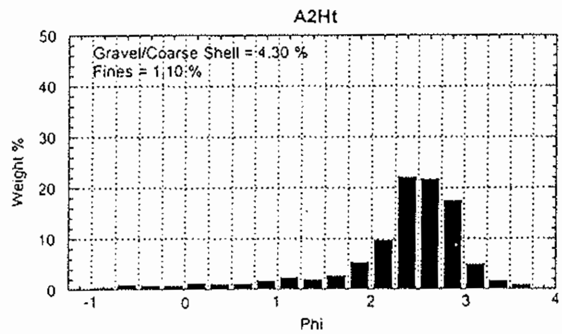

A2Fc
Cummulative Weight %
Phi

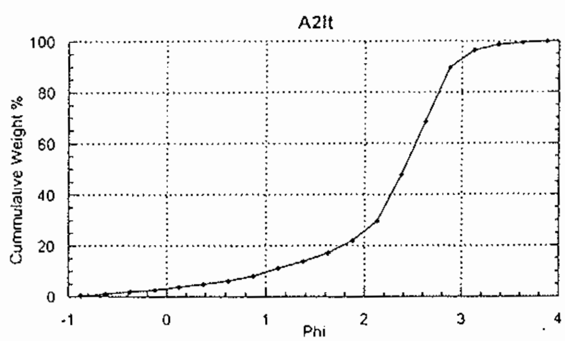

A2Fc
Gravel/Coarse Shell = 0.90 %
Fines = 1.40 %
Weight %
Phi

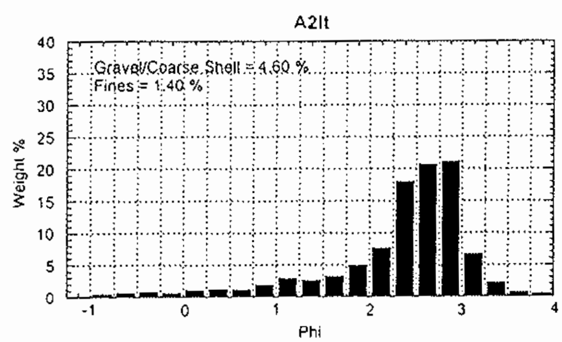

A2Gt
Cummulative Weight %
Phi

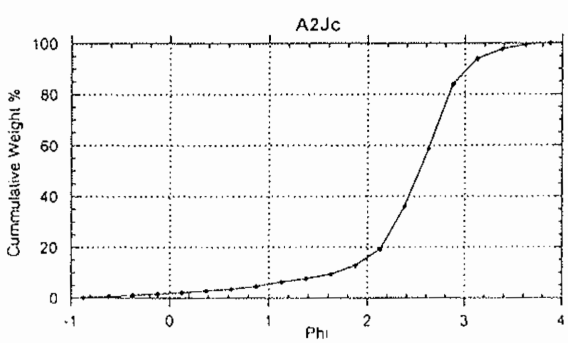

A2Gt
Gravel/Coarse Shell = 6.00 %
Fines = 3.20 %
Weight %
Phi

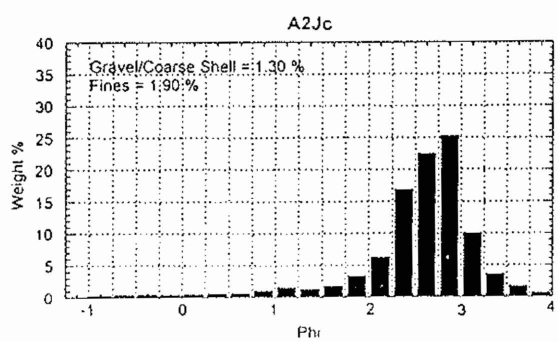

A2Ht
Cummulative Weight %
Phi

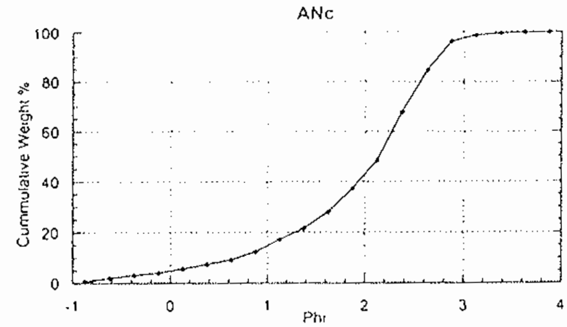

A2Ht
Gravel/Coarse Shell = 4.30 %
Fines = 1.10 %
Weight %
Phi

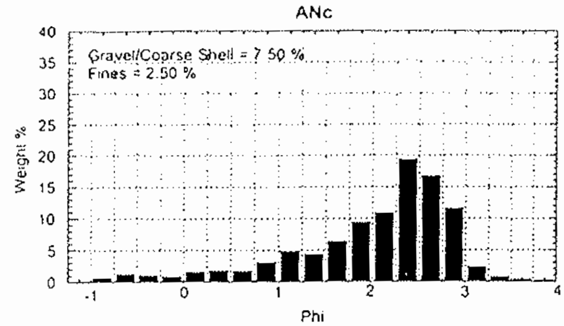

A2It
Cummulative Weight %
Phi

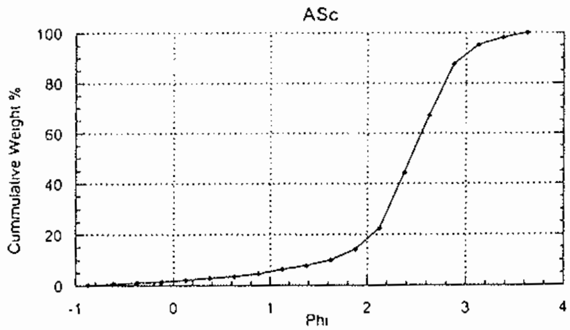

A2It
Gravel/Coarse Shell = 4.60 %
Fines = 1.40 %
Weight %
Phi

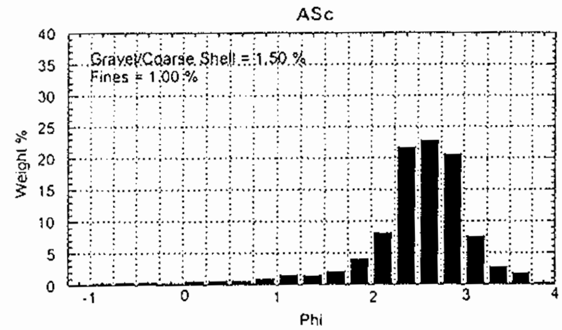

A2Jc
Cummulative Weight %
Phi

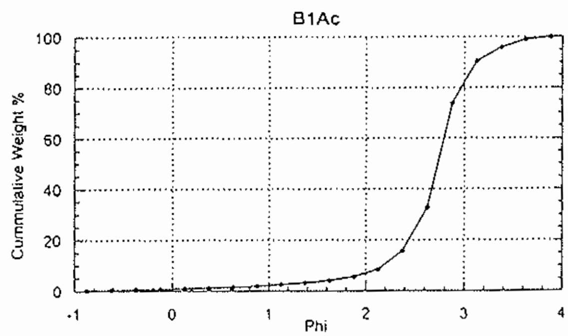

A2Jc
Gravel/Coarse Shell = 1.30 %
Fines = 1.90 %
Weight %
Phi

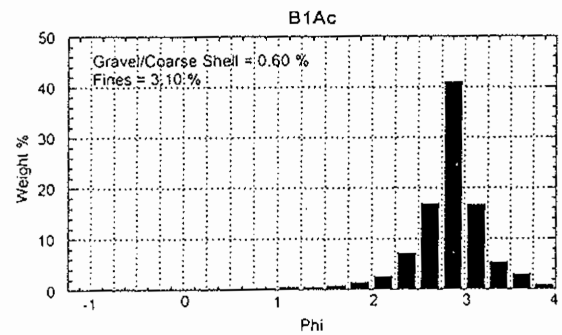

ANc
Cummulative Weight %
Phi

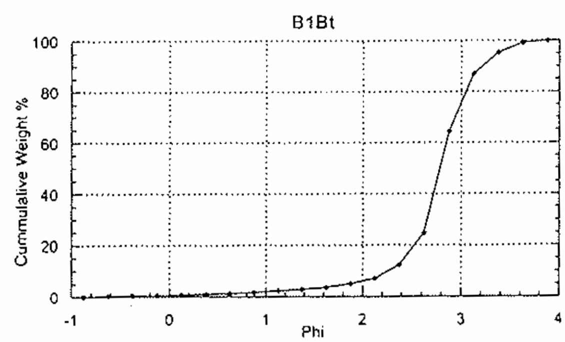

ANc
Gravel/Coarse Shell = 7.50 %
Fines = 2.50 %
Weight %
Phi

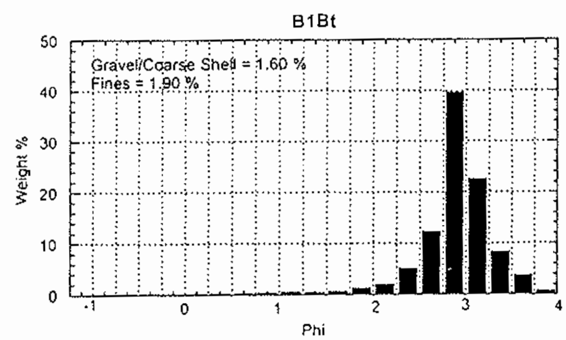

ASc
Cummulative Weight %
Phi

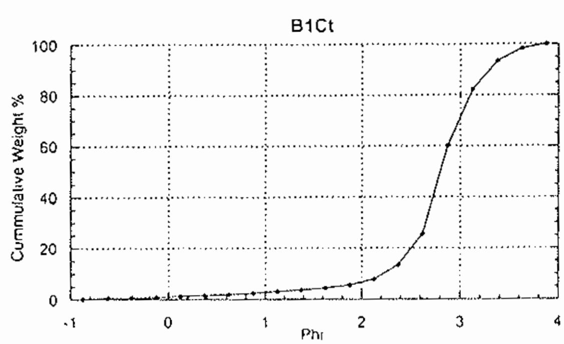

ASc
Gravel/Coarse Shell = 1.50 %
Fines = 1.00 %
Weight %
Phi

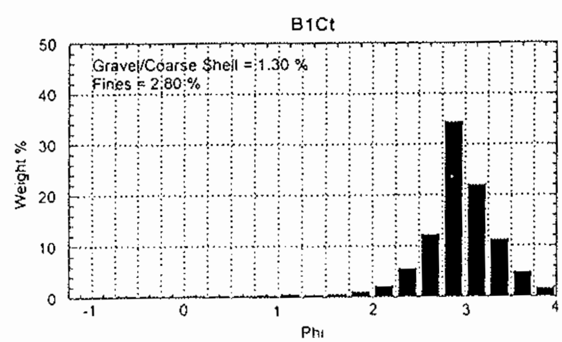

B1Ac
Cummulative Weight %
Phi

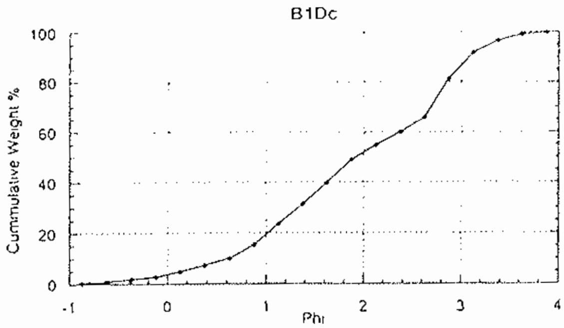

B1Ac
Gravel/Coarse Shell = 0.60 %
Fines = 3.10 %
Weight %
Phi

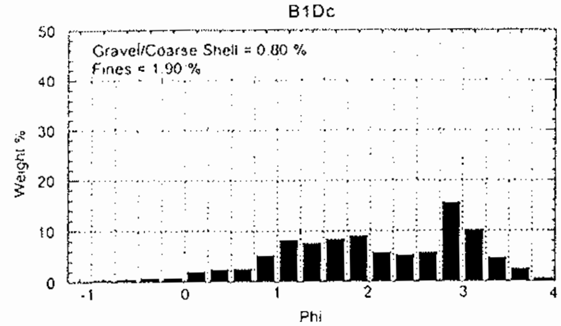

B1Bt
Cummulative Weight %
Phi

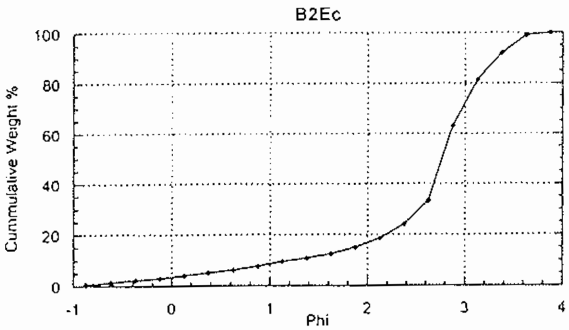

B1Bt
Gravel/Coarse Shell = 1.60 %
Fines = 1.90 %
Weight %
Phi

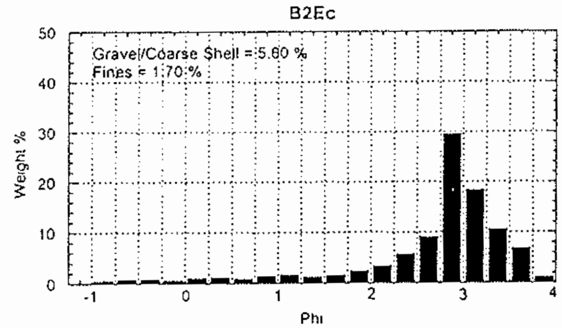

B1Ct
Cummulative Weight %
Phi

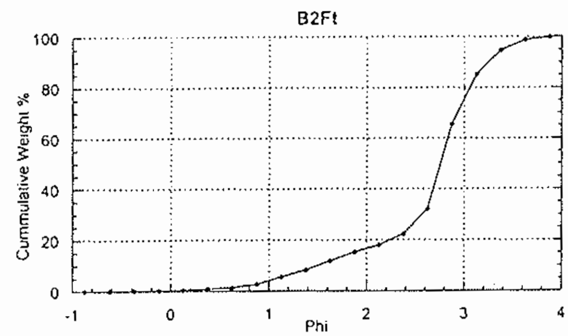

B1Ct
Gravel/Coarse Shell = 1.30 %
Fines = 2.80 %
Weight %
Phi

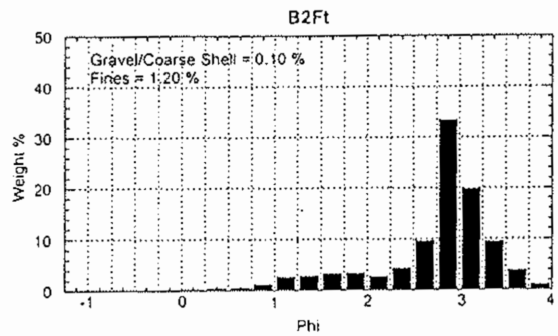

B1Dc
Cummulative Weight %
Phi

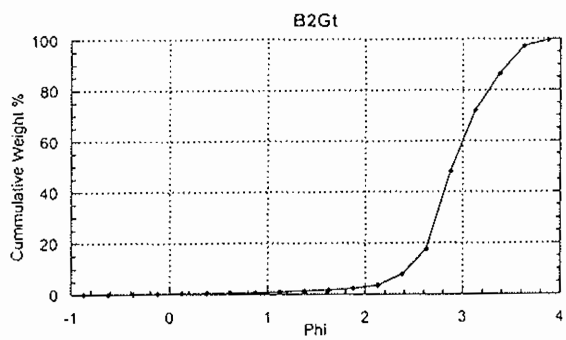

B1Dc
Gravel/Coarse Shell = 0.80 %
Fines = 1.90 %
Weight %
Phi

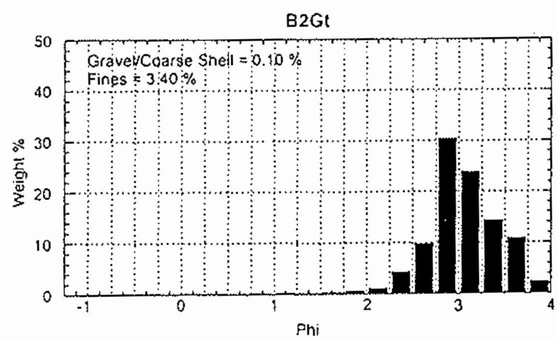

B2Ec
Cummulative Weight %
Phi

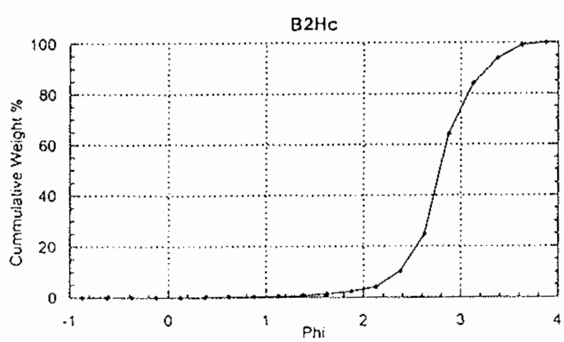

B2Ec
Gravel/Coarse Shell = 5.60 %
Fines = 1.70 %
Weight %
Phi


B2Ft
Cummulative Weight %
Phi


B2Ft
Gravel/Coarse Shell = 0.10 %
Fines = 1.20 %
Weight %
Phi


B2Gt
Cummulative Weight %
Phi


B2Gt
Gravel/Coarse Shell = 0.10 %
Fines = 3.40 %
Weight %
Phi


B2Hc
Cummulative Weight %
Phi

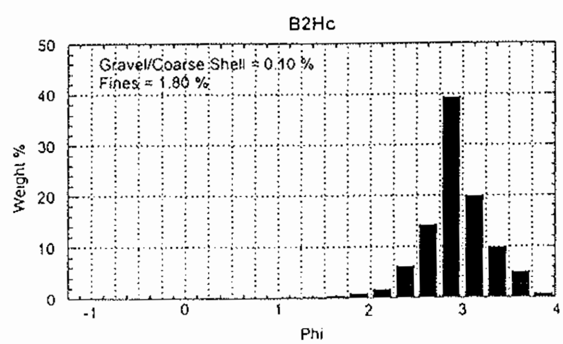

B2Hc
Gravel/Coarse Shell = 0.10 %
Fines = 1.80 %
Weight %
Phi

Table 1. Actual coordinates (in degrees - decimal minutes) of sites sampled in and adjacent to proposed sand Borrow Areas off Bogue Banks, NC. Sites are plotted on Figure 1.

Borrow Area 1		Control	
A1Bt		**A1Ac**	
N 34° 39.333'	W 76° 53.625'	N 34° 39.333'	W 76° 52.875'
A1Ct		**A1Ec**	
N 34° 39.333'	W 76° 54.375'	N 34° 39.333'	W 76° 55.875'
A1Dt		**A2Fc**	
N 34° 39.333'	W 76° 55.125'	N 34° 38.917'	W 76° 52.875'
A2Gt		**A2Jc**	
N 34° 38.917'	W 76° 53.625'	N 34° 38.917'	W 76° 55.875'
A2Ht		**ANc**	
N 34° 38.917'	W 76° 54.375'	N 34° 40.067'	W 76° 54.175'
A2It		**ASc**	
N 34° 38.917'	W 76° 55.125'	N 34° 38.183'	W 76° 54.375'
Borrow Area B-1*		**Control**	
B1Ct		**B1Ac**	
N 34° 41.06'	W 76° 49.652'	N 34° 41.261'	W 76° 45.706'
B1Bt		**B1Dc**	
N 34° 41.227'	W 76° 47.841'	N 34° 40.862'	W 76° 51.819'
Borrow Area B-2*		**Control**	
B2Ft		**B2Ec**	
N 34° 40.545'	W 76° 54.374'	N 34° 40.797'	W 76° 52.187'
B2Gt		**B2Hc**	
N 34° 40.245'	W 76° 56.44'	N 34° 39.891'	W 76° 58.752'

* sampled at 35' contour determined by standardizing for 37' at 34°41.023'N 34°49.702'W

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

MEMO May 18, 2000

TO: Dr. Charles Peterson and Dr. John T. Wells

FROM: Dr. Timothy Kana

RE: Bogue Banks Beach Restoration Project
Environmental Monitoring Report and Draft EIS Comments

Thank you for forwarding your draft final report dated May 10, covering the fall 1999 environmental surveys and which consisted of 7 pages of text, 4 figures, 11 tables, and appendices. We appreciate your work in getting this first sampling completed. I am writing on behalf of the CSE Baird and Stroud Engineering.

We have reviewed your draft and offer the following comments, questions, and recommendations for revisions. I am enclosing comments from NCDENR received on May 12 concerning our draft EIS (which contained your preliminary report of 28 January as Appendix C). Some of DENR's comments are related to benthic impacts. Therefore, I would like your help in addressing certain items (referenced below). We need to receive your revised final report as soon as possible, preferably by June 1. Following are our comments.

Comments from CSE Baird and Stroud

1) Please see the attached memorandum dated 20 January for guidance and incorporate those revisions as applicable.

2) We want you to re-organize "1. Background" because your draft mixes recommendations, sample design, methods, and opinions, and does not reference previous related studies. Divide the information appropriately in the following headers/subheaders:

   Introduction/Purpose (i.e., done in anticipation of Bogue Banks beach renourishment project under contract to county; to address environmental issues of concern quantitatively; represents first sampling of four planned; intended to characterize existing conditions before the project; why this is important)

   Previous Benthic Studies (reference literature)
   – Site specific to Bogue Banks area (summarize prior results and findings)
   – Related regional studies (summarize results and findings)
   The results and findings should specify for the respective studies rates of recovery or a finding of no recovery, if that is the case.

CSE

Sample Design (summarize the overall sample design noting how your study goes beyond previous work to sample demersal fish and assess potential impacts and provide baseline conditions) [Methods (subheader), Results (subheader), Discussion (subheader) to follow logically here]

Conclusions and Recommendations for Future Monitoring (This is where the "recommendations" in your "1. Background" should be placed.)

3) *RE: Literature Review* – We assume that you can draw on your extensive experience and previous studies to provide a synopsis of the relevant literature on benthic impacts (offshore borrow areas and nourishment areas) and rates of recovery for similar sites, noting which studies may be at odds with Reilly and Bellis (1983) or Peterson et al. (1999), etc., and what factors may have produced different results (e.g., too much mud, high frequencies of sand scraping, etc.). Your draft final report does not provide context or reflect what you know about the subject.

NOTE: If we are going to do a nourishment project along Bogue Banks, the county (and regulatory agencies) are looking to all of us for recommendations on how to do it right. The question for us is not whether to nourish but how to do it with the least environmental impact. The EIS states that there will be direct impacts to organisms and many will be killed. This is unavoidable. Your review of the literature should provide appropriate biological context. What studies proved rapid (<1 year), slow (<10 years), or no recovery (>10 years)? How will our sampling design isolate the effects of dredging the bottom from the effects of seasonal climate change, normal trawling operations through the area, etc.? What are the life cycles of the dominant species found in the proposed borrow areas or on the beach?

4) *RE: Methodology* – We suggest that you begin Section 2A by stating that replicate cores (for benthics) were obtained at 20 stations, ten of which are within proposed borrow areas A, B1, and B2, and ten in nearby control areas. At each station, ten replicate samples were collected to provide a statistical sampling following established protocols (?ref?). Thus, a total of 200 individual samples were obtained and analyzed (results in appendices). Leading the section with "200 samples" may suggest to casual reviewers that we sampled 200 sites. The only relevance of this number is whether ten replicates per station and the number of stations are representative and adequate to characterize the area.

CSE

Under demersal fish (or related literature review), you should note that no protocols exist for such sampling in connection with nourishment projects since none have been done in North Carolina (or regionally, if that is true). The sampling plan is therefore based on what? You will note in certain agency comments as well as your own (early in our planning for the project) that there are concerns for the fish. Are these concerns based on any previous data? If so, we should cite them. If not, we should emphasize that this sampling is unprecedented in order to reinforce our claim that we are serious about quantifying environmental impacts and reducing the amount of damage as much as possible.

6) *RE: Statistical Analysis* – Please provide statistical measures of species diversity, species richness, etc., as we requested in our January 20 comments on the interim report, so that these data can be normalized and compared objectively with future data sets. It would be useful to provide abbreviated tables showing summaries by higher taxa (e.g., bivalves, gastropods, amphipods, etc.) and corresponding histograms similar to Figure 2.

can't do power analysis

It is premature to indicate your ability "to detect a 20 percent change" in total infaunal density. Even if this were true, it is misleading because totals can be obtained by many combinations of species. We assume some species are better food sources than others, if for no other reason than their food mass is greater. Our hope should be that a diverse suite of species returns rapidly. Is there any literature that states what benthic species are more desirable? If so, can we do anything to encourage recruitment of these species after dredging? Given the exceedingly high standard deviations for most species and the possibility of ten-fold differences in seasonal abundance (according to many other studies), we need to be careful about setting standards for comparison.

7) *RE: Results* – Please provide summary pie charts or histograms of species composition (sorted by higher taxa) at the borrow and control sites to facilitate review by the agencies and aid in future comparisons. The figures in your draft final report are inadequate.

Provide reference to the sediment data that CSE Baird/Athena Technologies collected in and around the borrow areas (text section 3.16 and appendix E of the draft EIS) and note how these results are similar to or different from your data.

We would like to have more "examples" of beach/intertidal data included in your report from Lisa's work. In particular, it will be helpful to have some of her comparative data at select stations showing abundances during different seasons or pre and post scraping. The results section is the appropriate place to reference it. We realize that these data are still being analyzed, but some respondents in the agencies appear to be referencing this work in their comments.

8) *RE: Discussion* – The discussion should lead with a summary and comparisons of what is on the bottom rather than what is eating the bottom. Then it should progress logically from macrofauna to epifauna to the fish. Where comparisons with other studies are made, provide specific results in the text [e.g., Posey and Ambrose (1994) found (species) diversity __ percent higher than your study].

Why was species abundance generally higher in the proposed borrow areas than the control areas? From an ecological standpoint, which borrow areas are preferable for dredging? How do these benthic sampling results correlate with surficial grain size? Areas B1 and B2, after dredging, will tend to expose fine sand whereas area A will tend to leave coarser shelly sand and mud. Which is preferable for benthic recovery?

Will newly exposed substrate recolonize after dredging, and if so, what can we do to accelerate recolonization? Is there a difference between recolonization after hopper dredging versus traditional cutterhead dredging? Will a shallow cut (1-3 ft thick) favor recolonization compared to a deep cut (~10 ft thick)? Your report needs to relate the sampling results to the nourishment project and offer practical guidance to the county as well as the regulatory agencies.

Your assessment of demersal fish is important. If we dredge A or B, does that mean the fish will not come back next year? What is known about migratory patterns of fish over borrow areas? What factors cause fish to move on to other areas? Do benthic or fish populations fluctuate by orders of magnitude from season to season because of life-cycle timing, timing of fish grazing, temperature, rainfall/runoff, or trawling operations? How will one-time dredging modify these cycles? How would yearly dredging (same general area) modify these cycles? If there will be impacts to the local fishery due to dredging A and B, will it be proportional to the area dredged? What is the natural variation in fish populations and will the impact from nourishment be detectable? If it cannot be quantified, then so state.

You refer to "other gut data" but give no reference. Also, you refer to fish "feeding was active and intense" in late November without defining intense. In the third paragraph of the discussion, you refer to "high densities" of fish of "substantial value" without defining high density or substantial.

9) *RE: Conclusions and Recommendations* – To the extent you can apply your extensive experience and results of the first sampling analyses, we ask you to draw conclusions to assist the agencies in their review. If you know that no amount of sampling can prove cause and effect of dredging for any aspect of the work, please state. Similarly, if you know there will be unrecoverable impacts, please specify what they will be so we are sure to include them in the EIS.

   Your recommendations for follow-up sampling are good and should be consolidated at the end. I encourage you to write to the Carteret County Council immediately and emphasize to them how important a summer sampling will be for the EIS. This is an opportunity for you to fund students over the summer and help the county keep the project planning on track.

RE: Formatting – Please resubmit the text with minimum one-inch margins and bold the **HEADERS** and **Subheaders**.

Agency Comments (see attached comments)

NC Wildlife Resources Commission (dated 27 April)

- Please provide us with a copy of the Donaghue paper and Peterson et al. paper referenced in the comment (4th paragraph). We would appreciate your response to this concern.
- Will nourishment by dredge from A or B introduce spoil onto the beach that might attract foraging shorebirds?

NC Division of Marine Fisheries (dated 18 April)

- As expected, they would like to see one year of field surveys. Can you provide at least one year's worth of data for representative intertidal sites such as you reference for the 1997-1999 data collections by Lisa?

NC Division of Water Quality (dated 10 April)

- They prefer borrow area A as the exclusive sediment source. Is this consistent with your assessment of benthic impacts? (Would overall impact be greater or less if we reduce the number of borrow areas, but necessarily dig deeper?)

CSE

Finally, we would also like to receive a copy of the following references you cited: Day et al. (1971), Peterson et al. (1999), Warwick (1988). If you or Lisa Manning have some related papers on intertidal beach communities, we would also like to have them for review. The only paper we have from your group is Hickerson and Peterson (1992).

Please call if you have any questions about these comments. If you would like to discuss these comments with the county, I will be happy to come up on short notice and lend support. Your work is a key element of the EIS. This is an opportunity to showcase the research that UNC is doing and to demonstrate its relevance to the community. That is why we encourage you to make these changes.

cc: Carteret County
Stroud Engineering

Attachments

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1890
WILMINGTON, NORTH CAROLINA 28402-1890

IN REPLY REFER TO

February 28, 2001

Regulatory Division

Received
28 Feb 01

Carteret County
C/o County Manager
Courthouse Square
Beaufort, North Carolina 28516

Dear Sir:

I am replying in reference to you application for a Major CAMA Permit for Bogue Banks Beach Nourishment dated January 24, 2001. We have reviewed the application and accompanying EIS. The EIS refers to project construction and maintenance activities that would be conducted by the individual local governments within Carteret County. Therefore, to insure that permit conditions and requirements are associated with the appropriate local governments, we recommend that you amend your application by including the local governments as co-applicants. We can still utilize your EIS and cumulative impacts information to address the combined projects.

I am considering your application as incomplete until I receive a reply to this letter clarifying the applicant, who is responsible to insure that the terms and conditions of any authorization(s) are met. We would next want to conduct a scoping meeting with all the co-applicants and the appropriate resource agencies as quickly as possible to expedite your application. The project manager for this activity is Mr. Mickey Sugg of my staff and he can be reached at (910) 251-4811.

Sincerely,

Keith A. Harris
Chief, Wilmington Regulatory Field Office

APR-02-2001 10:38 FROM IMS TO 88037999481 P.02

cc: Town of Pine Knoll Shores.

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Institute of Marine Sciences
252-726-6841
FAX: 252-726-2426

The University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, North Carolina 28557

2 April 2001

Dr. Tim Kana
Mr. Bill Foreman
CSE-Baird
P.O. Box 8056
Columbia, SC 29202-8036
Fax-(803)-799-9481

RECEIVED
APR 02 2001
11:50 am

Dear Tim and Bill:

I was asked at the end of last week to serve as advisor to the NC Division of Marine Fisheries of DENR on what should be contained in the monitoring plans for the Pine Knoll Shores and other beach nourishment projects. It appears to me that continuing to work on the actual monitoring project as an ecological collaborator with you and your engineers would represent a conflict of interest. Consequently, I felt compelled to send you this note to indicate that I do not wish to be engaged in the monitoring of Bogue Banks.

I can suggest other benthic ecologists who would be capable of conducting the ecological monitoring. They include: Dr. Bill Kirby-Smith of the Duke University Marine Lab, Dr. Terry West of the Biology Department of East Carolina University, and Dr. Martin Posey of the Department of Biological Sciences of UNC-W.

I am pleased to make available to you or to the person with whom you contract to do this work any information that we have on the benthic and fish biology of Bogue Banks. As you know, much of the information is a raw data form, but some final copies of reports and a lot of raw data are at your disposal.

Sincerely,

Pete

CH Pete Peterson
Alumni Distinguished Professor

Fax

To: Timothy W. Kana, Ph.D. **From:** Stephen R. Florey

Of: Coastal Science & Engineering, LLC

Fax: 803-799-9481

Phone: 803-799-8949

Pages:

Date: 4-18-01

Comments:

Dear Dr. Kana:

Please find attached the draft proposal for the Bouge Banks Beach Nourishment project. The sampling and analysis are what we have performed in South Carolina at the direction of Bob Van Dolah for numerous beach nourishment projects. We can accommodate any sampling plan that the NC Marine Fisheries wants us to perform, but this should at least be the minimum permit requirements for monitoring. Please call me to discuss any question you might have.

Sincerely,

Stephen R. Florey

Coastal Science Associates, Inc.
P.O. Box 11687
Columbia, SC 29211
Ph.: 803-256-3081
Fax: 803-256-7475

CSAi COASTAL SCIENCE ASSOCIATES, INC.
P.O. Box 11687 • Columbia, South Carolina 29211 • 803-256-3081 • Fax 803-256-7375

April 18, 2001

Mr. Tim W. Kana, Ph.D.
Coastal Science & Engineering, LLC
P.O. Box 8056
Columbia, South Carolina 29202

RE: **Environmental Services Proposal**
Bouge Banks Beach Restoration
Bouge Bank, North Carolina
CSA*i* Proposal No. 01-132-EA

Dear Dr. Kana:

Coastal Science Associates, Inc. (CSA*i*) is pleased to submit this proposal to Coastal Science & Engineering, LLC (CSE) to perform the above referenced study as outlined in your letter dated April 6, 2001. This agreement is made as of April 18, 2001 by and between CSE, LLC (Client) and CSA*i*.

Background

The intent of the proposed ecological study is to assess the existing biological conditions of the of benthic invertebrates at the proposed offshore borrow areas for the Bouge Banks Beach Renourishment Project, located in Carteret County, North Carolina.

The ecological study will include benthic sampling and analysis from offshore borrow areas and near by controls. CSA*i* proposes to only use 50% of the stations previously sampled by the Institute of Marine Service, UNC. Benthic sampling will also be conducted at the beaches that have been proposed to be nourished. Benthic samples will also be collected on one of the adjacent un-nourished beaches to act as a control.

Otter trawls may also be performed to assess the demersal fish and invertebrate populations around the borrow areas and along the beach. CSA*i* recommends that four sampling events be performed to assess the recovery of the borrow sites and beach nourishment activities. Two sampling events should be conducted prior to the to dredging (Spring-fall) event, and two sampling events should be conducted after the nourishment activities have been completed (spring-fall). Based on the information provided, CSA*i* proposes the following scope of services:

TASK 1. Field Collection of Benthic Samples

The proposed borrow area to be sampled is located approximately 2 miles south of Salter

Path/Indian Beach, Carteret County, North Carolina. The depths in the sampling area range from 35 feet at the inshore areas, to 47-49 feet in the offshore areas. The proposed sampling will produce a total of 100 core samples (50% of the stations originally sampled by UNC in Fall 1999) from both the offshore borrows areas and control areas. Cores will be collected by divers using a cylindrical corer 9.9 cm in internal diameter. All station locations will be selected form the previous study performed by the Institute of Marine Sciences, UNC. All stations will be located by Differential Global Positioning System (DGPS). All benthic samples collected will be sieved in the field through a 0.5 mm stainless steel sieve bucket. All sediment and organisms retained in the bucket will be preserved in 10% buffered formalin with rose bengal stain.

In addition, four stations will be sampled on the proposed beach to be nourished. Two stations will be sampled within the project area and two will be sampled outside the project area to act as controls. A total of twelve corers will be collected along the beach. Every attempt will be made to perform the sampling at the same station location as the Lisa Manning report (NC Sea Grant, April 2000).

Task 2. Laboratory Methods

Once samples have been transported to the laboratory, core sediment samples will be carefully re-sieved through a 0.5 mm stainless steel sieve bucket and screen. This sediment reduction will expedite the sorting process. The remaining sediments and organisms will be placed in labeled, double-ziplock bags and initially preserved in 10 percent buffered formalin solution with Rose Bengal stain. Organisms will be allowed to harden for 48 hours and then transferred to 80 percent ethanol alcohol. After the hardening period, the organisms will be placed in sorting trays and submersed/diluted in de-ionized water to minimize any volatile alcohol vapor production during identification.

Organisms will then be sorted and enumerated in the laboratory and identified to the lowest possible taxon (species level in most cases) with the aid of a variable power dissecting microscope (Bausch & Lomb) and/or a compound microscope (Swift or Bristol). Organisms will be identified by an experienced biologists utilizing various identification keys for organisms expected to be collected (e.g., Abbott, 1974; Bousfield, 1965; Bynum and Fox, 1977; Dover 1979; Fauchald, 1977; Fox and Bynum, 1975; Gosner, 1978; Heard, 1982; Kaplan, 1988; Morris, 1975; Ruppert and Fox, 1988; Uebelacker and Johnson, 1984; Williams, 1984). Species identified for each station will then recorded on a laboratory bench sheet (per EPA, 1989).

Task 3. Data Analysis

Benthic data from the borrow area and control site will be statistically compared to evaluate changes in faunal abundance, and number of species present among sites and over time.

Analysis will include variance testing (ANOVA), or the non-parametric Kruskai-Wallis test, as necessary. Comparison among specific treatment groups will be completed using the Student-Newman-Keuls test (parametric and unparametric designs). Diversity indices will be computed for each area (all samples combined) using Shannon's diversity index (H), species richness (SR) and evenness (J). Changes in overall community composition among sites and seasons can be evaluated using a proportional similarity coefficient (Bray-Curtis) with flexible sorting strategy and a cluster intensity (ß) of -0.25.

Task 4. Reporting

Report for each sampling event, including details of field date collection, data presentation, analysis, and conclusions/results will be submitted to NC marine Fisheries within 120 days following completion of the field work portion of the work.

Response to CSE monitoring proposal of 25 April 2001 for Bogue Banks Nourishment Project

By

Charles H. Peterson, PhD

9 May 2001

This proposal fails to incorporate almost all of the substantive recommendations presented in the 5 April meeting of Mike Marshal, Rick Monaghan, Pete Peterson, Tim Kana, and Bill Foreman. Specifically, here are the shortcomings:

(1) There is no sampling of the surf fish by beach seine, comparing abundances, gut fullness, and gut prey contents in nourished and control areas during the summer season following nourishment. If benthos does not recover during that first summer, then this fish utilization monitoring should be continued until recovery has been demonstrated.

(2) The numbers of samples are presented for the benthic sampling of the offshore mining site and the numbers of sampling dates (4), but absolutely no statistical power analysis is provided to justify what magnitude of impact could be detected from such a sampling. Absent power to detect important effects, monitoring is less than worthless because it falsely implies an ability to assess impacts when the exercise is inconclusive by design. This analysis can be based on variability information available in the earlier IMS-UNC study.

(3) The spring sampling date (April) originally proposed for pre-project sampling of offshore benthos has already passed. So is this proposal designed for a winter 2002-3 project? This is unresolved.

(4) Beyond mention of 4 beach stations to be drawn from the Lisa Manning sites, there is no adequate design provided to describe the methodology of the intertidal beach sampling. Included in this absence of information is a total lack of attention to power of the design to detect effects of various magnitudes. Thus, this sampling design like that of the offshore benthic sampling fails to meet the standards of excellence of the discipline and may be less than useless to understanding impacts and recovery.

(5) The follow-up sampling is proposed for two sampling dates independent of whether recovery has been demonstrated. This is inappropriate, failing to continue monitoring if biological resources are still impacted.

RECEIVED
MAY 18 2001
CSE, LLC

Revised Environmental Services Proposal:

Bogue Banks Beach Restoration Project
Bogue Banks, North Carolina

Submitted to:

Coastal Science & Engineering PLLC
804 Arendell Street
Morehead City, NC 28557

Submitted by:

Coastal Science Associates, Inc.
328 second Avenue North
Jacksonville Beach, FL 32250

28 May 2001

Background

The purpose of this proposed ecological study is to assess the existing biological communities of benthic invertebrates and fish at the proposed Bogue Banks Beach Renourishment Project, located in Carteret County, North Carolina. This is a revised proposal, based on a public and agency meeting held May 11, 2001, at which recommendations were given from the UNC Institute of Marine Sciences (IMS), the U.S. Fish & Wildlife Service, the National Marine Fisheries Service, the U.S. Army Corps of Engineers, the North Carolina Department of Environment and Natural Resources, North Carolina Coastal Federation, and others. The general recommendation was to put more emphasis into fisheries surveys and impacts, and less into macroinvertebrate species identification.

The ecological study will include benthic sampling and analysis for proposed borrow and nourishment sites, and fish sampling and analysis for proposed nourishment sites, including reference sites. CSA*i* proposes to use up to 50% of the stations previously sampled by IMS (2000). Two sampling events (pre- and post-) are proposed in the first year, with an additional sampling event for each of the next three years. The scope of work is as follows.

TASK 1. Field Collection of Benthic Samples

The proposed borrow area to be sampled is located approximately 2 miles south of Salter Path/Indian Beach, Carteret County, North Carolina. The depths in the sampling area range from 35 feet at the nearshore areas, to 47-49 feet in the offshore areas. **A power analysis will be conducted following a review of previous studies conducted by IMS and based on preliminary sampling.** Assuming individual sample core size is appropriate, this analysis will determine the correct sample number to obtain an estimate of mean density of a species population within +/-10%. The proposed sampling will produce a useful number of core samples (50% of the stations originally sampled by UNC in Fall 1999) from both the offshore borrow areas and control areas.

All borrow station locations will be selected from the previous study performed by IMS. In addition, four stations will be sampled on the proposed beach to be nourished. Two stations will be sampled within the project area and two will be sampled outside the project area to act as references/controls. The number of cores will be determined in the above preliminary sampling. Every attempt will be made to perform the sampling at the same station location as in the Lisa Manning report (NC Sea Grant, April 2000). All stations will be located by Differential Global Positioning System (DGPS). Cores will be collected by SCUBA diving or wading using a four inch PVC cylindrical corer with an internal diameter of 9.9 cm (sampling an area of 77 sq cm). Benthic samples collected will be sieved in the field through a 0.5 mm stainless steel sieve bucket. All sediment and organisms retained in the bucket will be preserved in 10% buffered formalin with rose bengal stain.

Nearshore fish sampling will also be conducted at the four beach sample sites. This will consist of three hauls of a 100' beach seine at each of the sites. Species, numbers, and life stage will be field-determined to the extent possible; fish requiring further examination will be subsampled and preserved in 10% buffered formalin. A subsample of each of the more common species will be placed on ice for immediate gut content and volume/weight analysis at the nearby IMS laboratory.

Samples will be preserved as above, properly labeled inside and outside of the containers, and transported to the laboratory for identification using proper quality assurance/quality control procedures.

Task 2. Laboratory Methods

Once samples have been transported to the laboratory, core sediment samples will be carefully re-sieved through a 0.5 mm stainless steel sieve bucket and screen. This sediment reduction will expedite the sorting process. The remaining sediments and organisms will be placed in labeled, double-ziplock bags and initially preserved in 10 percent buffered formalin solution with Rose Bengal stain. Organisms will be allowed to harden in formalin for 48 hours and then transferred to 80 percent ethanol alcohol. After the hardening period, the organisms will be placed in sorting trays and submersed/diluted in de-ionized water to minimize any volatile alcohol vapor production during identification.

Organisms will then be sorted and enumerated in the laboratory and identified to a minimum of family level with the aid of a variable power dissecting microscope (Bausch & Lomb) and/or a compound microscope (Swift or Bristol). Organisms will be identified by experienced biologists using various identification keys (e.g., Abbott, 1974; Bousfield, 1965; Bynum and Fox, 1977; Dover, 1979; Fauchald, 1977; Fox and Bynum, 1975; Gosner, 1978; Heard, 1982; Kaplan, 1988; Morris, 1975; Ruppert and Fox, 1988; Uebelacker and Johnson, 1984; Williams, 1984). Taxa identified for each station will be recorded on a laboratory bench sheet (per EPA, 1989).

Gut contents will be analyzed at the nearby IMS laboratory; contents will be removed, weighed, volume determined, sorted, and identified. Depending on degree of degeneration, samples may alternatively be preserved in 10% formalin and washed for analysis. Organisms will be separated into general groups (e.g., penaeid shrimp, portunid crabs, etc.).

Task 3. Data Analysis

Organism data from the borrow area and control site will be statistically compared to evaluate changes in faunal abundance, and number of species present among sites and over time. Besides standard statistics, analyses will include variance testing (ANOVA), and equivalent parametric tests. Comparison among specific treatment groups will be completed using the Student-Newman-Keuls test (parametric design). Diversity indices will be computed for each area (all samples combined) using Shannon's diversity index (H), Margalef's species richness (SR) and evenness (J). Changes in overall community composition among sites and seasons can be evaluated using a proportional similarity coefficient (Bray-Curtis) with flexible sorting strategy and a cluster intensity (ß) of -0.25.

Task 4. Reporting

A report for each sampling event, including details of field data collection, data presentation, analysis, and conclusions/results will be submitted to CSE and the Towns, for review and dissemination to the reviewing agencies/groups, within 120 days following completion of the field work.

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Institute of Marine Sciences
252-726-6841
FAX: 252-726-2426

The University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, North Carolina 28557

3 June 2001

Mr. Mickey T. Suggs
US Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402-1890
FAX-(190)-251-4025

Daer Mr Suggs:

At the request of Mr. Bill Foreman of CSE, I address my comments on the 31 May 2001 Revised Biological Monitoring Proposal for the Bogue Banks Beach Nourishment Project to you. As you are aware, I have provided earlier comments to the applicant in person, through written response, and verbally at the scoping meeting in Morehead City.

The Revised Biological Monitoring Proposal fails to meet the most fundamental of the requests that I advocated in all three previous forums. Even as a Master's Degree student project, this proposal would receive a failing grade. I detail its shortcomings here, consistent with my earlier comments.

(1) Despite the availability of data to do so, this proposal does not conduct the standard statistical power analyses required to demonstrate whether the proposed monitoring of benthic invertebrates (either in the mining areas or on the beach) has the intrinsic capability of detecting impacts of any magnitude, let alone the 10% change that is claimed. Furthermore, the discussion of power that is incorporated fails to recognize the statistical basis of the design of the data collection. Only by replicating stations not by replicating samples at stations are degrees of freedom (independent replicates) enhanced to increase power. Without a proper power analysis, the design for offshore sampling at the mining sites and the design for sampling beach impacts cannot be justified as adequate to inform the public or the regulators. The proposal slavishly maintains a commitment to half the original offshore stations and only 4 beach stations without providing the necessary power analysis to demonstrate the adequacy of the design.

(2) All work on offshore benthic communities of the shelf in the Southeast, including recent work completed by Posey of UNC-W for the Wilmington US ACOE project, demonstrates the strong seasonality of the offshore benthic community. All previous monitoring projects have therefore sampled in multiple seasons, usually all four seasons as in the South Carolina studies done recently for Myrtle Beach and Hilton Head. The Carteret County plan in the Draft EIS for the Bogue Banks Beach Nourishment Project proposes sampling at two seasons, spring and fall. This new monitoring plan backs away even from that minimal

commitment to include but one sampling of the mining sites and controls per year. That reduction in scope of information gathering is utterly unjustified and fails to protect the public trust interest in an important fisheries habitat. This project should be required to sample at least in spring and fall before the start of the project and again on those identical biannual schedules afterwards until recovery is demonstrated with adequate statistical power.

(3) The specific sampling design for the beach sampling is not provided for review to ascertain its suitability. The need to control for elevation on shore and perhaps for sedimentological variables is not addressed. Preliminary data from Manning's work and in the Peterson et al. (2000) paper from JCR are sufficient to allow the applicant to fashion a specific design and conduct analysis of its power to detect impacts of various magnitudes. This has still not been done. The months and years proposed for sampling are not specified. Again, sampling needs to control for dramatic seasonal variation. Furthermore, monitoring should continue until recovery is demonstrated with a statistically powerful design. Sampling that cannot detect change is a waste of effort and misleading to the public, who justifiably expect that regulators are requiring something meaningful in the way of monitoring of impacts from permitted projects.

(4) I need to clarify one position that I took toward the end of the scoping meeting in Morehead City. While I am convinced that the identification to family level is an appropriate cost savings for the offshore benthic community monitoring at the mining site, the beach macrobenthos is far less diverse. There, species-level identification is not costly and definitely needs to be done to distinguish the two species of *Donax* clams. They are among the three most valuable prey items for surf fish and shorebirds on the beach and the two species of *Donax* engage in rather different dynamics, requiring their numbers to be distinguished in the monitoring. Note too that if species are not identified in the offshore sampling, then species diversity indices cannot be computed, as is inconsistently proposed in this revised monitoring plan.

(5) I applaud the inclusion of beach seining and gut contents analysis for surf fishes. Nevertheless, this component too is vague as to sample size and includes no power analysis to demonstrate whether it can detect impacts of a given magnitude.

While these comments represent my ongoing concerns with the adequacy of the monitoring plans proposed, they exclude the one important issue that I also am convinced needs to be addressed by the state and federal regulators. That is the issue of cumulative impacts on fisheries habitat and fish themselves from the enhanced numbers of nourishment projects statewide. This single applicant cannot be expected to design and conduct those studies, but the state and federal agencies can be. Furthermore, the separate projects that together may exert cumulative impacts of importance should be expected to share in funding those studies, even at the expense of some level of monitoring at each individual project. Here adequate environmental stewardship and leadership at state and federal levels are needed.

Sincerely,

C.H. Pete Peterson

Charles H. Peterson
Alumni Distinguished Professor

Cc: Bill Foreman, CSE
Mike Marshall, NC DMF
Ron Sechler, NMFS
Tracy Rice, USFWS

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

June 8, 2001

Mayor C. Reese Musgrave
Town of Pine Knoll Shores
100 Municipal Circle
Pine Knoll Shores NC 28512

Tel: 252-247-4353
Fax: 252-247-4355
Email: pksadmin@ncnets.net

RE: Coastal Engineering Services in Connection with a Beach Nourishment Project Along Pine Knoll Shores, North Carolina [2049]
Recommendations for Immediate Preproject Biological Sampling (Proposed Task 5B)

Dear Mayor Musgrave:

As you know, we have submitted two draft biological monitoring plans to state and federal agencies (18 April and 31 May) for their review and approval. So far, we have not received any agency recommendations or directives of what is required as a condition of permits. The comments we have received (on 11 May at the interagency meeting and on 3 June) were from Dr. Charles Peterson, consultant to North Carolina Division of Marine Fisheries. It does not appear that anything we submit will be entirely satisfactory to Dr. Peterson unless your community is willing to spend much more money on this work (beyond the approximately $150,000 that we understand you are able to apply toward biological monitoring at present).

We have proposed, through our consultants [Coastal Science Associates, Inc (CSA) – Dr. Bart Baca], up to four samplings plus an initial sampling for certain "power" analyses. CSA's revised proposal follows standard practice and is sufficiently adequate to assess impacts in our opinion. Further, it could be modified at a later date to adjust to preliminary findings and results of earlier samplings. As to when these samplings should occur remains debatable, but it appears that "spring" and "fall" samplings before nourishment will be required. It also remains debatable what the specific scope of work should be with respect to number of stations, number of samples, etc.

I am concerned that we could go round and round with Dr. Peterson indefinitely about the scope of work. Meanwhile, time is of the essence. Therefore, I wish to make the following recommendations and request action from your council at the earliest time.

CSE

1) Pine Knoll Shores should assume that the regulatory agencies will require two prenourishment biological samplings – one now and one in the fall prior to the planned November 2001 construction startup.

2) The initial sampling should be performed within the next ten (10) days and should follow Dr. Baca's latest proposal (enclosed).

3) CSA should double the number of offshore benthic stations to 20 for this first sampling to match all of Dr. Peterson's November 1999 stations. Half of the samples would be analyzed under this agreement as per CSA's present proposal, and half would be held in reserve should all 20 stations be required as a condition of the permits.

4) The Town of Pine Knoll Shores should authorize CSE and CSA to initiate field sampling immediately with costs not to exceed $30,000 for initial work.
(In the event that the Town of Indian Beach agrees to a similar proposal, we recommend that 70 percent be paid by Pine Knoll Shores and 30 percent be paid by Indian Beach on a pro-rata basis).

5) The Town of Pine Knoll Shores should continue to negotiate a mutually acceptable scope of work for biological monitoring with the regulatory agencies.

The above-listed recommendations will provide us with samples that can count later as a "spring" prenourishment sampling. CSA (Dr. Baca) is prepared to mobilize immediately, collect and preserve the specimens, and perform the initial sampling analyses. The extra ten (10) stations sampled (beyond CSA's present proposal) would not be analyzed until the town reaches agreement with the agencies regarding the scope of biological monitoring required for the entire project.

I am particularly concerned that if the agencies rely primarily on Dr. Peterson for guidance, the monitoring will remain open-ended. This is fiscally irresponsible. CSA's monitoring follows standard practice and will therefore be directly comparable to other studies of beach nourishment impacts. Certain of Peterson's recommendations are impractical and will not result in any definitive, quantitative conclusions about impacts. Further, he and some of the commenting agencies seem to be focusing on a select few studies that showed adverse impacts and ignoring the growing body of rigorous monitoring studies that confirm rapid recovery for most projects of this type.

If you have any questions about these recommendations, please call me or Bill Forman, and feel free to discuss the specific work plan with Dr. Baca (954-797-1185) at any time. Thank you for your consideration.

Yours truly,

Timothy W Kana PhD
Project Director

Enclosure

CSAi COASTAL SCIENCE ASSOCIATES, INC.
840 Nature's Cove Road • Dania, Florida 33004 • 954-926-5426 • Fax 954-926-1183

June 11, 2001

Tim Kana, Ph.D.
Coastal Science & Engineering, LLC
P.O. Box 8056
Columbia, SC 29201

RECEIVED
JUN 12 2001

Re: Bogue Banks beach nourishment

Dear Tim:

Having received two reviews on our submittal of a revised monitoring plan for the above project, I find it necessary to make a few comments. Although Dr. Pete Peterson's letter is unprofessional and charged with emotion, I will conversely address his acrid comments with objective facts, to wit:

(1) The data mentioned by Dr. Peterson as available are not recent enough to use in the upcoming project, nor are they suitably quantitative, for power analysis. For example, a Peterson et al. report (cover letter date April 6, 2000) describes February 1998 benthic sampling which is non-random, non-stratified, combining replicate cores, lacking proper identification of organisms, and using a sieve size which is inappropriate for macro-invertebrates (1mm *vs* the 0.5mm standard). In addition, the variability in organism abundance tied to changing seasonality precludes the use of a two-year old winter study to establish sample numbers for other seasons. The Final Report submitted by Peterson and Wells (September 11, 2000) has similar problems as the above but also provides a list of organisms which cannot be used for analyses. Common names are used for families, some of which could represent 10 or more species; some families have only one genus or species and therefore would automatically provide higher levels of taxonomic identification. In addition, as I discussed with Dr. Peterson, some organisms are known as opportunists which frequently occur in larger numbers than normal following nourishment; however, since they often belong to families with more evenly-distributed, less opportunistic species there is no way of observing this effect when only families are used. Diversity indices, species richness, and similar measures cannot be applied to these data.

For the above reasons, and as recommended by Green (1979; # 5 of his "Ten Principles"), we recommended preliminary sampling to establish the appropriate number of replicate samples. That power analysis study is an extra cost of $14,000, hardly an avoidance of quantitative sampling protocols. Through this preliminary study, a planned over-sampling effort (as Dr. Peterson might call "slavish"), satisfactory replicate numbers can be determined. For example, we can obtain the proportion of a given species in a population, selecting our probability of detecting it in subsequent samples at 90-95%, and determine the sample size *n*. There are several (other) methods available to conduct power analyses, but none are mentioned in any studies by Peterson et al. which we reviewed, although he stresses it in his reviews of our methods.

(2) As per discussions at a meeting held in Morehead, we looked for ways to cut sampling costs and slavishly assumed that extending the number of annual samplings (and reducing taxonomic efforts) was more important to the beach nourishment opponents than multi-seasonal sampling. However, we also prefer multi-season sampling.

(3) As stated above, the preliminary work done by Peterson and Manning cannot be used because of poor design and focus on a few of the larger invertebrates. The touted Peterson et al. (2000) JCR paper uses a sieve size of 3mm to sample macro-invertebrates which effectively eliminates a large percent of polychaetes, amphipods, and macro-invertebrate larvae, which can make up 90% or more of a beach sample, thus biasing the sample to make the data useless and unreliable. Donax clams and mole crabs are not always the most common, nor the most important, organisms in intertidal areas. No conclusions about the environmental effects of beach nourishment should rely on this bias sampling.

On the second point, as I mentioned at our Morehead meeting, the homeowner cannot be held hostage to an unending monitoring program. The agencies must have the knowledge and experience to agree on some manner of beach nourishment which they can assume, based on voluminous literature, will have little or no long-term negative environmental effects. And if it does have an effect, then we can mitigate for it or redesign future nourishment. The scientific fact remains, that if compatible material is used, and if the proper seasons are selected, then beach nourishment impacts are short-lived.

(4) Dr. Peterson states that identification to family is appropriate for offshore but not for beach samples. That is a variance from our meeting discussions and reflects the inadequate sampling techniques used by researchers in the past. As stated, macro-invertebrates are undersampled and standard macro-invertebrate protocol is ignored in some previous studies.

(5) The fish gut content analysis was one of the studies added to our monitoring plan based on comments from Dr. Peterson and his cohort agencies. At the Morehead meeting Dr. Peterson offered his nearby laboratory for our use since gut contents must be analyzed quickly. However, because of Dr. Peterson's outspoken opposition to this project, and his insistence on the use of sub-standard methods for macro-invertebrate surveys, we must find another nearby location. Our samples will be preserved to enable third party review if necessary.

The second comment letter, that of the U.S. Fish and Wildlife Service, does not go into sampling details but "reiterates those recommendations" of Dr. Peterson. However, their reliance on Peterson et al. (2000) and similar work reduces the credibility of their statements considering the problems we discussed with the sampling methods.

I will discuss our plan with you further, and we are excited that sampling can begin soon to meet seasonal deadlines. However, we must be careful that we do not follow guidelines which will subject our study to criticism from the scientific community. We should not be held to localized methods which purport to investigate national trends, thus reversing years of credible research. We will modify our study plan to maintain the standard of quality required by our state Quality Control certifications, while adding the needed focus on fisheries impacts. Sampling will be a stratified randomized design, with adequate replication to detect effects, in order to prove or disprove the null hypothesis that the beach nourishment had no long-term effects on borrow or fill site macro-invertebrates, or on fill site macro-invertebrates and nearshore fish.

Sincerely,

Bart Baca, Ph.D.

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Institute of Marine Sciences
252-726-6841
FAX: 252-726-2426

The University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, North Carolina 28557

RECEIVED
JUL 27 2001
CSE, LLC

17 July 2001

Mr. Ron Sechler
NOAA National Marine Fisheries Service
Southeast Fisheries Center
Pivers Island
Beaufort, NC 28516

Dear Ron:

I enclose my review of the revised monitoring proposal for the Bogue Banks Nourishment Project presented to agency personnel and in document form at a meeting in Beaufort yesterday on July 16, 2001. I apologize for my conflict that prevented me from attending the actual presentation. I did have access to the full set of illustrations to aid in my review of the revised plan.

I am sorry to report that I found only some and, in my judgement, insufficient progress on key issues that I addressed in my review of the previous monitoring plans. The attached formal review explains my reasons for reaching this conclusion.

Sincerely,

Pete Peterson

Charles H. Peterson
Alumni Distinguished Professor

Cc: Bill Foreman, CSE
Mike Marshall, NC DMF
Tracey Rice, USFWS
Mickey Suggs, US ACOE

Review of July 2001 Bogue Banks Beach Restoration Project
Monitoring Plan from Coastal Sciences Associates

By

Charles H. Peterson
UNC Institute of Marine Sciences
17 July 2001

I have examined the revised monitoring plan for the Bogue Banks Beach Nourishment project and present my reactions here to how well the revision addresses previously unanswered questions. Overall, the revised plan does not adequately provide the necessary detail about sampling design to be able to judge the plan scientifically adequate.

(1) The problem of power to detect potential impacts in the design remains. The proposers report something that they term results of a power analysis, but those results are not responsive to the issue. They report that 10 replicates per site was adequate to capture over 90% of the species. This may be so (no results are provided as support), but it is irrelevant. This monitoring study that is proposed will not make measurements at the species level. Even if it did, species counts do not reflect the value of the benthos as prey for surf fishes, crabs, and shorebirds. Densities (or biomass even better) of the two taxa that contribute over 95% of the biomass of the community, *Donax* spp. and *Emerita talpoida*, are the variables that must be estimated well to be able to detect impacts of importance to the predators that use the benthic macrofauna. Power is estimated very simply from any adequate pilot data, which the proposers now have, and the result is expressed in the form of curves that show how the probability of demonstrating an impact of a given size (20% for example) at an alpha of 0.05 varies as a function of replication (here as a function of numbers of sample sites) and other aspects of the sampling design. That has not been done. Consequently, the public and the resource agencies have no assurance for either the mining site or the beach deposition site that even a large impact of the project could be detected.

(2) The proposal makes a point to commit to using the previous locations sampled by Peterson et al. for the mining sites and by Peterson and Manning for the beach deposition sites. Yet, there is no statistical ANOVA design presented that incorporates those earlier sampling results into it to allow that earlier work to be used most effectively to help interpret impacts and recovery. The beach sampling is to be done using 0.5 mm mesh instead of the 1mm mesh used by Peterson and Manning. That major difference prevents comparisons among these data sets. Why would such a change be made? There is no discussion or justification of changing methods in mid stream. I presume that the sampling of the beach that has already been done in June used that 0.5 mm mesh, so that it has become impossible to compare to earlier samplings of Peterson and Manning.

(3) The dates (even seasons) of all samplings are unacceptably vague. Seasonality is a major determinant of benthic community composition and densities, so season must be controlled in any test of recovery. The sampling schedule for beach invertebrates should involve sampling during the warm season when abundances are high and importance to feeding surf fishes, crabs, and shorebirds is great. That is not assured. The failure to specify dates of sampling threatens ability of the entire design to estimate recovery rate. For example, a pre- and post-project sampling are proposed in the first year. Does first year mean first calendar year (i.e., 2001) or first fiscal year (June 2001-May 2002)? If it means first calendar year, the project does not begin until around December and does not end until around April, so there is no possible way to conduct a "post-project" sampling in the first calendar year. If it means first fiscal year, then the post-project sampling must occur in May, a month that does not hold month constant in the pre- and post-project periods. That design would prevent initial impact from being estimated because the difference between pre-project and post-project samples would confound seasonality with impact. This problem becomes even worse in successive

years because recovery rate must be judged against initial densities in the pre-project period, so month needs to be held constant for that comparison.

(4) This proposal still deviates from the commitment made in the Draft EIS for the Bogue Banks Nourishment Project in its monitoring of the mining sites. That EIS reported that a Fall and a Spring monitoring would be done prior to and after the project. Such a design could overcome the seasonality of this system adequately to estimate impacts to and recovery from the project. This monitoring proposal makes no mention of a Spring sampling before the project commences. It also does not specify season (month) of sampling for the subsequent post-project sampling in a design that assures that seasonality will not intrude to confound interpretation and does not replicate the Spring-Fall pattern. The numbers of stations (sites) to be sampled in the offshore monitoring are reduced to 15 from those 20 originally taken by Peterson et al in the single Fall 1999 sampling. No indication is given of which stations are to be dropped and whether the resulting design still can estimate impacts at all Borrow Areas. Furthermore, the modified design violates a cardinal rule in statistical design of monitoring by failing to maintain a balanced design of equal numbers of replicates for control and impact stations. This has negative effects on the power of the design to detect impacts and should be avoided.

(5) The proposal identifies Emerald Isle as a region within the project area. At the scoping meetings, concerns about cumulative impacts were addressed by the proposers by saying how the Emerald Isle portion of the area covered by the Bogue Banks draft EIS was not part of this project and would remain outside the project area. Why is it thus included as within the project area? This inconsistency prevents one from analyzing the adequacy of location of sample sites on the beach.

(6) Furthermore, the proposal reports that the previous Peterson and Manning beach sites will be used if possible. What would make this impossible? Which sites exactly will be used? If those sites are not used, what sites will be and why?

(7) The beach samples are to be taken by SCUBA diving and wading. The Peterson and Manning samples were all taken at low tide by walking on dry beach or in the swash. If tidal stage of sampling will be closer to high water for this monitoring, comparability with previous samples will be jeopardized.

(8) The details of the fish sampling are not sufficiently complete to allow evaluation of the adequacy of this component of the monitoring design. The mesh size of the seine is not given. The date (month) of sampling is not specified. It should be in late summer, when the surf fish demands on benthic prey are greatest and their abundances highest. The distance towed is not specified. Whether samples are day or night is not addressed. The critical need to seine during very low swell conditions is not mentioned. The problem of sampling on different days or at different times and tidal stages at different sites is not identified and defended. It is unclear what response variables will be measured. It should be abundance of each species of fish captured, perhaps subdivided by size class. What life stage implies is unclear. Methods for gut contents and "volume" analysis are not provided. Is gut fullness to be measured? How? That is not clear. How many fish will be examined and of which species?

(9) As I mentioned in my last review, species richness and diversity indices cannot be computed when animals are not identified to species, so that part of the data analysis section is inconsistent with the methods provided. ANOVA is a parametric test, as opposed to the implication made in the Data Analysis section. Non-metric MDS is a far more discriminating means of conducting multivariate analysis of community composition than the old-fashioned cluster analyses.

Tim Kana - CSE

From: "Bart Baca" <baca@nova.edu>
To: <t_kana@coastalscience.com>
Cc: <bfcsens@earthlink.net>
Sent: Wednesday, June 27, 2001 10:13 PM
Attach: Dear Tim.doc
Subject: Bogue

LETTER ALSO ATTACHED IN WORD

June 27, 2001

Tim Kana, Ph.D.
Coastal Science & Engineering LLC

Re: Beach nourishment impacts

Dear Tim:

After reviewing southeast literature, I noticed you guys had already covered most of what I had to say. At any rate, based on experience over the last 15 or so years, it is my opinion, and that of many other researchers, that beach nourishment projects have no long term environmental effects when compatible, low silt/clay materials are used, when borrow sites are properly selected, and when proper timing is adhered to. Following is a listing of some of our beach nourishment projects used to formulate our opinions:

· Indian River County Beach. Hardbottom surveys of fish, benthos, invertebrates, and flora for beach nourishment project. Applied Technology and Management, Gainesville, FL.
· Martin County Beach Nourishment. Nearshore benthic and artificial reef monitoring for assessment of long-term impacts to fish and macroinvertebrates. Applied Technology and Management, Gainesville, FL.
· Longboat Key Beach Nourishment. Nearshore benthic and artificial reef monitoring for assessment of long-term im-pacts to fish and macroinvertebrates. Applied Technology and Management, Gainesville, FL.
· City of Key West. Analyses of macro-invertebrate communities on Smathers and Rest Beaches for beach renourishment project. Post, Buckley, Schuh, and Jernigan, Miami, FL.
· John U. Lloyd beach nourishment project. Long-term specimen identification for determining impacts of a large beach nourishment project using offshore dredging. John U. Lloyd State Park, Dania, FL.
· Daufuskie Island beach nourishment. Monitoring surficial sediments and macrobenthic infauna assemblages at the proposed offshore borrow areas. Applied Technology and Management, Mt. Pleasant, SC.
· Seabrook Island beach nourishment project. Environmental surveys for determination of impacts resulting from shoal dredging for beach nourishment. Seabrook Island POA, Charleston, SC.
· Hunting Island beach- nourishment project. Environmental surveys for determination of environmental impacts of beach nourishment. SC Department of Parks, Recreation, and Tour-ism, Columbia, SC.

· Palmetto Dunes beach nourishment project. Collection, identification and report relative to the environmental effects of shoal scraping for a beach nourishment project on Hilton Head Island. Palmetto Dunes, Hilton Head, SC.
· Hog Inlet beach nourishment project. Collection, identification and report relative to the environmental effects of shoal scraping for a beach nourishment project on North Myrtle Beach. Coastal Science & Engineering, Columbia, SC.
· Pawleys Island Beach Nourishment. - Macroinvertebrate surveys for determination of environmental impacts. Town of Pawleys Island, SC.
· Myrtle Beach nourishment project. Long-term macroinvertebrate and turbidity studies conducted before and after major sand nourishment. Myrtle Beach, SC.
· Seabrook Island environmental study. A five-year study of the effects of a beach nourishment dredging project on the coastal vegeta-tion, birds, and other natural resources. Seabrook Island Company, Charleston, SC.

We published two symposia presentations on these projects and the literature relative to the severity of impacts from various forms of beach nourishment (Lankford and Baca 1989, Baca et al. 1991). We found that impacts to beach sites were few and short-lived but that impacts to borrow sites were more long-lived (see Table 1).

Table 1. Impacts to various communities as a result of different types of beach nourishment methods (H=high, M=medium, L=low impacts).

Impacts To Beach or Borrow Site Offshore Dredging Nearshore Dredging Shoal Scraping
Benthic macroinvertebrates Borrow M H M
Reefs and hardbottoms Borrow M M L
Fisheries Borrow M M L
Turtle nesting Beach L L L
Bird nesting Beach L L L
Diversity/richness Borrow M H L
Commercial/recreational value Borrow M H L

Macroinvertebrates, diversities, and commercial/recreational values were impacted by nearshore dredging; importantly, however, "high" is relative as these impacts were not significant or long-lived in most cases (reviewed in Lankford and Baca 1989). In a recent South Carolina study comparing pre- (CSAi 1999) and post-dredging impacts (CSAi 2000) on offshore areas, although impacts were noticeable, they had virtually disappeared after one year.

Most of the monitoring studies of beach nourishment projects in the southeastern U.S. show that macroinvertebrate community recovery is rapid once dredging and filling have ceased (Saloman 1974, Taylor Biological Co. 1978, Culter and Mahadevan 1982, Naqvi and Pullen 1982, Gorzelany 1983, Reilly and Bellis 1983, Gorzelany and Nelson 1987, Hurme and Pullen 1988). Within the caveate of proper borrow site selection and compatible, low silt/clay material, there is no research which contradicts this statement.

Our experience with the above Florida projects confirms this also. Over the years we have seen that the few papers published which indicate long term and/or significant impacts stand out and are easier to publish because of their rarity. Editors/reviewers have indicated they are not interested in the more usual "no impacts of nourishment papers".

Sincerely,
Bart Baca, Ph.D.

References Cited

Baca, B.J., R.E. Dodge, and C. Mattison. 1991. Predicting environmental impacts from beach nourishment projects. In: Proc. Beach Preservation Technology '91. Florida Shore and Beach Preservation Assoc.

CSAi. 1999. Daufuskie Island beach nourishment pre-dredge monitoring study. Rep. to Applied Technology & Management, Inc., Charleston, SC. 35pp. + attach.

CSAi. 2000. Daufuskie Island beach nourishment final post-dredge monitoring study. Rep. to Applied Technology & Management, Inc., Charleston, SC. 40pp + attach.

Cutler, J.K. and S. Mahadevan. 1982. Long-term effects of beach nourishment on the benthic fauna of Panama City Beach, Florida. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Misc. Report No. 82-2. 94 pp.

Gorzelany, J.F. 1983. The effects of beach nourishment on the nearshore benthic macrofauna of Indialantic and Melbourne Beach, Florida. M.S. Thesis. Florida Institute of Technology. 114 pp.

Gorzelany, J.F. and W. G. Nelson. 1987. The effects of beach replenishment on the benthos of a sub-tropical Florida beach. Mar. Environ. Res. 21:75-94.

Hurme, A.K. and E.J. Pullen. 1988. Biological effects of marine sand mining and fill placement for beach replenishment: lessons for other uses. Marine Mining 7: 123-136.

Lankford, T.W. and B.J. Baca. 1989. Comparative environmental impacts of various forms of beach nourishment. In: Proc. Coastal Zone Management '89, pp. 2046-2059.

Naqvi, S.M. and E.J. Pullen. 1982. Effects of beach nourishment and borrowing on marine organisms. U.S. Army Corps of Engineers. Coastal Engineering Research Center. Misc. Report No. 82-14. 44 pp.

Reilly, F.J. and V.J. Bellis. 1983. The ecological impact of beach nourishment with dredged materials on the intertidal zone at Bogue Banks, North Carolina. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Misc.Report 83-3. 74 pp.

Saloman, C.H. 1974. Physical, chemical, and biological characteristics of nearshore zone of Sandy Key, Florida, prior to breach restoration. Final Report, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Dr. Bart Baca
Nova Southeastern University Oceanographic Center
8000 North Ocean Drive
Dania, Florida 33004

Voice: (954) 920-1909
Fax: (305) 947-8559
E-mail: baca@ocean.nova.edu

Revised Environmental Services Proposal:

Bogue Banks Beach Restoration Project
Bogue Banks, North Carolina

Submitted to:

Coastal Science & Engineering PLLC
804 Arendell Street
Morehead City, NC 28557

Submitted by:

Coastal Science Associates, Inc.
328 second Avenue North
Jacksonville Beach, FL 32250

July 2001

Background

The purpose of this proposed ecological study is to assess the existing biological communities, and to assess impacts on benthic invertebrates and fish, at the proposed Bogue Banks Beach Renourishment Project, located in Carteret County, North Carolina. This the second revised proposal, based on a public and agency meeting held May 11, 2001, at which recommendations were given from the UNC Institute of Marine Sciences (IMS), the U.S. Fish & Wildlife Service, the National Marine Fisheries Service, the U.S. Army Corps of Engineers, the North Carolina Department of Environment and Natural Resources, North Carolina Coastal Federation, and others. The general recommendation was to put more emphasis into fisheries surveys and impacts, and less into macroinvertebrate species identification.

The ecological study will include benthic sampling and analysis of proposed borrow and nourishment sites, and fish sampling and analysis of proposed nourishment sites, including reference sites. CSA*i* proposes to use the stations previously sampled by IMS in all cases possible. Two sampling events (pre- and post-) are proposed in the first year, with an additional sampling event in each of the next three years.

A power analysis was conducted following a review of previous studies conducted by IMS and based on the initial spring (June) sampling. The analysis determined that 10 replicates per site was adequate to capture over 90% of the total species (beach and borrow stations). The proposed sampling should produce a useful number of core samples (including stations originally sampled by UNC in Fall 1999) from both the offshore borrows areas and control areas. The scope of work is as follows.

TASK 1. Field Collection of Samples

Beach Site Sampling

Five stations will be sampled on the proposed beach to be nourished. Three stations will be sampled within the project area (Emerald I., Indian Beach, Pine Knoll Shores) and two will be sampled outside the project area to act as references/controls. Three transects will be sampled at each station, and five elevations will be sampled at each station corresponding to elevations used by Peterson et al. studies (1999, 2000). Every attempt will be made to perform the sampling at the same station location as in the Lisa Manning report (NC Sea Grant, April 2000). All stations will be located by Differential Global Positioning System (DGPS). Cores will be collected by SCUBA diving or wading using a 10.2 cm (four inch) cylindrical corer with an internal diameter of 9.9 cm (sampling an area of 77 cm^2). Benthic samples collected will be sieved in the field through a 0.5 mm stainless steel sieve bucket. All sediment and organisms retained in the bucket will be preserved in 10% buffered formalin with rose bengal stain.

Nearshore fish sampling will also be conducted at the beach sample sites. This will consist of three hauls of a 100' beach seine at the sites (one at each beach) and three at controls. Species, numbers, and life stage will be field-determined to the extent possible; fish requiring further examination will be subsampled and preserved in 10% buffered formalin. Guts of a subsample of each of the more common species will be placed on ice for gut content and volume analysis at a nearby laboratory.

Borrow Site Sampling

The proposed borrow areas have been shown in the EIS and other submittals. Sites are designated as A (offshore), B1, and B2 (both nearshore). Sample sites previously used in work by Peterson et al. (1999, 2000) will be sampled in all cases possible. All stations will be located by Differential Global Positioning System (DGPS). Ten cores will be taken at each site for a total of 150 cores. Cores will be collected by SCUBA diving using a 10.2 cm (four inch) cylindrical corer with an internal diameter of 9.9 cm (sampling an area of 77 cm^2). Benthic samples collected will be sieved in the field through a 0.5 mm stainless steel sieve bucket. All sediment and organisms retained in the bucket will be preserved in 10% buffered formalin with rose bengal stain.

A summary of proposed monitoring sampling protocols is as follows:

Beach Site invert samples	**Beach Site invert replicates**	**Invert Device**	**Sieve**	**Beach Fish sampling**	**Other sampling**
3 transects per each of 3 beach sites (Emerald I., Indian B., Pine Knoll) + 3 for each of 2 controls	3 cores at each of 5 elevations (strata) per transect; total 225 total cores	77 cm^2	0.5mm	100'x6'x1" beach seine, 3 hauls for sites and 3 for controls; 10% gut content analysis	Ghost crab burrows - 4m wide section on each upper transect
Borrow Site inverts	**Borrow reps**			**Borrow fish**	
15 sites - 9 inside, 6 controls: B2 and B1 (2 each), and near-shore half of A	10 cores from each; 150 total	77 cm^2	0.5mm	None	None

Task 2. Laboratory Methods

Samples will be preserved as above, properly labeled inside and outside of the containers, and transported to the laboratory for identification using proper quality assurance/quality control procedures.

Once samples have been transported to the laboratory, core sediment samples will be carefully re-sieved through a 0.5 mm stainless steel sieve bucket and screen. This sediment reduction will expedite the sorting process. The remaining sediments and organisms will be placed in labeled, double-ziplock bags and initially preserved in 10 percent buffered formalin solution with Rose Bengal stain. Organisms will be allowed to harden in formalin for 48 hours and then transferred to 80 percent ethanol alcohol. After the hardening period, the organisms will be placed in sorting trays and submersed/diluted in de-ionized water to minimize any volatile alcohol vapor production during identification.

Organisms will then be sorted and enumerated in the laboratory and identified to a minimum of family level with the aid of a variable power dissecting microscope (Bausch & Lomb) and/or a compound microscope (Swift or Bristol). Organisms will be identified by experienced biologists using various identification keys (e.g., Abbott, 1974; Bousfield, 1965; Bynum and Fox, 1977; Dover, 1979; Fauchald, 1977; Fox and Bynum, 1975; Gosner, 1978; Heard, 1982; Kaplan, 1988; Morris, 1975; Ruppert and Fox, 1988; Uebelacker and Johnson, 1984; Williams, 1984). Taxa identified for each station will be recorded on a laboratory bench sheet (per EPA, 1989).

Task 3. Data Analysis

Organism data from the borrow area and control site will be statistically compared to evaluate changes in faunal abundance, and number of species present among sites and over time. Besides standard statistics, analyses will include variance testing (ANOVA), and equivalent parametric tests. Comparison among specific treatment groups will be completed using the Student-Newman-Keuls test (parametric design). Diversity indices will be computed for each area (all samples combined) using Shannon diversity index, Margalef's species richness and evenness. Changes in overall community composition among sites and seasons can be evaluated using a proportional similarity coefficient (e.g., Bray-Curtis) with flexible sorting strategy and a cluster intensity (ß) of -0.25.

Task 4. Reporting

A report for each sampling event, including details of field data collection, data presentation, analysis, and conclusions/results will be submitted to NC Department marine Fisheries within 120 days following completion of the field work portion of the work.

References

Abbott, R.T. 1974. American Seashells Second Edition. Van Nostrand Reinhold Co. 450 West 33rd Street, New York, N.Y. 663pp.

Brower, J.E., Zar, J.H., and von Ende, C.N. 1998. Field and Laboratory Methods for

General Ecology, 4^{th} Edition. The McGraw-Hill Co. Inc., 273pp.
Dover, C.W. 1979. Field Guide to Common Marine Invertebrates. Duke University Marine Laboratory, 78pp.
EPA. 1989. Rapid Bioassessment Protocols for use in Streams and Rivers. U.S. EPA /444/4-89-001, Washington D.C.
Fauchald, K. 1977. The polychaete worms: definitions and keys to the orders, families, and genera. Nat. Hist. Mus., Los Angeles Ca., Science Series No. 28, 161pp.
Gosner, K.L. 1978. A field guide to the Atlantic seashore. Houghton Mifflin Co., Boston, Mass., 329 pp.
Gosner, K.L. Guide to Identification of Marine and Estuarine Invertebrates. Wiley Interscience.
Humann, P. 1999. Reef Fish Identification/ Florida, Caribbean, and Bahamas. New World Publications, Inc., Jacksonville, FL, 396pp.
Morris, P.A. 1975. A Field Guide to Shells, Atlantic and Gulf Coasts and the West Indies. Houghton Mifflin Co., Boston, Mass., 330 pp.
Patil, G.P., and C. Taillie. 1982. Diversity as a concept of its measurement. J. Amer. Statist. Assoc. Vol. 77, p.548-561.
Uebelacker, J.M. and P.G. Johnson. 1984. Taxonomic Guide to the Polychaetes of the Northern Gulf of Mexico. U.S. Dept. of Interior. Seven Volumes.
Williams, A.B. 1984 Shrimps, Lobsters, and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida. Smithsonian Institution Press, Washington, D.C. 550 pp.

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

July 18, 2001

Mr. Ron Sechler
NMFS
101 Pivers Island Road
Beaufort NC 28516

Tel: 252-728-5090
Fax:

RE: Carteret County – Bogue Banks Beach Restoration Project – Federal ID# 200000362]
Environmental Monitoring Plan [2049-5]

Dear Ron:

Thank you for meeting with Dr. Baca, Bill Forman, and me on Monday. I appreciate your time and the input that we received on the environmental monitoring plan from Larry Settle, Rick Monaghan, and Mickey Sugg. Since April, we seem to be making small steps toward resolving the plan. However, I am writing to reiterate that we need to make some big steps immediately; otherwise, Phase I will not be possible in winter 2001-2002.

I am writing with these recommendations which I believe are consistent with previous comments.

1) Environmental monitoring should be performed twice per year using June and November as the baseline months – June because of our initial samples by CSA last month and November because of UNC's fall 1999 baseline.

2) Offshore benthics should be sampled at 15 stations within and around borrow areas A, B2, and B2 with a minimum number of replicates as recommended by Larry and Bart. (Peterson and CSA sampled 10 replicates, but it appears from the initial data that seven may be adequate.)

3) Beach benthics should be sampled at 15 stations (5 strata) as shown on the map we provided on Monday at your offices.

4) Beach seining for gut analysis should be sampled at five of the beach stations (three treatment and two control) as described on Monday.

5) Statistical analyses should include comparisons of organism densities using graphics recommended by Larry and Bart.

6) Postproject sampling should be performed twice per year (June and November) following each phase of construction. We anticipate the following schedule of sampling whereby post-Phase I also serve as pre-Phase II, etc.

June 2001	Initial preproject / power analysis sampling
November 2001	Pre Phase I

CSE

June 2002	Post Phase I
November 2002	6 month / post Phase I / pre Phase II
June 2003	12-month post-Phase I / post Phase II
November 2003	18-month post-Phase I / 6-month post Phase II / pre Phase III
June 2004	24-month post-Phase I / 12-month post Phase II / post Phase III
November 2004	30-month post-Phase I / 18-month post Phase II / 6-month post Phase III
June 2005	Contingency postproject sampling
November 2005	Contingency postproject sampling

Funds are presently committed for Phase I sampling (five events). Future phases will provide for a minimum of five additional sampling periods, budgeted as part of the soft costs for the Emerald Isle reaches (subject to funding for construction).

Because of the sequencing of construction, particular sections of the beach will be nourished each month. Therefore, contemporaneous sampling in June and November will represent a sequence of months after completion. This will give us some idea of the rate of recovery along the beach (ie, for a section nourished in February, the June and November samplings are "3-months" and "9-months" after; the "6, 12, 18-month" intervals above are nominal, in other words).

It remains our opinion that the goal of the monitoring should be to document what organisms are present before the project and what are present six months to two years after the project. If recovery follows the experience at most other nourishment sites, the above-listed scope and schedule should be more than adequate to determine that. We are recommending two contingency sampling periods in 2005 if data indicate the populations have not returned to levels similar to unnourished sections within two years. We request that no further sampling be required once two successive periods demonstrate recovery as defined by quantitative measures agreeable to your reviewers and feasible under Dr. Baca's sampling plan.

Please let us know immediately if this extended sampling schedule is acceptable. We need to move on with this. Thank you for your consideration.

Yours truly,

Tim Kana

Timothy W Kana PhD
Project Director

cc: NMFS St. Petersburg, Eric Hawk
NC Division of Marine Fisheries, Rick Monaghan
USACE, Mickey Sugg
Carteret County, Peter Allen
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
Town of Emerald Isle, Mayor Barbara Harris (c/o Frank Rush)
CSE, Bill Forman

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Institute of Marine Sciences
252-726-6841
FAX: 252-726-2426

The University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, North Carolina 28557

5 August 2001

Mr. Ron Sechler
NOAA National Marine Fisheries Service
Southeast Fisheries Center
Pivers Island
Beaufort, NC 28516

Dear Ron:

I write in response to the letter sent to you on 18 July by Dr. Tim Kana containing suggested modifications of the proposed monitoring proposal for the Bogue Banks Nourishment Project. It is unclear from this letter whether Dr. Kana had yet received my review sent to you on 17 July about continuing deficiencies in the monitoring because no reference was made to my comments and none of the substantive issues in my review was addressed in Dr. Kana's letter.

There is little need for me to repeat my comments of the 17 July review. None of the concerns has been fully addressed. Even the issue of timing of sampling, which is more completely provided in Kana's letter, is incompletely presented. Specifically, was the offshore area sampled in June 2001 by Baca to provide two pre-project samplings? That is not clear and, if it has not been done, that contradicts the commitment made in the Draft EIS. Most critically, there is no mention of the problem of power to detect impacts and thus no progress in providing the necessary statistical information that would insure that the sampling design can detect those effects of most significance to protecting essential fish habitat and its function.

Sincerely,

CH Pete Peterson

Charles H. Peterson
Alumni Distinguished Professor

Cc: Bill Foreman, CSE
Mike Marshall, NC DMF
Tracey Rice, USFWS
Mickey Suggs, US ACOE

North Carolina
Department of Environment and Natural Resources
Division of Coastal Management

Michael F. Easley, Governor
William G. Ross Jr., Secretary
Donna D. Moffitt, Director

NCDENR

August 7, 2001

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Carteret County
c/o Dave Clark, County Engineer
Courthouse Square
Beaufort, NC 28516

RECEIVED
AUG 08 2001
CSE

Dear Sirs:

Please reference your application request under the Coastal Area Management Act to undertake the Bogue Banks Beach Nourishment Project. Processing of your application, which was received by the Division's Morehead City regional office on February 9, 2001, was placed on administrative hold on April 30, 2001 pending completion of a North Carolina Environmental Policy Act (NCEPA) review. Barring any unforeseen circumstances, I expect the NCEPA review to be concluded within the next few days. However, it has been determined that an additional piece of information will be required prior to the Division resuming processing of your application. This additional information item is summarized below:

1) In a June 20, 2001 letter to this office, the N.C. Division of Marine Fisheries has stated that

   "The Division of Marine Fisheries is unable to adequately review this project becuse of the lack of specificity in the revised Biological Monitoring Plan. We recommend that the application process be put on hold until a satisfactory Biological Monitoring Proposal, with specifics, is in hand and approved as an integral part of the total project."

   I concur with the Division of Marine Fisheries that the requested information is essential in making a determination on the significance of any impacts to fisheries resources. Therefore, the Division must place processing of your permit application in abeyance until such time as this office obtains written notification from the Division of Marine Fisheries that the requested information has been submitted. It is my understanding that your agents are in the process of working this matter out with DMF staff, so I am hopeful that this issue will have minimal impact on the timeline for this Division taking final action on your application. Should you wish to discuss this matter further with Division of Marine Fisheries staff, you should contact Mr. Rick Monaghan at (252) 726-7021.

As required by T15A:07J.0204(d), during the pendency of any termination of processing, the permit processing period will not run. Upon receipt by this office of the requested information, the Division of Coastal Management will resume processing of the application at the point where it was terminated. If you have any questions concerning this matter, please feel free to contact me at (919) 733-2293.

Sincerely,

Doug Huggett
Major Permits Coordinator

cc: DCM - Morehead City
Rick Monaghan, DMF
Town of Pine Knoll Shores ✓
Town of Indian Beach
Bill Foreman, CSE

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

September 20, 2001

Colonel James W. DeLony
District Engineer, Wilmington District
U.S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Dear Colonel DeLony:

The U.S. Fish and Wildlife Service (Service) has reviewed your July 2001 Biological Assessment (BA) for the Bogue Banks Beach Nourishment Project in Carteret County, North Carolina, and its potential impacts on Federally-listed threatened and endangered species. Our comments are provided in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543; Act). Please note that additional correspondence on this project is forthcoming pursuant to technical assistance under the Fish and Wildlife Coordination Act, specifically with regards to our concerns on sediment compatibility.

The proposed project consists of excavating, by hydraulic dredge, up to 6.7 million cubic yards of sediment from ocean borrow areas situated 0.5 to 3.0 miles offshore of the project area. Sediment would be pumped onto the beach between the toe of the existing dune and the low water line and shaped by bulldozers into a profile that closely matches the natural beach. Approximately 50 percent of the excavations would be deposited by run-out from the discharge point between mean low water and the outer bar (approximately 500 feet offshore). Typical fill sections would add approximately 44 to 113 cubic yards per linear foot of beach and advance the shoreline 50 to 125 feet. The work would be performed in phases covering all or portions of each of six designated reaches according to the following schedule: (1) Phase I (Reaches 4, 5 and 6) - Towns of Pine Knoll Shores and Indian Beach, 7.2 miles and up to 3.1 million cubic yards, (2) Phase II (Reach 3 and eastern half of Reach 2) - Town of Emerald Isle, 3.0 miles and up to 1.7 million cubic yards, and (3) Phase III (Reach 1 and western half of Reach 2) - Town of Emerald Isle, 6.7 miles and up to 1.9 million cubic yards. The proposed work is scheduled to occur between November 2001 and April 2002 for Phase I, November 2002 to April 2003 for Phase II, and November 2003 to April 2004 for Phase III.

The material proposed for disposal on the oceanfront beach has the potential to impact Federally-listed species, such as loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), Kemp's ridley (*Lepidochelys kempi*), hawksbill (*Eretmochelys imbricata*) and green sea turtles (*Chelonia mydas*), and seabeach amaranth (*Amaranthus pumilus*). However, based on the information provided in your BA and implementation of the following conservation measures, we could concur with a determination that the proposed project is "not likely to adversely affect" any Federally-listed endangered or threatened species, their formally designated critical habitat, or species currently proposed for Federal listing under the Act. Please note, continuation of formal consultation with the Federal action agency and the preparation of a biological opinion will be required if any of the following conditions cannot be implemented. Formal consultation may also be required if: (1) new information reveals impacts that may affect listed species or critical habitat in a manner not previously considered; (2) this action is subsequently modified in a manner that was not considered in this review; or, (3) a new species is listed or critical habitat determined that may be affected by the identified action.

1. The project must be conducted during the period when sea turtle nesting and hatching and seabeach amaranth germination are not likely to occur (i.e., November 16 through April 30). Note that activities that cannot be completed during this period may be subject to formal consultation which would take an estimated minimum of 135 days, and no activities are permitted during the formal consultation process and the preparation of a biological opinion.

2. All fill material placed on beaches must be sand that is similar to that already existing at the beach site in both coloration and grain size distribution. All such fill material must be free of construction debris, rocks, organic materials, or other foreign matter and shall not contain, on average, greater than 10 percent fines (i.e., silt and clay; passing the # 200 sieve) and shall not contain, on average, greater than 5 percent coarse gravel or cobble, exclusive of shell material (retained by the # 4 sieve). Note that this is a region-wide guideline for reducing potential adverse effect to sea turtles. The Service has sediment compatibility concerns related to other fish and wildlife resources that are being discussed with the Corps and which may be addressed in subsequent Fish and Wildlife Coordination Act correspondence.

3. A daily, early-morning sea turtle nest monitoring program must be implemented. The monitoring program should continue for six years after initial sediment disposal occurs and should include sea turtle nesting success (i.e., nests and false crawls) and hatching or emergence success during the sea turtle nesting and hatching season (May 1 - November 15) of each year. This monitoring program is intended to address our concerns with potential sediment incompatibility and its affects on nesting sea turtles. Please note, these beaches may already be surveyed on a regular basis by volunteers participating in the North Carolina Wildlife Resources Commission's Sea Turtle Volunteer Program. It is possible that the collection of this data might be coordinated through the volunteer program.

4. Immediately after completion of sediment placement on beaches and prior to April 1 for three subsequent years, sand compaction must be monitored in the placement area. At a minimum, the protocol provided under 4a and 4b below shall be followed. If required, the area shall be tilled to a depth of 36 inches. All tilling activity should be completed prior to April 1 so that they can be evaluated prior to the sea turtle nesting and hatching season and the seabeach amaranth germination period (May 1 through November 15). A report on the results of compaction monitoring shall be submitted to the Service prior to any tilling actions being taken. An annual summary of compaction surveys and the actions taken shall be submitted to the Service. Note that the requirement for compaction monitoring can be eliminated if the decision is made to till regardless of post-construction compaction levels. Also, out-year compaction monitoring and remediation are not required if placed material no longer remains on the beach.

   4a. Compaction sampling stations shall be located at 500 ft (152 m) intervals along the placement area. One station shall be at the seaward edge of the dune line (when material is placed in this area), and one station shall be midway between the dune line and the high water line (normal wrack line).

At each station, the cone penetrometer shall be pushed to a depth of 6, 12, and 18 inches three times (three replicates). Material may be removed from the hole if necessary to ensure accurate readings of successive levels of sediment. The penetrometer may need to be reset between pushes, especially if sediment layering exists. Layers of highly compact material may lay over less compact layers. Replicates shall be located as close to each other as possible, without interacting with the previous hole and/or disturbed sediments. The three replicate compaction values for each depth shall be averaged to produce final values for each depth at each station. Reports shall include all 18 values for each transect line, and the final six averaged compaction values.

4b. If the average value for any depth exceeds 500 psi for any two or more adjacent stations, then that area shall be tilled prior to April 1 (to allow time for inspection/evaluation before the sea turtle nesting season). If values exceeding 500 psi are distributed throughout the placement area but in no case do those values exist at two adjacent stations at the same depth, then consultation with the Service shall be required to determine if tilling is required. If a few values exceeding 500 psi are present randomly within the placement area, tilling shall not be required.

5. Sand compaction data must be collected on beaches scheduled for sediment disposal prior to the disposal operation following the protocols described above. Such pre-disposal beach compaction data would establish a range of values for areas in which sea turtles actually nest. These data would form a valuable baseline for comparison with post-disposal compaction values and could influence the necessity for post-disposal tilling.

6. Visual surveys for escarpments along the project area must be made immediately after completion of the sediment placement and prior to April 1 for three subsequent years. Results of the surveys must be submitted to the Service prior to any action being taken. Escarpments that interfere with sea turtle nesting or exceed 18 inches in height for a distance of 100 ft (30 m) must be leveled to the natural beach contour by April 1. The Service shall be contacted immediately if subsequent reformation of escarpments that interfere with sea turtle nesting or exceeding 18 inches in height for a distance of 100 ft (30 m) occurs during the nesting and hatching season to determine the appropriate action to be taken. An annual summary of escarpment surveys and actions taken shall be submitted to the Service. Out-year escarpment monitoring and remediation are not required if placed material no longer remains on the beach.

7. Seabeach amaranth surveys will be conducted for a period of three years along the entire project (Phase I, Phase II and Phase III). Due to the staging of this project in three distinct phases over three years, surveys will be conducted one to two years prior to and/or after sediment disposal. In addition, plant surveys shall be initiated prior to sediment disposal and/or tilling activities. If plants are discovered in areas where they may be affected by sediment disposal, and/or tilling and construction activities, the plants shall be protected by an adequate buffer zone. The protected area shall not identify the plants to protect them from collectors, but shall be of adequate size to obscure the specific plant site.

8. No construction equipment or pipes shall be stored on the beach from May 1 through November 15.

Thank you for your cooperation with our agency in protecting Federally-listed species. Again, please note that this correspondence relates to resolution of endangered species issues and that correspondence on other environmental impacts of the proposed project may be provided. Please continue to advise us of the progress of this project, including your consideration of implementing the proposed conservation measures and an official determination of the impacts of this project on Federally-protected species. If you have any questions or comments, please contact Mr. Dale Suiter of this office at (919) 856-4520 extension 18.

Sincerely,

Tom Augspurger

For Dr. Garland B. Pardue
Ecological Services Supervisor

cc: USACE, Wilmington, NC (Micky Sugg)
USFWS, Jacksonville, FL (Sandy MacPherson)

FWS/R4:DSuiter:9-20-01:919.856.4520extension18:\Bogue Banks Informal Consultation.wpd

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive North
St. Petersburg, Florida 33702-2432

September 26, 2001

RECEIVED
Sept 26 2001
Regulatory
Wilmington Field Office

Colonel James W. DeLony
District Engineer, Wilmington District
Department of the Army, Corps of Engineers
P. O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Mr. Mickey Sugg

Dear Colonel DeLony:

This responds to your September 14, 2001, request for the National Marine Fisheries Service's (NMFS) comments on the August 17, 2001, letter from Coastal Science and Engineering (CSI). CSI is the consultant for Carteret County in their plan to renourish county beaches located on Bogue Banks (**Action ID No. 200000362**). The 16.8-mile-long project would be constructed in three phases over a period of three years and up to 8 million cubic yards of material would excavated from offshore sites and placed on eroded beaches.

The CSI letter largely responds to NMFS comments, dated June 25, 2001, which addresses unresolved issues related to the project. Also involved are matters which were discussed at meetings on June 20, July 16, and August 27, 2001, that were attended by representatives from CSI, the Corps of Engineers (COE), the U.S. Fish and Wildlife Service (FWS), the North Carolina Division of Marine Fisheries (NCDMF), the NOAA Center for Coastal Fisheries and Habitat Research (CCFHR), and Dr. Charles Peterson, University of North Carolina Institute for Marine Science (IMS).

Areas of Agreement:

1. Following completion of Phase I and prior to initiation of Phases II and/or III, the COE agrees to consult with state and Federal resource agencies. This consultation will address a full range of issues including the adequacy of completed monitoring and resource management implications associated with the study results. Other points of discussion include, but are not limited to, evaluation of other sand sources, and the acceptability of the dredging and disposal techniques employed.

2. The project will include a seasonal restriction that limits dredging and discharge of dredged material on ocean beaches to the period between November 15 and April 15. This restriction applies to all phases of the project and any extension on this seasonal restriction will be limited to not more than two (2) weeks. Additionally, state and Federal resource agencies must be notified not less than two (2) weeks in advance of the desired extension.

3. Success criteria for recovery of impacted areas, as described in the August 23, 2001, monitoring plan are acceptable with the following revisions. A 90 percent recovery of the established baseline diversity level will be used. In addition, successful recovery of donax (*Donax* spp.) and mole crab (*Emerita talpoida*) abundance (population size) shall be set at 90 percent due to the importance of these species as food for surf zone fishes. If the success criteria for recovery of species diversity and abundance have not be achieved by the completion of Phase II (estimated date 2003) then additional monitoring will be required in Phase III. In the event that Phase III is not constructed and recovery has not been achieved, up to (2) additional years of monition may be required.

4. Due to limited depth of the borrow sites (2-3 feet below existing bottom elevations) excavation shall be conducted by hopper dredge. It is also agreed that two dredges may work simultaneously during the allowed dredging periods.

Unresolved issues:

1. The NMFS, in consultation with the CCFHR, the NCDMF and Dr. Charles Peterson have consistently recommended that the monitoring plan must provide sufficient statistical power to detect project related changes in the benthic infauna populations in the surf zone and in the offshore borrow sites. Following the September 10, 2001, meeting, the NCDMF agreed to conduct an independent analysis of the plan. We understand that data generated by pre-project baseline sampling were recently given to the NCDMF and that the results of their analysis will soon be provided.

2. The FWS has determinated that material to be placed on the beach (a mix of materials from two different borrow sites) is not compatible with existing beach materials and is likely result in compaction that hamper sea turtle nesting. The NMFS is also concerned over the sand compatibility issue; however, we will defer our final position on this matter until ongoing analyses, which are being conduced by the COE, are completed. In this regard, we note that the a mixture of grain sizes found in the dredged material is likely to undergo rapid sorting in the high energy surf zones and areas having suitable substrates for colonization by invertebrates are likely to develop.

3. According to COE, the applicant's Environmental Assessment may meet any Federal requirement related to the National Environmental Policy Act and related procedural requirements. While this determination rests with the COE as the lead Federal agency, the NMFS has advised that an EIS may be warranted based on the severity of possible impacts and determination by the COE's Planning and Environmental Assessment Division that an EIS would be prepared all future Civil Works projects where beach nourishment is considered.

We appreciate the opportunity to provide these comments and we hope that they are useful in efforts to resolve issues and ensure that environmental concerns and needs are adequately addressed. Please direct related comments or questions to the attention of Mr. Ron Sechler at our Beaufort Facility. He can be reached at 101 Pivers Island Rd, Beaufort, North Carolina 28516, or at (252) 728-5090.

Sincerely,

Andreas Mager, Jr.
Assistant Regional Administrator
Habitat Conservation Division

cc: FWS, Raleigh, NC
EPA, Athens, GA
NCDENR, Raleigh, NC
SAFMC, Charleston, SC
F/SER4
F/SER45

State of North Carolina
Department of Environment
and Natural Resources
Division of Marine Fisheries

Michael F. Easley, Governor
William G. Ross, Jr., Secretary
Preston P. Pate, Jr., Director

NCDENR
NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

September 27, 2001

Mr. Doug Huggett
Division of Coastal Management
1638 Mail Service Center
Raleigh, NC 27699-1638

Re: Permit Application for beach nourishment project along 16.8 miles of Bogue Banks

Dear Mr. Huggett:

The Division of Marine Fisheries recommends approval of the project only if the following conditions are met:

1) For each sampling period, i.e. June and November, benthic sampling at each beach station should be conducted during the same portion of the tidal cycle. Beach benthos, especially *Donax* spp., migrate along the beach face in response to the water level. Sampling all five locations along each transect as close together, temporally, as possible will prevent sampling the same group of animals twice. We are aware that sampling in this manner was not adhered to in the June 2001 sampling, and this violation of sampling protocol cannot be allowed in future samples.

2) We have spent considerable time in reviewing the various iterations of the sampling design to monitor impacts to benthos from the beach and borrow areas and to the fish along the beach. We agree to proceed with the basic procedures described in the sampling design dated August 31, 2001, submitted by Coastal Science Associates **for Phase I only**. Our concerns with the plan are:

    a. Number 1 listed above must be adhered to.
    b. We require that a sampling design for Phase II and Phase III be developed according to the Division of Marine Fisheries' satisfaction before these phases begin.

3) The dredging/pumping window for this project shall be 16 November to 15 April.

4) Phase I dredging and pumping shall begin at the eastern end of the project to minimize impacts to the stop net fishery, unless consultations with local fishermen indicate otherwise.

P.O. Box 769, Morehead City, North Carolina 28557-0769 Telephone 252-726-7021 FAX 252-726-0254

If these conditions are not met the Division of Marine Fisheries will vigorously oppose this project.

Sincerely,

James Patrick Monaghan, Jr.

James Patrick Monaghan, Jr.
Supervisory Biologist

Cc: Preston Pate
David Taylor
Mike Marshall
Mike Street

P.O. Box 769, Morehead City, North Carolina 28557-0769 Telephone 252-726-7021 FAX 252-726-0254

THE TOWN OF PINE KNOLL SHORES

100 Municipal Circle, Pine Knoll Shores, North Carolina 28512

(252) 247-4353 • Fax (252) 247-4355 • E-mail: admin@townofpks.com

September 24, 2001

Colonel James W. DeLony, District Engineer
Wilmington District
U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402

Re: Bogue Banks Nourishment Project – Permit Action ID 200000362
Comments dated 20 September 2001 from USF&WS

Dear Colonel DeLony:

We are in receipt of comments dated 20 September 2001 from the USF&WS on the above referenced project. This is to confirm our acceptance of all conditions (Items 1 through 8, inclusive) as outlined in the letter from Garland Pardue.

We will continue to advise the USG&WS of our progress on the project as they have requested, and will submit the required monitoring data soon after it is obtained, as applicable.

Thank you for your consideration and your support is greatly appreciated.

Yours truly,

Reese Musg

C. Reese Musgrave, Mayor

TOWN OF INDIAN BEACH
Post Office Box 306
Salter Path, North Carolina 28575
(252) 247-3344

September 24, 2001

Colonel James W. DeLony, District Engineer
Wilmington District
U. S. Army Corps of Engineers
PO Box 1890
Wilmington, North Carolina 28402

Re: Bogue Banks Nourishment Project - Permit Action ID 200000362
Comments dated 20 September 2001 from USF&WS

Dear Colonel DeLony:

We are in receipt of comments dated 20 September 2001 from the USF&WS on the above referenced project. This is to confirm our acceptance of all conditions (Items 1 through 8, inclusive) as outlined in the letter from Garland Pardue.

We will continue to advise the USF&WS of our progress on the project as they have requested, and will submit the required monitoring data soon after it is obtained, as applicable.

Thank you for your consideration,

W. L. Fugate

W. L. Fugate, Mayor

WLF/bb
cc: Tim Kana, CSE

(856)

The Town of Emerald Isle

Mayor
Barbara M. Harris

Mayor Pro Tem
Emily Farmer

Commissioners
John F. Wootten
W. Emory Trainham
Jay Murphy
Pat McElraft

7500 Emerald Drive
Emerald Isle, North Carolina 28594-9320
Phone (252) 354-3424 Fax (252) 354-5068
www.emeraldisle-nc.org

Frank A. Rush, Jr
Town Manager

Harris, Farmer, Wootten, Trainham, Murphy, McElraft

September 24, 2001

Colonel James W. DeLony, District Engineer
Wilmington District
U.S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402

Re: Bogue Banks Nourishment Project - Permit Action ID 200000362
Comments dated 20 September 2001 from USF&WS

Dear Colonel DeLony:

We are in receipt of comments dated 20 September 2001 from the USF&WS on the above referenced project. This is to confirm our acceptance of all conditions (Items 1 through 8, inclusive) as outlined in the letter from Garland Pardue.

We will continue to advise the USF&WS of our progress on the project as they have requested, and will submit the required monitoring data soon after it is obtained, as applicable.

Thank you for your consideration.

Yours truly,

Frank A. Rush, Jr.
Town Manager

copy: Mayor Harris and Board of Commissioners

A Family Beach

Board of Commissioners
Doug Brady, Chairman
Jonathan Robinson, Vice-Chairman
Bettie Bell
David Wheatly
Jimmy LuShan
Sam Stell
Mac Wells

County Manager
Pete Allen
Tel: (252) 728-8450
Fax: (252) 728-2092
petea@co.carteret.nc.us
www.co.carteret.nc.us

September 21, 2001

Colonel James W. Delony, District Enigneer
Wilminton District
U. S. Army Corps of Engineers
Post Office Box 1890
Wilminton, North Carolina 28402-1890

Re: Bogue Banks Nourishment Project – Permit Action ID 200000362
Comments date 20 September 2001 from USF&WS

Dear Colonel Delony:

We are in receipt of comments dated 20 September 2001 from the USF&WS on the above referenced project. This is to confirm our acceptance of all conditions (Items 1 through 8, inclusive) as outlined in the letter from Dr. Garland Pardue.

We will continue to advise the USF&WS of our progress on the project as they have requested, and will submit the monitoring data soon after it is obtained, as applicable.

Thank you for your consideration.

Sincerely yours,

Pete Allen
Carteret County Manager

cc: Chairman Brady & Members of the County Board of Commissioners

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1890
WILMINGTON, NORTH CAROLINA 28402-1890

REPLY TO
ATTENTION OF

October 1, 2001

Regulatory Division

Action ID No. 200000362

Mr. Garland Purdue
U.S. Fish and Wildlife Service
Post Office Box 33726
Raleigh, North Carolina 27636-3726

Dear Mr. Purdue:

This letter confirms the receipt of your September 20, 2001 letter, regarding Section 7 consultation, pursuant to the Endangered Species Act (ESA) of 1973, for the Bogue Banks beach nourishment project along 16.8 miles of Bogue Banks Barrier Island, in Carteret County, North Carolina.

In summary, you state that, if the applicants agree to implement the conservation measures enclosed in your letter, the Fish and Wildlife Service would concur with a determination that the proposed project is "not likely to adversely affect" any Federally-listed endangered or threatened species, designated critical habitat, or species proposed for Federal listing under ESA and would terminate formal consultation.

In a response, the applicants have confirmed, by enclosed correspondence, to accept all conservation conditions set forth in your letter. Additionally, this agreement was verified during our October 1, 2001 meeting with Messrs. Dale Suiter and David Rabon of your staff and the applicant's agent, Mr. Tim Kana of Coastal Science and Engineering. With this agreement and the implementation of the conservation measures as a permit condition, we have determined that the dredging and disposal of material associated with the beach nourishment is "not likely to adversely affect" sea beach amaranth (*Amaranthus pumilus)* and the following sea turtle species: Loggerhead (*Caretta caretta*), Leatherback (*Dermochelys coriacea*), Kemp's ridley (*Lepidochelys kempi*), Hawksbill (*Eretmochelys imbricata*), and Green (*Chelonia mydas*).

By copy of this letter, we have verified the applicant's consent to comply with the conservation measures and, at this time, concur with the discontinuation of formal consultation. If you have questions or comments, they may be addressed to Mr. Mickey Sugg, Wilmington Regulatory Field Office, at (910) 251-4811.

Sincerely,

G. Wayne Wright, Chief
Wilmington Regulatory Division

Copies Furnished:

Mr. William Cox, Chief
Wetlands Section- Region IV
U.S. Environmental Protection Agency
61 Forsyth Street, SW
Atlanta, Georgia 30303

Mr. Doug Huggett
Division of Coastal Management
North Carolina Department of Environment,
and Natural Resources
1638 Mail Service Center
Raleigh, North Carolina 27699-1638

Mr. David Rackley
National Marine Fisheries Service
219 Fort Johnson Road
Charleston, South Carolina 29412-9110

Mr. Ron Sechler
National Marine Fisheries Service
101 Pivers Island Road
Beaufort, North Carolina 28516

Mr. Pete Allen, Manager
Carteret County
Courthouse Square
Beaufort, North Carolina 28516

Mayor C. Reese Musgrave
Town of Pine Knoll Shores
100 Municipal Court
Pine Knoll Shores, North Carolina 28512

Mayor William L. Fugate
Town of Indian Beach
Post Office Box 306
Salter Path, North Carolina 28575

Mayor Barbara M. Harris
Town of Emerald Isle
7500 Emerald Drive
Emerald Isle, North Carolina 28594-9320

Mr. Bill Forman
804 Arendell Street
Suite 1
Morehead City, North Carolina 28557

APPENDIX A-2

Permit

Permit Class
NEW

Permit Number
124-01

STATE OF NORTH CAROLINA

Department of Environment and Natural Resources
and
Coastal Resources Commission

Permit

for

X Major Development in an Area of Environmental Concern pursuant to NCGS 113A-118

X Excavation and/or filling pursuant to NCGS 113-229

Issued to **Carteret, County of, Courthouse Square, Beaufort, NC 28516**

Authorizing development in Carteret County at Atlantic Ocean, Bogue Banks Beaches

, as requested in the permittee's application dated 1/24/01, incl. drawings (19), 1,2,3a-3e, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 & 14 of 14, all dated 1/19/01 and 3f of 14 dated 8/29/01, and 1/24/01 AEC Hazard Notice

This permit, issued on October 5, 2001, is subject to compliance with the application (where consistent with the permit), all applicable regulations, special conditions and notes set forth below. Any violation of these terms may be subject to fines, imprisonment or civil action; or may cause the permit to be null and void.

1) In addition to the permittee listed above, the Towns of Pine Knoll Shores, Indian Beach and Emerald Isle have all submitted documentation requesting that their municipalities be added as co-applicants to Carteret County's permit application. Consequently, these three Towns are hereby added to this permit as co-permittees, and as such are bound by all permit conditions contained herein.

Beach Nourishment Activities

2) Prior to the initiation of any beach nourishment activity above mean high water (MHW) within the limits of the permittee's jurisdiction (e.g. Pine Knoll Shores), easements from all property owners within that specific community must be obtained.

(See attached sheets for Additional Conditions)

This permit action may be appealed by the permittee or other qualified persons within twenty (20) days of the issuing date. An appeal requires resolution prior to work initiation or continuance as the case may be.

This permit must be accessible on-site to Department personnel when the project is inspected for compliance.

Any maintenance work or project modification not covered hereunder requires further Division approval.

All work must cease when the permit expires on

December 31, 2004

In issuing this permit, the State of North Carolina agrees that your project is consistent with the North Carolina Coastal Management Program.

Signed by the authority of the Secretary of DENR and the Chairman of the Coastal Resources Commission.

Donna D. Moffitt, Director
Division of Coastal Management

This permit and its conditions are hereby accepted.

Signature of Permittee

ADDITIONAL CONDITIONS

3) Prior to the initiation of any beach nourishment activity, the existing mean high water line and the first line of stable natural vegetation used as the reference point for measuring future oceanfront setbacks must be delineated and the line approved by representatives from the Division of Coastal Management. The approved lines must be surveyed in and the survey submitted to Division. If nourishment activity for a particular community is not initiated within sixty (60) days and/or there is a major shoreline change prior to the commencement of beach nourishment, a new survey must be conducted.

4) In order to protect threatened and endangered species and to minimize adverse impacts to offshore, nearshore, intertidal and beach resources no beach nourishment activity may occur from April 1 to November 15 of any year without prior approval from the North Carolina Division of Coastal Management in consultation with the NC Division of Marine Fisheries and the NC Wildlife Resources Commission.

NOTE: The permittee is advised that there may be additional timing restrictions placed on the authorized project by the U.S. Army Corps of Engineers as part of the Federal permit process. Nothing in this State Permit should be construed as overriding or superceding any such Federal permit requirement.

5) This permit authorizes beach nourishment activities to be carried out one (1) time along the entire reach of the requested project area. Any request to carry out additional activities within an area where nourishment activities have been completed will require a modification of this permit.

6) All excavation activities must take place within one of the three borrow areas (A, B1, and B2) as shown on the attached workplat drawings. Excavation from borrow area A shall not exceed –3' below existing contours while excavation from borrow area B1 and B2 shall not exceed –4' below existing contours.

7) Temporary dikes must be used to retain and direct flow of material parallel to the shoreline to minimize surf zone turbidities. The temporary dikes shall be removed and the beach graded in accordance with approved profiles upon completion of pumping activities within each specific area.

8) Only beach quality sand shall be used for beach nourishment purposes. Furthermore, sand of similar grain size to the existing beach will be used to reduce any changes in physical characteristics of the beach.

9) Should the dredging operations encounter any non-beach compatible sand, the dredge shall immediately cease operation and move to an approved area where suitable material does exist.

10) The seaward nourishment limit varies among the six nourishment plan reaches. However, the seaward nourishment limit for each reach must be conducted in accordance with the approved work plats labeled Nourishment Plan Reach 1 through 6, each dated January 19, 2001 except for reach six which is dated August 29, 2001.

11) In order to prevent leakage, dredge pipes shall be routinely inspected. If leakage is found and repairs cannot be made immediately, pumping of material shall stop until such leaks are fixed.

ADDITIONAL CONDITIONS

12) Once a section is complete, piping and heavy equipment shall be removed or shifted to a new section and the area graded and dressed to final approved slopes.

13) Land-based equipment necessary for beach nourishment work shall be brought to the site through existing accesses. Should the work result in any damage to existing accesses, the accesses must be restored to pre-project conditions immediately upon project completion in that specific area.

14) Where oceanfront development exists at elevations nearly equal to that of the native beach, a low protective dune will be pushed up along the backbeach to prevent slurry from draining towards the development.

15) Dune disturbance shall be kept to a minimum. Any alteration of existing dunes shall be coordinated with the Division of Coastal Management as well as the pertinent property owner. All disturbed areas must be restored and revegetated immediately following project completion in that specific area.

16) The applicant has committed to the installation of dune fencing and plantings where appropriate. Any such proposal involving sand fence installation shall be submitted to the Division of Coastal Management for approval to insure that such installation does not impede public access or emergency vehicles and does not endanger nesting sea turtles. Any derelict sand fencing shall be immediately removed from the beach.

17) Prior to any beach nourishment activity, all exposed remnants of or debris from failed erosion control structures must be removed by the permittee.

18) The permittee shall begin dredging and pumping at the eastern end of the project to minimize impacts to the stop net fishery, unless consultations with the Division of Marine Fisheries indicate otherwise.

Endangered Species Protection

19) An observer shall be present on the hopper dredge except during the colder months of January and February to document any takes of sea turtles or other endangered species. Any encounters with threatened or endangered species will be recorded and reported to the Division of Coastal Management, the Wildlife Resources Commission, the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service. In addition, a turtle deflector draghead shall be properly used.

20) Only beach quality sand suitable for sea turtle nesting, successful incubation and hatchling emergence shall be used for beach nourishment purposes. Furthermore, sand of similar grain size to the existing beach will be used to reduce any changes in physical characteristics of the beach that may affect nest survival.

ADDITIONAL CONDITIONS

21) In accordance with commitments made in the EIS prepared for this project, immediately after completion of any phase of the beach nourishment project, and prior to the next three nesting seasons, beach compaction shall be monitored and tilling shall be conducted as necessary to reduce the likelihood of impacting sea turtle nesting and hatching activities. All tilling must be done to a depth of 36 inches and must be completed no later than May 1. An annual report on the beach compaction monitoring shall be provided to the Division of Coastal Management and the NC Wildlife Resources Commission by June 1st of each year in which monitoring takes place.

22) In accordance with commitments made in the EIS prepared for this project, immediately after completion of any phase of the beach nourishment project, and prior to the next three nesting seasons, monitoring shall be conducted to determine if escarpments are present that would affect nesting sea turtles or public access. If such escarpments are present, they should be leveled as necessary to reduce the likelihood of impacting sea turtle nesting and hatching activities.

23) Should any work take place within the sea turtle nesting period of May 1st to November 15th, sea turtle crawl and nest monitoring will take place each morning. Any necessary nest relocations will be coordinated with the NC Wildlife Resources Commission and carried out by qualified personnel prior to the construction of that project section.

Biological Monitoring Requirements

24) The sampling procedures and protocols described in the August 31, 2001 sampling design submitted by Coastal Science Associates will be carried out for the 2001-02 dredging window only. Prior to the initiation of activities any future dredging windows, a sampling design shall be developed in coordination with the N.C. Division of Marine Fisheries (DMF) that further satisfies DMF concerns. A copy of this monitoring protocol, as well as written approval of its acceptance by the DMF, must be provided to the Division of Coastal Management prior to initiation on dredging during these future dredge windows. All conditions and stipulations of this modified monitoring plan must be strictly adhered to.

25) For each sampling period (i.e. June and November), benthic sampling at each beach station shall be conducted during the same portion of the tidal cycle. Beach benthos, especially *Donax spp.*, migrate along the beach face in response to water level. Sampling all five locations along the transect as close together temporally as possible will prevent sampling the same group of animals twice.

26) Unless altered herein, the permittee shall implement the biological sampling and monitoring program outlined in Appendix C of the Environmental Impact Statement prepared for this project.

Post Nourishment Beach Sediment Monitoring

27) Beach compaction shall be monitored and tilling shall be conducted in any areas where the post-nourishment beach is harder than 500 CPU's. The monitoring and tilling shall also be done in accordance with Condition No. 21 of this Permit.

ADDITIONAL CONDITIONS

Sedimentation and Erosion Control

NOTE: An Erosion and Sedimentation Control Plan will be required for this project. This plan must be filed at least thirty (30) days prior to the beginning of any land disturbing activity. Submit this plan to the Department of Environment and Natural Resources, Land Quality Section, 127 Cardinal Drive Extension, Wilmington, NC 28405.

Cultural Resource Protection

29) The N.C. Department of Cultural Resources (NCDCR) has identified six archaeological sites along the Bogue Banks Beaches. These sites are listed as follows:

- 001BBB – Iron Steamer Pier Wreck Site
- 002BBB – Gun Emplacement Site
- 003BBB – Salter Path Site
- 004BBB – Cupulo Site
- 005BBB – Emerald Isle Pier Wreck Site
- 006BBB – Ocean Reef Site

The exact locations of these six sites may be confirmed by contacting a representative of the NCDCR at (919) 733-4763. All authorized work shall avoid these areas unless prior approval is obtained from NCDCR.

30) As referenced in the text addendum to the permit application, the western portion of Borrow Area B-2 shall be avoided due to the presence of 10 magnetic anomalies.

31) There exists the possibility that the authorized activities may unearth a beached shipwreck. Should such a finding occur, the permittee shall immediately move to another area. The NCDCR Underwater Archaeology Branch must also be contacted at (910) 458-9042 to determine appropriate response procedures.

General

32) The permittee and/or his contractor shall schedule a pre-construction conference with a Division of Coastal Management representative prior to the initiation of any dredging activities. No attempt will be made by the permittee to prevent the full and free use by the public of all navigable waters at or adjacent to the authorized work.

33) The authorized activity must not cause an unacceptable interference with navigation.

34) The permittee shall comply with all U.S. Coast Guard regulations.

ADDITIONAL CONDITIONS

35) All commitments made during the environmental review process as found in the Final Environmental Impact Statement must be adhered to, including the basic procedures described in the sampling design dated August 31, 2001 and with the associated Biological Monitoring Proposal.

36) This permit does not grant any property rights or exclusive privileges to the permittee.

37) The permittee shall obtain any necessary authorizations or approvals from the USACOE prior to initiation of permitted activity. All conditions of this Federal approval must be adhered to, including the commitment made by the permittee to provide public access consistent with Federal regulations and policies.

38) The permittee and/or his contractor shall provide for proper storage and handling of all oils, chemicals, hydraulic fluids, etc., necessary to carry out the project.

39) This permit does not authorize any permanent or long-term interference with the public's right of access and/or usage of all State lands and waters.

NOTE: This permit does not eliminate the need to obtain any additional state, federal or local permits, approvals or authorizations that may be required.

NOTE: The permittee is advised that the State of North Carolina claims title to all lands raised above the mean high water line.

NOTE: Future nourishment activities may require a modification of this permit. Contact a representative of the Division at (252) 808-2808 prior to the commencement of any such activity for this determination.

NOTE: The permittee and/or his contractor is urged to meet with a representative of the Division prior to project initiation.

NOTE: The N.C. Division of Water Quality has authorized the proposed project under General Water Quality Certification No. 3274 (DWQ Project No. 010324), which was issued on 03/23/01.

APPENDIX A-2

Permit Application

MAJOR CAMA PERMIT APPLICATION

BOGUE BANKS BEACH NOURISHMENT

January 24, 2001

Applicant:

County of Carteret
Courthouse Square
Beausfort, North Carolina
Carteret County

Submitted to:

Division of Coastal Management
Morehead City Regional Office
151-B Highway 24
Morehead City, North Carolina 28557

Form DCM-MP-1

APPLICATION

(To be completed by all applicants)

1. APPLICANT

a. Landowner: Carteret County
c/o County Manager
Name Mr. Robert Murphy

Address Courthouse Square

City Beaufort State NC

Zip 28516 Day Phone 252-728-8450

Fax 252-728-2092

b. Authorized Agent:

Name Mr. Dave Clark, PE, County Engineer

Address Carteret County Courthouse Square

City Beaufort State NC

Zip 28516 Day Phone 252-728-8452

Fax 252-728-2092

c. Project name (if any)
Bogue Banks Beach Nourishment

NOTE: Permit will be issued in name of landowner(s), and/or project name.

2. LOCATION OF PROPOSED PROJECT

a. County Carteret

b. City, town, community or landmark
Pine Knoll Shores, Salter Path, Indian Beach, Emerald Isle

c. Street address or secondary road number
Beach front from Shipwreck Lane (Emerald Isle) to Pine Knoll Shores/Atlantic Beach boundary

d. Is proposed work within city limits or planni jurisdiction? ✓ Yes ____ No
Within city above MHW; owned by state below MHW

e. Name of body of water nearest project (e.g. rive creek, sound, bay) Atlantic Ocean

3. DESCRIPTION AND PLANNED USE OF PROPOSED PROJECT

a. List all development activities you propose (e.g building a home, motel, marina, bulkhead, pier, an excavation and/or filling activities.
Excavation and filling by dredge and pipeline; beach nourishment

b. Is the proposed activity maintenance of an existin project, new work, or both? New work

c. Will the project be for public, private or commercia use? Public use

d. Give a brief description of purpose, use, methods o construction and daily operations of propose project. If more space is needed, please attacl additional pages.
See attached under Project Description, and METHODS OF CONSTRUCTION

4. LAND AND WATER CHARACTERISTICS

a. Size of entire tract 16.8 miles by 1000 feet

b. Size of individual lot(s) N/A

c. Approximate elevation of tract above MHW or NWL Berm at +7 ft NGVD (+5 ft MHW) with logistics activities on construction berm seaward of natural dunes and vegetation

d. Soil type(s) and texture(s) of tract Mixed sand (FS/MS/CS) and shell (~25%)

e. Vegetation on tract Sand placement seaward of vegetation, except where dunes are too low for storm protection

f. Man-made features now on tract Dune walkovers, seawalls, and fishing piers

g. What is the CAMA Land Use Plan land classification of the site? *(Consult the local land use plan.)*
Tables attached for each municipality

______ Conservation	______ Transitional
______ Developed	______ Community
______ Rural	______ Other

h. How is the tract zoned by local government?
Tables attached for each municipality

i. Is the proposed project consistent with the applicable zoning? ✓ Yes ______ No
(Attach zoning compliance certificate, if applicable)
Tables attached for each municipality

j. Has a professional archaeological assessment been done for the tract? ✓ Yes ______ No
If yes, by whom? Tidewater Atlantic Research Inc (Appendix B of EIS)

k. Is the project located in a National Registered Historic District or does it involve a National Register listed or eligible property?
______ Yes ✓ No

l. Are there wetlands on the site? ____ Yes ✓ No
Coastal (marsh) ______ Other ______
If yes, has a delineation been conducted? ________
(Attach documentation, if available)

m. Describe existing wastewater treatment facilities.
Wastewater on Bogue Banks by subsurface treatment and/or package plants with on-site disposal

n. Describe location and type of discharges to water of the state. (For example, surface runoff, sanitar wastewater, industrial/commercial effluent, "wasl down" and residential discharges.)
See attached under Project Description Turbidity

o. Describe existing drinking water supply source.
Potable water on Bogue Banks provided by municipal and private water utilities; source is wells

5. ADDITIONAL INFORMATION

In addition to the completed application fo the following items must be submitted:

- **A copy of the deed** (with state application only) or other instrument under which the applicant claims title to the affected properties. If the applicant is not claiming to be the owner of said property, then forward a copy of the deed or other instrument under which the owner claims title, plus written permission from the owner to carry out the project.

- **An accurate, dated work plat** (including plan view and cross-sectional drawings) drawn to scale in black ink on an 8 1/2" by 11" white paper. (Refer to Coastal Resources Commission Rule 7J.0203 for a detailed description.)

  Please note that original drawings are preferred and only high quality copies will be accepted. Blue-line prints or other larger plats are acceptable only if an adequate number of quality copies are provided by applicant. (Contact the U.S. Army Corps of Engineers regarding that agency's use of larger drawings.) A site or location map is a part of plat requirements and it must be sufficiently deta to guide agency personnel unfamiliar with the area to the site. Include highway or secondary road (SR) numbers, landmarks, and the like.

- A Stormwater Certification, if one is necessary.

- **A list of the names and complete addresses of the adjacent waterfront (riparian) landowners and signed return receipts as proof that such owners have received a copy of the application and plats by certified mail.** Such landowners must be advised that they have 30 days in which to submit comments on the proposed project to the Division of Coastal Management. Upon signing this form, the applicant further certifies that such notice has been provided.

Name Mailings from each community are proceeding
Address
Phone

Name
Address
Phone

Name
Address
Phone

- **A list of previous state or federal permits issued for work on the project tract.** Include permit numbers, permittee, and issuing dates.

None for beach nourishment

- **A check for $250** made payable to the Department of Environment, Health, and Natural Resources (DEHNR) to cover the costs of processing the application.

- A signed AEC hazard notice for projects in oceanfront and inlet areas.

- A statement of compliance with the N.C. Environmental Policy Act (N.C.G.S. 113A - 1 to 10) If the project involves the expenditure of public funds or use of public lands, attach a statement documenting compliance with the North Carolina Environmental Policy Act.
NC EPA review of EIS is underway
This application is being submitted concurrently

6. CERTIFICATION AND PERMISSIO[N] TO ENTER ON LAND

I understand that any permit issued in response to thi[s] application will allow only the development described i[n] the application. The project will be subject to condition[s] and restrictions contained in the permit.

I certify that to the best of my knowledge, the propose[d] activity complies with the State of North Carolina'[s] approved Coastal Management Program and will b[e] conducted in a manner consistent with such program.

I certify that I am authorized to grant, and do in fact grant permission to representatives of state and federa[l] review agencies to enter on the aforementioned lands in connection with evaluating information related to thi[s] permit application and follow-up monitoring of th[e] project.

I further certify that the information provided in thi[s] application is truthful to the best of my knowledge.

This is the 24th day of January, 2001.

Print Name Dave Clark, PE

Signature Dave Clark
Landowner or Authorized Agent

Please indicate attachments pertaining to your proposed project.

✓ DCM MP-2 Excavation and Fill Information
___ DCM MP-3 Upland Development
___ DCM MP-4 Structures Information
___ DCM MP-5 Bridges and Culverts
___ DCM MP-6 Marina Development

NOTE: Please sign and date each attachment in the space provided at the bottom of each form.

EXCAVATION AND FILL

(Except bridges and culverts)

Attach this form to Joint Application for CAMA Major Permit, Form DCM-MP-1. Be sure to complete all other sections of the Joint Application that relate to this proposed project.

Describe below the purpose of proposed excavation or fill activities. **All values to be given in feet.**

	Length	Width	Average Existing Depth	Final Project Depth
Access channel (MLW) or (NWL)				
Canal				
Boat basin				
Boat ramp				
Rock groin				
Rock breakwater				
Other (Excluding shoreline stabilization) Fill	90,000	1,000	-2 MLW	+8 MLW and below
Excavation:				
Area A	11,000	10,000	-45 MLW	-48 MLW
Area B1	27,000	1,000	-35 MLW	-39 MLW
Area B2	27,000	1,000	-35 MLW	-39 MLW

1. EXCAVATION

a. Amount of material to be excavated from below MHW or NWL in cubic yards Up to 8,000,000

b. Type of material to be excavated See attached under Project Description Borrow Area Characteristics

c. Does the area to be excavated include coastal wetlands (marsh), submerged aquatic vegetation (SAVs) or other wetlands? ____ Yes ✓ No

d. Highground excavation in cubic yards None

2. DISPOSAL OF EXCAVATED MATERIAL

a. Location of disposal area See sheets 1 and 2 on work plats

b. Dimensions of disposal area See attached under Project Description Fill Placement on Beach

c. Do you claim title to disposal area?
____ Yes ✓ No
If no, attach a letter granting permission from the owner.
Easements for areas above MHW are being obtained

d. Will a disposal area be available for future maintenance? ✓ Yes ____ No
If yes, where? Future beach fill will be necessary for maintenance and replacement

e. Does the disposal area include any coastal wetlands (marsh), SAVs or other wetlands?
_____ Yes __✓__ No

f. Does the disposal include any area in the water?
__✓__ Yes _____ No

3. SHORELINE STABILIZATION

a. Type of shoreline stabilization
__N/A__ Bulkhead _____ Riprap

b. Length __N/A__

c. Average distance waterward of MHW or NWL
N/A

d. Maximum distance waterward of MHW or NWL
N/A

e. Shoreline erosion during preceding 12 months
N/A
(Source of information) _____

f. Type of bulkhead or riprap material _____
N/A

g. Amount of fill in cubic yards to be placed below water level
(1) Riprap __N/A__
(2) Bulkhead backfill _____

h. Type of fill material __N/A__

i. Source of fill material __N/A__

4. OTHER FILL ACTIVITIES
(Excluding Shoreline Stabilization)

a. Will fill material be brought to site?
__✓__ Yes _____ No
See attached under
Project Description Fill Placement on Beach

If yes,
(1) Amount of material to be placed in the water __See * below__
(2) Dimensions of fill area __See attached under Project Description__
(3) Purpose of fill __Beach nourishment__

b. Will fill material be placed in coastal wetland (marsh), SAVs or other wetlands?
_____ Yes __✓__ No
If yes,
(1) Dimensions of fill area _____
(2) Purpose of fill _____

*Placement above water, with slurry forming fill approximately 50% above MLW, 50% below MLW. See attached under Project Description Fill Placement on Beach

5. GENERAL

a. How will excavated or fill material be kept on site and erosion controlled? __See attached under Project Description Turbidity and METHODS OF CONSTRUCTION__

b. What type of construction equipment will be used (for example, dragline, backhoe, or hydraulic dredge)?
Hydraulic dredge

c. Will wetlands be crossed in transporting equipment to project site? _____ Yes __✓__ No
If yes, explain steps that will be taken to lessen environmental impacts. _____

Dave Clark, PE, for Carteret County
Applicant or Project Name

Dave Clark
Signature

24-January 2001
Date

Attached comments for "Bogue Banks Beach Nourishment" Permit Application

3.d. DESCRIPTION AND PLANNED USE OF PROPOSED PROJECT

PURPOSE AND USE

Project Setting — Bogue Banks is a 25-mile-long barrier island along the southern margin of Carteret County (Sheet 1 of 14). It comprises about one-third of the county's ocean shoreline and is the only developed and vehicle-accessible beach in the area. The remaining 55 miles of barrier islands of the county, including Shackleford Banks and Core Banks up to Ocracoke Inlet, are inaccessible wildlife preserves that will remain undeveloped in perpetuity as part of the Cape Lookout National Seashore. The western two-thirds of Bogue Banks from Pine Knoll Shores to Emerald Isle (beach survey lines 76 to 8 on Sheet 2) has sustained severe erosion and damage to numerous structures since 1995 as a result of five landfall hurricanes. This ~16.8-mile length of Bogue Banks has a sand deficit compared to adjacent beaches which has left property unprotected and has diminished recreational use of the beach. The county and local municipalities propose a beach nourishment project to restore the sand deficit and provide improved storm protection and recreational beach area.

Project Description — The proposed project consists of excavating by hydraulic dredge up to 8 million cubic yards (cy) of beach-quality sediment from ocean borrow areas (designated A, B1, and B2 in water depths averaging 35-45 feet), situated 0.5-3.0 miles offshore of Pine Knoll Shores, Indian Beach, and Emerald Isle (Sheets 11-14). Shallow excavations (~2-3 ft deep, typical) (Sheet 10) would be made by hopper dredge or specialty suction dredge and pumped via submerged pipe to the beach. The nourishment area consists of six reaches totaling 16.8 miles and designated (1) Emerald Isle-West, (2) EI-Central, (3) EI-East, (4) Indian Beach-Salter Path, (5) Pine Knoll Shores-West, and (6) PKS-East (Sheets 3a-3f). Sediment would be spread via land-based equipment and shaped into a recreational beach between the existing toe of the foredune and low watermark. Approximately 50 percent of the excavations would be deposited between existing mean low water and the outer bar (about 500-750 ft offshore). The remaining excavations would be placed above existing mean low water and graded to match the natural beach with berm elevations at approximately +7 ft NGVD (~+5 ft above mean high water) (Sheets 4-9). The fill quantity for each reach varies according to the profile deficit, background erosion rate, and quality of the fill material (overfill factor).

<u>Coordination with Municipalities</u>. It is anticipated that individual communities would assume responsibility for project execution within a particular reach and control the timing of implementation, scale, and scope of the work (up to the maximum quantities listed herein). However, the county, on behalf of municipalities along Bogue Banks, is requesting a permit for the entire project

so that the full scope of work can be coordinated. As such, the **county requests permit(s) that will allow the municipalities of Pine Knoll Shores, Indian Beach, Emerald Isle, and the unincorporated area of Salter Path (c/o Carteret County) to implement nourishment in their respective reaches under the same permit.** An EIS for the project has been prepared and submitted for review (presently approved by NCDENR offices and in review with state "clearinghouse" agencies, January 2001).

Borrow Area Characteristics. Three offshore borrow areas (A, B1, B2) are proposed based on extensive borings in 1999 and 2000 off Bogue Banks (detailed in the EIS for the project). All areas are dominated by sandy sediments and are situated seaward of the littoral zone in water depths averaging 35-48 feet (ft). See Sheets 11-14 for detailed sediment characteristics. Borrow area A has composite overfill ratios of about 1.16. Borrow areas B1 and B2 have composite overfill ratios of about 1.97 to 2.19. Because nourishment pumping costs increase with distance, it is anticipated that borrow areas B1 and B2 will yield lower unit construction costs that borrow area A. However, because of sediment quality differences and higher overfill ratios, more volume will have to be excavated from borrow areas B1 and B2 to equal the performance of sediments from borrow area A. The nourishment plan for each reach optimizes the borrow area and cost, based on best-available information. **The applicant requests permits that allow any combination of reach and borrow areas.** Assuming the average excavation depth is 3 ft, borrow area(s) totaling a maximum of ~2.58 square miles will be required to provide up to 8 million cubic yards. If all sediment is derived from borrow A, approximately 5.1 million cubic yards will be required, encompassing an area of 1.65 square miles. Portions of the borrow area(s) will be left undisturbed so that biological recovery may be accelerated via recruitment from adjacent areas. The anticipated impacted area for excavations represents 2.1 to 3.4 percent of the ocean bottom off Bogue Banks within state territorial waters (3-mile limit).

Fill Placement on Beach. Sediment from borrow areas A, B1, and/or B2 will be pumped to the beach and distributed alongshore with the aid of land-based equipment and open-ended training dikes. The slurry mixture of sediments and seawater will be discharged parallel to shore between the toe of the existing foredune and a temporary dike pushed up about 150-200 ft seaward of the foredune. Coarsest sediments will tend to settle out near the discharge point and finer sediments will tend to wash down-profile and be discharged in the surf zone, where they will build up the underwater profile. Muddy sediments, which comprise <4 percent of the borrow deposits in total, are expected to wash seaward of the outer bar before settling. The final distribution of grain sizes across the littoral zone is expected to be similar to the natural gradation that presently exists (ie, fining in the offshore direction). The indicated fill profiles (Sheets 4-9) show the "base" fill quantity (if overfill ratios were 1.0 and the borrow and native sediment matched perfectly) and the extra volume required to account for "overfill." The overfill portion shown on the drawings represents the anticipated maximum volume required if borrow areas B1 or B2 are used. This portion of the fill volume will be reduced if borrow area A is used.

The final dimensions of the nourished beach will vary according to the site-specific deficit and particular borrow area used. The landward 100-250 ft will consist of subaerial beach (dry-sand berm and upper beach face) shaped to match a natural profile. Typical elevations will range from +7 ft NGVD at the toe of the foredune (most landward edge of nourishment) to 0 ft NGVD along the beach face. Below the mid beach face contour, waves will rework and shape the nourishment sediments into a natural profile. Nourishment sand is expected to partially fill the inner trough between the existing beach face and outer bar, a width of ~500 ft. The outer bar will provide a natural toe for the fill. Only the most landward sections of the nourishment profile above mean high water (see Sheets 3a-3f) are controllable during construction. The underwater section will be controlled by waves and will vary with the contours according to conditions at the time of placement.

Turbidity. The project will produce temporary and localized increases in turbidity, normally associated with dredging operations. Because ~96 percent of the excavated material is in the sand-size class or larger, it will settle almost immediately and not remain in suspension. Silts which constitute a major portion of the mud percentage, likewise, have settling rates measured in minutes, not hours. The clay-sized particles released with the slurry have the longest settling times and may leave localized plumes for hours. The effect of the project on turbidity levels in the surf zone is expected to fall within the natural range of turbidities associated with fair weather and storm conditions. The construction methodology provides for separation of fines either during loading of hopper dredges or during discharge along the beach. Mechanical shaping of the fill berm will preclude formation of settling basins where fines may concentrate and be buried under the nourished beach.

Purpose and Need — Carteret County and the communities on Bogue Banks recognize the ocean-front beaches and adjacent properties as a valuable public economic and ecological resource. They desire to protect these valuable resources. From an economic perspective, the need for the proposed Bogue Banks beach nourishment project is to protect and preserve the largest portion of the county's overall economy. Tourism is, by far, the largest industry in Carteret County. The industry contributes ~$208 million annually to the economy of Carteret County, with a direct payroll of more than $38 million to over 3,400 workers.

Bogue Banks represents less than 1 percent of Carteret County's land area but accounts for ~43 percent (over $2 billion of the county's $5.4 billion tax base) of Carteret County's ad valorem property tax base (1997). Approximately 61 percent of all locally generated revenues in the county derive from property taxes with the remainder from sales taxes, occupancy taxes, and fees. Nearly 80 percent of Carteret County's tax levy funds Carteret County schools. Out of 8,483 students in Carteret County schools, only 537 (6.3 percent) reside on Bogue Banks (1997-98). Thus, property owners on Bogue Banks provide almost half the funds for county schools but make up less than 10 percent of the school population. Any reduction of the effective subsidy derived from Bogue Banks property and economic activity would result in increased property taxes over the remainder of the county. Loss of the first row of oceanfront properties (which alone comprise nearly 10 percent of the county tax base) would result in a county-wide tax increase of ~$0.05/$100 (from $0.51/$100 to $0.56/$100; 2000-2001 fiscal year) to make up for the reduced tax base.

Oceanfront properties represent an inordinate share of total property tax revenues to the Bogue Banks municipalities. Emerald Isle has a total tax base of ~$1,000,000,000 with ~$300,000,000 of the tax base deriving from oceanfront property. The loss of the oceanfront row of properties in Emerald Isle would result in a property tax increase of ~$0.09/$100 from $0.195/$100 to $0.285/$100. Pine Knoll Shores has a total tax base of ~$415,000,000 with ~45 percent ($185,000,000) of the tax base deriving from oceanfront property. The loss of the oceanfront row in Pine Knoll Shores would result in a property tax increase of ~$0.13/$100 from $0.16/$100 to $0.29/$100. Indian Beach has a total tax base of ~$100,000,000 with $60,000,000 of the tax base deriving from oceanfront property. The loss of the oceanfront row of properties in Indian Beach would result in a property tax increase of ~$0.26/$100 from $0.17/$100 to $0.43/$100.

The county also recognizes the beaches of Bogue Banks as a valuable ecological resource. Of over 70 miles of barrier island shoreline located in Carteret County, Bogue Banks is the only developed portion. The remainder, made up of Shackleford Banks and Core Banks to Ocracoke Inlet, will remain undeveloped in perpetuity as part of the Cape Lookout National Seashore. Bogue Banks serves to draw human activity away from the pristine beaches and ecosystems of Shackleford and Core Banks. The health of the beach environment is essential to a positive experience for the beach visitor. The damage associated with severe storms results in the loss of high oceanfront dunes, scrub and maritime forests. Easily accessible wide dry beach areas, high dunes and maritime forests harbor a wide range of wildlife resources and, because of the effects of erosion, are becoming increasingly rare along North Carolina's shoreline.

The sportfishing industry in Carteret County is second in size only to Dare County. The health of those activities (including fishing, boat building, and outfitting and supply) is dependent on the health of the marine environment.

Project Planning Objectives – In undertaking the beach nourishment project, Carteret County has several objectives that the project must meet. Those objectives are summarized as follows:

- Preservation of the environmental, cultural and aquatic resources of the county.
- Provide an easily accessible recreational beach available to all citizens of the county.
- Provide protection of oceanfront property as a resource of tax revenues to the municipalities of Bogue Banks and the county.
- Maintain the economic viability of tourism, the county's largest industry.

PROJECT FORMULATION

Fill Profile — Beach nourishment may be performed at a continuum of scales, depending on the goals of the project, availability of borrow sediment, method of construction, and budget. Since the proposed project area has not been nourished, there are no site-specific data to use as a guide other than the existing natural profile and available erosion rate estimates. Nearby Atlantic Beach has been nourished twice, but its sediment characteristics (after nourishment) differ from those in the proposed project area.

CSE Baird-Stroud (1999) evaluated the condition of the beach and inshore zone along Bogue Banks, using the profile volume method (Kana, 1993; Kana and Mohan, 1996). This method establishes site-specific criteria by which volume deficits can be determined against an ideal or desirable profile volume (ie, one which contains sufficient dimensions to sustain daily, seasonal, and storm fluctuations of the beach without significant damage to the backshore). The profile volume method, if performed to the estimated depth of closure, integrates all cross-shore variations in profile geometry and is therefore insensitive to the timing of surveys.

Prior analyses (CSE Baird-Stroud, 1999) demonstrated that there is a profile deficit averaging ~40 cubic yards per foot (cy/ft) along the 16.8-mile reach from western Emerald Isle to Pine Knoll Shores (profiles 8-76), compared to the existing profile volume along Atlantic Beach. Considering the fact that Atlantic Beach sustained Hurricanes *Dennis* and *Floyd* (1999) as well as *Fran* (1996) with only minor damage compared to other sections of Bogue Banks, its profile volume yields a rational minimum value. During final design, the profile volume will be analyzed quantitatively to estimate the level of protection provided.

The desired fill volume is one that restores the deficit (with respect to the criteria and goals of the project) and adds "advance nourishment" to increase longevity. Advance nourishment is generally related to the anticipated average annual losses from the project area (ie, the background erosion rate). The Bogue Banks Beach Preservation Task Force evaluated projects which factored in 5-year, 10-year, and 20-year advance nourishment requirements based on best-available background erosion rates. It was the decision of the task force to formulate the project around the 10-year nourishment project (ie, initial deficit averaging 40 cy/ft plus 10-year advance nourishment averaging 10 cy/ft).

This provides a reasonable time period over which the first project can be evaluated and provides a project scale that is practical for dredging. Small-scale projects do not afford economies of scale during construction and result in more frequent nourishments and the associated disruption to normal beach use by people and animals. Bogue Banks is generally considered a good candidate site for nourishment because its background erosion rate is relatively low and it is less exposed to north-easters because of its sheltering by Cape Lookout.

METHODS OF CONSTRUCTION

The proposed fill will be placed by hydraulic dredge between the base of the foredune and the outer bar. Only the profile above high water is controllable in nourishment construction. Intertidal and underwater portions of the profile will be subject to natural adjustment by waves. Given the relatively high back-beach elevations along most of Bogue Banks and the issue of easements for construction, the majority of the fill will be placed no higher than +7 ft NGVD (the natural elevation of the berm) and seaward of the existing toe of the foredune and all development. Along portions of eastern Emerald Isle, a low dune (elevations <+12 ft NGVD) will be constructed as part of the project to prevent the dredge slurry from flowing landward across developed property (where the foredune is missing).

Equipment

- *Ocean-certified hopper dredge* – Self-propelled hopper dredges with built-in, pump-out capability are feasible for borrow areas A, B1, and B2. Ocean-certified equipment typically requires ~25 ft minimum operational depth and is efficient for excavating shallow cuts of the order 1-2 ft (Sheet 10). During excavation and loading, the slurry drains via scuppers discharging some fines in situ and leaving coarser material in the hopper compared to the excavated material. When loaded, the dredge travels to a temporary mooring and submerged pipeline near the project site. It hooks up to the pipeline and pumps the material from the hopper to the beach where it is spread mechanically by dozers.

- *Ocean-certified suction dredge equipped for shallow cuts* – This "dustpan" dredge (so nicknamed) is used primarily for beach nourishment involving thin borrow areas offshore. The dredge works most efficiently if the borrow area is close to the project area (e.g., excavations paralleling the beach less than one mile offshore). The slurry is pumped directly to the beach via submerged pipeline and distributed with the aid of dozers and other land-based equipment. In contrast to self-contained hopper dredges, the excavations are pumped only once and therefore transfer more fines to the beach according to the quality of the sediment in the borrow area. Unit costs may be substantially lower than all other methods if the pumping distances are short. This method is considered most feasible for borrow areas B1 and B2.

Construction Schedule — The proposed project involves a substantial volume of sand (>4.5 million cubic yards in-place after gradual erosion of overfill). Based on project experience elsewhere, one ocean-certified dredge can excavate and place on the order of 15,000-30,000 cy in a 24-hour period. The average production per day varies widely according to transportation distance and specifications of the project. In any case, a substantial period of time will be required to complete the project. For example, if production averages 20,000 cy/day, upward of 400 calendar days (~13 months) will be required to place the base volume plus overfill for all six reaches. It is anticipated that three reaches (#6 PKS-East, #5 PKS-West, and #4 IB/SP) will be scheduled for nourishment in 2001-2002, pending results of community funding referendums and receipt of permits. Other reaches would be completed no earlier than the 2002-2003 construction window. Reaches 4-6 comprise about 40 percent of the project length and about 45 percent of the nourishment volume requirement.

Work will progress in sections within the borrow area(s) and along the beach. The borrow area will be left to adjust naturally and to recolonize while other areas are being excavated. Fill placement along the beach will typically involve completion of 200-500 ft per day. Construction activities will involve movement of heavy equipment and pipe along ~1 mile reaches over a period of 2-3 weeks. Once a section is complete, piping and heavy equipment will be shifted to a new section and the process repeated. As soon as practicable, sections will be graded and dressed to final slopes and left to respond naturally. Other than equipment staging areas, individual lots along the oceanfront will experience disruption due to construction for one month or less, in general. Fill sections will be left to adjust naturally as soon as the required volumes are pumped into place and confirmed by surveys.

Land-based equipment will be brought to the site over public roads and will enter the beach through existing permanent accesses or temporary accesses. Any alteration of dune vegetation/topography necessary for equipment access will be performed in consultation with state regulatory agencies, local officials, and property owners. Temporary accesses will be restored to preconstruction conditions at the conclusion of work in a given reach or combination of reaches. Daily equipment staging will be on the constructed beach seaward of the dune line and any native vegetation. Construction contracts will provide for proper storage and handling of oils, chemicals, and hydraulic fluids, etc., necessary for operation in accordance with state and federal regulations.

Preliminary discussions with environmental agencies indicate construction during colder months is favored because biological productivity tends to be lowest then. Construction during winter also avoids disruption of the peak tourism season.

The following two general construction schedules were the two workable conclusions reached in the EIS. Both are requested for this permit.

Construction during limited "environmental" windows between 1 November and 15 May

- *Advantages* – Direct environmental impacts occur during periods of lowest biological productivity. Avoids prime tourist season. Yields early benefits if the project can be initiated in fall 2001.

- *Disadvantages* – A five-to-six month construction window is insufficient to complete the entire project unless more than one dredge is used. Each dredge introduces large mobilization costs, increasing the total cost of the project. The narrower the dredging window, the fewer contractors will be willing to bid the project, further raising the cost of construction. Down time for weather is more likely during winter than summer. Delays project benefits for at least one year if the winter 2001-2002 construction window is missed.

Construction during two or more seasons within limited "environmental" windows

- *Advantages* – The only viable schedule in the event only one dredge is available for the project. Generally similar environmental advantages but produces direct impacts over multiple seasons rather than one (not along the same project reaches).

- *Disadvantages* – Will require at least two mobilizations, increasing the project costs. Postpones project benefits (wider beach, improved storm protection, etc.) for the areas uncompleted during the first window. Causes disruption to habitats over multiple seasons instead of one.

Requested Construction Schedule — We request the two above schedules, namely, construction during environmental windows which may extend into the fall and spring. Specifically, we request permission to commence construction as early as 1 November and continue construction as late as 15 May, and during multiple years, if necessary.

ENVIRONMENTAL MONITORING

We expect that reviewing agencies will specify environmental monitoring. Based on our understanding to date, we propose the following:

1) Biological monitoring aboard each dredge during all hours of operation, except in January and February. Any encounters with endangered or threatened species will be recorded and reported to the appropriate agencies.

2) Sea turtle crawl and nest monitoring will take place each morning on the nourishment beach between the calendar dates specified by the agencies. Nest relocation will be performed by qualified personnel prior to construction of that project section.

3) The beach sampling, benthic sampling, and fish trawls as listed in the program outlined in Appendix C of the EIS.

4) Sampling for mud content in the placed nourishment sand.

5) Other environmental sampling specified as conditions in the permits.

4. LAND AND WATER CHARACTERISTICS

g. What is the CAMA Land Use Plan land classification of the site?
The following is provided based on query of planning staff in each municipality and the county.

Municipality (Site)	Land-Use Classification
Pine Knoll Shores	Developed
Indian Beach	Developed
Salter Path	Developed, Conservation
Emerald Isle	Developed

h. How is the tract zoned by local government?
i. Is the proposed project consistent with applicable zoning?

Municipality (Tract/Proposed Project)	(h) Zoning*	(i) Zoning Consistency
Pine Knoll Shores	R/C/I/Rec	Yes
Indian Beach	R	Yes
Salter Path	R	Yes
Emerald Isle	R/C	Yes

[*R – residential / C – commercial / Rec – recreational / I – institutional]

5. ADDITIONAL INFORMATION

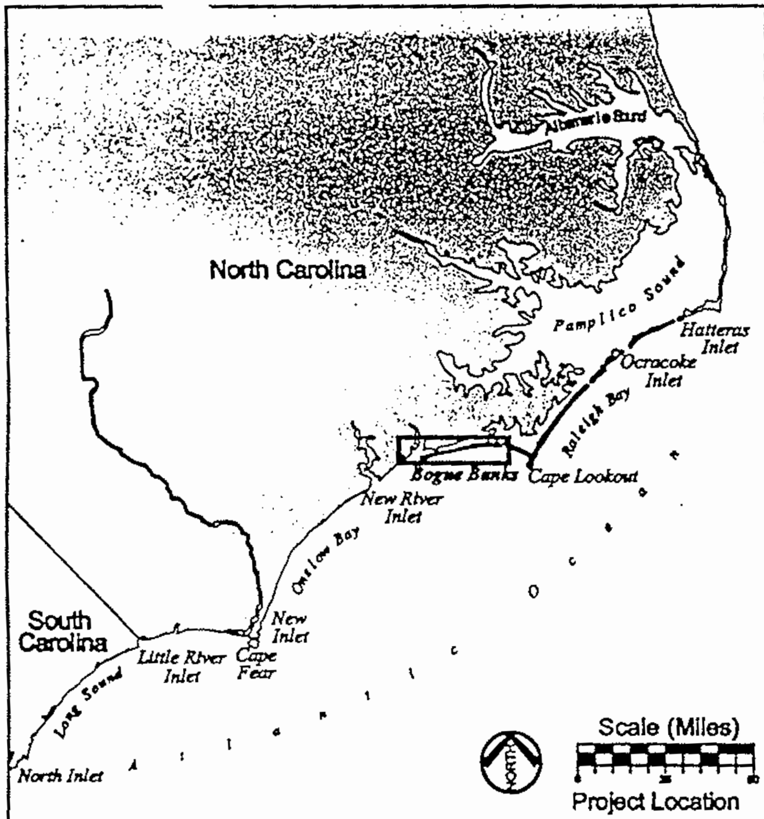
Deed — All project areas below mean high water (MHW) are within the 3-mile limit and are, therefore, owned by the State of North Carolina, not by the federal government. All project areas above MHW are within Carteret County, but are owned by individual landowners. Pine Knoll Shores and Indian Beach are now actively pursuing easements. **Applicant requests that permitting proceed for the overall project, with the condition that each community's section would be permitted once easements are complete for that community.**

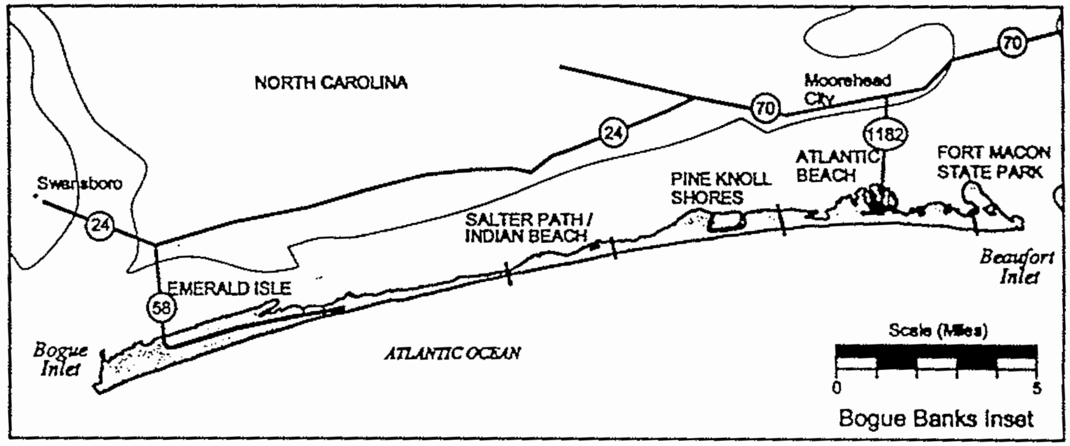
Work Plats — Drawings by the project engineer are attached to this application and are included in the packages sent to oceanfront landowners.

Names and Addresses of Adjacent Waterfront Landowners — This permit applies to four different communities, and each of those towns is assembling copies of this application for mailing to oceanfront landowners. In view of the unusually large number of mailings, which will take some time, **applicant requests that permitting proceed while registered mailings are underway.** Once each community completes and transmits the receipts to the agencies, permitting could then be completed.

AEC Hazard Notice — A hazard notice signed by the county is attached to this application.

Compliance with NC Environmental Policy Act — An Environmental Impact Statement (EIS) has been submitted for interagency review, comments have been received, the EIS has been revised, and a final EIS has been submitted for agency review. As of the date of submittal of this application, final approval of the EIS has not yet been received. Therefore, this permit application is being submitted concurrently with the final EIS review process, with the understanding that this application cannot be approved until the EIS is accepted.

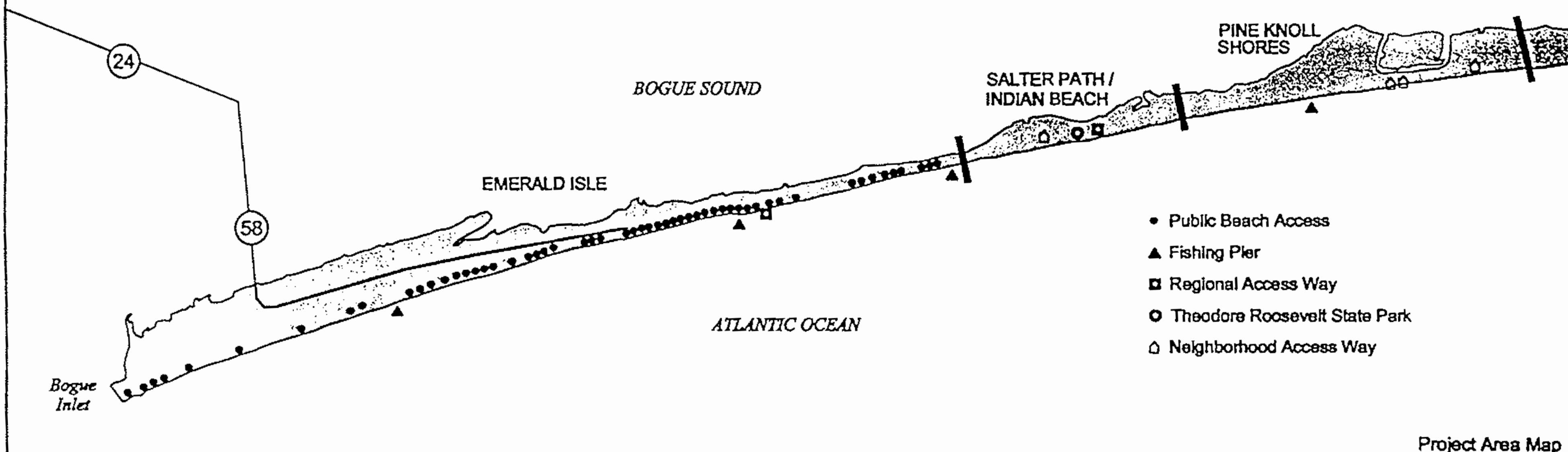




Directions:

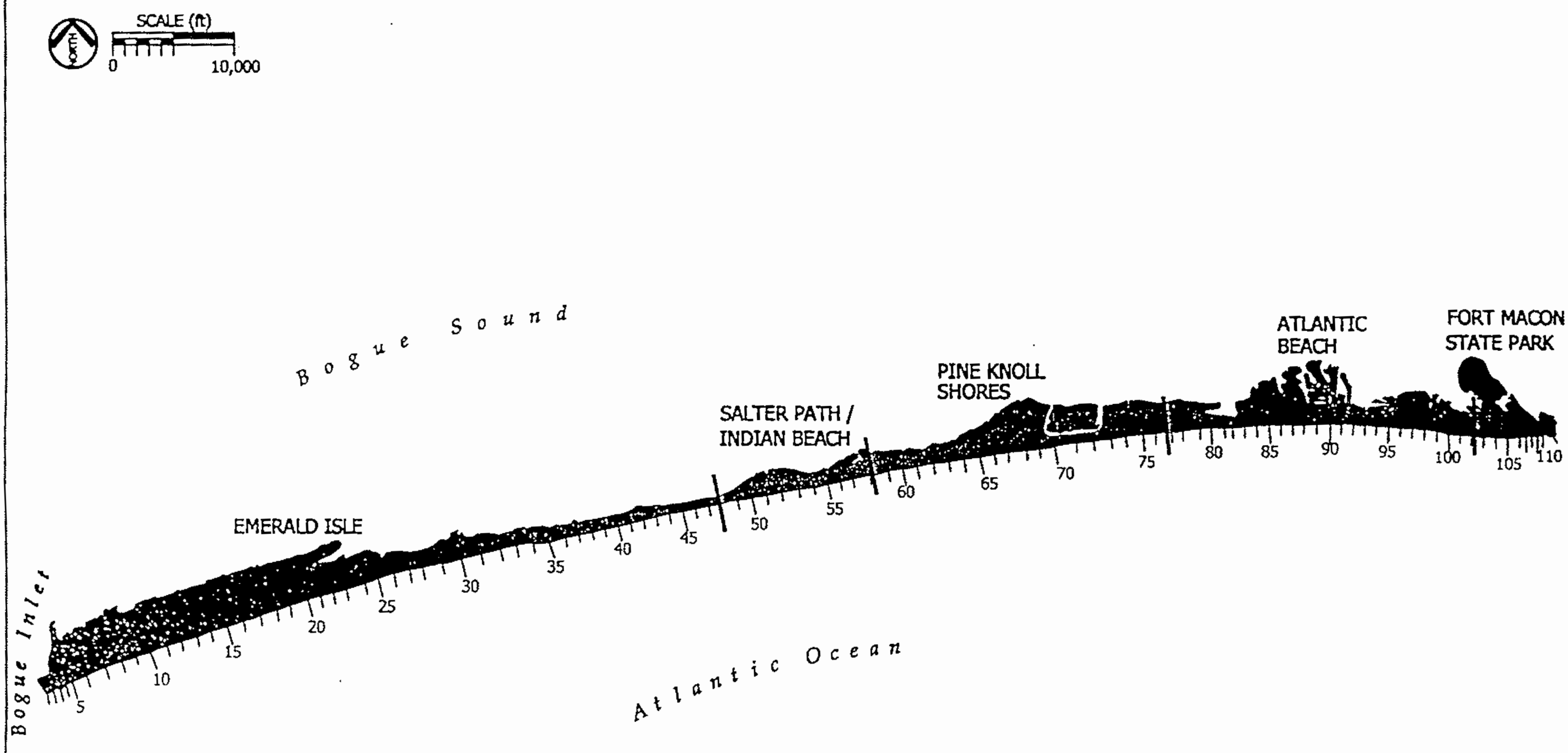
From Swansboro take Hwy 24 toward Morehead City. Turn right on Hwy 58 towards Emerald Isle. Follow signs to public beach access. (general locations below)

From Morehead City take Hwy 70 (Arendell Ave) towards Swansboro. Turn left on Hwy 1182 towards Atlantic Beach. Turn right at the first light onto Hwy 58. Follow signs to public beach access. (general locations below)



Project Area Map

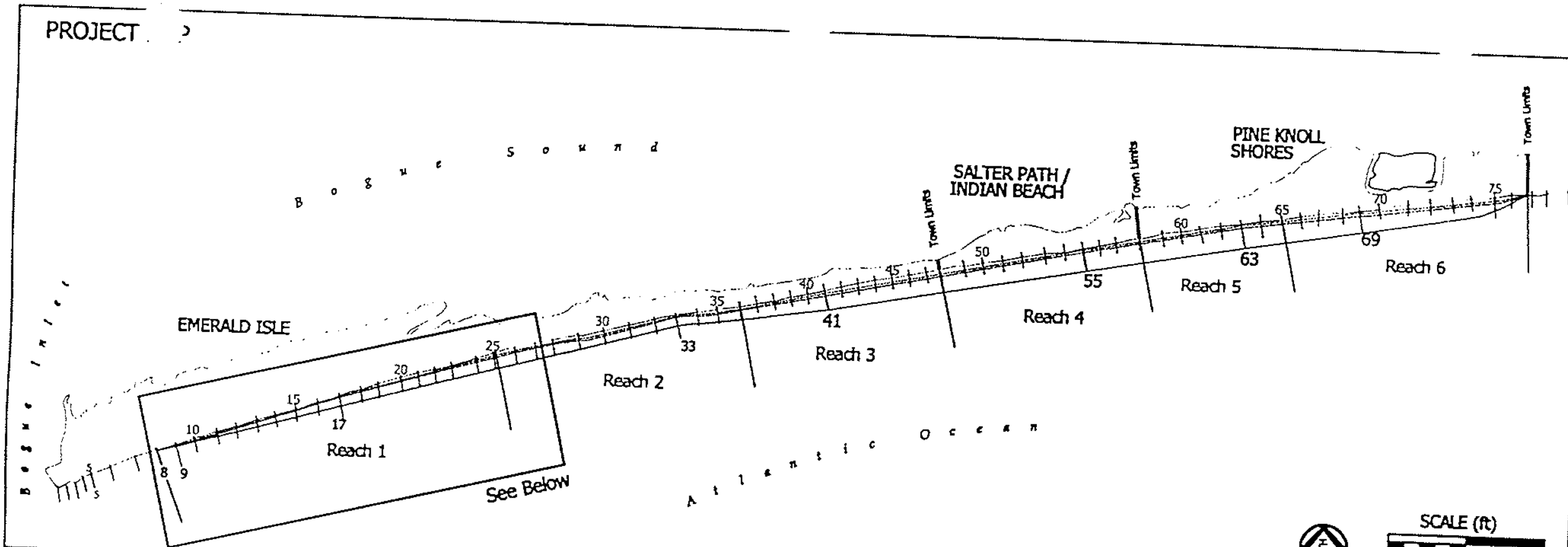
SITE MAP	PROJECT NAME: Bogue Banks Beach Nourishment Project	CSE	APPLICANT: Carteret County

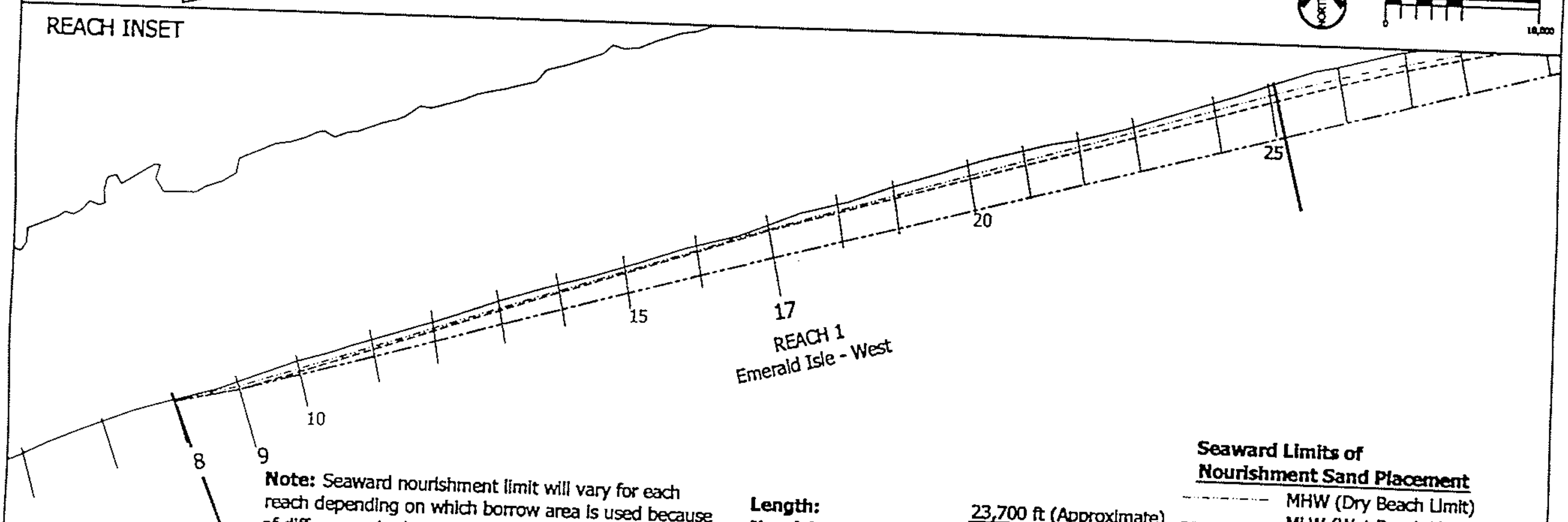


NOTES:
1. Beach survey lines established June 1999 by Stroud Engineering PA.
2. Surveys completed in June 1999, September 1999 (18 stations only) and June 2000.
3. Survey limits - foredune/backshore to outerbar. (See CSE. 2000. Survey report 2000: Bogue Banks North Carolina. Prepared for Carteret County by Coastal Science & Engineering LLC, Columbia, SC, 32 pp + app.)

COMMUNITIES AND BEACH SURVEY LINE LOCATIONS

PROJECT NAME:		APPLICANT:
Bogue Banks Beach Nourishment Project		Carteret County Jan 19 2001





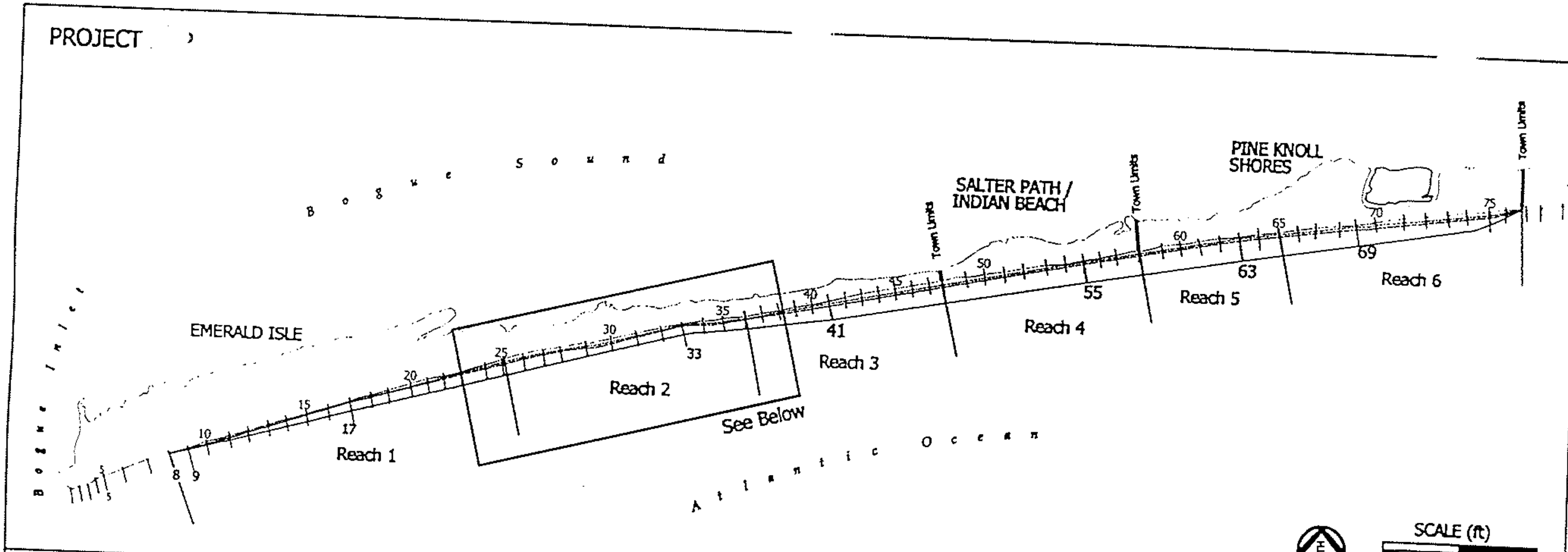
Note: Seaward nourishment limit will vary for each reach depending on which borrow area is used because of differences in the overfill ratio. (degree to which the borrow sediment matches the natural sediment.)

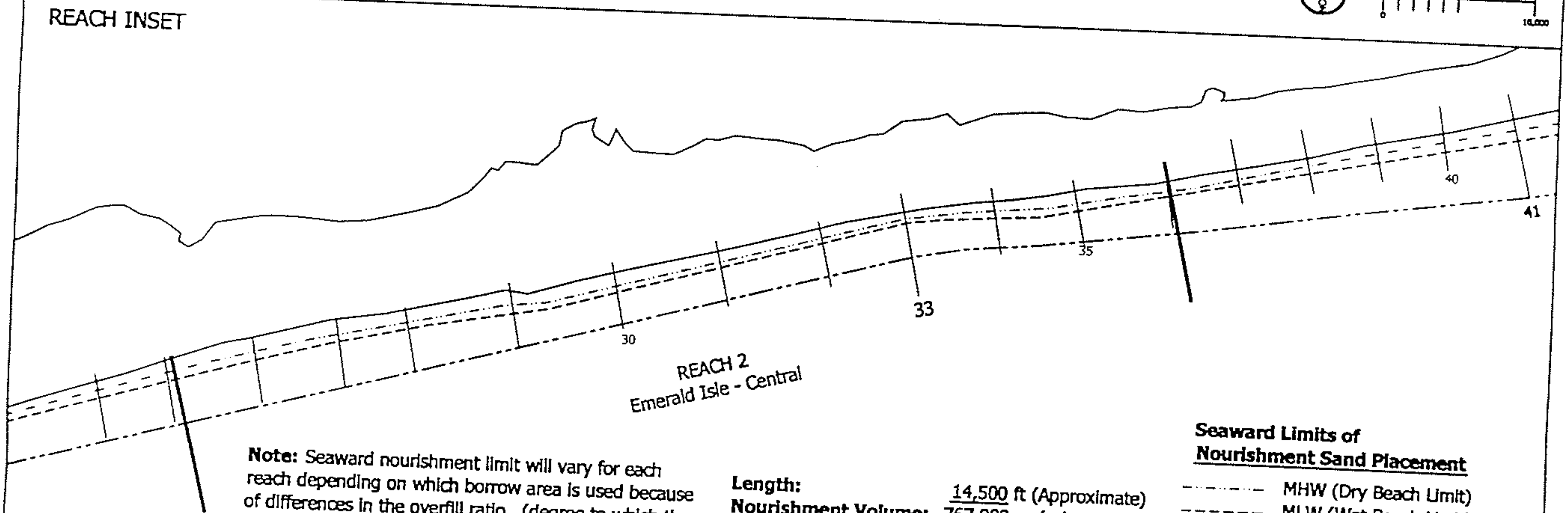
Length: 23,700 ft (Approximate)
Nourishment Volume: 753,000 cy (w/o overfill)

Seaward Limits of Nourishment Sand Placement

- MHW (Dry Beach Limit)
- MLW (Wet Beach Limit)
- Seaward Nourishment Limit
- Existing Shoreline

NOURISHMENT PLAN REACH 1	PROJECT NAME: Bogue Banks Beach Nourishment Project	CSE Coastal Science & Engineering, LLC	APPLICANT: Carteret County Jan 19 2001





Note: Seaward nourishment limit will vary for each reach depending on which borrow area is used because of differences in the overfill ratio. (degree to which the borrow sediment matches the natural sediment.)

Length: 14,500 ft (Approximate)

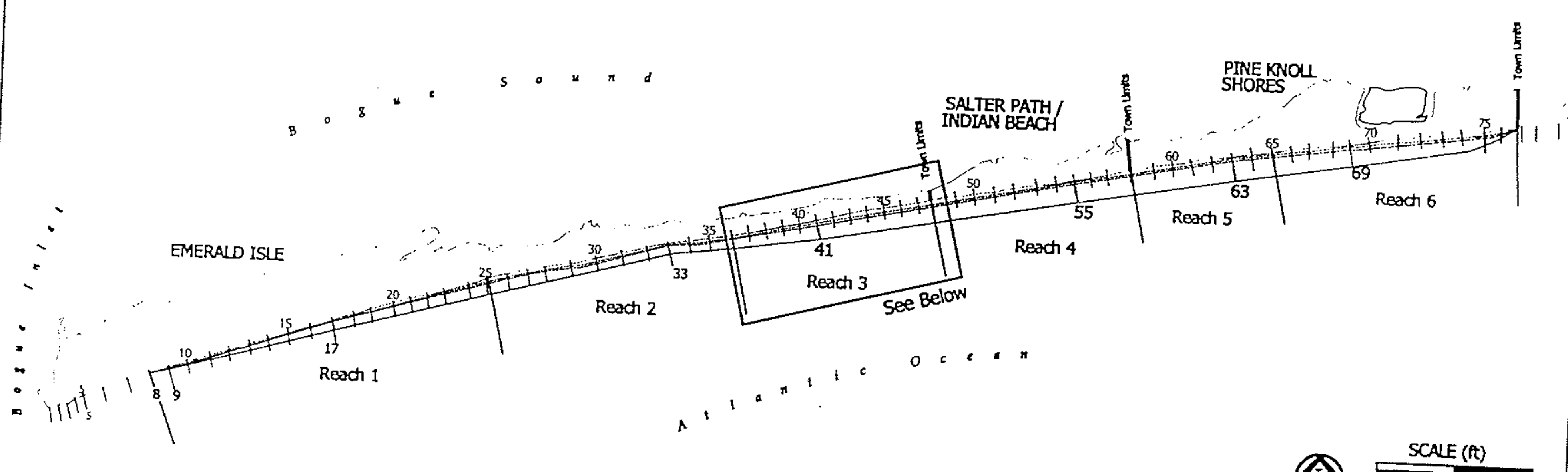
Nourishment Volume: 767,000 cy (w/o overfill)

Seaward Limits of Nourishment Sand Placement

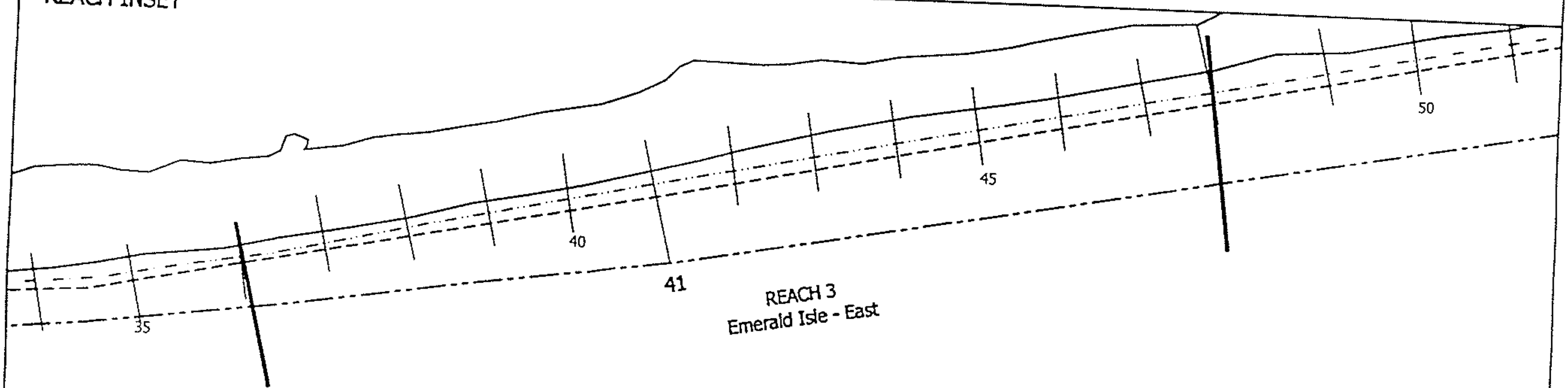
- MHW (Dry Beach Limit)
- MLW (Wet Beach Limit)
- Seaward Nourishment Limit
- Existing Shoreline

NOURISHMENT PLAN REACH 2	PROJECT NAME: Bogue Banks Beach Nourishment Project	CSE Coastal Science & Engineering, LLC	APPLICANT: Carteret County Jan 19 2001 Sheet 3b of 14

PROJECT MAP



REACH INSET



Note: Seaward nourishment limit will vary for each reach depending on which borrow area is used because of differences in the overfill ratio. (degree to which the borrow sediment matches the natural sediment.)

Length: 12,900 ft (Approximate)
Nourishment Volume: 970,000 cy (w/o overfill)

Seaward Limits of Nourishment Sand Placement

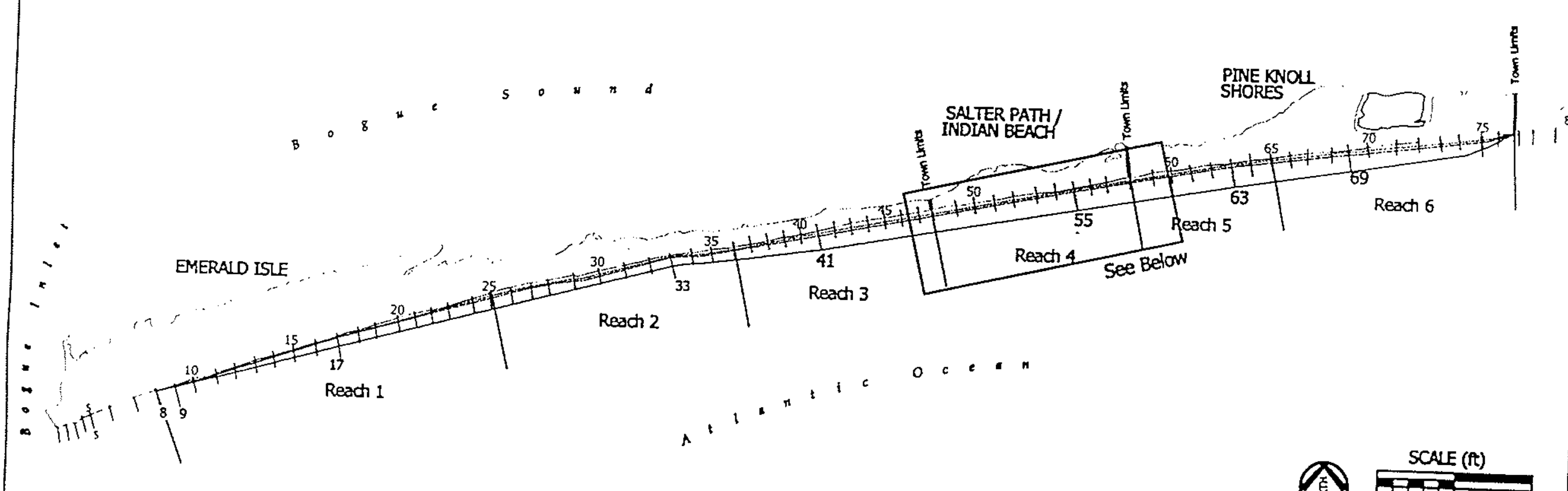
- MHW (Dry Beach Limit)
- MLW (Wet Beach Limit)
- Seaward Nourishment Limit
- Existing Shoreline

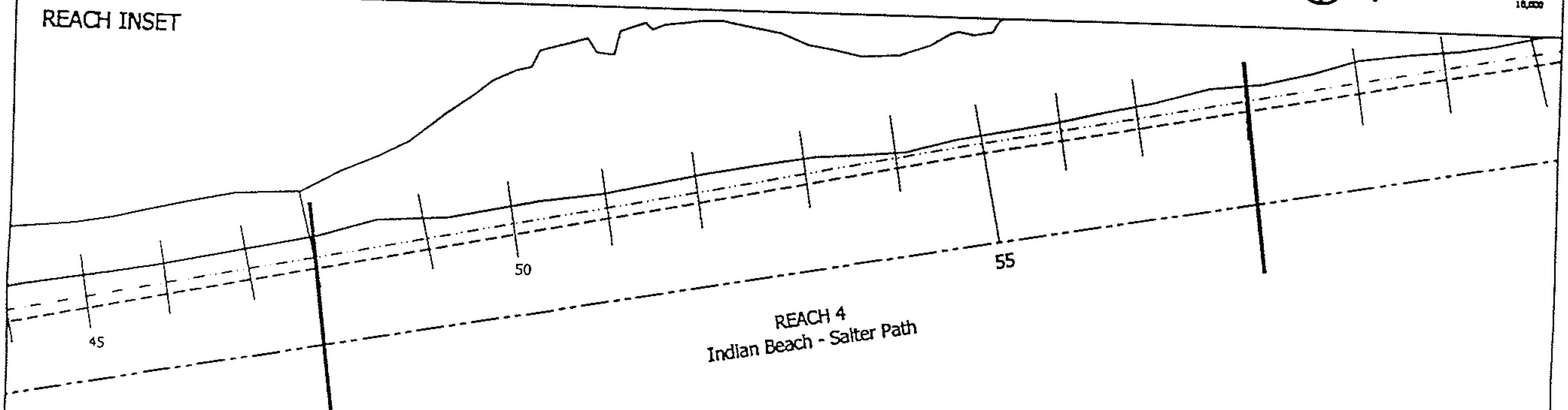
NOURISHMENT PLAN REACH 3

PROJECT NAME:
Bogue Banks
Beach Nourishment Project

Coastal Science & Engineering, LLC

APPLICANT:
Carteret County





Note: Seaward nourishment limit will vary for each reach depending on which borrow area is used because of differences in the overfill ratio. (degree to which the borrow sediment matches the natural sediment.)

Length: 13,400 ft (Approximate)

Nourishment Volume: 550,000 cy (w/o overfill)

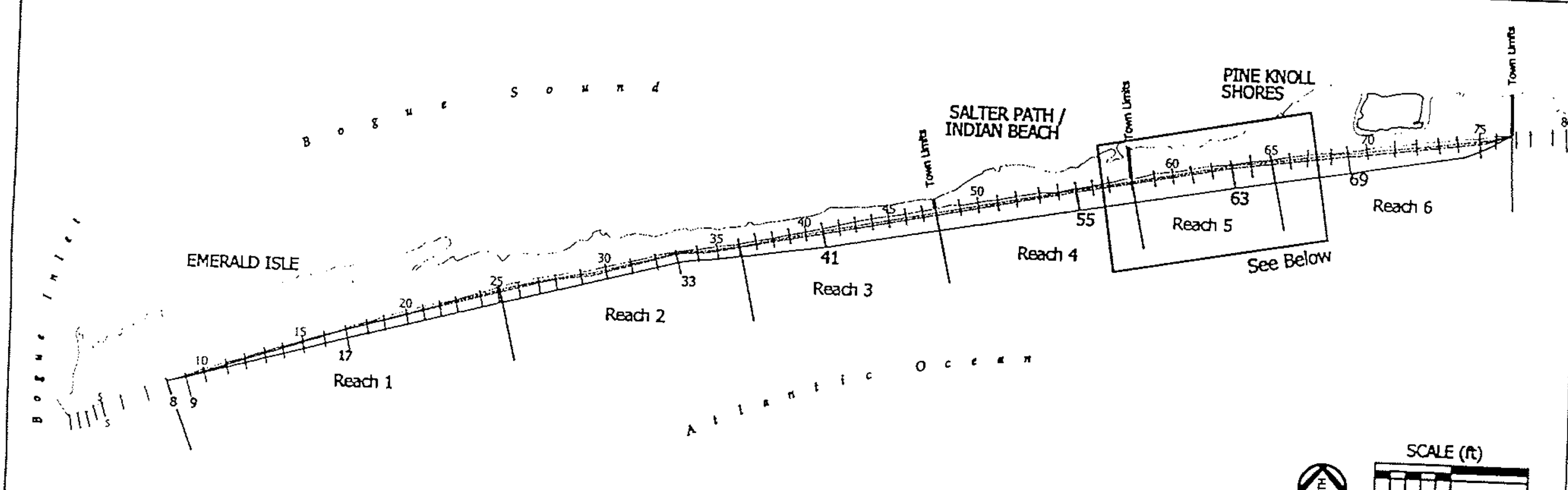
Seaward Limits of Nourishment Sand Placement

- MHW (Dry Beach Limit)
- MLW (Wet Beach Limit)
- Seaward Nourishment Limit
- Existing Shoreline

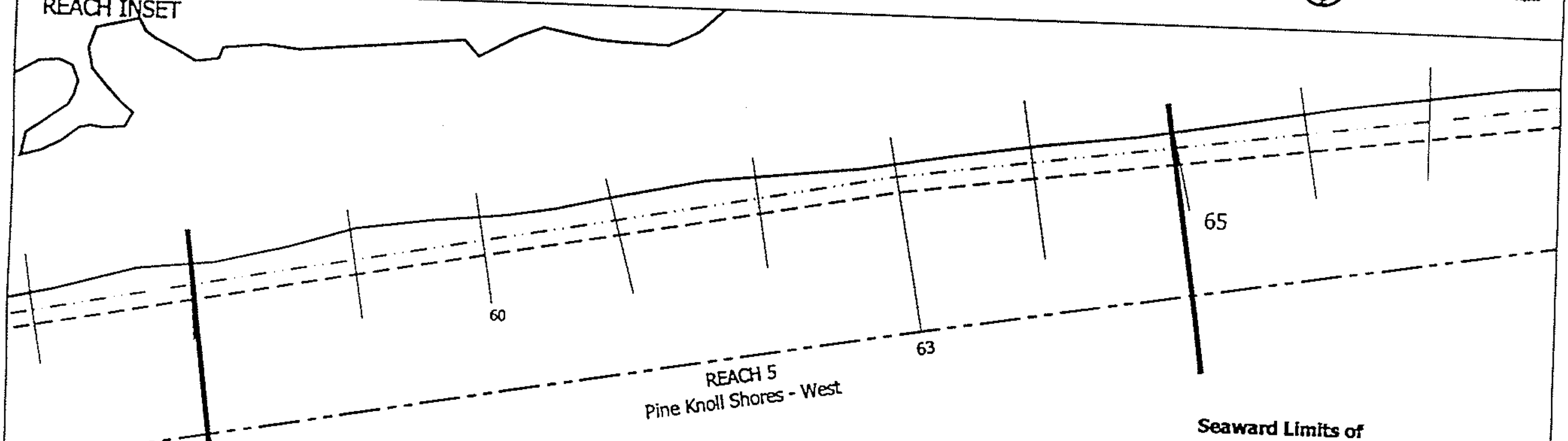
NOURISHMENT PLAN REACH 4	PROJECT NAME: Bogue Banks Beach Nourishment Project	CSE Coastal Science & Engineering, LLC	APPLICANT: Carteret County

Jan 19 2001

PROJECT MAP



REACH INSET



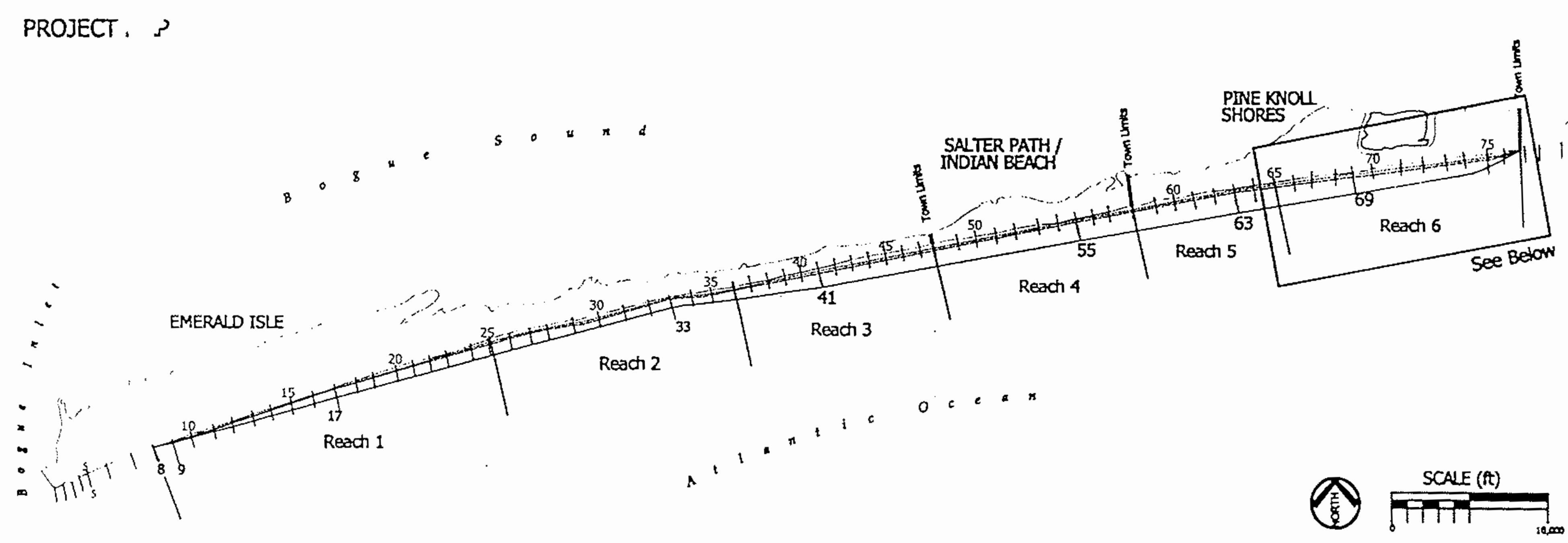
Note: Seaward nourishment limit will vary for each reach depending on which borrow area is used because of differences in the overfill ratio. (degree to which the borrow sediment matches the natural sediment.)

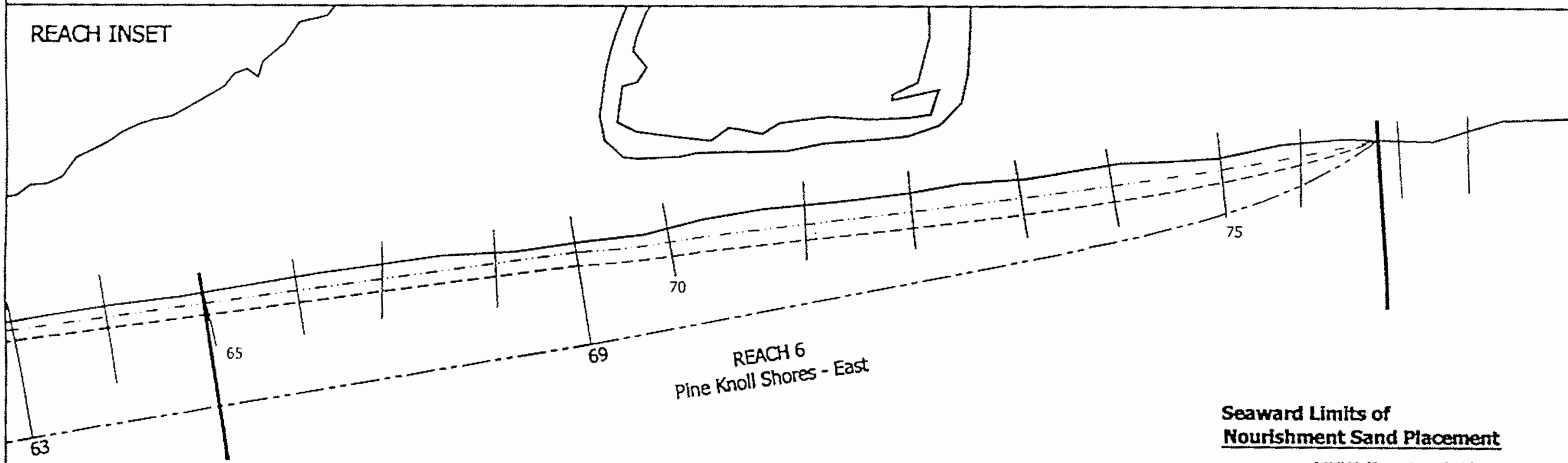
Length: 8,800 ft (Approximate)
Nourishment Volume: 480,000 cy (w/o overfill)

Seaward Limits of Nourishment Sand Placement

- MHW (Dry Beach Limit)
- MLW (Wet Beach Limit)
- Seaward Nourishment Limit
- Existing Shoreline

NOURISHMENT PLAN REACH 5	PROJECT NAME: Bogue Banks Beach Nourishment Project	CSE Coastal Science & Engineering, LLC	APPLICANT: Carteret County Jan 19 2001





Note: Seaward nourishment limit will vary for each reach depending on which borrow area is used because of differences in the overfill ratio. (degree to which the borrow sediment matches the natural sediment.)

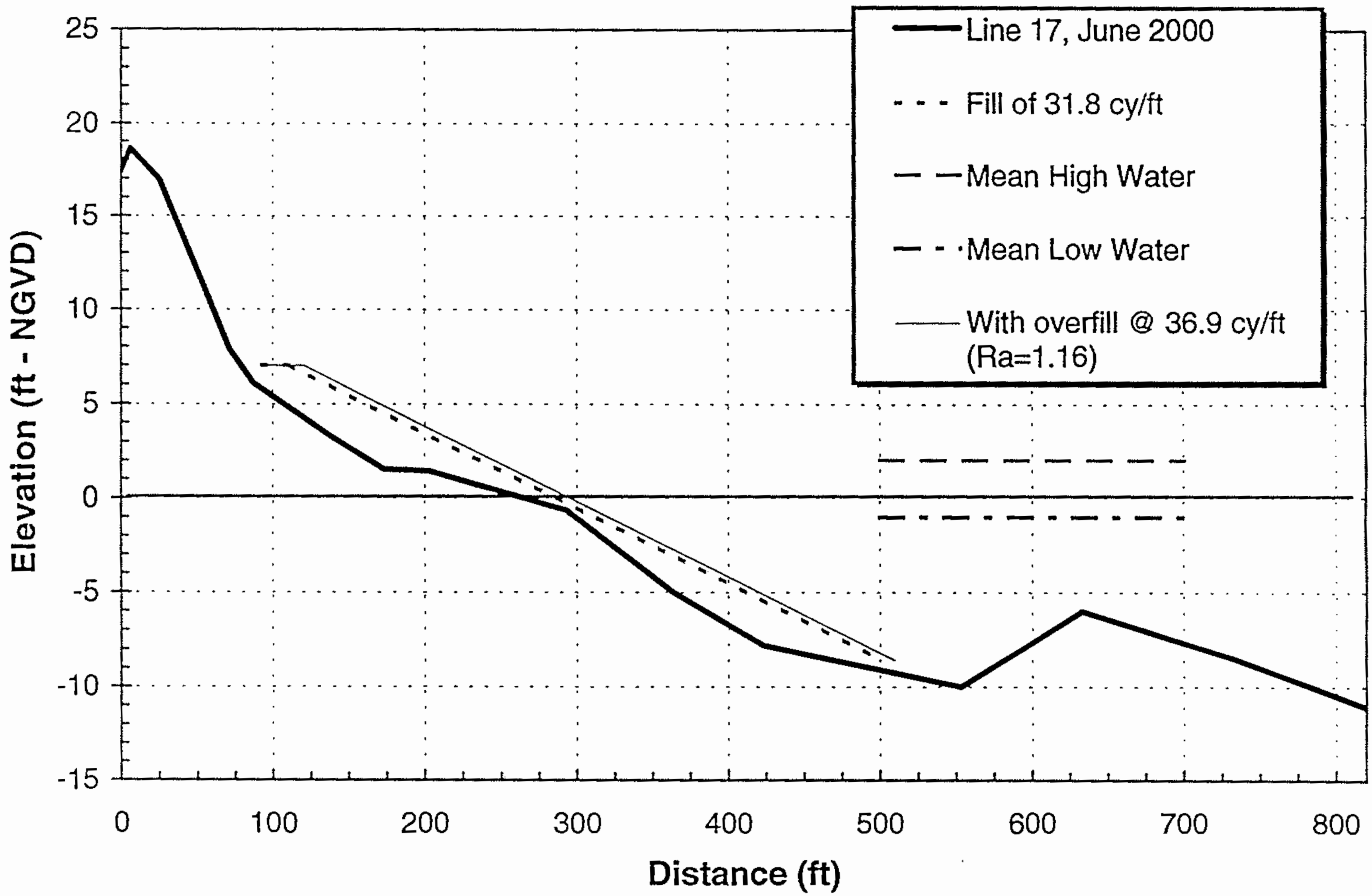
Length: 15,400 ft (Approximate)
Nourishment Volume: 905,000 cy (w/o overfill)

Seaward Limits of Nourishment Sand Placement

- MHW (Dry Beach Limit)
- MLW (Wet Beach Limit)
- Seaward Nourishment Limit
- Existing Shoreline

NOURISHMENT PLAN REACH 6	PROJECT NAME: Bogue Banks Beach Nourishment Project	CSE Coastal Science & Engineering, LLC	APPLICANT: Carteret County Jan 19 2001 Sheet 25 of 1[illegible]

Reach 1: Fill at Emerald Isle West

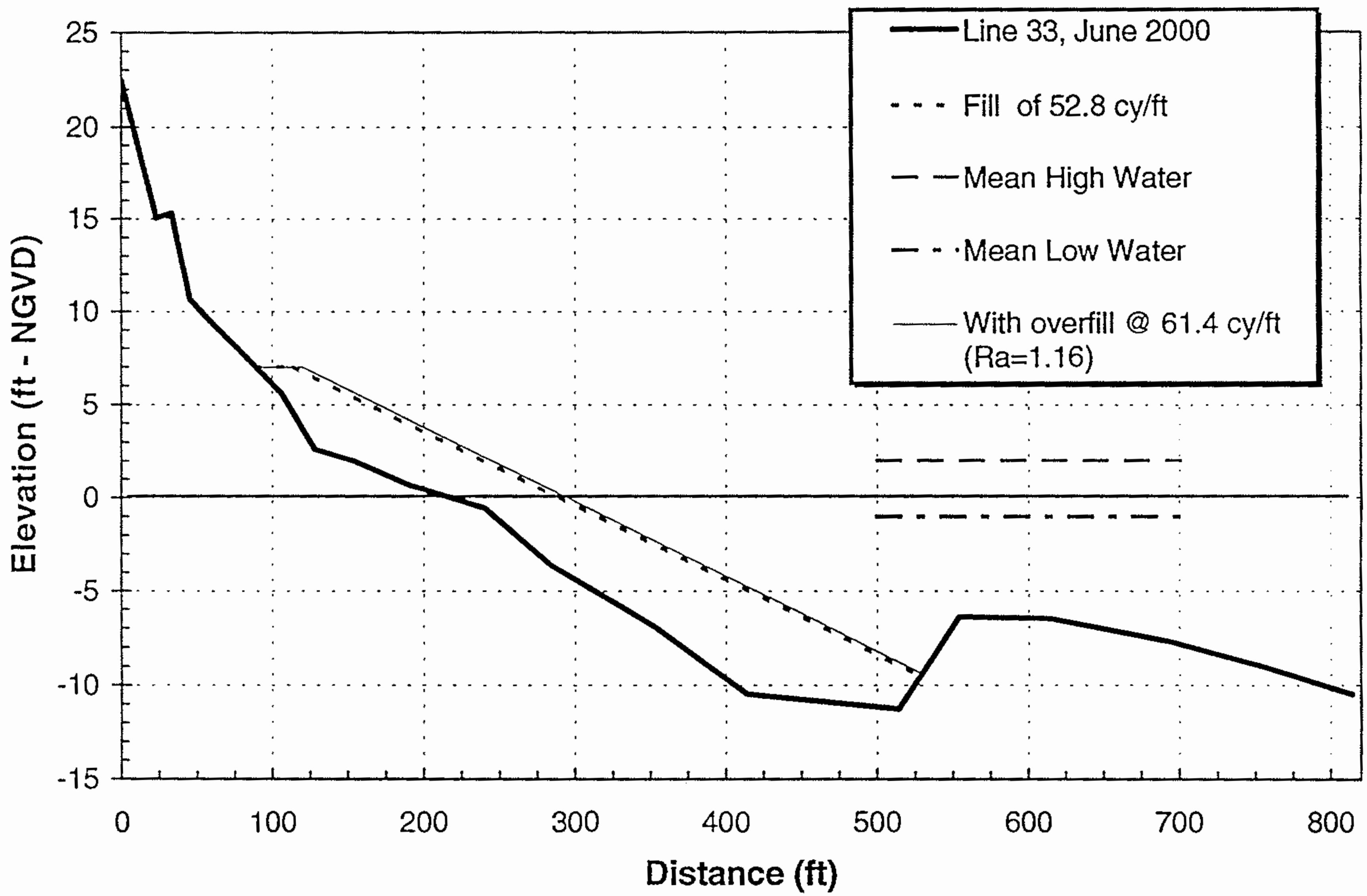


NOTES:
1. Fill of 31.8 cy/ft is the post-construction volume, after washing out of fine sand and mud.
2. % mud in borrow area A is about 4%.
3. Overfill ratio of 1.16 means about 14% of sediment will erode more rapidly than native sediment over the 10 year project period.

TYPICAL CROSS SECTION IN REACH 1

PROJECT NAME: Bogue Banks Beach Nourishment Project	CSE	APPLICANT: Carteret County

Reach 2: Fill at Emerald Isle Central

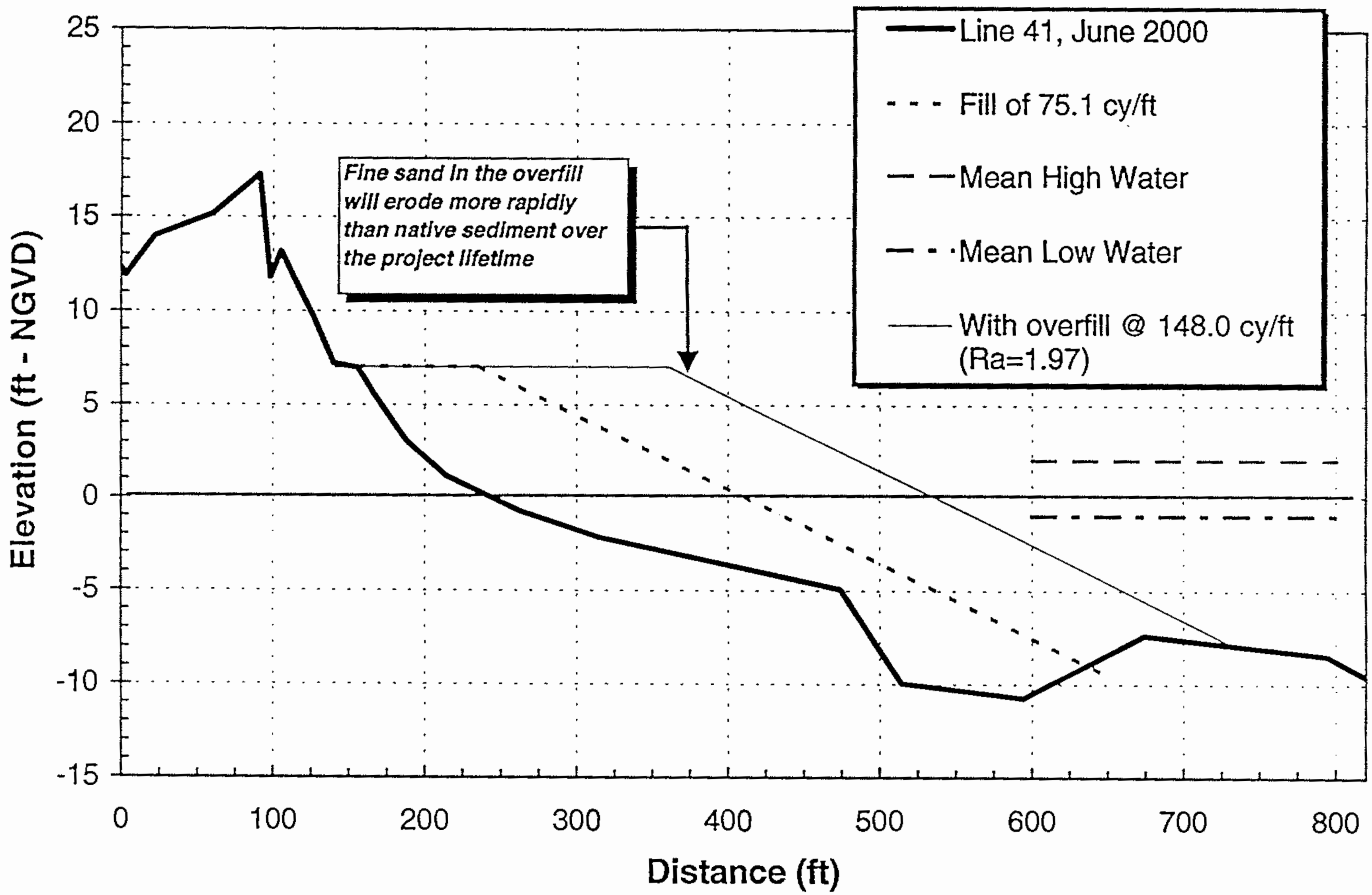


NOTES:
1. Fill of 52.8 cy/ft is the post-construction volume, after washing out of fine sand and mud.
2. % mud in borrow area A is about 4%.
3. Overfill ratio of 1.16 means about 14% of sediment will erode more rapidly than native sediment over the 10 year project period.

TYPICAL CROSS SECTION IN REACH 2

PROJECT NAME: Bogue Banks Beach Nourishment Project	Coastal Science & Engineering, LLC	APPLICANT: Carteret County Jan 19 2001 Sheet 5 of 14

Reach 3: Fill at Emerald Isle East



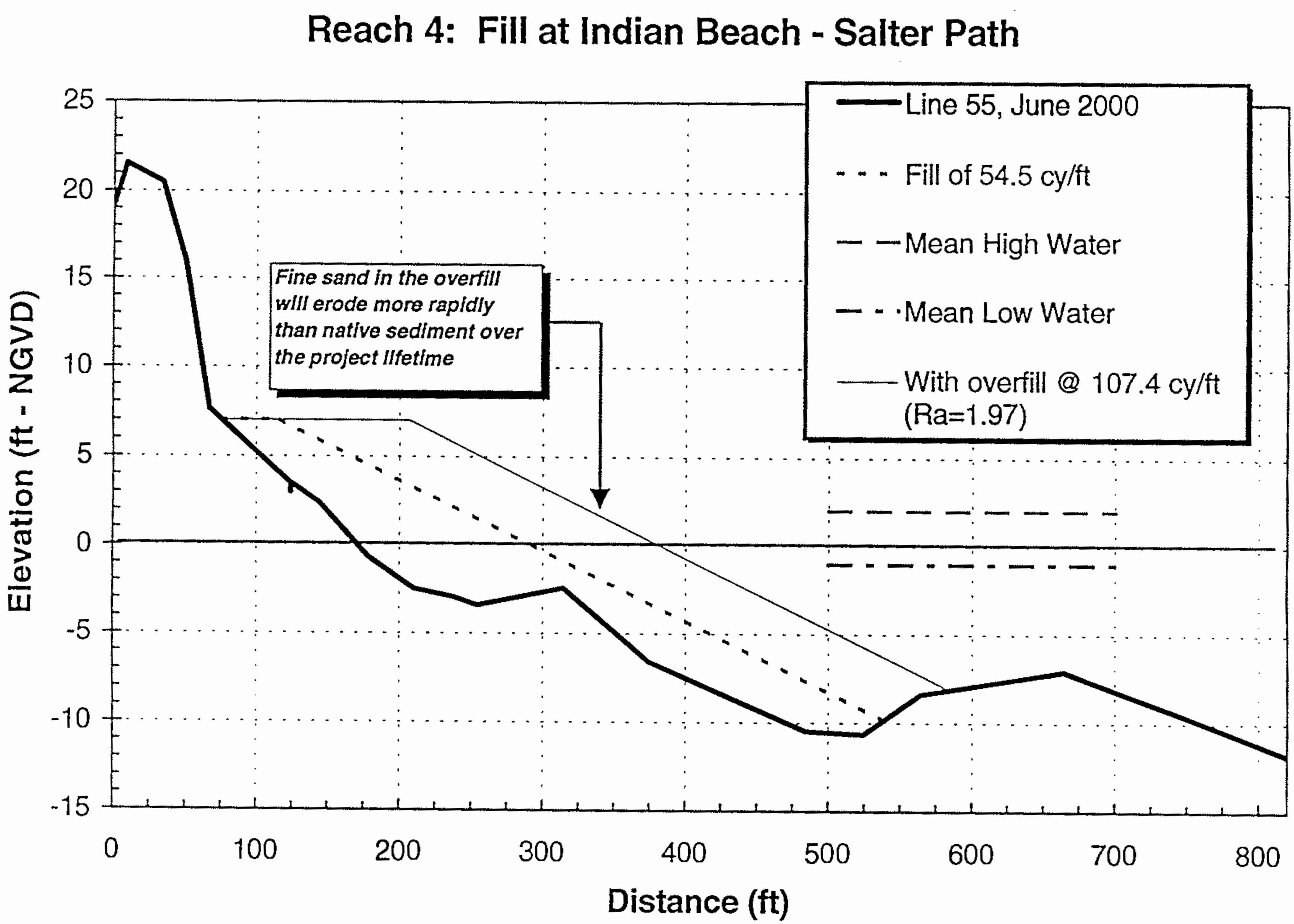
NOTES:
1. Fill of 75.1 cy/ft is the post-construction volume, after washing out of fine sand and mud.
2. % mud in borrow area B1 is about 4.1%.
3. Overfill ratio of 1.97 means about 49% of sediment will erode more rapidly than native sediment over the 10 year project period.

TYPICAL CROSS SECTION IN REACH 3

PROJECT NAME:
Bogue Banks
Beach Nourishment Project

Coastal Science & Engineering, LLC

APPLICANT:
Carteret County
Jan 19 2001



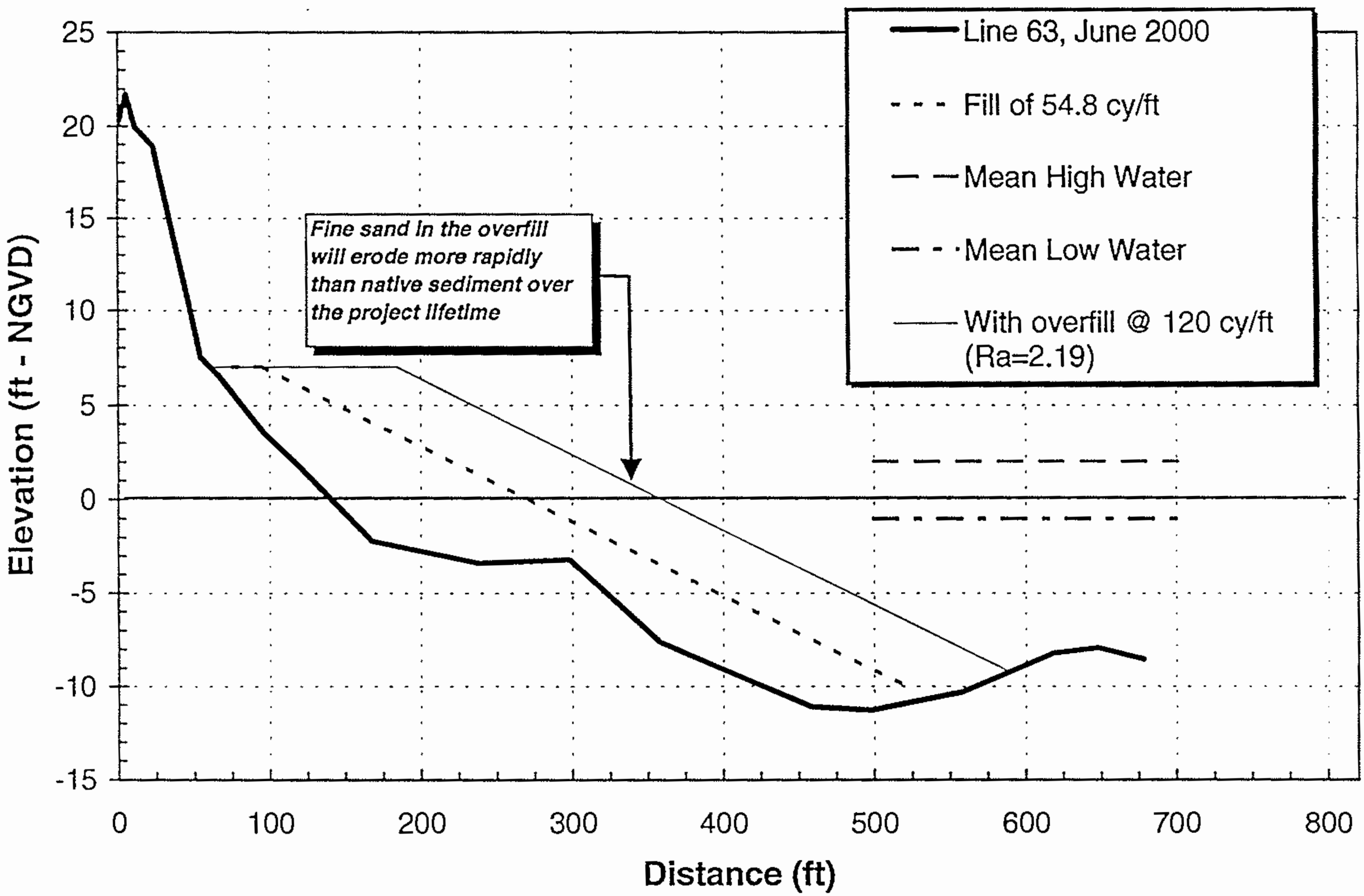
NOTES:

1. Fill of 54.5 cy/ft is the post-construction volume, after washing out of fine sand and mud.
2. % mud in borrow area B1 is about 4.1%.
3. Overfill ratio of 1.97 means about 49% of sediment will erode more rapidly than native sediment over the 10 year project period.

TYPICAL CROSS SECTION IN REACH 4

PROJECT NAME:		APPLICANT:
Bogue Banks Beach Nourishment Project	CSE Coastal Science & Engineering, LLC	Carteret County Jan 19 2001 Sheet 7 of 14

Reach 5: Fill at Pine Knoll Shores West



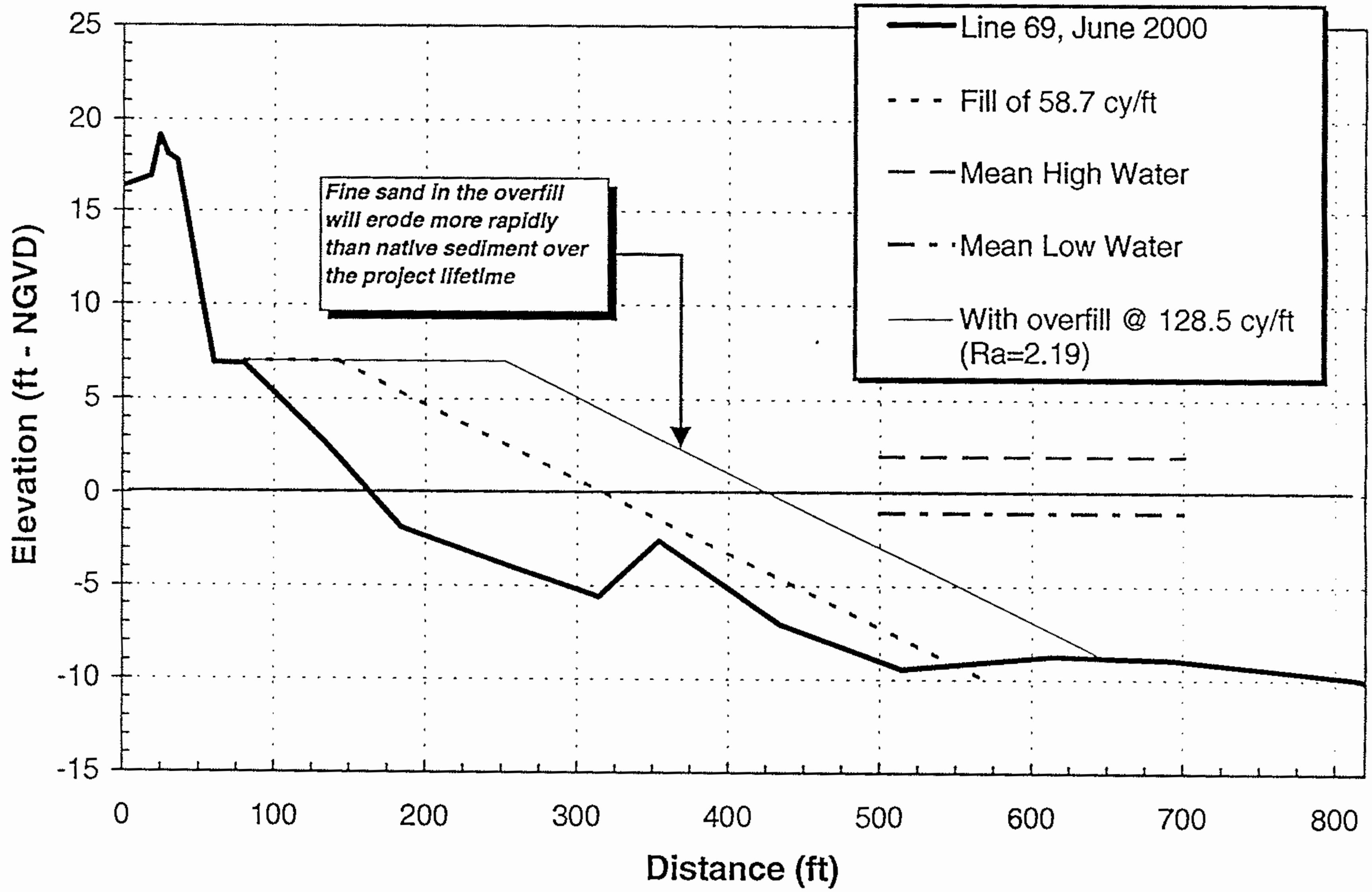
NOTES:

1. Fill of 54.8 cy/ft is the post-construction volume, after washing out of fine sand and mud.
2. % mud in borrow area B1 is about 2.6%.
3. Overfill ratio of 2.19 means about 54% of sediment will erode more rapidly than native sediment over the 10 year project period.

TYPICAL CROSS SECTION IN REACH 5

PROJECT NAME:		APPLICANT:
Bogue Banks Beach Nourishment Project	CSE Coastal Science & Engineering, LLC	Carteret County

Reach 6: Fill at Pine Knoll Shores East



NOTES:
1. Fill of 58.7 cy/ft is the post-construction volume, after washing out of fine sand and mud.
2. % mud in borrow area B1 is about 2.6%.
3. Overfill ratio of 2.19 means about 54% of sediment will erode more rapidly than native sediment over the 10 year project period.

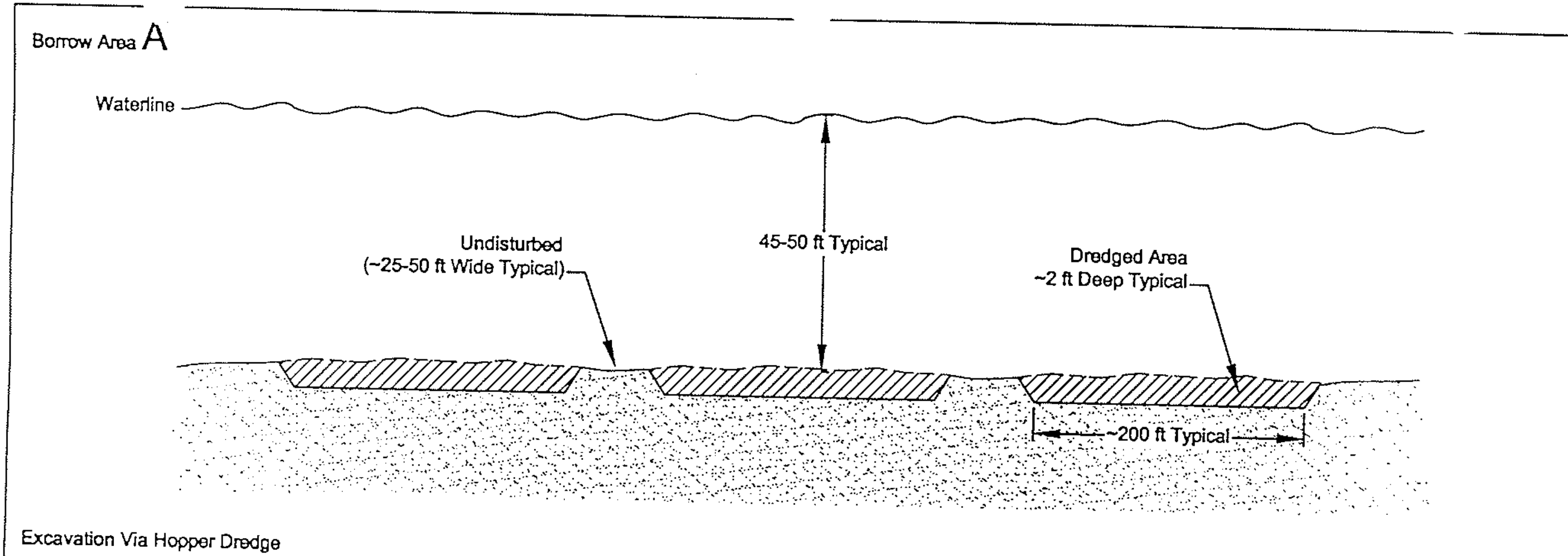
TYPICAL CROSS SECTION IN REACH 6

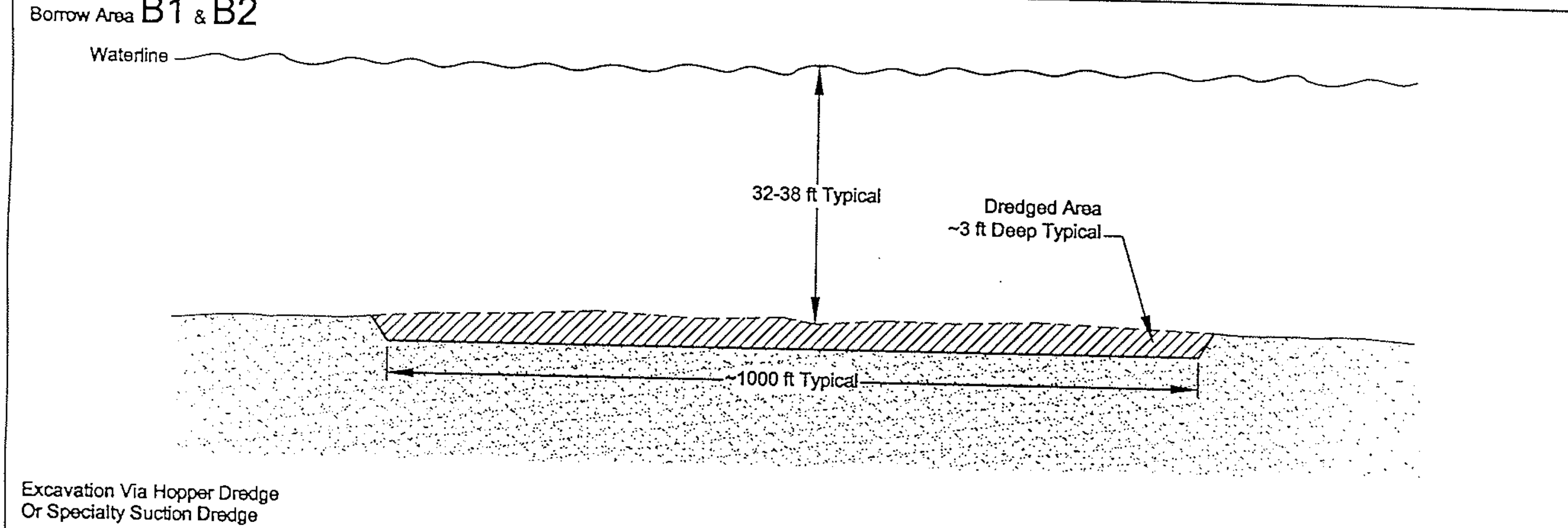
PROJECT NAME:
Bogue Banks
Beach Nourishment Project

CSE Coastal Science & Engineering, LLC

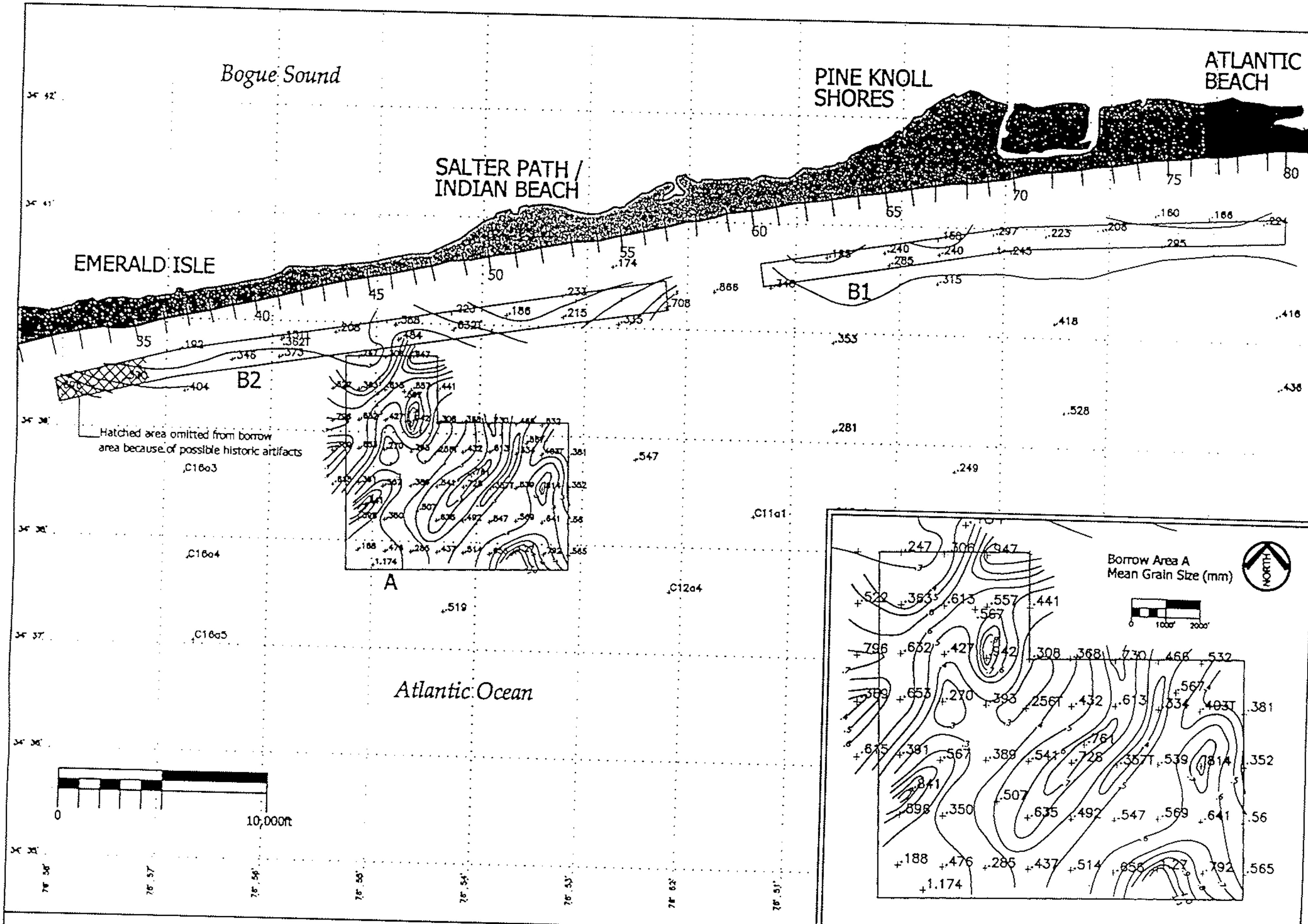
APPLICANT:
Carteret County

Jan 19 2001





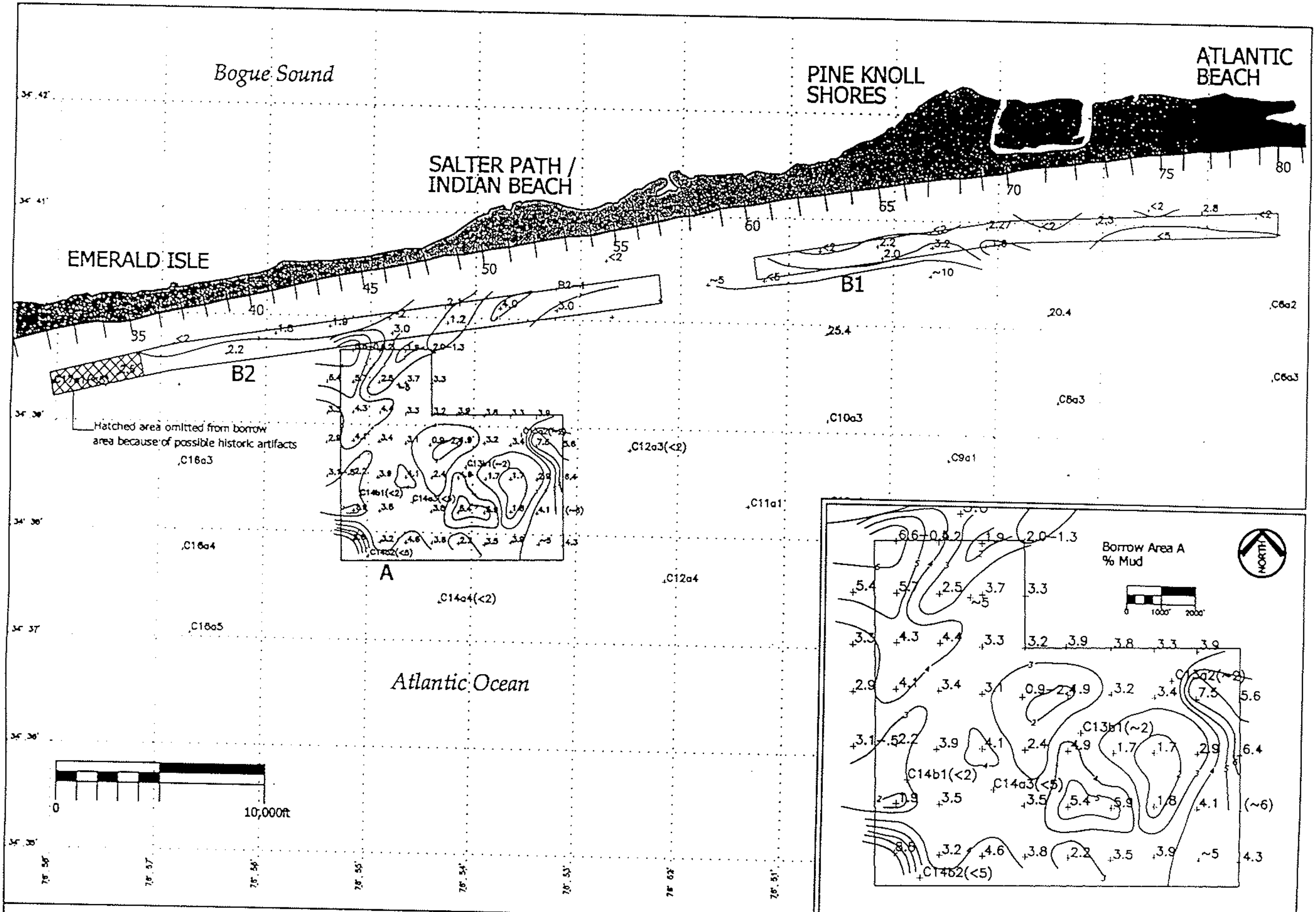
TYPICAL BORROW AREA CROSS SECTIONS	PROJECT NAME: Bogue Banks Beach Nourishment Project	Coastal Science & Engineering, LLC	APPLICANT: Carteret County



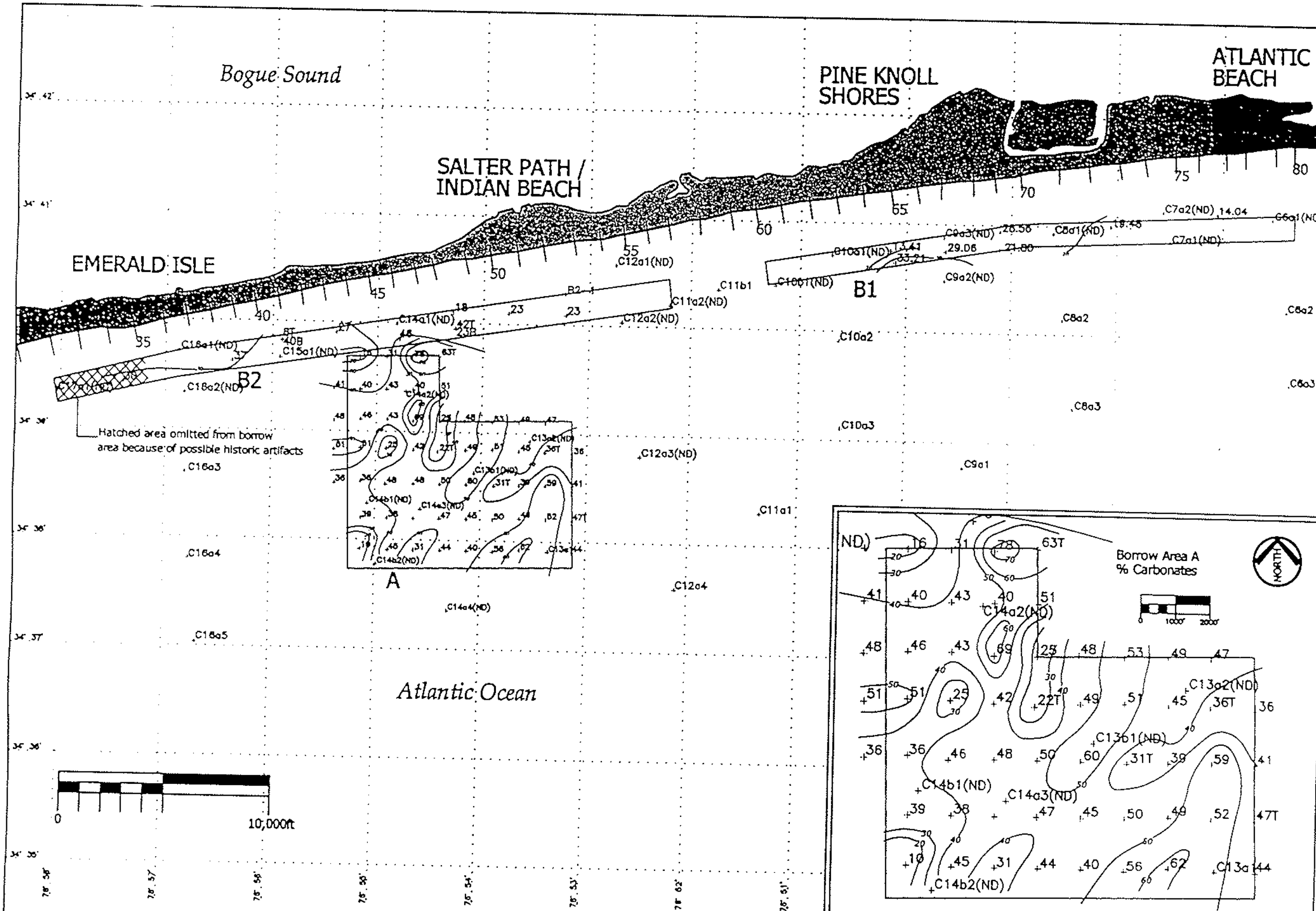
Mean grain size in potential borrow areas off Bogue Banks

PROJECT NAME:
Bogue Banks
Beach Nourishment Project

APPLICANT:
Carteret County



Percentage of mud in potential borrow areas off Bogue Banks	PROJECT NAME: Bogue Banks Beach Nourishment Project	CSE	APPLICANT: Carteret County

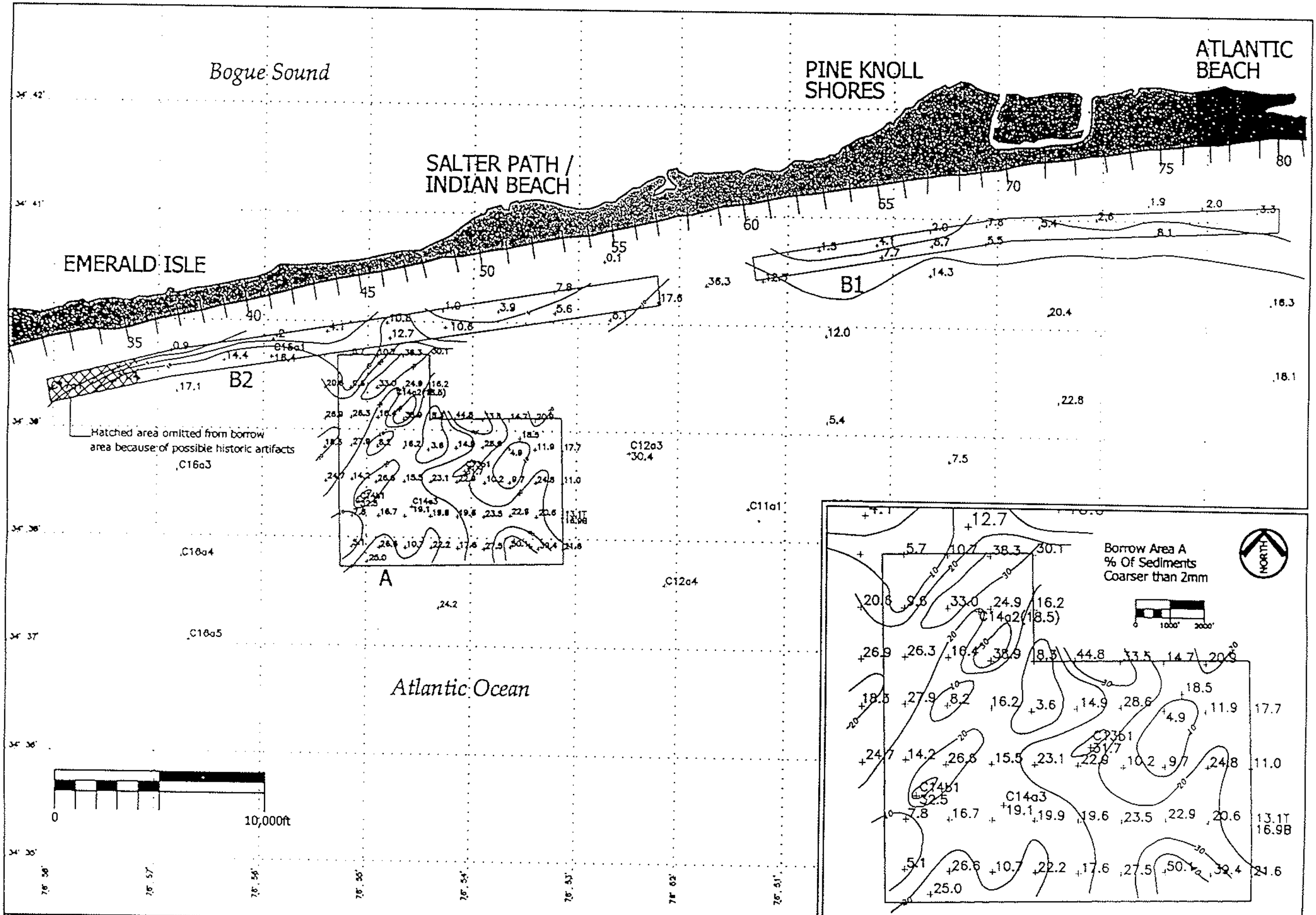


Percentage of carbonate material (shell) in potential borrow areas off Bogue Banks

PROJECT NAME:
Bogue Banks
Beach Nourishment Project

CSE
Coastal Science & Engineering, LLC

APPLICANT:
Carteret County
Jan 19 2001



Percentage of sediments coarser than 2mm diameter in potential borrow areas off Bogue Banks

PROJECT NAME:
Bogue Banks
Beach Nourishment Project

APPLICANT:
Carteret County
Jan 19 2001

AEC HAZARD NOTICE

ɔject Is In An: _x_ Ocean Erodible Area ____ High Hazard Flood Area ____ Inlet Hazard Area

Date Lot Was Platted: N/A

This notice is intended to make you, the applicant, aware of the special risks and conditions associated with development in this area, which is subject to natural hazards such as storms, erosion and currents. The rules of the Coastal Resources Commission require that you receive an AEC Hazard Notice and acknowledge that notice in writing before a permit for development can be issued.

The Commission's rules on building standards, oceanfront setbacks and dune alteration are designed to minimize, but not eliminate, property loss from hazards. By granting permits, the Coastal Resources Commission does not guarantee the safety of the development and assumes no liability for future damage to the development.

The best available information, as accepted by the Coastal Resources Commission, indicates that the annual ocean erosion rate for the area where your property is located is 1 - 3 feet per year.

The rate was established by careful analysis of aerial photographs of the coastline taken over the past 50 years.

Studies also indicate that the shoreline could move as :h as 25 feet landward in a major storm.

The flood waters in a major storm are predicted to be about 12 feet deep in this area.

Preferred oceanfront protection measures are beach nourishment and relocation of threatened structures. Hard erosion control structures such as bulkheads, seawalls, revetments, groins, jetties and breakwaters are prohibited. Temporary devices, including sand bags, may be allowed under certain conditions.

This structure shall be relocated or dismantled within two years of becoming imminently threatened.

The applicant must acknowledge this information and requirements by signing this notice in the below space. Without the proper signature, the application will not be complete.

x Dave Clark, P.E.
Applicant's Signature

x 24 January 2001
Date

SPECIAL NOTE: This hazard notice is required for development in areas subject to sudden and massive storms and erosion. Permits issued for development in this area expire on December 31 of the third year following the year in which the permit was issued. Shortly before work begins on the project site, the Local Permit Officer will determine the vegetation line and setback distance at your site. If the property has seen little change and the proposed development can still meet the setback requirement, the LPO will inform you that you may begin work. It is important that you check with the LPO before the permit expires for official approval to continue the work after the permit has expired. Generally, if foundation pilings have been placed and substantial progress is continuing, permit renewal may not be necessary. If substantial progress has not been made, the permit must be renewed and a new setback line established. It is unlawful to continue work after permit expiration without this approval.

For more information, contact:

____
Local Permit Officer

____
Address

____
Locality

____
Phone

APPENDIX A-3

6 June 2001

USDA Environmental Assessment

USDA

United States
Department of
Agriculture

Rural
Development
TDD (919) 873-2003

2044-C Hwy 11/55 South
P. O. Box 6189
Kinston, NC 28501-0189

Area Office
Phone: (252) 526-9799 ext. 5 *Fax:* (252) 526-9607

Single Family Housing
Phone: (252) 523-7681 ext. 4 *Fax:* (252) 523-9071

June 6, 2001

Mr. C. Reese Musgrave, Mayor
Town of Pine Knoll Shores
100 Municipal Circle
Pine Knoll Shores, NC 28512

RE: Copy of Class II Environmental Assessment
Beach Restoration Project

Dear Mayor Musgrave:

Enclosed please find a copy of our Class II Environmental Assessment for the above mentioned project This information should be made available to other agencies contributing to the project, other interested parties, and persons that may be affected by the requirements of our assessment.

Please advise if you have questions regarding the above.

Sincerely,

EDWIN W. CAUSEY
Rural Development Manager

EWC/acs

Enc.

H:\word\Pine Knoll Shores - Musgrave - Copy of EA 060601.doc

CLASS II
ENVIRONMENTAL ASSESSMENT
TOWNS OF
INDIAN BEACH
AND
PINE KNOLL SHORES

PREFACE

USDA, Rural Development (USDA, RD) has recently received pre-applications from the towns of Indian Beach and Pine Knoll Shores in Carteret County, North Carolina for a beach nourishment project. While RD has recently become involved in the project, the towns have been considering and planning it for several years. They have worked closely with Coastal Science and Engineering, LLC of Columbia, South Carolina and Stroud Engineering, P.A. of Morehead City, North Carolina in planning the project. These consultants have prepared an Environmental Impact Statement (EIS) that meets the requirements of the State Environmental Policy Act (SEPA). USDA, RD has reviewed the EIS and considered the findings and conclusions therein and is in concurrence with same. The EIS appears to be very thorough and addresses all environmental issues which Rural Development has tentatively identified for this project. With enforcement of the mitigation measures that have been established through the review and comment phase of the EIS, RD does not believe the project as proposed will have a major impact on the human environment. Therefore RD does not believe at this time it is necessary to prepare an environmental impact statement for this project under the National Environmental Policy Act (NEPA). USDA, RD must still meet the requirements of the National Environmental Protection Act (NEPA) and must still complete an independent environmental review of the project. Therefore, RD has prepared an environmental assessment to meet the requirements of NEPA and RD Instruction 1940-G. As part of the RD review, the EIS has been reviewed in detail.

This Class II Environmental Assessment has the same findings as the EIS. Rural Development plans to issue a Finding of No Significant Impact (FONSI) for this project and to formally notify the public of this determination. The EIS is included as **Attachment 4** to this assessment and is intended to be used in conjunction with same. Rural Development's assessment contains numerous references to the EIS. Also included within **Attachment 4** to this assessment is the Supplement to the Final EIS that was prepared in connection with the federal review for the permit application for the project.

There will be several federal permit applications required for this project. An important point in RD's mitigation measures for this project is that RD will not authorize construction of the project or provide any financial assistance for the project until all applicable permits have been obtained. Therefore RD recognizes that further environmental review of the project will take place during the permit application process. Should significant issues arise during the application for federal permits that would trigger the need for an EIS under NEPA, RD does reserve the right to re-open environmental review of the project and prepare either independently or in cooperation with other federal agencies, an EIS for this project.

I. PROJECT DESCRIPTION AND NEED

Carteret County has sustained accelerated beach erosion along Bogue Banks as a result of five hurricanes passing over or in close proximity to the area. This frequency of occurrences is far greater than normal for this area since 1995. The county, the municipalities of Emerald Isle, Indian Beach, Pine Knoll Shores, and the unincorporated area of Salter Path desire to perform beach nourishment at the earliest time possible. This report addresses the specific needs of Indian Beach and Pine Knoll Shores.

The proposed nourishment project will consist of placing beach quality sediment along the coastline of both Pine Knoll Shores and Indian Beach. Figure 1 (EIS, Appendix B) shows the proposed locations at which sand is to be placed. Figure 2 (EIS, Appendix B) is a schematic diagram, which shows the general configuration of the sand to be deposited. Nourishment sand will be excavated from up to three borrow areas by hopper dredge or hydraulic dredge and placed along the three reaches that compose this project. The width of the beach will be extended approximately 100' with this project.

Three potential borrow areas have been sampled and delineated offshore of the project area. Sediment quality in each borrow area was compared with native beach sediment to determine compatibility indices. Final selection of borrow areas will be based on several factors, including sediment quality, dredging and transportation, economic/environmental impacts, and cultural resource impacts. See EIS, Appendix B, Figure 1 and Figure 2, which outline the various reaches.

II. PRIMARY BENEFICIARIES

The primary beneficiaries of the project will be the citizens of Indian Beach and Pine Knoll Shores, the citizens of Carteret County, as well as visitors from all over eastern North Carolina. (Also, see Exhibit 7, Survey Report 2000 Bogue Banks, NC and Shoreline Assessment & Preliminary Beach Restoration Plan (Sept 1999.)

The citizens of Indian Beach and Pine Knoll Shores get the direct benefit of protecting the physical integrity of their town as well as the tax base. The total Bogue Banks area represents less than one per cent of Carteret County land area but accounts for 43% of the county's tax base. Nearly 80% of Carteret County's tax base funds Carteret County Schools. Thus, the financial integrity of the entire county is closely associated with the towns of Indian Beach and Pine Knoll Shores.

The county also recognizes the beaches of Bogue Banks as a valuable ecological resource. Of the 70 miles of barrier island shoreline located in Carteret County, Bogue Banks is the only developed portion. Bogue Banks serves to draw human activity away from the pristine beaches and ecosystems of Shackleford and Core Banks.

III. DESCRIPTION OF PROJECT AREA

The towns of Indian Beach and Pine Knoll Shores are located on Bogue Banks in Carteret County, North Carolina. The 1990 census listed the permanent population of Pine Knoll Shores as 1360 and Indian Beach as 153. Tourism is the foundation of the local economy. Much of the population is made up of retired families. There are numerous second homes.

The area is an excellent candidate for nourishment because of the historically low erosion rate. Most of the Bogue Banks area is situated favorably away from tidal inlets where shoreline changes tend to be more erratic and much greater in magnitude. The major contributor to erosion along the beaches of these towns is the occurrence of large storms such as hurricanes that either skirt the coast on the east side of the towns or cross the coastline and proceed inland. This impact is magnified when several storms occur in an unusually short time frame. The benefits of nourishment can be seen in Atlantic Beach, which has received sand on two occasions from USALE projects. Atlantic Beach is located just north of Pine Knoll Shores.

IV. ENVIRONMENTAL IMPACT

AIR QUALITY:

The Air Quality Section of the North Carolina Department of Environment and Natural Resources has jurisdiction over air quality in Carteret County. According to the Wilmington District Office, ambient air quality in Carteret County is in compliance with the National Ambient Air Quality Standards.

A slight increase in total suspended particulate (TSP) is expected for a temporary period in the immediate area of construction. However, all sediment materials moved will be moist, thus minimizing the amount of suspended particulate matter escaping to surrounding air. Most of the material placed will consist of medium to large sand particles, which are less susceptible to becoming airborne. The construction period of the project should be six months or less. The resulting impact on the ambient air quality standard is considered minor.

WATER QUALITY: (EIS 3.9 and 3.10 page 3-5)

The proposed project will not affect water quality of surface or ground water.

Water quality around Bogue Banks is generally high due to large tidal flows and resultant flushing associated with Bogue Inlet and Beaufort Inlet. Waters of Bogue Sound, west of a line from the mouth of Gales Creek to Rock Point in Indian Beach, are classified as outstanding resource waters (ORW), which are waters of the state that are unique and of a special state or national recreational or ecological importance that require special protection to maintain existing uses. Waters east of Rock Point in Bogue Sound are classified SA. SA waters are suitable for shell fishing for human consumption. Ocean waters of Onslow Bay off of Bogue Banks are of high quality. This quality is due to the fact that no rivers draining large urbanized watersheds discharge directly into Onslow Bay. The White Oak River in the western end of the county and the Newport River in the east have relatively small agricultural, forested, and lightly developed watersheds.

Groundwater is plentiful throughout Bogue Banks. It is near the surface in many places, especially in the early spring and winter. The underlying limestone deposits of the Castle Hayne formation are the source of water supplies on Bogue Banks. These formations are below the surficial aquifers in the island consisting of a fresh water lens which varies in depth depending on rainfall amounts and has water that is often salty or has high concentrations of dissolved iron and hydrogen sulfide.

SOLID WASTE MANAGEMENT:

The project will not involve demolition or construction of any permanent structures. The contractor will be required to remove all supplies and equipment from the project area upon completion of sand pumping. Disposal of pipe, cable, or any expendable items will be prescribed in contract documents with penalties for violations including, at minimum, retrieval of items dumped accidentally at sea or on the project beach.

LAND USE: (EIS 3.1.1 page 3-1)

Bogue Banks is a barrier island with a southward facing ocean shoreline stretching some 25 miles between two large tidal inlets, Bogue Inlet to the west and Beaufort Inlet to the east. The Banks are surrounded by Bogue Sound on the north and Onslow Bay of the Atlantic Ocean on the south. The island is made up of the Fort Macon State Park, the Towns of Atlantic Beach, Pine Knoll Shores, Indian Beach, and Emerald Isle and the unincorporated area of Salter Path.

Over 70 miles of barrier island shoreline located in Carteret County, Bogue Banks is the only developed area. The remainder, made up of Shackleford Banks and Core Banks to Ocracoke Inlet, will remain undeveloped in perpetuity as part of the Cape Lookout National Seashore. Bogue Banks is the only ocean shoreline. Dune ridge elevations reach 40 feet (ft) above sea level at some locations.

Bogue Banks' soils vary with Newhan sandy soils in the nearshore, beach and dune zones; Duckston, Corrolla and Newhan soils in the scrub zones; Duckston, Corrolla and Fripp soils in the maritime forest zones; and Carteret soils in the salt marsh zones. Corrolla soils are fine sands, moderately to poorly drained that occur behind the frontal dune line. Fripp sands are excessively well drained and make up the interior dune ridge areas. Duckston fine sands are poorly drained and are in the troughs between dune ridges and on flats between dunes and marshes. Newhan fine sands are excessively well drained and make up the dune ridges that parallel the ocean shoreline. Carteret soils are the fine organic muck found in the salt marsh environment.

Vegetation on Bogue Banks reflects elevation and the amount of exposure to salt spray. As distance from the shoreline increases, sparse beach grasses merge with dense scrub vegetation. Maritime forests thrive in areas where the island is wide enough to provide sufficient protection from salt spray for forest growth. Maritime forests generally occur on lands that have been stable for at least 50 years. Vegetation typical of freshwater wetlands and tidal flats populate flood prone areas and natural and manmade drainage ways.

TRANSPORTATION:

All of the construction activity will occur on the ocean or beachfront. There will be no major adverse impact on transportation in the area. The borrow area from which the materials for beach nourishment will be obtained are not located in or near shipping channels. There may be some minor inconvenience to fishing boats, shrimp trawlers, etc., as they have to detour around the dredges and pipeline.

NATURAL ENVIRONMENT:

It is determined that this construction will have no major impact on important land resources.

HUMAN POPULATION:

No persons will be relocated as a direct result of the proposed project. The proposed development could accommodate a moderate amount of population increase. It is not expected that any population changes, other than those that would ordinarily occur, will occur as a result of the proposed project. Therefore, no demands will be placed on community services such as schools, health care, social services, and fire protection that have not already been planned.

CONSTRUCTION:

The location of the planned improvements is located such that minimal disruption will occur for anyone. The majority of planned improvements will occur at a time of year that will further minimize disruption. The actual construction may necessitate the actual closing of sections of the beach for a period of one-month maximum. In addition, there could be a temporary discoloration of waters around the dredge intake and a temporary decrease in aesthetic value of the beach area due to the noise impact from the machinery operating on the beach.

V. ENERGY IMPACTS

The project will not alter energy supplies and uses. Construction will require local fuel purchases to run self-contained dredging equipment and trucks. No construction will require connection to the local power grid.

VI. COASTAL ZONE MANAGEMENT ACT (EIS 2.5.1 page 2-5)

The project is located in a county covered by the Coastal Zone Management Act. Coastal Science and Engineering, LLC prepared an environmental impact statement.

CAMA representatives will submit copies of the EIS to the Army Corps of Engineers for Federal agencies' review. The Corps coordinates federal review of both the EIS and the CAMA Major Development Permit application. Federal review includes Corps review of compliance with section 10 of the Rivers and Harbors Act of 1899 for work within navigable waters. The Corps also reviews for compliance with Section 404 or the Clean Water Act, covering discharge of dredged materials into navigable waters.

The Corps distributes copies of EIS and permit applications to other federal agencies, including the Environmental Protection Agency, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. These agencies review and comment on the EIS, and these comments must be received and considered by the Corps prior to the coordinated Federal response to the EIS. Likewise these agencies' responses must be received and considered prior to issuance of a Federal permit.

North Carolina's Division of Coastal Management coordinates the entire review process, both to state agencies and to the Corps. State approvals required include certification of compliance with the Coastal Area Management Act, the Dredge Fill Act, Water Quality Certification (Section 401), and Easement in Public Trust Areas.

For both the EIS review and the permit-application review, DCM distributes copies to state agencies that include the Wildlife Resources Commission, the Department of Administration, the Department of Transportation, and Divisions of Water Quality, Land Quality, Marine Fisheries, Environmental Health, Archives and History, and Community Assistance. DCM receives and reviews comments from these agencies and the coordinated Federal response prior to approval of Finding of No Significant Impact (FONSI) or a requirement for changes in this Plan.

The project requires compliance with NC EPA. This Environmental Impact Statement is the document being submitted to demonstrate such compliance. Based on the review, DCM either issues the FONSI or requires amendments to this Plan.

VII. COMPLIANCE WITH ADVISORY COUNCIL ON HISTORIC REGULATIONS

Rural Development Instructions 1901-F. 1A have been reviewed and the proposed site does not contain or affect a historic place listed in the National Register of Historic Places. The comments of the State Historical Preservation Officer (SHPO) were considered in the EIS and are included as mitigation measures. The SHPO has further requested that everyone be sensitive to the potential of unearthing a beached shipwreck and to call the Underwater Archaeology Branch at 910-458-9042 if needed.

VIII. CULTURAL RESOURCES (EIS 5.7 page 5-3)

To determine the impact of the proposed dredging and beach fill operation on potentially significant submerged cultural resources, a remote sensing survey of the proposed borrow areas was conducted by Tidewater Atlantic Research, Inc. (TAR) of Washington, North Carolina. The survey was designed to locate and identify submerged cultural resources in the study area, generate sufficient data to make an initial assessment of teach target's significance, and provide insight into the necessity for avoidance or additional investigation. The survey was carried out between 7 and 13 December 1999. No magnetic or acoustic anomalies were identified in either borrow area A or borrow area B-1. In borrow area B-2, ten magnetic anomalies were identified near the western end of survey area. Seven of those targets contained signature characteristics indicative of submerged cultural resources. Because they could be associated with an historic shipwreck, either avoidance or additional investigation to positively identify the nature and significance of the material generating the seven anomalies was recommended. To avoid the areas of the seven anomalies identified by the survey, the western portion of borrow area B-2 will be eliminated as a potential source of sand for the project (mitigation measure).

During the clearinghouse review process, the N. C. Dept. of Cultural Resources expressed concern about possible damages to unknown artifacts associated with old shipwrecks that might be uncovered during the construction process. Rural Development has considered those comments and has prepared a mitigation measure to address this concern. It is included in Section XXI of this document.

IX. COMPLIANCE WITH THE WILD AND SCENIC RIVERS ACT

Based on a review of the Wild and Scenic Rivers Inventory list for North Carolina, the proposed development will not affect a river or portion of a river included in the National Wild and Scenic Rivers System. The project area includes the approximate 10 miles of beach on which sand will be placed and the offshore borrow area from which the sand will be obtained.

X. COMPLIANCE WITH THE ENDANGERED SPECIES ACT

Attached herein are EIS Section 3.15 pages 3-9 through 3-13 (ATTACHMENT 1) which outlines species to be considered in the environmental evaluation and a description of same. The US Fish and Wildlife Service and National Marine Fisheries Service provided the list of species.

EIS Section 5.15 through 5.18 pages 5-6 through 5-11 (ATTACHMENT 2) is also attached and contains a description of potential impacts to these species as a result of the proposed beach nourishment project. These sections also outline some actions that will be taken to minimize actions. Section 5.18 of the EIS also further outlines mitigation measures that will be taken to minimize potential impacts to threatened and endangered species. Rural Development will require both towns to agree to these mitigation measures as a condition for funding.

USDA will require that concurrence of U. S. Fish and Wildlife Service is obtained for all planned mitigative requirements. The U.S. Fish and Wildlife Service concurrence will be obtained through the process of obtaining the 404 permit through the Army Corps of Engineers.

XI. COMPLIANCE WITH FARMLAND PROTECTION POLICY ACT

None of the planned improvements will occur on land protected by the Farmland Protection Policy Act. Therefore, no specific mitigation requirements will be required.

XII. COMPLIANCE WITH EXECUTIVE ORDER 11988, FLOODPLAIN MANAGEMENT AND EXECUTIVE ORDER 11990, PROTECTION OF WETLANDS

None of the project improvements are planned for areas that are considered wetlands. All of the improvements are planned for areas that are considered floodplain. Exhibits 5 and 6 contain the applicable floodplain maps.

The preliminary notification of possible impacts to floodplains was published in the Carteret County News-Times. The notice for Indian Beach was published on March 30, April 1 and 4, 2001. The notice for Pine Knoll Shores was published on April 4, 6 and 8, 2001. The Affidavits of Publication are included as Exhibit 4 for Indian Beach and Pine Knoll Shores. The primary purpose of the project is to increase the width of the current beach. However, during flood events, such as associated with a typical hurricane, there will be little if any actual change to the 100-year floodplain.

Both the Town of Indian Beach and the Town of Pine Knoll Shores are more than 90% built up. The proposed project is intended to protect existing valuable resources as opposed to significantly expanding development in the floodplain area. The beach re-nourishment project will not create any additional land on which development will take place.

XIII. COMPLIANCE WITH COASTAL BARRIERS RESOURCE ACT

None of the project area lies within areas protected by the Coastal Barriers Resource Act. The project location area is fully developed. There are areas within the COBRA system within Carteret County, however those areas are generally located along Shackleford and Core Banks.

XIV. STATE ENVIRONMENTAL POLICY ACT

An EIS has been prepared to satisfy requirements of SEPA for the project.

The project has been thoroughly reviewed by all appropriate State environmental protection agencies. No questions of inconsistencies with the SEPA have been raised. Therefore, USDA, Rural Development has determined the project to be in compliance with the State Environmental Policy Act.

XV. CONSULTATION REQUIREMENTS OF EXECUTIVE ORDER 12372, INTERGOVERNMENTAL REVIEW OF FEDERAL PROGRAMS

Comments of the State Clearinghouse Review are attached as Exhibit 2 for Indian Beach and Exhibit 3 for Pine Knoll Shores. Coastal Science and Engineering, LLC considered all comments in the final preparation of the EIS recommendations. The EIS report will be submitted to the Army Corps of Engineers for issuance of the 404 permit. The Corps will have further consultation with all State agencies to ensure that all concerns are considered.

XVI. ENVIRONMENTAL ANALYSIS OF PARTICIPATING FEDERAL AGENCY

No other Federal agency is participating in the proposed project.

XVII. REACTION TO PROJECT

Reaction to the projects has been extremely positive from both the Towns of Pine Knoll Shores and Indian Beach. Both towns have voted on bond referendums to do the project with strong support. In addition, USDA received no adverse comments regarding the project for either town during the 30-day comment period.

XVIII. CUMULATIVE IMPACTS

The project will allow the towns of Indian Beach and Pine Knoll Shores to physically improve the protection of their southeastern coastal boundaries. This protection will enhance the tax base and economic benefits for the entire county. Moreover, the responsible maintenance of the entire Bogue Banks will lessen pressure for more human utilization of other barrier islands in Carteret County.

XIX. ADVERSE IMPACTS

After analyzing the cumulative impacts of the proposed project, it is determined that the proposed project will have no permanent impact on the environment. There will be some minor temporary adverse impacts associated with construction such as increased noise levels. After analyzing the magnitude and duration of the potential impacts and mitigation measures as identified in Section XXI, these impacts are determined not to be significant.

XX. ALTERNATIVES

Section 4.0 through 4.4.4.3, pages 4-1 through 4-10 entitled "ALTERNATIVES" (ATTACHMENT 3) of the EIS that was prepared by Coastal Science & Engineering, LLC is included herein because of its detailed discussion of alternatives.

Based on the discussion presented, the project as proposed is the most environmentally sensitive proposal that can be economically developed.

XXI. MITIGATION

All mitigation measures as outlined in the EIS will be required in addition to the following:

SOLID WASTE MANAGEMENT

The disposal of all pipe, cable, and expendable items will be disposed strictly in accordance with the contract documents. Any material accidentally dumped in the ocean will be retrieved.

PERMITS

The Army Corps of Engineers will coordinate the Federal Review of the proposed project and the CAMA Major Development Permit. USDA will not authorize the project for construction until the Corps has reviewed the projects and issued a permit/certification outlined in section 10 of the Rivers and Harbors Act of 1899 for work within navigational waters as well as Section 404 of the Clean Water Act.

CULTURAL RESOURCES

To avoid areas of the seven anomalies identified by the referenced survey, the western portion of borrow area B-2 will be eliminated as a potential source of sand for the project.

During the clearinghouse review, the N. C. Department of Cultural Resources raised a concern about the possibility of previously unknown and unrecorded shiprwrecks or portions thereof being unearthed during the construction process. They further expressed the desirability of any artifacts of this type being studied, catalogued, and possibly salvaged prior to their destruction. In order to accomplish this objective Rural Development will require the Towns to adopt the following mitigation measure:

Rural Development will require the Towns to use standard construction contract documents provided by the agency. These documents already contain a provision requiring a contractor to stop work if archaeological artifacts are uncovered. A clause will also be included within the contract documents that will provide compensation for the contractor for re-mobilization if it becomes necessary for him to stop work to allow for study and possible salvage of artifacts. In addition a representative of the N. C. Dept. of Cultural Resources will be invited to the preconstruction conference to provide information and education to the contractor and his work superintendent that would alert them to the discovery of artifacts. The project construction inspector and project engineer will also be required to attend this briefing. The N. C. Dept. of Cultural Resources will be invited to observe and inspect the construction site at will to help insure that any existing artifacts are not inadvertently destroyed.

All mitigation measures identified above will be incorporated into the Letter of Conditions for any financial assistance for the project authorized by Rural Development. Rural Development will require the Towns to adopt an ordinance agreeing to the mitigation measures, thus making them binding on the Towns.

XXII. COMPLIANCE WITH ENDANGERED SPECIES ACT

The applicant has worked diligently on Section 5.15 and 5.18 to define potential impacts to endangered species and to provide appropriate mitigation. Concurrence of the U.S. Fish and Wildlife Service will be obtained on all needed mitigation through the Corps of Engineers permitting process.

XXIII. CONSISTENCY WITH RD ENVIRONMENTAL POLICIES

The proposed action is consistent with the Agency's environmental policies. The project has been planned so as to minimize the impact on the environment.

Based on an examination and review of the foregoing information and such supplemental information attached herein, I recommend that the approving official determine that this project will have

______ a significant effect on the quality of the human environment and an Environmental Impact Statement must be prepared;

or, will not have

X a significant effect on the quality of the human environment.

I recommend that the approving official make the following compliance determinations for the below listed environmental requirements.

Not In Compliance	In Compliance	
	X	Clean Air Act
	X	Federal Water Pollution Control Act
	X	Safe Drinking Water Act - Section 142(e)
	X	**Endangered Species Act**
	X	Coastal Barrier Resources Act
	X	Coastal Zone Management Act Section 307 (C)(1) & (2)
	X	Wild and Scenic Rivers Act
	X	National Historic Preservation Act
	X	Archaeological and Historic Preservation Act
	X	Executive Order 11988, Floodplain Management
	X	Executive Order 11990, Protection of Wetlands
	X	Farmland Protection Policy Act
	X	Department Regulations 9500-3, Land Use Policy
	N/A	State Office Natural Resource Management Guide

I have reviewed and considered the types and degrees of adverse environmental impacts identified by this addendum to the assessment. I have also analyzed the proposal for its consistency with RD environmental policies, particularly those related to important farmland protection, and have considered the potential benefits of the proposal. Based upon a consideration and balancing of these factors, I recommend from an environmental standpoint that the project

X be approved

______ not be approved because of the attached reasons

EDWIN W. CAUSEY
Rural Development Preparer

5-17-01
DATE

THURMAN BURNETTE
PROGRAM CHIEF
Concurring Official

5-17-01
DATE

I have reviewed this environmental assessment and supporting documentation. Following are my positions regarding its adequacy and the recommendations reached by the preparer. For any matter in which I do not concur, my reasons are attached as Exhibit ________.

Do Not Concur	Concur	
	X	Adequate Assessment
	X	Environmental Impact Determination
	X	Compliance Determinations
	X	Project Recommendation

THOMAS V. HONEYCUTT, JR.
Assistant State Environmental Coordinator

5/17/01
DATE

EXHIBITS

1. 2006-28 "Civil Rights Impact Analysis"
   with Attachment

2. Clearinghouse Comments – Indian Beach
   - NCDENR Comments
   - NC Wildlife Resource Comm. Comments
   - SHPO Comments

3. Clearinghouse Comments – Pine Knoll Shores
   - NCDENR Comments
   - NC Wildlife Resource Comm. Comments
   - SHPO Comments

4. AFFIDAVID OF PUBLICATON
   - Indian Beach
   - Pine Knoll Shores

5. FEMA 81-93 – Indian Beach
   - Floodplain maps

6. FEMA 81-93 – Pine Knoll Shores
   - Floodplain maps

7. Preliminary Engineering Report
   - Survey Report 2000, Bogue Banks, NC
   - Shoreline Assessment & Preliminary Beach Restoration Plan (Sept. 1999)

APPENDIX A-4

23 August 2001
Environmental Monitoring Plan

Revised Environmental Services Proposal:

Bogue Banks Beach Restoration Project

Bogue Banks, North Carolina

Submitted to:

Coastal Science & Engineering PLLC
804 Arendell Street
Morehead City, NC 28557

Submitted by:

Coastal Science Associates, Inc.
328 second Avenue North
Jacksonville Beach, FL 32250

August 23, 2001

Introduction

The Towns of Pine Knoll Shores, Indian Beach and Emerald Isle propose to place approximately six million cubic yards of sand over approximately 16.8 miles of ocean shoreline along Bogue Banks in Carteret County, North Carolina. The sand will be dredged from three offshore borrow areas using hopper or cutter head hydraulic dredges. The work will be completed in three phases over a three year period. The first phase will include nourishment of 7.2 miles of beach in Pine Knoll Shores and Indian Beach with approximately 3 million cubic yards of sand. The first phase will be completed during the winter of years 2001 and 2002. Phase Two will include nourishment of three miles of beach in Emerald Isle with 1.7 million cubic yards of sand. Phase three, if implemented will include nourishment of 6.7 miles of beach with 1.9 million cubic yards of Sand. Phases two and three will be implemented during the winters months of 2002/2003 and 2003/2004 respectively.

The monitoring plan described herein will measure pre and post-dredging biological impacts associated with phases one and tow of the proposed project. Monitoring associated with Phase three is not proposed because funding for that phase is not being addressed at this point by the Town of Emerald Isle. If the third phase is implemented and the monitoring results from the phases one and two indicate a need for monitoring of a third phase, the plan will be modified to include an additional phase.

Purpose of Study

The purpose of this proposed ecological study is to assess the existing biological communities, and to assess impacts on benthic invertebrates and fish (to the extent feasible), at the proposed Bogue Banks Beach Nourishment Project, located in Carteret County, North Carolina. This study is based on a series of reviews and meetings with UNC Institute of Marine Sciences (IMS), the U.S. Fish & Wildlife Service, the National Marine Fisheries Service, the U.S. Army Corps of Engineers, the North Carolina Department of Environment and Natural Resources, North Carolina Coastal Federation, and others.

Based on experience of the authors and other researchers over the last 15+ years, beach nourishment projects have little or no long term environmental effects when compatible, low silt/clay materials are used and when borrow sites are properly selected and used. Following is a listing of southeast beach nourishment projects conducted by the authors which bear this out::

Daufuskie Island beach nourishment. Monitoring surficial sediments and macrobenthic infauna assemblages at the proposed offshore borrow areas. Applied Technology and Management, Mt. Pleasant, SC.

Hunting Island beach nourishment project. Environmental surveys for determination of environmental impacts of beach nourishment. SC Department of Parks, Recreation, and Tourism, Columbia, SC.

Indian River County Beach. Hardbottom surveys of fish, benthos, invertebrates, and flora for beach nourishment project. Applied Technology and Management, Gainesville, FL.

John U. Lloyd beach nourishment project. Long-term specimen identification for determining impacts of a large beach nourishment project using offshore dredging. John U. Lloyd State Park, Dania, FL.

City of Key West. Analyses of macro-invertebrate communities on Smathers and Rest Beaches for beach renourishment project. Post, Buckley, Schuh, and Jernigan, Miami, FL.

Longboat Key Beach Nourishment. Nearshore benthic and artificial reef monitoring for assessment of long_term impacts to fish and macroinvertebrates. Applied Technology and Management, Gainesville, FL.

Martin County Beach Nourishment. Nearshore benthic and artificial reef monitoring for assessment of long_term impacts to fish and macroinvertebrates. Applied Technology and Management, Gainesville, FL.

Myrtle Beach nourishment project. Long-term macroinvertebrate and turbidity studies conducted before and after major sand nourishment. Myrtle Beach, SC.

Palmetto Dunes beach nourishment project. Collection, identification and report relative to the environmental effects of shoal scraping for a beach nourishment project on Hilton Head Island. Palmetto Dunes, Hilton Head, SC.

Pawleys Island Beach Nourishment. Macroinvertebrate surveys for determination of environmental impacts. Town of Pawleys Island, SC.

Seabrook Island beach nourishment project. Environmental surveys for determination of impacts resulting from shoal dredging for beach nourishment. Seabrook Island POA, Charleston, SC.

Seabrook Island environmental study. A five_year study of the effects of a beach nourishment dredging project on the coastal vegetation, birds, and other natural resources. Seabrook Island Company, Charleston, SC.

Impacts relating to beach nourishment projects can be summarized as follows (from Lankford and Baca 1989; H=high, M=medium, L=low impacts):

Impacts	To Beach or Borrow Site	By Offshore Dredging	By Nearshore Dredging	By Shoal Scraping
Benthic macroinvertebrates	Borrow	M	H	M
Reefs and hardbottoms	Borrow	M	M	L
Fisheries	Borrow	M	M	L
Turtle nesting	Beach	L	L	L
Bird nesting	Beach	L	L	L
Species diversity/richness	Borrow	M	H	L

Commercial/recreational value	Borrow	M	H	L

Macroinvertebrate communities, species diversities, and commercial/recreational values are impacted by nearshore dredging; importantly, however, these impacts were not significant or long-lived in nearly all cases reviewed. In a recent South Carolina study comparing pre- (CSAi 1999) and post-dredging impacts (CSAi 2000) on offshore areas, although impacts were noticeable, they had virtually disappeared after one year. A long-term, comprehensive environmental study of beach nourishment conducted along the coast of New Jersey (ACOE 2001) had similar results. Beach and borrow fauna generally recovered in a few months time; borrow site taxa and biomass required longer to recover (up to 2.5 years).

Preliminary Results and Analyses

Last June 2001, a survey was conducted of beach and borrow sites as described in the methods of this plan. For the June study, organisms were identified to the lowest praticable taxon, usually species, and some preliminary analyses were performed.

A power analysis was used as a means of determining the proper sample number for this project, with the aim of insuring meaningful sampling while saving resources. The "power" of the test is the ability to reject the "no effects" null hypothesis when it is false. Although a large variety of biological parameters can be used to sample and measure populations, following are examples relating to species counts:

1. Species population changes by ±10%, with a 5% chance of error (Green 1979)
2. Subsampling to obtain 90% of the total species (Livingston et al. 1976)
3. Sampling to detect species whose abundance is a proportion of the population ((Dennison and Hay 1967)

Numbers of individuals and species for some of the first samples analyzed from the June survey are given in Appendix A. As shown, samples are relatively homogeneous and dominance is consistent. For beach samples, without lumping samples from different strata along each transect gives 9 replicate cores per site and lumping the two similar lower strata gives 18 replicate cores per site. As shown in the Appendix, any of three cores were necessary to capture 90% of the species, and the species missed on some cores were caught on others. For borrow samples, the numbers were higher but also fairly consistent. The 10 replicate cores showed low variation and many can be lumped to represent large areas of borrow site.

Looking at abundance in the preliminary survey is the preferred method of some researchers, although the patchy distribution of organisms tends to increase variability in total numbers more than in species numbers. Standard Methods (1997) recommends the following equation for determining sample number:

$$N = ((t \times s) / (D \times M))^2$$

Where N = number of samples, t = tabulated t value, s = standard deviation of samples, D = required precision, and M = mean density.

Using three subtidal cores from the attached 24th and Ocean example:

$N=((2.0 \times 26) / (0.3 \times 84.3))^2$
N= 4.2 or 5

Therefore, the 9 cores collected from each beach stratum of the three transects at each beach, should be more than adequate.

For the 10 cores of the borrow site station B2GE,

$N=((2.0 \times 18.4) / (0.3 \times 46.3))^2$
N= 7

Therefore, analysis of 7 of the 10 cores should be adequate without combining cores from each borrow site.

In summary, the preliminary survey was useful to determine variability and to establish the parameters for analysis. The proposed sampling should produce a useful number of core samples (including stations originally sampled by UNC in Fall 1999) from both the offshore borrow areas and control areas.

The following ecological study includes benthic sampling and analysis of proposed borrow and nourishment sites, and fish sampling and analysis of proposed nourishment sites, including reference sites. CSA*i* proposes to use the stations previously sampled by IMS as well as additional stations as needed.

TASK 1. Field Collection of Samples

Beach Site Sampling

Five stations will be sampled on the proposed beach to be nourished. Three stations will be sampled within the project area (Emerald I., Indian Beach, Pine Knoll Shores) and two will be sampled outside the project area to act as references/controls. Three transects will be sampled at each station, and five elevations will be sampled at each station corresponding to elevations used by Peterson et al. studies (1999, 2000). Every attempt will be made to perform the sampling at the same station location as in the Lisa Manning report (NC Sea Grant, April 2000). All stations will be located by Differential Global Positioning System (DGPS). Cores will be collected by SCUBA diving or wading using a 10.2 cm (four inch) cylindrical corer with an internal diameter of 9.9 cm (sampling an area of 77 cm^2). Benthic samples collected will be sieved in the field through a 0.5 mm stainless steel sieve bucket. All sediment and organisms retained in the bucket will be preserved in 10% buffered formalin with rose bengal stain.

Nearshore fish sampling will also be conducted at the beach sample sites. This will consist of three hauls of a 100' beach seine at the sites (one at each beach) and three at controls. Species, numbers, and life stage will be field-determined to the extent possible; fish requiring further examination will be subsampled and preserved in 10% buffered formalin. Guts of a subsample of each of the more common species will be placed on ice for gut content and volume analysis at a nearby laboratory.

Borrow Site Sampling

The proposed borrow areas have been shown in the EIS and other submittals. Sites are designated as A (offshore), B1, and B2 (both nearshore). Sample sites previously used in work by Peterson et al. (1999, 2000) will be sampled in all cases possible (see Figure A). All stations will be located by Differential Global Positioning System (DGPS). Ten cores will be taken at each site for a total of 150 cores. Cores will be collected by SCUBA diving using a 10.2 cm (four inch) cylindrical corer with an internal diameter of 9.9 cm (sampling an area of 77 cm^2). Benthic samples collected will be sieved in the field through a 0.5 mm stainless steel sieve bucket. All sediment and organisms retained in the bucket will be preserved in 10% buffered formalin with rose bengal stain.

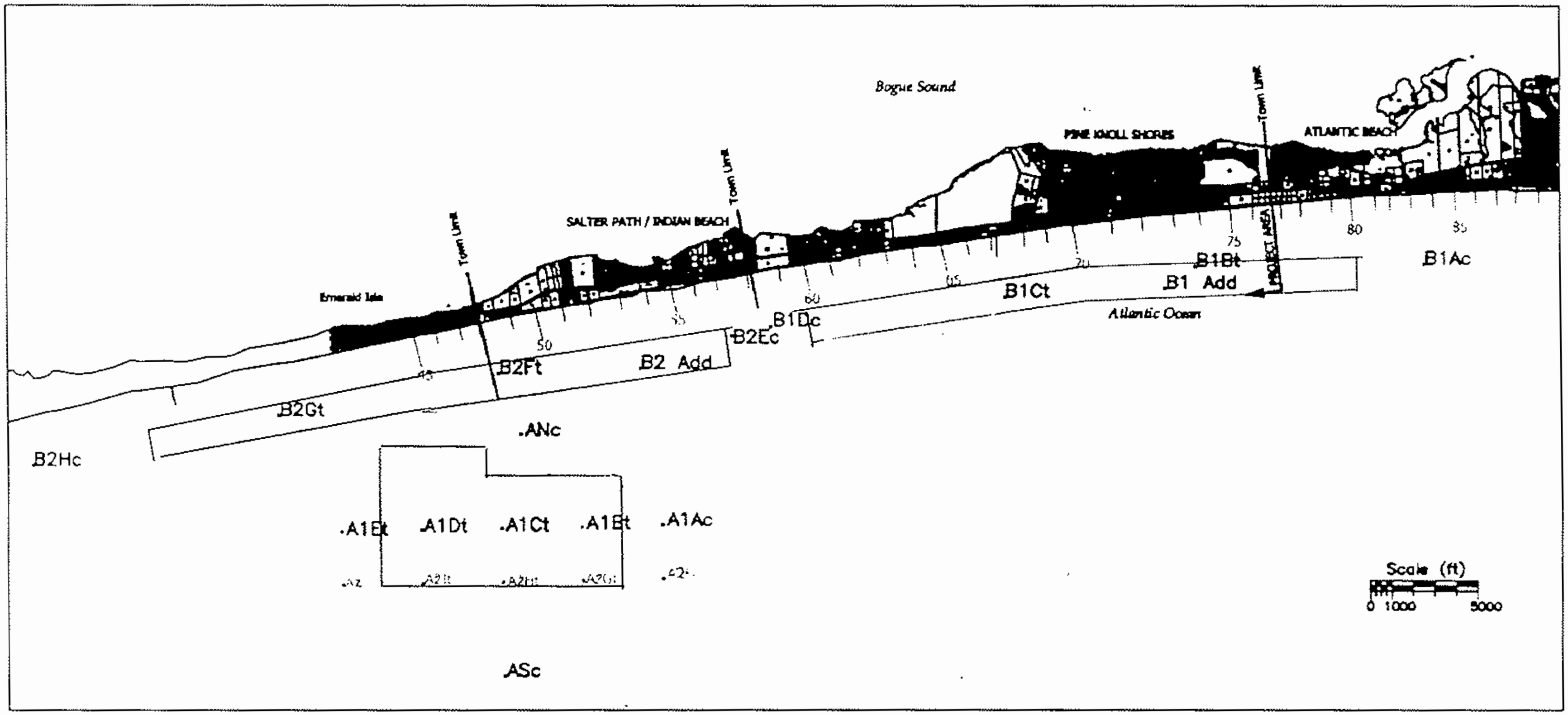


FIGURE A. Environmental monitoring stations established in November 1999 by UNC-IMS and resurveyed in June 2001 by CSA. The revised monitoring plan calls for omitting station A2 F-J because they are outside the revised area to be dredged.

A summary of proposed monitoring sampling protocols is as follows:

Beach Site invert samples	Beach Site invert replicates	Invert Device	Sieve	Beach Fish sampling	Other sampling
3 transects per each of 3 beach sites (Emerald I., Indian B., Pine Knoll) + 3 for each of 2 controls	3 cores at each of 5 elevations (strata) per transect; total 225 total cores	77 cm^2	0.5mm	100'x6'x1" beach seine, 3 hauls for sites and 3 for controls; 10% gut content analysis	Ghost crab burrows - 4m wide section on each upper transect
Borrow Site inverts	**Borrow reps**			**Borrow fish**	
15 sites - 9 inside, 6 controls: B2 and B1 (2 each), and near-shore half of A	10 cores from each; 150 total	77 cm^2	0.5mm	None	None

Schedule

The following schedule is for the proposed Phase I project (in bold); Phase II is also shown in the event the Emerald Isle component is permitted. Three sampling events (two pre- and one post-) are planned in the first year, with two additional sampling events in each of the next two years. In addition, two more years are planned as requirements of the Emerald Isle Phase II of this project, and these will be added on to the monitoring for Phase I.

DATE	SAMPLE
June 2001	**Pre-dredging; spring sample**
November 2001	**Pre-dredging, fall sample**
Nov 2001 - April 2002	***Beach nourishment, Phase 1***
June 2002	**Post-dredging, spring sample**
November 2002	**Post-dredging, fall sample**
June 2003	**Post-dredging, spring sample**
November 2003	Pre-dredging, fall sample
Nov 2002 - April 2003	***Beach nourishment, Phase 2***
June 2004	Post-dredging, spring sample
November 2004	Post-dredging, fall sample
June 2005	Post-dredging, spring sample
November 2005	Post-dredging, fall sample

Task 2. Laboratory Methods

Samples will be preserved as above, properly labeled inside and outside of the containers, and transported to the laboratory for identification using proper quality assurance/quality control procedures.

Once samples have been transported to the laboratory, core sediment samples will be carefully re-sieved through a 0.5 mm stainless steel sieve bucket and screen. This sediment reduction will expedite the sorting process. The remaining sediments and organisms will be placed in labeled, double-ziplock bags and initially preserved in 10 percent buffered formalin solution with Rose Bengal stain. Organisms will be allowed to harden in formalin for 48 hours and then transferred to 80 percent ethanol alcohol. After the hardening period, the organisms will be placed in sorting trays and submersed/diluted in de-ionized water to minimize any volatile alcohol vapor production during identification.

Organisms will then be sorted and enumerated in the laboratory and identified to a minimum of family level with the aid of a variable power dissecting microscope (Bausch & Lomb) and/or a compound microscope (Swift or Bristol). Organisms will be identified by experienced biologists using various identification keys (e.g., Abbott, 1974; Bousfield, 1965; Bynum and Fox, 1977; Dover, 1979; Fauchald, 1977; Fox and Bynum, 1975; Gosner, 1978; Heard, 1982; Kaplan, 1988; Morris, 1975; Ruppert and Fox, 1988; Uebelacker and Johnson, 1984; Williams, 1984). Taxa identified for each station will be recorded on a laboratory bench sheet (per EPA, 1989).

Task 3. Data Analysis

Organism data from the borrow area and control site will be statistically compared to evaluate changes in faunal abundance, and number of species present among sites and over time. Besides standard statistics, analyses will include variance testing (ANOVA), and equivalent parametric tests. Comparison among specific treatment groups will be completed using the Student-Newman-Keuls test (parametric design). Diversity indices will be computed for each area (all samples combined) using Shannon diversity index, Margalef's species richness and evenness. Changes in overall community composition among sites and seasons can be evaluated using a proportional similarity coefficient (e.g., Bray-Curtis) with flexible sorting strategy and a cluster intensity (ß) of -0.25.

Recovery will be assumed when 90% of the species have returned to a particular site. All other indices will be monitored to determine when, or if, taxa and numbers return to 90% or better than pre-project or reference sites status.

Task 4. Reporting

A report for each sampling event, including details of field data collection, data presentation, analysis, and conclusions/results will be submitted to NC Department marine
Fisheries within 120 days following completion of the field work portion of the work.

Termination of Monitoring

An element of this monitoring plan is that if results from data analysis from a post dredging beach or borrow area sampling event show that benthic organisms have recovered to preourishment baseline conditions within a 5 percent confidence interval, the monitoring of the area where the recovery has taken place will be stopped. Verification of the analysis indicating recovery will be indicated in the periodic reports prepared by CSAi and confirmed by the Corps of Engineers, Regulatory Branch and by the N.C. Division of Marine Fisheries.

References

Abbott, R.T. 1974. American Seashells Second Edition. Van Nostrand Reinhold Co. 450 West 33rd Street, New York, N.Y. 663pp.

Bousfield, E.L. 1965. Haustoriidae of New England (crustacea: amphipoda). Proc. U.S. Nat. Mus., Vol. 117(3512). 159 pp.

Brower, J.E., Zar, J.H., and von Ende, C.N. 1998. Field and Laboratory Methods for General Ecology, 4th Edition. The McGraw-Hill Co. Inc., 273pp.

Bynum, K.H., Fox, R.S. 1977. New and Noteworthy Amphipod Crustaceans from North Carolina, U.S.A., Chesapeake Science Vol. 18, No. 1 p. 1-33.

Coastal Science Associates, Inc. (CSAi). 2001. Standard Operating Procedures Manual and Quality Assurance Plan. SCDHEC certified lab #40008.

CSAi. 1999. Daufuskie Island Beach Nourishment. Pre-Dredge Monitoring Study. Rep. to Applied Technology & Management, Inc., Charleston, SC.

CSAi. 2000. Daufuskie Island Beach Nourishment: Final Post-nourishment Monitoring Study. Rep. to Applied Technology & Management, Inc., Charleston, SC. 15pp + appen.

Dennison, J.M. and W.H. Hay. 1967. Estimating the needed sampling area for subaquatic ecologic studies. J. Paleont. 41:706-708.

Dover, C.W. 1979. Field Guide to Common Marine Invertebrates. Duke University Marine Laboratory, 78 pp.

EPA. 1989. Rapid Bioassessment Protocols for use in Streams and Rivers. U.S. EPA /444/4-89-001, Washington D.C.

Fauchald, K. 1977. The polychaete worms: definitions and keys to the orders, families, and genera. Nat. Hist. Mus., Los Angeles Ca., Science Series No. 28, 161 pp.

Fox, R.S., Bynum, K.H. 1975. The Amphipod Crustaceans of North Carolina Estuarine

Waters. Chesapeake Science Vol. 16, No. 4 p.223-237
Gosner, K.L. 1978. A field guide to the Atlantic seashore. Houghton Mifflin Co., Boston, Mass., 329 pp.
Gosner, K.L. Guide to Identification of Marine and Estuarine Invertebrates. Wiley Interscience.
Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. Wiley Interscience, NY. 257pp.
Heard, R.W. 1982. Guide to Common Tidal Marsh Invertebrates of the Northeastern Gulf of Mexico. Mississippi-Alabama Sea Grant Consortium, 82 pp.
Hurme, A.K., R.M. Yancey, and E.J. Pullen. 1979. Sampling macroinvertebrates on high-energy beaches. U.S. Army Corps of Engineers, CERC, Ft. Belvoir, Va., Coastal Eng. Tech. Aid No. 79-3, 37 pp.
Kaplan, E.H. 1988. Southeastern and Caribbean Seashores. Houghton Mifflin Co., Boston, Mass., 425 pp.
Lankford, T.E., and B.J. Baca. 1989. Comparative environmental impacts of various forms of beach nourishment. In Proc. Coastal Zone 89, Charleston, SC, pp 2046_2059.
Livingston, R.J., R.S. Lloyd, and M.S. Zimmerman. 1976. Determination of sampling strategy for benthic macrophytes in polluted abd unpolluted waters. Bull. Mar. Sci. 26:569-575.
Morris, P.A. 1975. A Field Guide to Shells, Atlantic and Gulf Coasts and the West Indies. Houghton Mifflin Co., Boston, Mass., 330 pp.
Patil, G.P., and C. Taillie. 1982. Diversity as a concept of its measurement. J. Amer. Statist. Assoc. Vol. 77, p. 548-561.
Ruppert, E.E., and R.S. Fox. 1988. Seashore animals of the southeast. Univ. of South Carolina Press. Columbia. 429 pp.
Uebelacker, J.M. and P.G. Johnson. 1984. Taxonomic Guide to the Polychaetes of the Northern Gulf of Mexico. U.S. Dept. of Interior. Seven Volumes.
U.S. ACOE, Burlas et al. 2001. The New York District's Biological Monitoring Program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section Beach Erosion Control Project. Final Report. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.
Williams, A.B. 1984 Shrimps, Lobsters, and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida. Smithsonian Institution Press, Washington, D.C. 550 pp.

APPENDICES

APPENDICES

Bogue Banks Beach Nourishment

Beach Sample Atlantic Beach Control Station #2

Taxonomy		Subtidal #1	Subtidal #2	Subtidal #3	Low inter-tidal #1	Low inter-tidal #2	Low inter-Line #3	Mid Inter-tidal #1	Mid Inter-tidal #2	Mid Inter-Line #3	High Inter-tidal #1	High Inter-tidal #2	High Inter-Line #3	High Tide Line #1	High Tide Line #2	High Tide Line #3
Phylum Rhynchocoela																
Rhynchocoela sp.A		72														
Phylum Mollusca																
Pelecypoda																
Donacidae																
Donax variabilis		1	10	3	12	11	8									
Phylum Annelida																
Polychaeta																
Spionidae																
Scolelepis squamata		1	38	1	17	6	24									
Phylum Arthropoda																
Amphipoda																
Haustoriidae																
Amphiporeia virginiana			1			7	7									
Amphipoda																
Haustoriidae																
Haustorius canadensis						1										
Decapoda																
Hippidae																
Emerita talpoida		1			2	3										
SPECIES/REP	TOTALS	4	3	2	3	5	3	0	0	0	0	0	0	0	0	0
INDIVID/REP	TOTALS	75	49	4	31	28	39	0	0	0	0	0	0	0	0	0
INDIVID/REP	MEANS	18.8	16.3	2.0	10.3	5.6	13.0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
INDIVID/REP	SD	35.5	19.3	1.4	7.6	3.8	9.5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		Subtidal	Low Inter	Mid Inter	High Inter	High Tide										
OVERALL	TOTALS	128	98	0	0	0										
OVERALL	MEANS	42.7	32.7	0.0	0.0	0.0										
OVERALL	SD	35.9	5.7	0.0	0.0	0.0										
% DOM SPEC		56.3	48.0	#DIV/0!	#DIV/0!	#DIV/0!										
% RARE SPEC		0.8	1.0	#DIV/0!	#DIV/0!	#DIV/0!										

DAUFUSKIE ISLAND BEACH NOURISHMENT
PRE-DREDGE MONITORING STUDY

Prepared for:

Mr. Tim Mason
Applied Technology & Management, Inc.
4651 Salisbury Road
Mt. Pleasant, South Carolina 32256

Prepared by:

Coastal Science Associates, Inc.
P.O. Box 11687
Columbia, South Carolina 29211
SCDHEC Certified Lab I.D. #40008

November 1999

TABLE OF CONTENTS

1.0 INTRODUCTION

On August 31, 1998, Coastal Science Associates, Inc. (CSA*i*) was contracted by Applied Technology & Management, Inc. (ATM) to monitor surficial sediments and macrobenthic infauna assemblages for the Daufuskie Island Beach Nourishment Project. The project site is located approximately 2,000 yards south of Braddock Point, Hilton Head Island, South Carolina (Fig. 1).

This report presents the results of the data taken during the pre-dredge monitoring event. Sampling for this study was conducted on September 15 and 16, 1998. All sampling and analyses for this study were performed in accordance with CSA*i*'s SCDHEC-approved Standard Operating Procedures Manual and Quality Assurance Plan (CSA*i*, 1999).

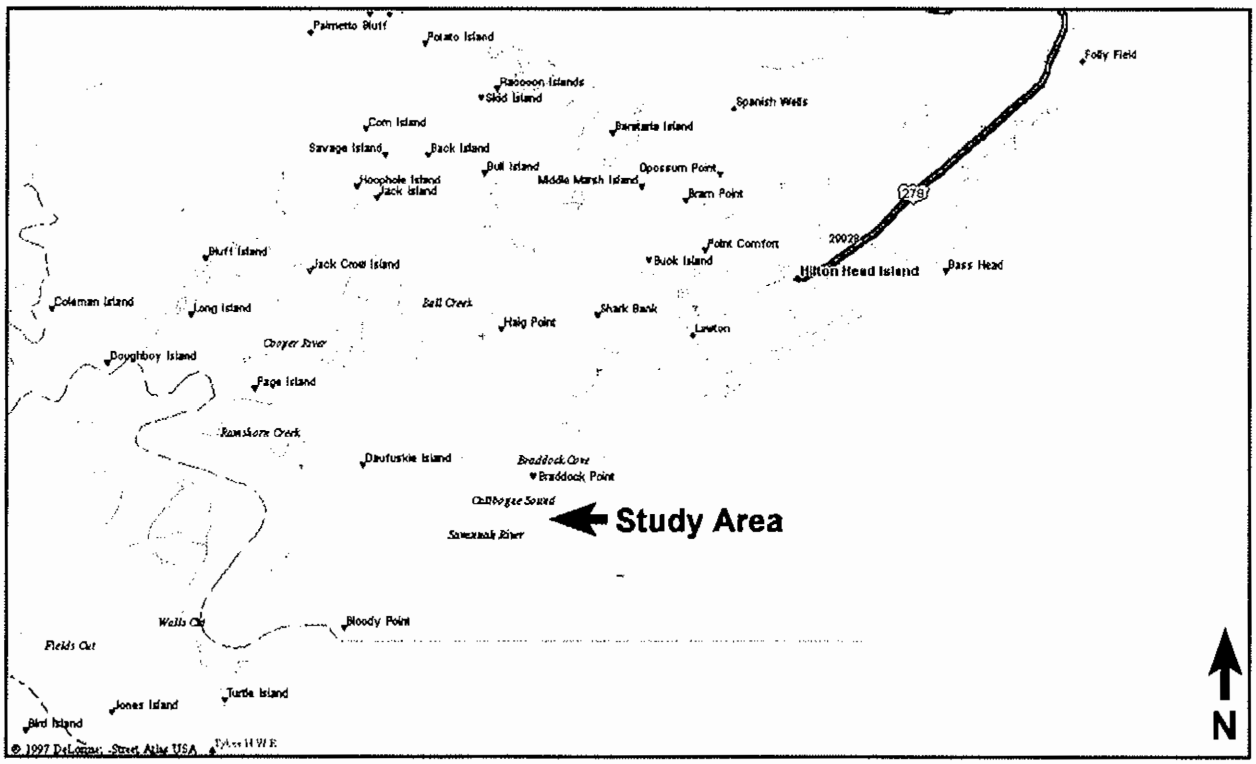


Figure 1. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study, Daufuskie Island, SC. Site location map showing the approximate location of the study area.

2.0 METHODS

2.1 Sample Areas

The Borrow Area (BA) is located approximately 1.1 miles south of Braddock Point on Hilton Head Island, South Carolina (Fig. 2). The area that was selected is just south of Braddock Point on one of the nearshore shoals in the inlet. This area was selected after several test cores from the area revealed that the sediment composition contained coarse grain sand, the type of sand desired for the proposed Beach Nourishment Project.

During storm conditions and strong longshore currents that are frequent in the area, the coarse grain sand tends to better withstand erosion compared with less coarse grain sands. Another factor in the selection of the location of BA was the proximity of the compatible sand to the area of the project site, resulting in project cost reductions. The depths in BA range from 1 to 19 feet (MLLW, 1930-1980) (Table 1).

The Control Area (CA) is located approximately 0.85 miles south of BA (Fig. 2). The CA, also a nearshore shoal, was selected for its similar bottom relief, depths, habitat, and close proximity to the BA. The depths in CA range from 4 to 17 feet (MLLW, 1930-1980) (Table 2).

Ten sample stations in each area, BA and CA, were randomly chosen. Based on similar depths, stations are paired in order to compare similar benthic community habitats (Fig. 3). The locations of all twenty stations were recorded with a Magellan 5000 DLX global positioning system with differential unit (DGPS) to ensure that all subsequent sampling events are sampled at the same locations (Tables 1 and 2). The depths of the stations were recorded using a Hummingbird Wide Eye™ electronic depth finder.

Table 1. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Borrow area sample station coordinates and depths (September 15 and 16, 1998).

Sample Station	Latitude	Longitude	Depth
BA-1	32°05'29.88537"	80°49'00.48159"	5 ft.
BA-2	32°05'20.92984"	80° 48 59.19932	5 ft.
BA-3	32°05'19.80410"	80°48'46.66598"	15 ft.
BA-4	32°05'09.65339"	80°48'53.19169"	8 ft.
BA-5	32°05'07.40401"	80°48'29.89976"	7 ft.
BA-6	32°04'58.66553"	80°48'38.66958"	12 ft.
BA-7	32°04'45.39602"	80°48'44.96540"	10 ft.
BA-8	32°04'55.06702"	80°48'53.69547"	15 ft.
BA-9	32°04'58.70956"	80°49'07.52349"	8 ft.
BA-10	32°05'08.48084"	80°49'16.25441"	18 ft.

Table 2. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Control area sample station coordinates and depths (September 15 and 16, 1998).

Sample Station	Latitude	Longitude	Depth
CA-1	32°04'39.55622"	80°49'03.95468"	8 ft.
CA-2	32°04'33.67805"	80°48'51.45240"	13 ft.
CA-3	32°04'25.77258"	80°48'40.64419"	16 ft.
CA-4	32°04'18.15006"	80°48'37.99961"	14 ft.
CA-5	32°04'19.67290"	80°48'27.93585"	19 ft.
CA-6	32°04'13.17238"	80°48'17.94706"	18 ft.
CA-7	32°04'06.02683"	80°48'27.01303"	15 ft.
CA-8	32°04'08.31925"	80°48'38.63181"	17 ft.
CA-9	32°04'19.10604"	80°48'51.86461"	16 ft.
CA-10	32°04'25.94015"	80°49'02.21961"	19 ft.

2.2 Sample Collection and Identification

2.2.1 Macrobenthic Sampling

Grab samples were collected using a 0.05 m^2 weighted ponar grab sampler. A minimum of 80% of the volume of the ponar grab sampler must be obtained for the sample to be considered viable. If less than the minimum is obtained, the sample location is moved 2 to 3 ft and re-sampled. This process is repeated until the 80% minimum is achieved. Grab samples were processed in the field by measuring the volume of each sample in a graduated 19-liter bucket and recording the data in the field logbook (Table 3). From the grab sample, a 3.5 cm (inside dia.) x 10 cm core sub-sample was taken for sediment analysis.

Table 3. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Ponar grab sample volumes (September 15 and 16, 1998).

Sample Station	Ponar Grab Sample Volume, BA	Ponar Grab Sample Volume, CA
1	5.0 liters	5.0 liters
2	6.0 liters	5.5 liters
3	5.0 liters	5.0 liters
4	5.0 liters	5.0 liters
5	5.0 liters	5.0 liters
6	6.0 liters	5.0 liters
7	5.0 liters	6.5 liters
8	5.0 liters	5.0 liters
9	6.0 liters	5.0 liters
10	5.0 liters	4.5 liters

The remaining sediment was then carefully sieved through a 0.5 mm stainless steel sieve bucket and screen. The remaining sediments and organisms were placed in labeled, double-ziplock bags and initially preserved in a 10 percent buffered formalin solution with

Rose Bengal stain. Organisms were allowed to harden for 48 hours and then transferred to 80 percent ethanol alcohol. After the hardening period, the organisms were placed in sorting trays and submersed/diluted in de-ionized water to minimize any volatile alcohol vapor production during identification.

Organisms were sorted and enumerated in the laboratory and identified to the lowest possible taxon (species level in most cases) with the aid of a variable power dissecting microscope (Bausch & Lomb) and/or a compound microscope (Swift or Bristol). Organisms were identified by an experienced biologists utilizing various identification keys for organisms expected to be collected (e.g., Abbott, 1974; Bousfield, 1965; Bynum and Fox, 1977; Dover, 1979; Fauchald, 1977; Fox and Bynum, 1975; Gosner, 1978; Heard, 1982; Kaplan, 1988; Morris, 1975; Ruppert and Fox, 1988; Uebelacker and Johnson, 1984; Williams, 1984). Species identified for each station were then recorded on a laboratory bench sheet (per EPA, 1989).

2.2.2 Water Quality Sampling

Water quality physical parameters were recorded at each of the sample stations. Water samples were taken at mid-depth using a Wildco Alpha water sampling bottle. Meters were calibrated prior to use according to calibration procedures outlined in CSA/'s approved Standard Operating Procedures Manual and Quality Assurance Plan (CSA/, 1999). The physical parameters and corresponding meters used for measurement are listed below:

- Water sampling bottle - Wildco Alpha
- Dissolved oxygen (DO) - YSI Meter - Model 57
- Temperature - Orion Conductivity Meter - Model 128
- Conductivity - Orion Conductivity Meter - Model 128
- pH - Orion pH Meter - Model 230A
- Turbidity - Hach 2100P Turbidimeter
- Salinity - Aquafauna refractometer

2.2.3 Sediment Sampling

The core sub-samples taken from the ponar grab samples were placed into doble-ziplock freezer bags and transported to Athena Technologies, Inc. (see Appendix B for chain-of-custody form). Athena Technologies, Inc. first cataloged the samples, and then dried them in a low heat oven. The dried samples were weighed and the shell material content was visually estimated. The dried samples were then washed through a 0.0625 mm (4.0 phi) sieve to remove silt and clay sized particles from the sample. After the wash, the samples were again dried in a low heat oven. After drying, a final weight was recorded and compared to the initial dry weight in order to determine the sand and fine particle percentages.

Grain size analysis was performed according to applicable American Society for Testing and Materials (ASTM) standards using a 0.5 phi interval sieve stack starting at -1.0 phi (2.0 mm) and ending with 4.0 phi (0.06325 mm). A 115 g composite split was taken for particle size analysis, and passed through the aforementioned sieve set. All of the samples were analyzed with shell material intact, which generally accounts for the total weight of the -1.0 phi and -0.5 phi sieves. The sieve was then Ro-tapped and the weight of material remaining in each sieve was recorded in order to calculate statistical data for each sample.

2.3 Macrobenthic Data Analyses

Six quantitative analyses were used to generate relevant statistical data based on taxonomic information gathered from the sediment samples.

1. Shannon-Wiener species diversity.
2. Species Richness - as total number of species.
3. Species Abundance - as total number of individuals.
4. Evenness.
5. T-test

The data were summarized for analysis on a data summary sheet listing the above five measures (Tables 4 - 5).

Table 4. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Summary of the of species diversity indices for samples taken September 15 and 16, 1998.

Taxa	BA		CA	
	Species Richness	**Abundance**	**Species Richness**	**Abundance**
Cnidaria	0	0	0	0
Rhynchocoela	2	10	0	0
Aschelminthes	1	6	0	0
Chaetognatha	1	1	1	2
Mollusca	3	12	5	28
Annelida	16	50	13	64
Arthropoda	31	802	26	938
Echinodermata	0	0	1	7
Chordata	1	1	0	0
Total Abundance/ sample area		882		1,039
Total Species Richness/ sample area	55		46	
Mean Species Richness	6.9		5.8	
Shannon-Wiener	3.761		3.677	
Evenness	0.651		0.666	

Table 5. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Summary of statistical analyses for samples taken September 15 and 16, 1998. Marked differences are significant at $p < 0.05$.

Sample Areas	Variable	T-Test
BA vs. CA	Species Richness	0.173
BA vs. CA	Abundance	0.667

3.0 RESULTS AND DISCUSSION

3.1 Macrobenthic Sampling

3.1.1 Macrobentic Taxa Analysis

A complete listing of the organisms collected at each station for BA and CA is given in Tables 1 and 2 of Appendix 6.1. Comparisons of the organisms sampled are shown in Table 4 with the diversity indices. As Table 4 shows, the dominant phyla found during this sampling event were Arthropoda and Annelida (see Appendix 6.1, Fig. 1). Within Arthropoda, the dominant organisms found were amphipods, mysid shrimp, and crab megalopa. Within the annelids, no one dominant organism was present; the class Polychaeta was dominant in this phylum.

3.1.2 Macrobenthic Data Analyses

The Shannon-Wiener species diversity index was calculated using the species richness, or number of taxa (Table 4). A diversity index of 2 or greater is said to be favorable (Patil and Taillie, 1982; Brower, Zar, and von Ende, 1998). As can be seen, both sample areas had a diversity index of greater than 3.5, indicating diverse macrobenthic communities. Additionally, the mean abundance was calculated for both sample areas, which is indicated graphically in Appendix 6.1, Figure 2.

The evenness or relative diversity for each area was determined (Table 4). The evenness was calculated to be 0.651 and 0.666 for BA and CA, respectively. Evenness is measured from 0 to 1. If the evenness is at or near 0, then the population's species diversity is different from the ideal community distribution (Brower, Zar, and von Ende, 1998). If the evenness is at or near 1, the population's species diversity is not different from the ideal community distribution (Brower, Zar, and von Ende, 1998).

For the T-test at the 0.05 significance level, the comparison of species richness/replicate sample and abundance/replicate sample for BA to CA resulted in a values of 0.173 and 0.667 respectively. These calculation indicate that no significant differences exist between populations.

3.2 Water Quality and Physical Data

A summary of *in-situ* water quality and other data are presented in Tables 1 and 2 of Appendix 6.2. Water quality parameter values were in the acceptable range for the time of year and weather conditions encountered during the sampling event. Turbidity levels were found to be relatively high; however, both the weather and tide may have caused this factor to be larger than normal by agitating the bottom.

3.3 Sediment Sampling

The final weight of the sediment samples were compared to the initial dry weight in order to determine the sand and fine (<0.0625 mm) particle percentages (Table 1, Appendix 6.3). The raw sediment data were input it into the U.S. Army Corps of Engineers ACES software package. Using this software cumulative frequency and histogram grain size curves were produced. Statistical data is shown on each graph outlining mean size, median size, standard deviation, skewness, and kurtosis (see Figs 1-6., Appendix 6.3). The original report from Athena Technologies, Inc. is presented in Appendix 6.4.

The sediment analysis for grain size composition indicated that all of the samples in BA had a large sand content with the average being 97.8%. The sediment analysis for grain size composition indicated that all of the samples in CA also had a large sand content with the average being 97.5%.

4.0 SUMMARY AND CONCLUSIONS

The analysis of macrobenthic populations from the Borrow Area (BA) and Control Area (CA) indicated that the populations are diverse with high numbers for species richness, Shannon-Wiener diversity, and evenness.

Comparing the populations' species richness and abundance using a t-test at the 0.05 significant level, no significant differences were seen. This can most likely be attributed to both sample areas being located on similar nearshore shoals with compatible depths, grain size, and water quality.

5.0 REFERENCES

Abbott, R.T. 1974. American Seashells Second Edition. Van Nostrand Reinhold Co. 450 West 33rd Street, New York, N.Y. 663 pp.

Bousfield, E.L. 1965. Haustoriidae of New England (crustacea: amphipoda). Proc. U.S. Nat. Mus., Vol. 117(3512). 159 pp.

Brower, J.E., Zar, J.H., and von Ende, C.N. 1998. Field and Laboratory Methods for General Ecology, 4th Edition. The McGraw-Hill Co. Inc., 273pp.

Bynum, K.H., Fox, R.S. 1977. New and Noteworthy Amphipod Crustaceans from North Carolina, U.S.A., Chesapeake Science Vol. 18, No. 1 p. 1-33.

Coastal Science Associates, Inc. (CSAi). October 12, 1999. Standard Operating Procedures Manual and Quality Assurance Plan. For SCDHEC certified lab #40008.

Dover, C.W. 1979. Field Guide to Common Marine Invertebrates. Duke University Marine Laboratory, 78 pp.

EPA. 1989. Rapid Bioassessment Protocols for use in Streams and Rivers. U.S. EPA /444/4-89-001, Washington D.C.

Fauchald, K. 1977. The polychaete worms: definitions and keys to the orders, families, and genera. Nat. Hist. Mus., Los Angeles Ca., Science Series No. 28, 161 pp.

Fox, R.S., Bynum, K.H. 1975. The Amphipod Crustaceans of North Carolina Estuarine Waters. Chesapeake Science Vol. 16, No. 4, p. 223-237.

Gosner, K.L. 1978. A field guide to the Atlantic seashore. Houghton Mifflin Co., Boston, Mass., 329 pp.

Gosner, K.L. Guide to Identification of Marine and Estuarine Invertebrates. Wiley Interscience.

Heard, R.W. 1982. Guide to Common Tidal Marsh Invertebrates of the Northeastern Gulf of Mexico. Mississippi-Alabama Sea Grant Consortium, 82 pp.

Hurme, A.K., R.M. Yancey, and E.J. Pullen. 1979. Sampling macroinvertebrates on high-energy beaches. U.S. Army Corps of Engineers, CERC, Ft. Belvoir, Va., Coastal Eng. Tech. Aid No. 79-3, 37 pp.

Kaplan, E.H. 1988. Southeastern and Caribbean Seashores. Houghton Mifflin Co., Boston, Mass., 425 pp.

Morris, P.A. 1975. A Field Guide to Shells, Atlantic and Gulf Coasts and the West Indies. Houghton Mifflin Co., Boston, Mass., 330 pp.

Patil, G.P., and C. Taillie. 1982. Diversity as a concept of its measurement. J. Amer. Statist. Assoc. Vol. 77, p. 548-561.

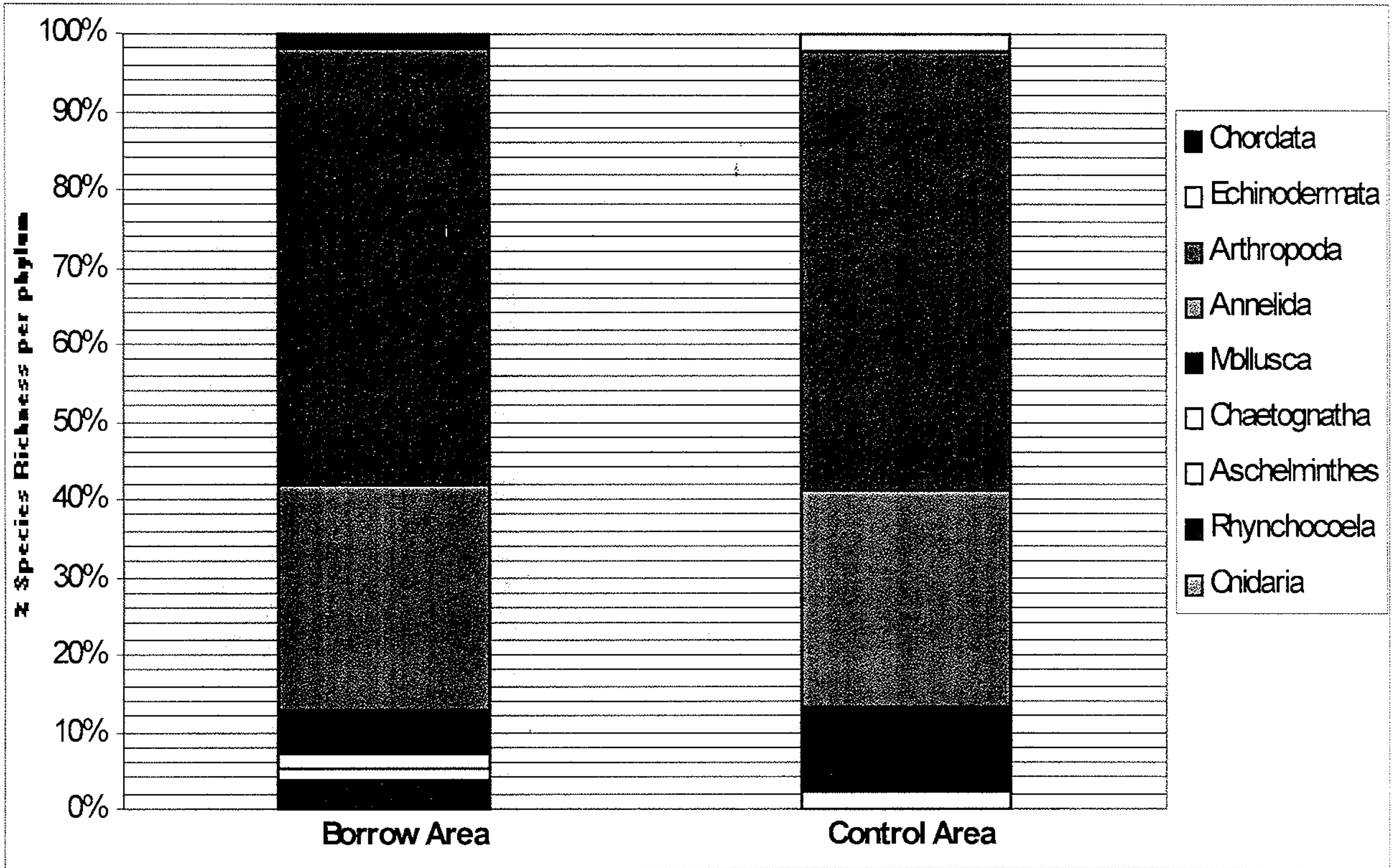
Ruppert, E.E., and R.S. Fox. 1988. Seashore animals of the southeast. Univ. of South Carolina Press. Columbia. 429 pp.

Uebelacker, J.M. and P.G. Johnson. 1984. Taxonomic Guide to the Polychaetes of the Northern Gulf of Mexico. U.S. Dept. of Interior. Seven Volumes.

Williams, A.B. 1984 Shrimps, Lobsters, and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida. Smithsonian Institution Press, Washington, D.C. 550 pp.

6.0 APPENDICES

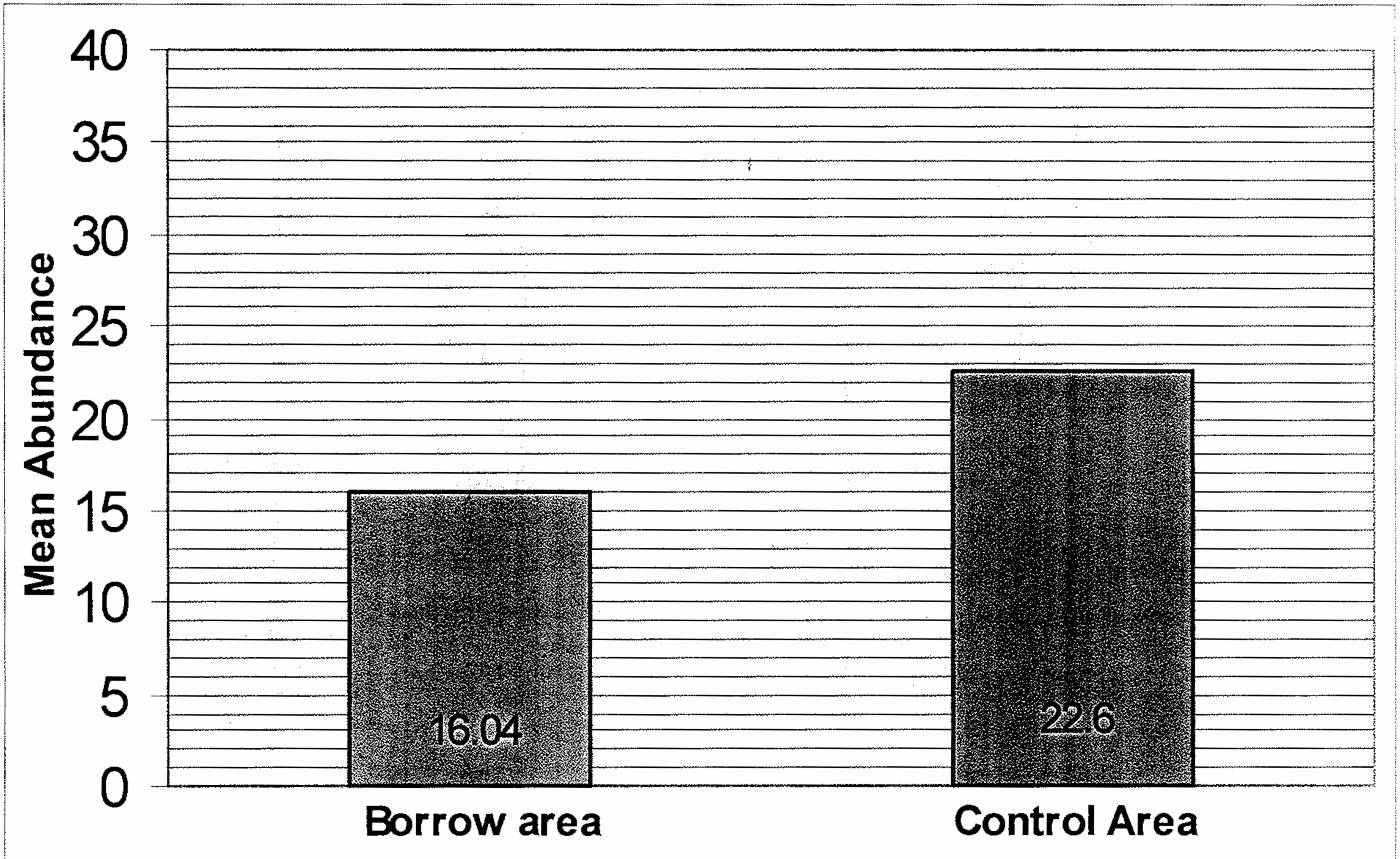
6.1 Benthic Data



Coastal Science Associates, Inc.
P.O. Box 11687
Columbia, SC 29211
Tel. (803)-256-3081
Fax (803)-256-7475

Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Graph indicating the percent species richness of organisms sampled in both of the sample areas.

Date: September 15-16, 1998
Figure 1



Coastal Science Associates, Inc.
P.O. Box 11687
Columbia, SC 29211
Tel. (803)-256-3081
Fax (803)-256-7475

Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Graph indicating the mean abundance of organisms sampled in both BA and CA. BA mean abundance = 16.04 with a standard error = 6.25 and CA mean abundance = 22.6 with a standard error = 8.11.

Date: September 15-16, 1998
Figure 2

Table 1. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study results for the borrow area, BA. Sampled on September 15 and 16, 1998.

Taxonomy	BA-1	BA-2	BA-3	BA-4	BA-5	BA-6	BA-7	BA-8	BA-9	BA-10
Phylum Rhynchocoela										
Enopla *Enopla* sp. A						5	4			
Enopla *Enopla* sp. B							1			
Phylum Aschelminthes										
Nematoda *Nematoda* sp.					4					2
Phylum Chaetognatha										
Sagitta sp.	1									
Phylum Mollusca										
Gastropoda Olividae *Olivella mutica*				1	1	1				1
Gastropoda Turridae *Mangelia plicosa*					1		1			
Pelecypoda Donacidae *Donax variabilis*	3	1						1		1
Phylum Annelida										
Polychaeta Orbiniidae *Leitoscoloplos fragilis*	2									
Polychaeta Orbiniidae *Scoloplos rubra*		1	1							
Polychaeta Cirratulidae *Cirriformia spionidae*										8
Polychaeta Glyceridae *Glycera sphyrabrancha spiomidae*							1			
Polychaeta Nephtyidae *Aglaophamus verrilli*		1								
Polychaeta Nephtyidae *Armandia agilis*						2				

Polychaeta Nephtyidae *Nephtys bucera*								3	5	3
Polychaeta Nephtyidae *Nephtys picta*		1	1		3	3				
Polychaeta Nephtyidae *Nephtys squamosa*		1							2	
Polychaeta Phyllodocidae *Phyllodocidae* sp.					1					
Polychaeta Pilargidae *Sigambra tentaculata*										2
Polychaeta Syllidae *Parapionosyllis* sp.									3	
Polychaeta Spionidae *Dispio uncinata*									1	2
Polychaeta Spionidae *Scolelepis squamata*							1			
Polychaeta Spionidae *Spiophanes missionensis*										1
Polychaeta Spionidae *Streblospio benedicti*									1	
Phylum Arthropoda										
Amphipoda Haustoriidae *Protohaustorius wigleyi*	33	1		3		23	15	2	3	7
Amphipoda Haustoriidae *Acanthohaustorius intermedius*			3					4		
Amphipoda Haustoriidae *Neohaustorius schmitzi*	5		1		2	1	20			
Amphipoda Haustoriidae *Parahaustorius longimerus*	60	2						2		
Amphipoda Oedicerotidae *Monoculodes edwardsi*					4					

Amphipoda Gammaridae *Gammarus* sp.										2
Crustacea Balanidae *Balanus crenatus*										12
Crustacea Copepoda *Calanoida* sp.	4	1	1	3	1	2		1		5
Crustacea Cumacea *Leptocuma minor*	1									
Crustacea Cumacea *Oxyurostylis smithi*					1	4				4
Crustacea Cumacea *Almyracuma proximoculi*	12				3				2	
Decapoda Anomuran crab zoea	1									
Decapoda Brachyuran crab megalopa	55	9	3	32	3	84	41	18	36	44
Decapoda Brachyuran crab zoea	1		1		1		2	2		4
Decapoda Paguridae *Pagurus longicarpus*							10	1	3	
Decapoda Hippidae *Emerita talpoida*		3						1		
Decapoda glancothoe of pagurid crab					1					
Decapoda Penaeidae *Penaeus* sp. (juvenile)					1	2		1		
Decapoda Penaeidae *Penaeus* sp. zoea						1	1	1		4
Decapoda Pinnotheridae *Pinnixa* sp.	1									
Decapoda Portunidae *Portunidae* sp.	1									
Decapoda Sergestidae *Acetes carolinae*			1	1	1	2			1	4

Isopoda Idoteidae *Chiridotea coeca*		4		2				9		
Isopoda Idoteidae *Edotea montosa*										1
Isopoda Idoteidae *Edotea triloba*	1								1	
Isopoda Sphaeromidae *Ancinus depressus*	1	3			2	1	1	1		3
Mysidacea Mysidae *Bowmaniella portoricensis*	16	3	1	8	3	23	4	1	19	13
Mysidacea Mysidae *Brasilomysis castroi*										1
Mysidacea Mysidae *Mysidopsis bigelowi*										37
Mysidacea Mysidae *Mysis* sp.	3				1	5	1			1
Tanaidacea Tanaidae *Tanais* sp.							1		1	1
Phylum Chordata										
Cephalochordata *Amphioxus* sp.										1
Abundance	201	31	13	50	34	159	104	48	78	164
Species Richness	18	13	9	7	18	15	15	15	13	25
Total Species Richness	55									
Total Abundance	882									

Table 2. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study results for the control area, CA September 15 and 16, 1998.

Taxonomy	CA-1	CA-2	CA-3	CA-4	CA-5	CA-6	CA-7	CA-8	CA-9	CA-10
Phylum Chaetognatha										
Sagitta sp.									1	1
Phylum Mollusca										
Gastropoda Turridae *Mangelia plicosa*		3								
Gastropoda Olividae *Olivella mutica*		1	4		1	1		1	1	1
Pelecypoda Donacidae *Donax variabilis*						4	5		1	
Pelecypoda Tellinidae *Strigilla mirabilis*	1		1		1					
Pelecypoda Arcidae *Anadara transversa*		1		1						
Phylum Annelida										
Polychaeta Orbiniidae *Lleitoscoloplos fragilis*			3		1				1	
Polychaeta Cirratulidae *Cirriformia spionidae*					3			2		8
Polychaeta Magelonidae *Magelona pettiboneae*	1									
Polychaeta Glyceridae *Glycera dibranchiata*				1		1				
Polychaeta Glyceridae *Glycera* sp.	1			1						
Polychaeta Nephtyidae *Nephtys bucera*										3
Polychaeta Nephtyidae *Nephtys picta*		1	2	3	2	1	1	3	2	

Polychaeta Nephtyidae *Nephtys squamosa*	3	3	3				3	1	2	
Polychaeta Pilargidae *Sigambra tentaculata*										2
Polychaeta Spionidae *Dispio uncinata*										2
Polychaeta Spionidae *Prionospio dayi*			1							
Polychaeta Spionidae *Spiophanes missionensis*										1
Polychaeta Spionidae *Spiophanes* sp.	1	1								
Phylum Arthropoda										
Amphipoda Haustoriidae *Parahaustorius longimerus*									5	
Amphipoda Haustoriidae *Protohaustorius wigleyi*		6	31	3		18	3	1	56	16
Amphipoda Haustoriidae *Neohaustorius schmitzi*	2			2	2	1	13		2	1
Amphipoda Gammaridae *Gammarus* sp.	4		1		2	1				1
Amphipoda Oedicerotidae *Monoculodes edwardsi*		3		1	1					
Crustacea Copepoda *Calanoida* sp.		1	3	1	2	5	2	1	9	2
Crustacea Cumacea *Oxyurostylis smithi*		5	7	2		1			9	2
Crustacea Cumacea *Almyracuma proximoculi*		1				4		5	2	2
Crustacea Balanidae *Balanus crenatus*	1									

Decapoda Pinnotheridae *Dissodactylus mellitae*				1						
Decapoda Anomuran crab zoea								1	4	1
Decapoda Brachyuran crab megalopa		15	48	29	8	15	27	7	145	15
Decapoda Brachyuran crab zoea				4	3	6	6	7	16	11
Decapoda Hippidae *Emerita talpoida*			1	2			1			
Decapoda Leucosiidae *Persephona aquilonaris*		1								
Decapoda Penaeidae *Penaeus* sp. (Juvenile)						6		1	6	3
Decapoda Pinnotheridae *Pinnixa* sp.	1									
Decapoda Sergestidae *Acetes carolinae*	3		2		2		1		1	1
Decapoda Sergestidae *Lucifer faxoni borradaili*						1			2	1
Isopoda Idoteidae *Chiridotea coeca*			1			2	2	1		
Isopoda Sphaeromidae *Ancinus depressus*		4		7	1		3	2		2
Mysidacea Mysidae *Bowmaniella portoricensis*	9	13	38	13	12	12	11	7	70	5
Mysidacea Mysidae *Mysidopsis bigelowi*	1	4	13	10	4	2	2	3	11	6
Mysidacea Mysidae *Mysis* sp.						1			1	2
Tanaidacea Paratanaidae *Leptognatha* sp.								6		

Tanaidacea Tanaidae *Tanais* sp.							5	4		
Phylum Echinodermata										
Clypeasteroida Mellitidae *Mellita quinquiesperforata*		2		1	1		1		1	1
Abundance	28	65	159	82	46	82	86	53	348	90
Species Richness	12	17	16	17	16	18	16	17	22	24
Total Species Richness	46									
Total Abundance	1,039									

6.2 Water Quality Tables

Table 1. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study water quality samples for the borrow area, BA. Sampled on September 15 and 16, 1998.

Sample Station	Temperature	Dissolved Oxygen	pH	Conductivity	Salinity	Turbidity
BA - 1 TOP	27.2° C	6.7 mg/L	6.59	48.3 mS/cm	36 ppm	6.21 NTU
BA - 1 BOTTOM	27.0° C	6.5 mg/L	6.94	48.2 mS/cm	33 ppm	7.55 NTU
BA - 2 TOP	27.4° C	6.6 mg/L	7.01	47.3 mS/cm	31 ppm	5.87 NTU
BA - 2 BOTTOM	27.5° C	6.8 mg/L	7.96	47.1 mS/cm	31 ppm	7.47 NTU
BA - 3 TOP	27.8° C	6.6mg/L	7.43	46.8 mS/cm	32 ppm	6.55 NTU
BA - 3 BOTTOM	27.5° C	6.5mg/L	7.62	46.4 mS/cm	33 ppm	8.47 NTU
BA - 4 TOP	28.0° C	6.4 mg/L	7.59	46.8 mS/cm	32 ppm	6.45 NTU
BA - 4 BOTTOM	27.5° C	6.8 mg/L	7.66	46.5 mS/cm	31 ppm	8.62 NTU
BA - 5 TOP	28.0° C	7.2 mg/L	7.17	46.7 mS/cm	32 ppm	7.21 NTU
BA - 5 BOTTOM	28.0° C	7.4 mg/L	7.54	46.3 mS/cm	34 ppm	7.54 NTU
BA - 6 TOP	28.0° C	7.0 mg/L	7.28	46.2 mS/cm	38 ppm	4.75 NTU
BA - 6 BOTTOM	28.0° C	7.1 mg/L	6.79	46.0 mS/cm	32 ppm	5.85 NTU
BA - 7 TOP	28.0° C	7.1 mg/L	7.16	46.0 mS/cm	33 ppm	12.3 NTU
BA - 7 BOTTOM	28.0° C	7.3 mg/L	7.52	46.5 mS/cm	33 ppm	4.83 NTU
BA - 8 TOP	28.1° C	7.3 mg/L	7.72	46.5 mS/cm	36 ppm	3.48 NTU
BA - 8 BOTTOM	28.1° C	7.2 mg/L	6.98	45.8 mS/cm	35 ppm	3.68 NTU
BA - 9 TOP	28.2° C	7.6 mg/L	7.50	46.4 mS/cm	33 ppm	4.47 NTU
BA - 9 BOTTOM	28.1° C	7.2 mg/L	7.14	46.2 mS/cm	30 ppm	4.85 NTU
BA - 10 TOP	28.0° C	7.1 mg/L	7.77	46.4 mS/cm	36 ppm	5.98 NTU
BA - 10 BOTTOM	27.9° C	7.0 mg/L	7.20	46.3 mS/cm	31 ppm	11.2 NTU
AVERAGE	27.8° C	6.97 mg/L	7.33	44.6 mS/cm	33.1 ppm	6.67 NTU

Table 2. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study water quality samples for the control area, CA. Sampled on September 15 and 16, 1998.

Sample Station	Temperature	Dissolved Oxygen	pH	Conductivity	Salinity	Turbidity
CA - 1 TOP	28.6° C	7.5 mg/L	7.85	47.5 mS/cm	36 ppm	5.90 NTU
CA - 1 BOTTOM	28.5° C	7.6 mg/L	7.49	47.0 mS/cm	34 ppm	6.97 NTU
CA - 2 TOP	28.5° C	7.6 mg/L	7.63	46.5 mS/cm	35 ppm	10.8 NTU
CA - 2 BOTTOM	28.4° C	7.4 mg/L	7.62	46.5 mS/cm	39 ppm	9.38 NTU
CA - 3 TOP	28.4° C	7.3 mg/L	7.42	47.5 mS/cm	40 ppm	9.15 NTU
CA - 3 BOTTOM	28.0° C	7.4 mg/L	7.72	47.5 mS/cm	35 ppm	10.4 NTU
CA - 4 TOP	27.9° C	7.2 mg/L	7.47	47.9 mS/cm	34 ppm	7.85 NTU
CA - 4 BOTTOM	28.0° C	7.1 mg/L	7.60	47.9 mS/cm	35 ppm	15.6 NTU
CA - 5 TOP	27.7° C	7.1 mg/L	7.50	48.4 mS/cm	31 ppm	9.32 NTU
CA - 5 BOTTOM	27.7° C	7.3 mg/L	7.52	48.4 mS/cm	33 ppm	10.7 NTU
CA - 6 TOP	27.9° C	7.0 mg/L	7.49	48.5 mS/cm	35 ppm	6.99 NTU
CA - 6 BOTTOM	28.1° C	7.3 mg/L	7.58	48.8 mS/cm	35 ppm	6.95 NTU
CA - 7 TOP	28.1° C	7.4 mg/L	7.55	48.7 mS/cm	34 ppm	5.36 NTU
CA - 7 BOTTOM	27.9° C	7.5 mg/L	7.35	48.7 mS/cm	37 ppm	6.57 NTU
CA - 8 TOP	27.9° C	7.2 mg/L	7.45	48.8 mS/cm	34 ppm	6.23 NTU
CA - 8 BOTTOM	28.0° C	7.3 mg/L	7.53	48.7 mS/cm	32 ppm	14.3 NTU
CA - 9 TOP	27.9° C	7.1 mg/L	7.30	49.0 mS/cm	34 ppm	6.40 NTU
CA - 9 BOTTOM	27.8° C	7.2 mg/L	7.47	49.0 mS/cm	32 ppm	7.34 NTU
CA - 10 TOP	27.7° C	7.2 mg/L	7.42	49.1 mS/cm	33 ppm	5.27 NTU
CA - 10 BOTTOM	27.6° C	7.2 mg/L	7.40	49.1 mS/cm	33 ppm	29.5 NTU
AVERAGE	27.8° C	7.3 mg/L	7.52	48.2 mS/cm	34.5 ppm	9.55 NTU

6.3 Sediment Data

Table 1. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Data table showing pre-dredge percent sand, percent fines, and percent shell material. Sampled on September 15 and 16, 1998. Data provided by Athena Technologies, Inc.

Sample Station	Percent Sand	Percent Fines	Percent Shell
BA - 1	97.43	2.57	3%
BA - 2	98.89	1.11	5%
BA - 3	97.77	2.23	2%
BA -4	97.76	2.24	5%
BA - 5	97.93	2.07	3%
BA - 6	97.76	2.24	7%
BA - 7	96.44	3.56	10%
BA - 8	97.98	2.02	15%
BA - 9	97.42	2.58	4%
BA - 10	97.50	2.50	10%
CA - 1	89.86	10.14	1%
CA - 2	98.51	1.49	2%
CA - 3	98.65	1.35	2%
CA - 4	98.48	1.52	10%
CA - 5	98.80	1.20	15%
CA - 6	98.14	1.86	2%
CA - 7	98.18	1.82	2%
CA - 8	98.58	1.42	3%
CA - 9	98.03	1.97	1%
CA - 10	97.81	2.19	1%

Figure 1. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Graph showing pre-dredge sediment sample data for the borrow area percent sand composition. Sampled on September 15-16, 1998.

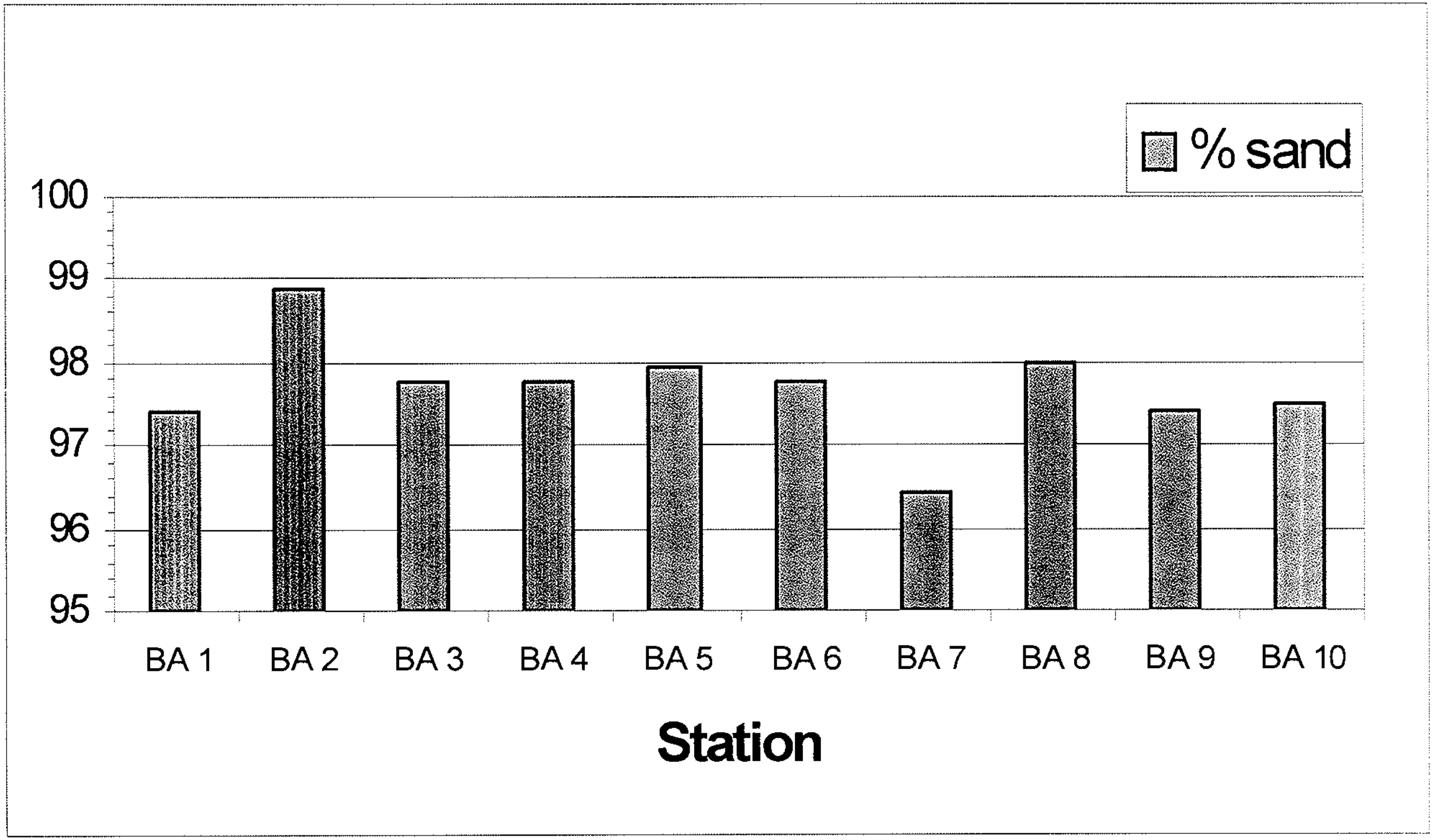


Figure 2. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Graph showing pre-dredge sediment sample data for the borrow area percent fines composition. Sampled on September 15-16, 1998.

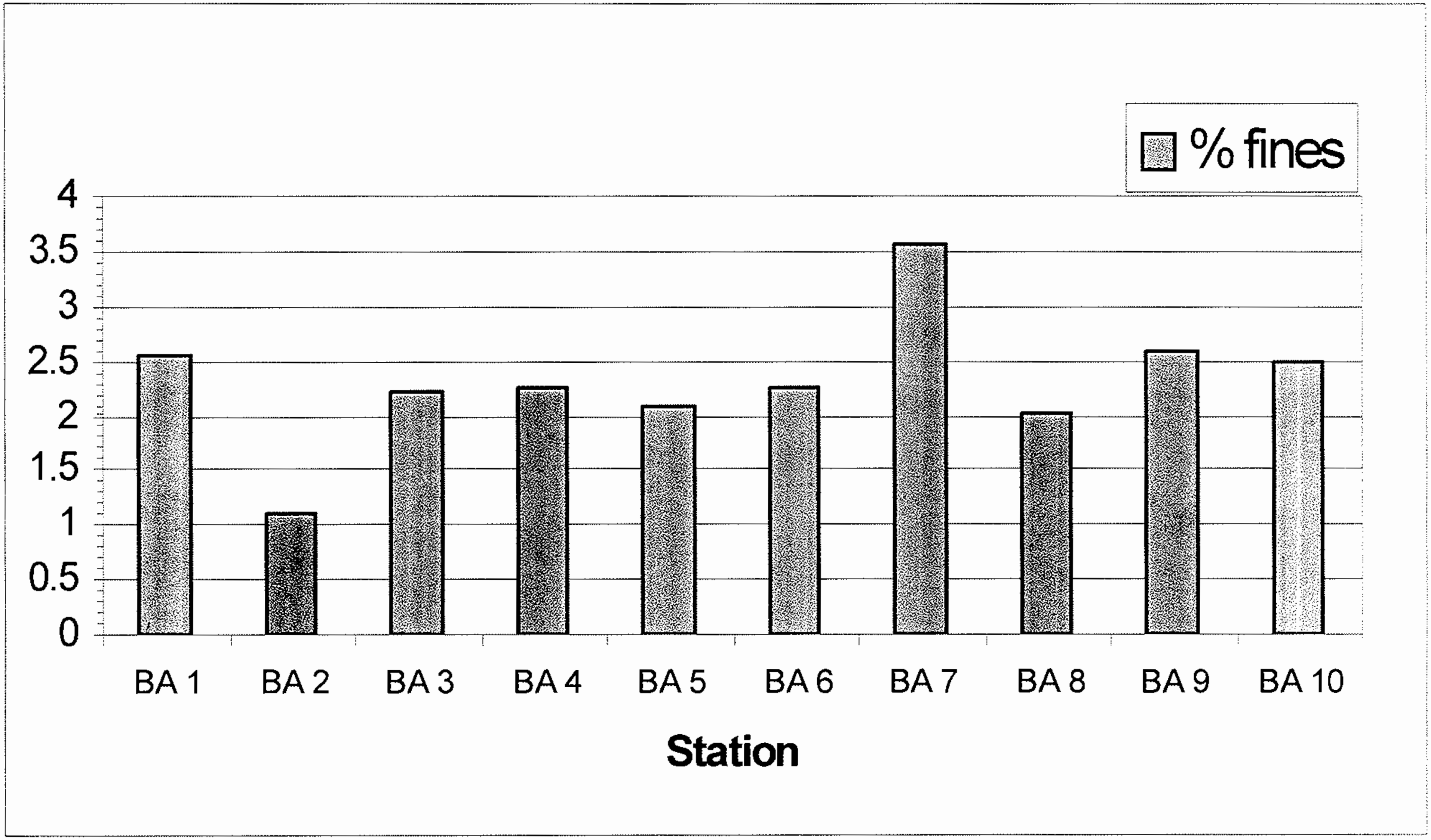


Figure 3. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Graph showing pre-dredge sediment sample data for the borrow area percent shell composition. Sampled on September 15-16, 1998.

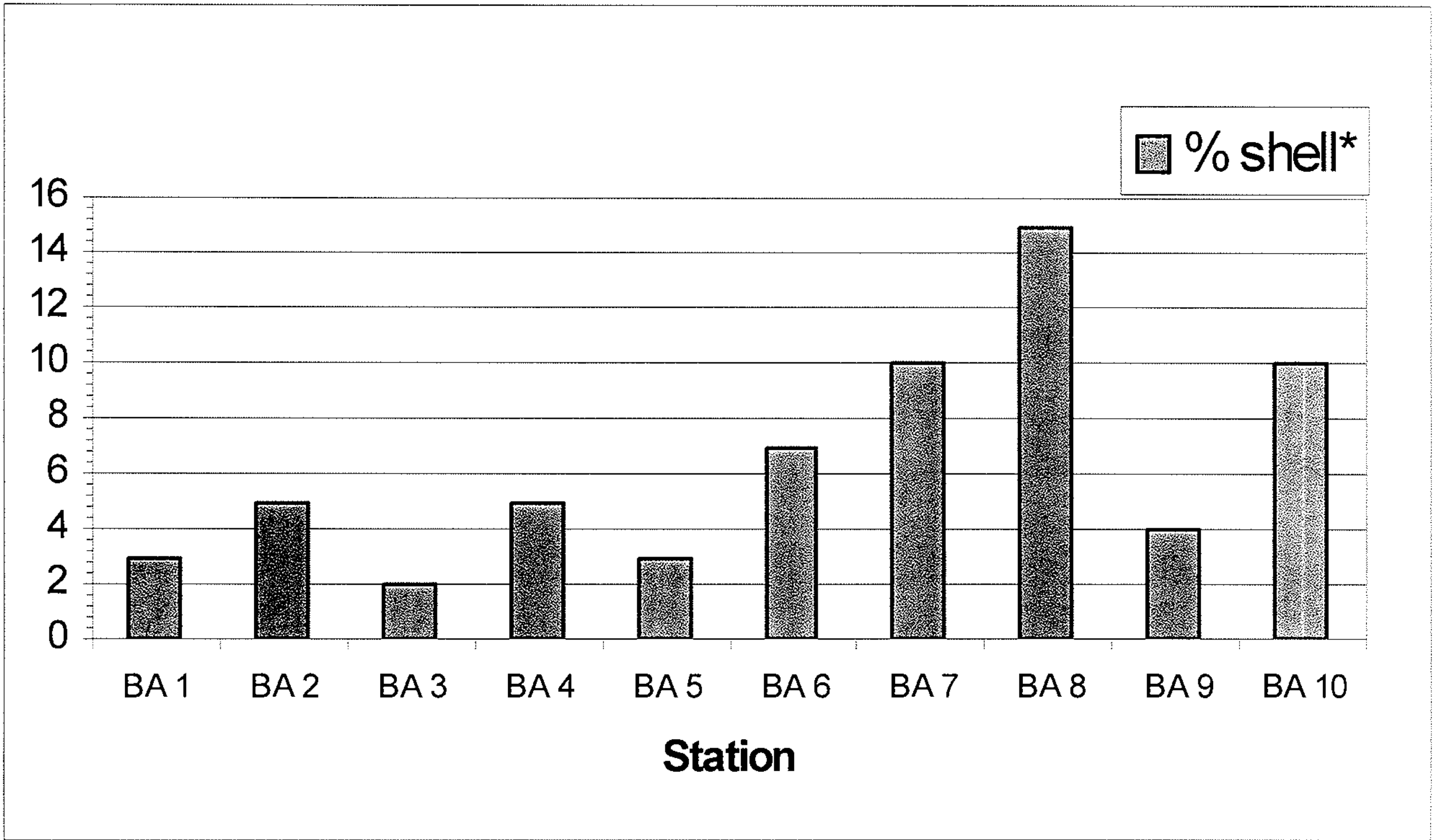


Figure 4. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Graph showing pre-dredge sediment sample data for the control area percent sand composition. Sampled on September 15-16, 1998.

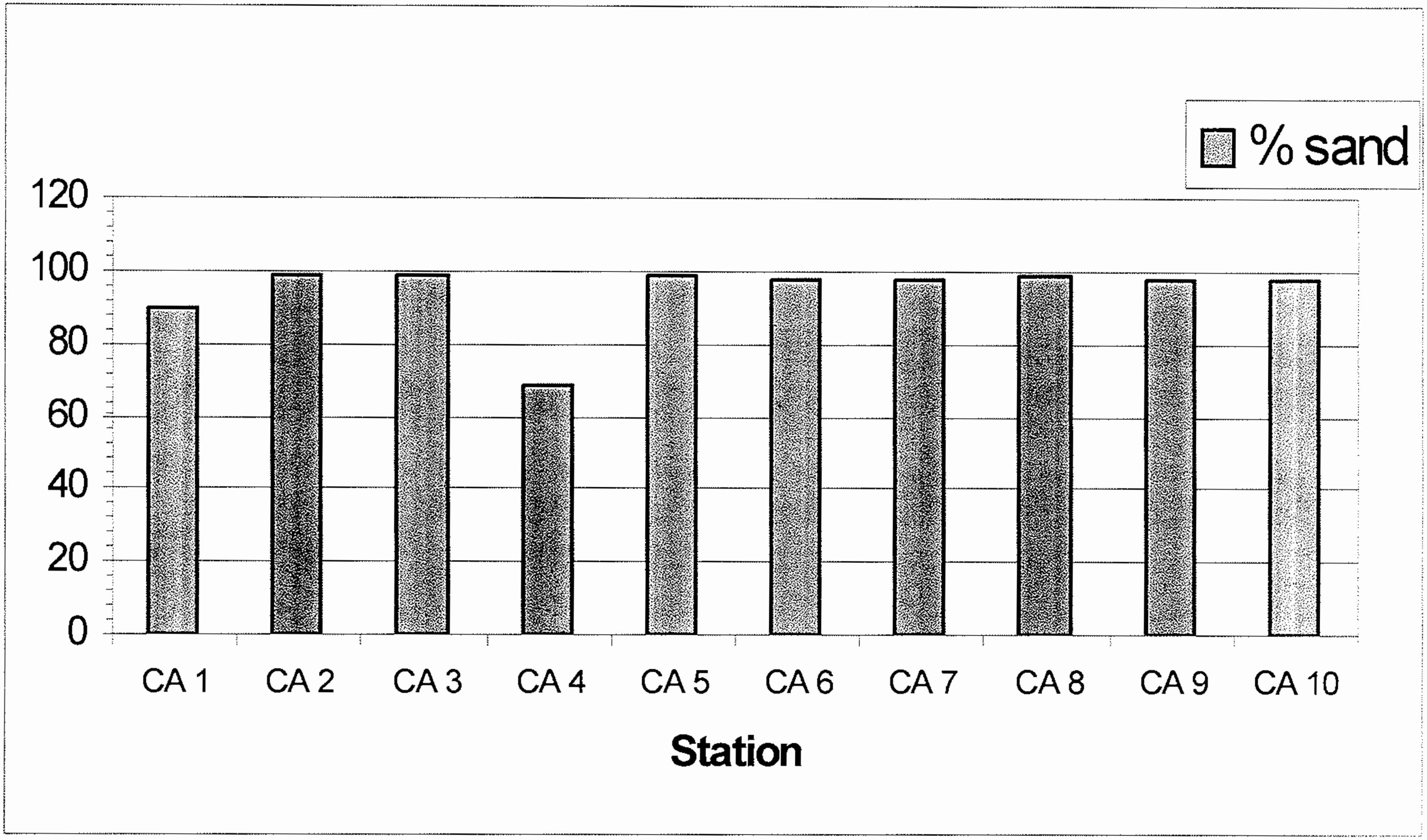


Figure 5. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Graph showing pre-dredge sediment sample data for the control area percent fines composition. Sampled on September 15-16, 1998.

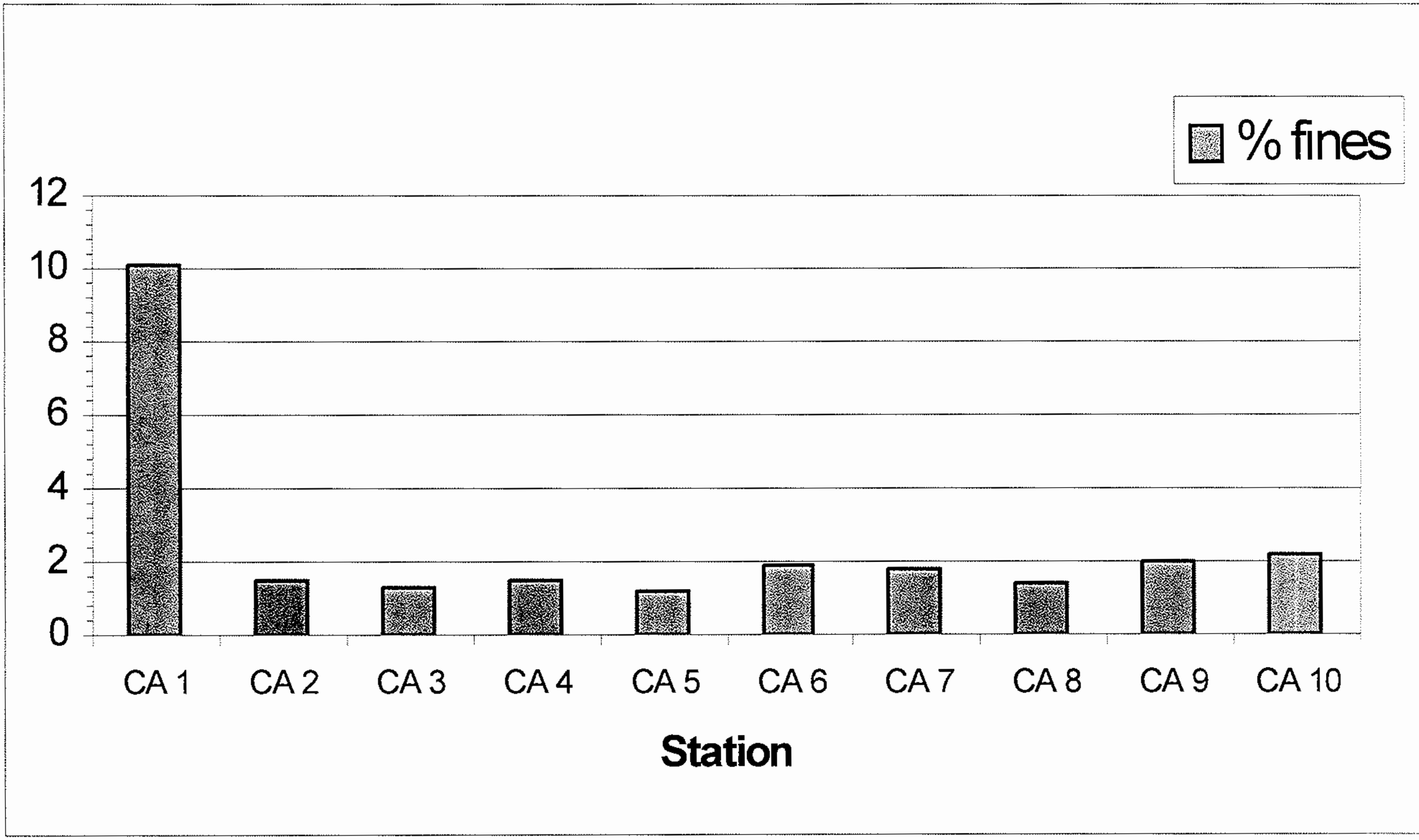
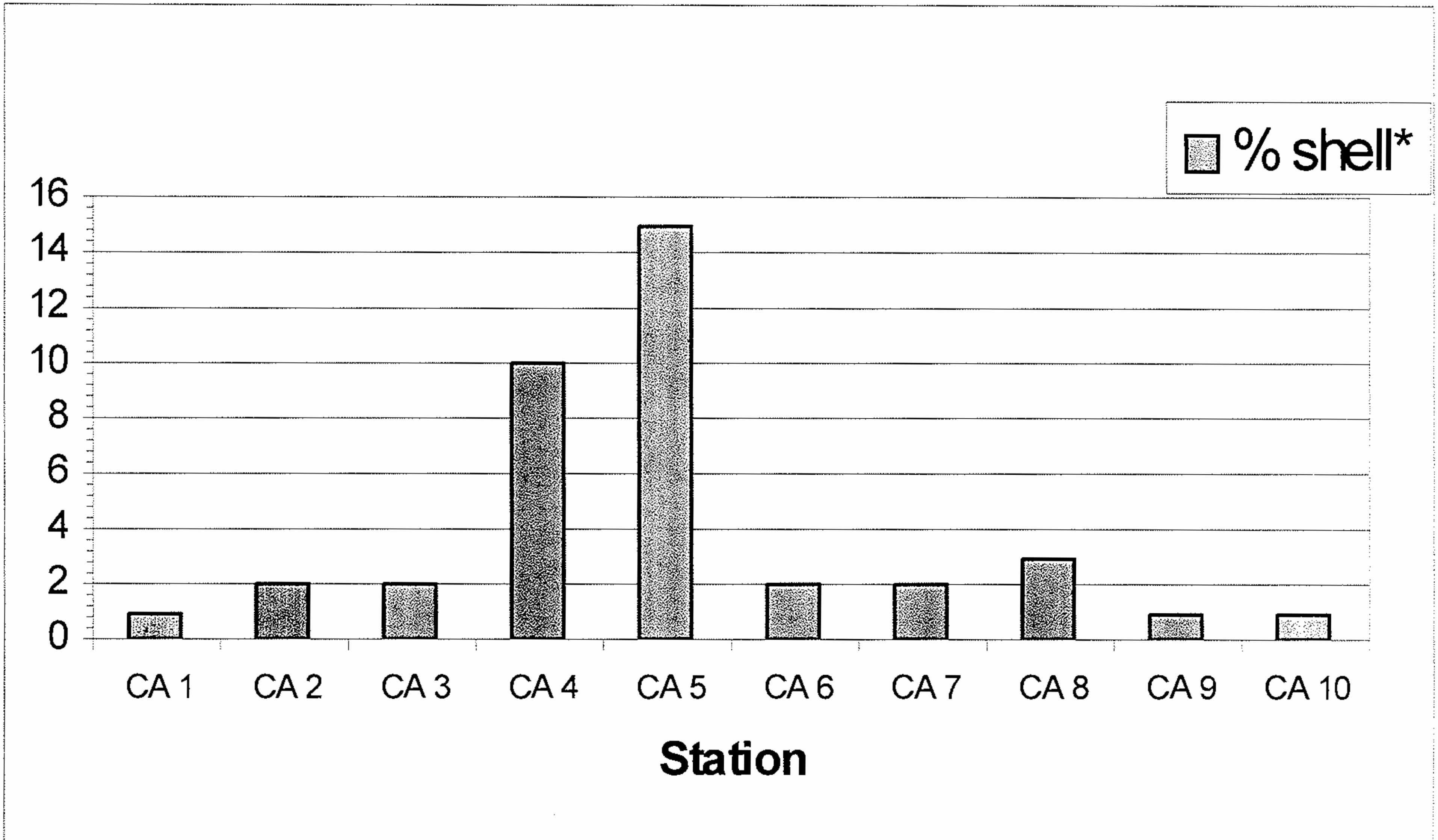


Figure 6. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Graph showing pre-dredge sediment sample data for the control area percent shell composition. Sampled on September 15-16, 1998.



DAUFUSKIE ISLAND BEACH NOURISHMENT
FINAL POST-DREDGE MONITORING STUDY

Prepared for:

Mr. Tim Mason
Applied Technology & Management, Inc.
4651 Salisbury Road
Mt. Pleasant, South Carolina 32256

Prepared by:

Coastal Science Associates, Inc.
P.O. Box 11687
Columbia, South Carolina 29211
SCDHEC Certified Lab I.D. #40008

May 2001

TABLE OF CONTENTS

1.0 INTRODUCTION

On August 31, 1998, Coastal Science Associates, Inc. (CSA/) was contracted by Applied Technology & Management, Inc. (ATM) to monitor surficial sediments and macrobenthic infauna assemblages for the Daufuskie Island Beach Nourishment Project. The project site is located approximately 2,000 yards south of Braddock Point, Hilton Head Island, South Carolina (Fig. 1).

This report presents the results of the data collected during the final post-dredge monitoring event. Sampling for this study was conducted on July 6, 7, and 11, 2000. All sampling and analyses for this study were performed in accordance with CSA/'s SCDHEC-approved Standard Operating Procedures Manual and Quality Assurance Plan (CSA/, 1999).

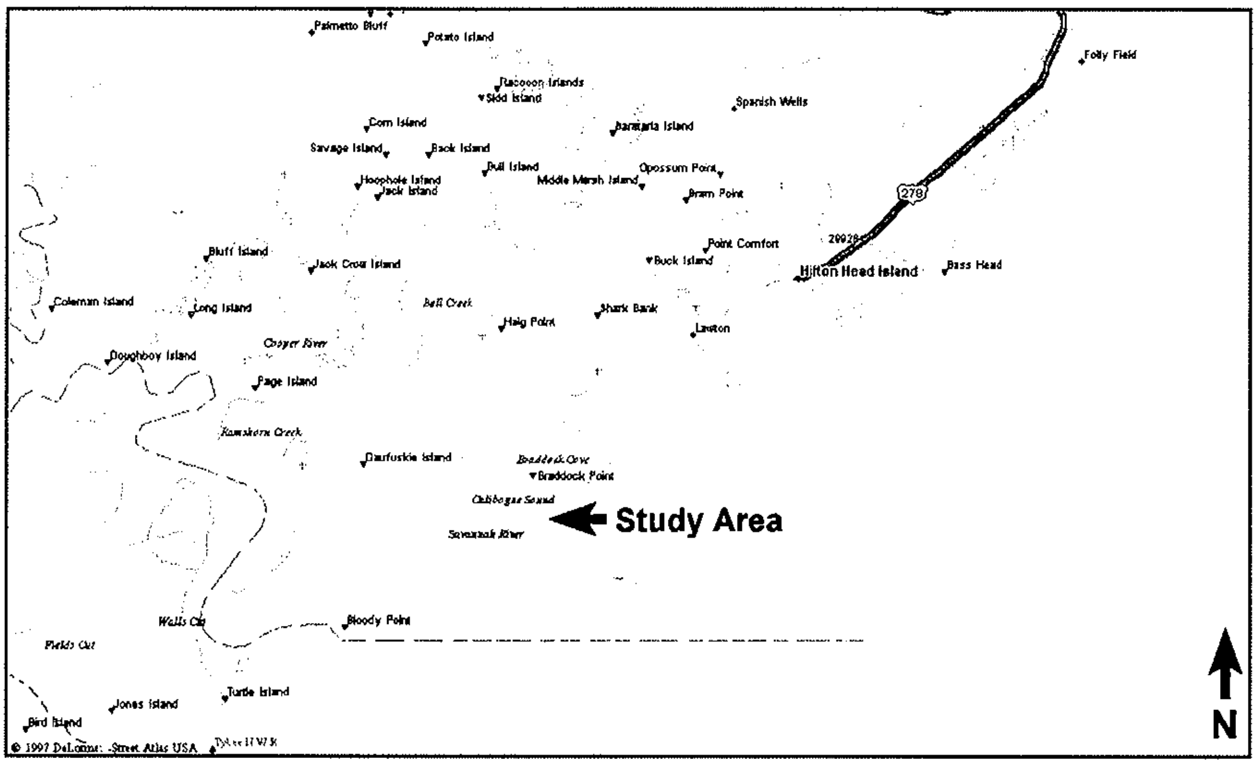


Figure 1. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study, Daufuskie Island, SC. Site location map showing the approximate location of the study area.

2.0 METHODS

2.1 Sample Areas

The Borrow Area (BA) is located approximately 1.1 miles south of Braddock Point on Hilton Head Island, South Carolina (Fig. 2). The area that was selected is just south of Braddock Point on one of the nearshore shoals in the inlet. This area was selected after several test cores from the area revealed that the sediment composition contained coarse grain sand, the type of sand desired for the proposed beach nourishment project.

During storm conditions and strong longshore currents that are frequent in the area, the coarse grain sand tends to better withstand erosion compared with less coarse grain sands. Another factor in the selection of the location of the BA, was the proximity of the compatible sand to the area of the project site, resulting in project cost reductions. The depths range from 1 to 19 feet (MLLW 1930-1980) (Table 1).

The Control Area (CA) is located approximately 0.85 miles south of the BA (Fig. 2). The CA, also a nearshore shoal, was selected for its similar bottom relief, depths, habitat, and close proximity to the BA. The depths in CA range from 4 to 17 feet (MLLW, 1930-1980) (Table 2).

Ten sample stations in each area were randomly chosen. Based on similar depths, stations were paired in order to compare similar benthic community habitats (Fig. 3). The locations of all twenty stations were recorded with a Magellan 5000 DLX (with differential unit) differential global positioning system (DGPS) to ensure that all subsequent sampling events are sampled at the same locations (Tables 1 and 2). The depths of the stations were recorded using a Hummingbird Wide Eye™ electronic depth finder.

Table 1. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Borrow area sample station coordinates and depths (July 6, 7, & 11, 2000).

Sample Station	Latitude	Longitude	Depth
BA - 1	32°05'23.58794"	80°48'52.14964"	5 ft.
BA - 2	32°05'17.77383"	80°48'47.89683"	8 ft.
BA - 3	32°05'14.81246"	80°48'39.46601"	9 ft.
BA - 4	32°05'23.20786"	80°49'02.48210"	19 ft.
BA - 5	32°05'19.30100"	80°48'56.69107"	21 ft.
BA - 6	32°05'13.08211"	80°48'52.97366"	20 ft.
BA - 7	32°05'13.15081"	80°48'46.16344"	18 ft.
BA - 8	32°05'06.85568"	80°48'44.38719"	19 ft.
BA - 9	32°05'06.15333"	80°48'38.07847"	21 ft.
BA - 10	32°05'00.55877"	80°48'35.11558"	19 ft.

Table 2. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Control Area sample station coordinates and depths (July 6, 7, & 11, 2000).

Sample Station	Latitude	Longitude	Depth
CA - 1	32°04'39.55622"	80°49'03.95468"	8 ft.
CA - 2	32°04'33.67805"	80°48'51.45240"	10 ft.
CA - 3	32°04'25.77258"	80°48'40.64419"	10 ft.
CA - 4	32°04'18.15006"	80°48'37.99961"	10 ft.
CA - 5	32°04'19.67290"	80°48'27.93585"	12 ft.
CA - 6	32°04'13.17238"	80°48'17.94706"	14 ft.
CA - 7	32°04'06.02683"	80°48'27.01303"	12 ft.
CA - 8	32°04'08.31925"	80°48'38.63181"	26 ft.
CA - 9	32°04'19.10604"	80°48'51.86461"	18 ft.
CA - 10	32°04'25.94015"	80°49'02.21961"	16 ft.

2.2 Sample Collection and Identification

2.2.1 Macrobenthic Sampling

Grab samples were collected using a 0.05 m^2 weighted ponar grab sampler. A minimum of 80% of the volume of the ponar grab sampler must be obtained for the sample to be considered viable. If less than the minimum is obtained, the sample location is moved 2 to 3 ft and re-sampled. This process is repeated until the 80% minimum is achieved. Grab samples were processed in the field by measuring the volume of each sample in a graduated 19-liter bucket and recording the data in the field logbook (Table 3). From the grab sample, a 3.5 cm (inside dia.) x 10 cm core sub-sample was taken for sediment analysis.

Table 3. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Ponar grab sample volumes (July 6, 7, & 11, 2000).

Sample Station	Ponar Grab Sample Volumes, BA	Ponar Grab Sample Volumes, CA
1	6.2 liters	6.0 liters
2	6.0 liters	5.5 liters
3	6.0 liters	6.0 liters
4	7.0 liters	6.0 liters
5	6.0 liters	7.0 liters
6	7.0 liters	5.5 liters
7	5.5 liters	6.0 liters
8	6.0 liters	5.0 liters
9	5.0 liters	6.0 liters
10	5.0 liters	5.0 liters

The remaining sediment was carefully sieved through a 0.5 mm stainless steel sieve bucket and screen. The remaining sediments and organisms were placed in labeled, double-ziplock bags and initially preserved in 10 percent buffered formalin solution with

Rose Bengal stain. Organisms were allowed to harden for 48 hours and then transferred to 80 percent ethanol alcohol. After the hardening period, the organisms were placed in sorting trays and submersed/diluted in de-ionized water to minimize any volatile alcohol vapor production during identification.

Organisms were sorted and enumerated in the laboratory and identified to the lowest possible taxon (species level in most cases) with the aid of a variable power dissecting microscope (Bausch & Lomb) and/or a compound microscope (Swift or Bristol). Organisms were identified by an experienced biologists utilizing various identification keys for organisms expected to be collected (e.g., Abbott, 1974; Bousfield, 1965; Bynum and Fox, 1977; Dover, 1979; Fauchald, 1977; Fox and Bynum, 1975; Gosner, 1978; Heard, 1982; Kaplan, 1988; Morris, 1975; Ruppert and Fox, 1988; Uebelacker and Johnson, 1984; Williams, 1984). Species identified for each station were then recorded on a laboratory bench sheet (per EPA, 1989).

2.2.2 Water Quality Sampling

Water quality physical parameters were recorded at each of the sampling stations. Water samples were taken at mid-depth using a Wildco Alpha water sampling bottle. Meters were calibrated prior to use according to calibration procedures outlined in CSA/'s approved Standard Operating Procedures Manual and Quality Assurance Plan (CSA/, 1999). The physical parameters and corresponding meters for measurement are listed below.

- Dissolved Oxygen (DO) - YSI DO Meter - Model 57
- Temperature - Orion Conductivity Meter - Model 128
- Conductivity - Orion Conductivity Meter - Model 128
- pH - Orion pH Meter - Model 230A
- Turbidity - Hach 2100P Turbidimeter
- Salinity - Aquafauna Refractometer

2.2.3 Sediment Sampling

The core sub-samples taken from the ponar grab samples were placed into doble-ziplock freezer bags and transported to Athena Technologies, Inc. (see Appendix B for chain-of-custody form). Athena Technologies, Inc. first cataloged the samples and then dried them in a low heat oven. The dried samples were weighed and the shell material content was visually estimated. The dried samples were then washed through a 0.0625 mm (4.0 phi) sieve to remove silt and clay sized particles from the sample. After the wash, the samples were again dried in a low heat oven. After drying, a final weight was recorded and compared to the initial dry weight in order to determine the sand and fine particle percentages.

Grain size analysis was performed according to applicable American Society for Testing and Materials (ASTM) standards using a 0.5 phi interval sieve stack starting at -1.0 phi (2.0 mm) and ending with 4.0 phi (0.06325 mm). A 115 g composite split was taken for particle size analysis and passed through the aforementioned sieve set. All of the samples were analyzed with shell material intact, which generally accounts for the total weight of the -1.0 phi and -0.5 phi sieves. The sieve was then Ro-tapped and the weight of material remaining in each sieve was recorded in order to calculate statistical data for each sample.

2.3 Macrobenthic Data Analyses

Six quantitative analyses were used to generate relevant statistical data based on taxonomic information gathered from the sediment samples.

1. Shannon-Wiener species diversity.
2. Species Richness - as total number of species.
3. Species Abundance - as total number of individuals.
4. Evenness.
5. T-test

The data were summarized for analysis on a data summary sheet listing the above five measures (Tables 4 - 5).

Table 4. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Summary of the of species diversity indices for samples taken July 6, 7, & 11, 2000.

Taxa	BA		CA	
	Species Richness	Abundance	Species Richness	Abundance
Cnidaria	2	79	1	113
Rhynchocoela	2	44	2	34
Aschelminthes	1	1	0	0
Chaetognatha	1	2	1	4
Mollusca	10	284	6	198
Annelida	20	186	23	199
Arthropoda	34	1559	32	1381
Echinodermata	3	7	2	6
Chordata	0	0	1	4
Total Abundance/ sample area		2162		1939
Total Species Richness/ sample area	73		68	
Mean Species Richness	9.1		8.5	
Shannon-Wiener	3.929		4.174	
Evenness	0.635		0.686	

Table 5. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Summary of statistical analyses for samples taken July 6, 7, & 11, 2000. Marked differences are significant at $p < 0.05$.

Sample Areas	Variable	T-Test
BA vs. CA	Species Richness	0.425
BA vs. CA	Abundance	0.676

3.0 RESULTS AND DISCUSSION

3.1 Macrobenthic Sampling

3.1.1 Macrobentic Taxa Analysis

A complete listing of the organisms collected at each station for BA and the CA is given in Tables 1 and 2 of Appendix 6.1. Comparisons of the organisms sampled are shown in Table 4 with the diversity indices. The dominant phyla found during this sampling event were Arthropoda, Mollusca, and Annelida (see Appendix 6.1, Fig. 1). The dominant organisms identified within the phylum Arthropoda were amphipods, copepods, mysid shrimp, and crab larva. For the phylum Annelida, the dominant organisms identified were *Magelona pettiboneae, Caulleriella* sp., *Nephtys picta*, *Lleitoscoloplos fragilis,* and *Glycera* sp. For the phylum Mollusca, the dominant organisms identified were of the species *Tellina versicolor* and, *Olivella mutica.*

3.1.2 Macrobenthic Data Analyses

The Shannon-Wiener species diversity index was calculated using the species richness and abundance (Table 4). A diversity index of 2 or greater is said to be favorable (Patil and Taillie, 1982; Brower, Zar, and von Ende, 1998). As shown in Table 4, both sample areas have a diversity index of greater than 3.75, indicating diverse macrobenthic communities. Additionally, the mean abundance was calculated for both sample areas, which is indicated graphically in Appendix 6.1, Figure 2.

The evenness or relative diversity for each area was determined (Table 4). The evenness was 0.635 and 0.686 for BA and CA, respectively. Evenness is measured from 0 to 1. If the evenness is at or near 0, then the population's species diversity is different from the ideal community distribution (Brower, Zar, and von Ende, 1998). If the evenness is at or near 1, the population's species diversity is not different from the ideal community distribution (Brower, Zar, and von Ende, 1998).

For the T-test at the 0.05 significance level, the comparison of species richness/replicate sample and abundance/replicate sample for BA to CA resulted in a values of 0.425 and 0.676 respectively. These calculation indicate that no significant differences exist between populations.

3.1.3 Final Post-dredge Study Compared to Previous dredge Studies

The macrobenthic samples collected from BA indicated that the species composition has changed slightly from the previous two studies (CSA*i*, November, 1999): as shown in Table 6 significant increases in the number of individuals from the phyla Mollusca, Annelida, and Arthropoda were observed; and species richness has increased from 55 and 61 during the previous two studies to 73 for this study. Species abundance has also increased from 882 and 1,268 during the previous two studies to 2,162 for this study. The species diversity remained relatively the same, 3.761 and 3.713 during the previous two studies as compared to 3.929 for this study. Evenness also remained relatively the same, 0.651 and 0.626 as compared to 0.635 for this study. The two previous pre and post studies are included in Appendix 6.5 for comparison purposes.

Compared to the previous two studies, the species composition from CA stayed relatively the same. The exceptions were an increase in the number of individuals from the phylum Mollusca, phylum Arthropoda, and phylum Cnidaria. The species richness has increased from 46 during the previous two studies to 68 for this study. Species abundance has also increased from 1,039 to 713 during the previous two studies to 1,939 for this study. The species diversity remained relatively the same, 3.676 and 3.702 during the previous two studies as compared to 4.174 for this study. Evenness also remained relatively the same, 0.666 and 0.670 during the previous two studies as compared to 0.686 for this study.

The rise in species richness, species diversity, and species abundance at both BA and CA may be attributed to the time frame of the sampling event. This sampling event occurred during the summer when benthic communities are at a population high because of the water temperature and higher nutrient levels.

Table 6. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Summary of the of species diversity indices for the pre, post, and final post-dredge Monitoring Studies.

Taxa	BA-2000		CA-2000		BA-1999		CA-1999		BA-1998		CA-1998	
	Species Richness	Abundance	Species Richness	Abundance	Species Richness	Abundance	Species Richness	Abundance	Species Richness	Abundance	Species Richness	Abundance
Cnidaria	2	79	1	113	1	1	0	0	0	0	0	0
Rhynchocoela	2	44	2	34	3	45	3	28	2	10	0	0
Aschelminthes	1	1	0	0	1	2	0	0	1	6	0	0
Chaetognatha	1	2	1	4	0	0	0	0	1	1	1	2
Mollusca	10	284	6	198	5	155	5	29	3	12	5	28
Annelida	20	186	23	199	32	336	21	193	16	50	13	64
Arthropoda	34	1559	32	1381	17	724	15	450	31	802	26	938
Echinodermata	3	7	2	6	1	4	2	13	0	0	1	7
Chordata	0	0	1	4	1	1	0	0	1	1	0	0
Total Abundance/ sample area		2,162		1,939		1,268		713		882		1,039
Total Species Richness/ sample area	73		68		61		46		55		46	
Mean Species Richness	9.1		8.5		7.6		5.8		6.9		5.8	
Shannon-Wiener	3.929		4.174		3.714		3.703		3.761		3.677	
Evenness	0.635		0.686		0.626		0.670		0.651		0.666	

3.2 Water Quality and Physical Data

A summary of *in-situ* water quality data for all parameters measured is presented in Tables 1 and 2 of Appendix 6.2. Water quality parameter values appeared to be in the normal range for the time of year and weather conditions encountered during the sampling event. Turbidity levels appeared to be higher than normal. The high winds and tidal action encountered during the sampling event may have caused turbidity to be greater than normal.

3.3 Sediment Sampling

The final weights of the sediment samples were compared to the initial dry weights in order to determine the sand and fine (<0.0625 mm) particle percentages (Table 1, Appendix 6.3). The raw sediment data were input it into the U.S. Army Corps of Engineers ACES software package. Using this software, cumulative frequency and histogram grain size curves were produced. Statistical data are shown on each graph outlining mean size, median size, standard deviation, skewness, and kurtosis (see Figs 1-6., Appendix 6.3). The original report from Athena Technologies, Inc. is presented in Appendix 6.4.

The sediment analysis for grain size composition indicated that all of the samples in BA had a large sand content with the average being 95.2%. The sediment analysis for grain size composition indicated that all of the sample in the CA also had a large sand content with the average being 86.7%. The sand content in the samples in both BA and CA have slightly decreased relative to the previous study.

4.0 SUMMARY AND CONCLUSIONS

The analyses of macrobenthic populations from the Borrow Area (BA) and Control Area (CA) indicated that the populations are diverse with high numbers for species richness, Shannon-Wiener diversity, and evenness.

Comparing the populations' species richness/replicate sample using a t-test at the 0.05 significance level, no significant differences were seen. A t-test was also performed on the abundance/replicate sample. The test registered no difference between the two populations at the 0.05 significance level

Compared to the two previous studies, the species composition at BA has changed slightly, with observed increases in the number of individuals from the phyla Cnidaria, Mollusca, and Arthropoda. This has lead to an increase in species richness, while species diversity and evenness remained relatively the same.

At CA, compared to the two previous studies, the species composition has changed slightly, with observed increases in the number of individuals from the phyla Cnidaria, Mollusca, and Arthropoda. This has lead to an increase in species richness and species diversity, while the evenness remained relatively the same.

Based upon numerous benthic impact studies and data gathered during this study, it appears that the environmental impacts for this project were minimal and that the impacted communities are returning to the pre-project conditions.

5.0 REFERENCES

Abbott, R.T. 1974. American Seashells Second Edition. Van Nostrand Reinhold Co. 450 West 33rd Street, New York, N.Y. 663pp.

Bousfield, E.L. 1965. Haustoriidae of New England (crustacea: amphipoda). Proc. U.S. Nat. Mus., Vol. 117(3512). 159 pp.

Brower, J.E., Zar, J.H., and von Ende, C.N. 1998. Field and Laboratory Methods for General Ecology, 4th Edition. The McGraw-Hill Co. Inc., 273pp.

Bynum, K.H., Fox, R.S. 1977. New and Noteworthy Amphipod Crustaceans from North Carolina, U.S.A., Chesapeake Science Vol. 18, No. 1 p. 1-33.

Coastal Science Associates, Inc. (CSA*i*). November, 1999. Daufuskie Island Beach Nourishment Pre-dredge Monitoring Study. Report to Applied Technology and Management, Inc. 36 pp.

Coastal Science Associates, Inc. (CSA*i*). November, 1999. Daufuskie Island Beach Nourishment Post-dredge Monitoring Study. Report to Applied Technology and Management, Inc. 37 pp.

Coastal Science Associates, Inc. (CSA*i*). October 12, 1999. Standard Operating Procedures Manual and Quality Assurance Plan. For SCDHEC certified lab #40008.

Dover, C.W. 1979. Field Guide to Common Marine Invertebrates. Duke University Marine Laboratory, 78 pp.

CSA*i*. October 12, 1999. Standard Operating Procedures Manual and Quality Assurance Plan. For SCDHEC certified lab #40008.

EPA. 1989. Rapid Bioassessment Protocols for use in Streams and Rivers. U.S. EPA /444/4-89-001, Washington D.C.

Fauchald, K. 1977. The polychaete worms: definitions and keys to the orders, families, and genera. Nat. Hist. Mus., Los Angeles Ca., Science Series No. 28, 161 pp.

Fox, R.S., Bynum, K.H. 1975. The Amphipod Crustaceans of North Carolina Estuarine Waters. Chesapeake Science Vol. 16, No. 4 p.223-237

Gosner, K.L. 1978. A field guide to the Atlantic seashore. Houghton Mifflin Co., Boston, Mass., 329 pp.

Gosner, K.L. Guide to Identification of Marine and Estuarine Invertebrates. Wiley Interscience.

Heard, R.W. 1982. Guide to Common Tidal Marsh Invertebrates of the Northeastern Gulf of Mexico. Mississippi-Alabama Sea Grant Consortium, 82 pp.

Hurme, A.K., R.M. Yancey, and E.J. Pullen. 1979. Sampling macroinvertebrates on high-energy beaches. U.S. Army Corps of Engineers, CERC, Ft. Belvoir, Va., Coastal Eng. Tech. Aid No. 79-3, 37 pp.

Kaplan, E.H. 1988. Southeastern and Caribbean Seashores. Houghton Mifflin Co., Boston, Mass., 425 pp.

Morris, P.A. 1975. A Field Guide to Shells, Atlantic and Gulf Coasts and the West Indies. Houghton Mifflin Co., Boston, Mass., 330 pp.

Patil, G.P., and C. Taillie. 1982. Diversity as a concept of its measurement. J. Amer. Statist. Assoc. Vol. 77, p. 548-561.

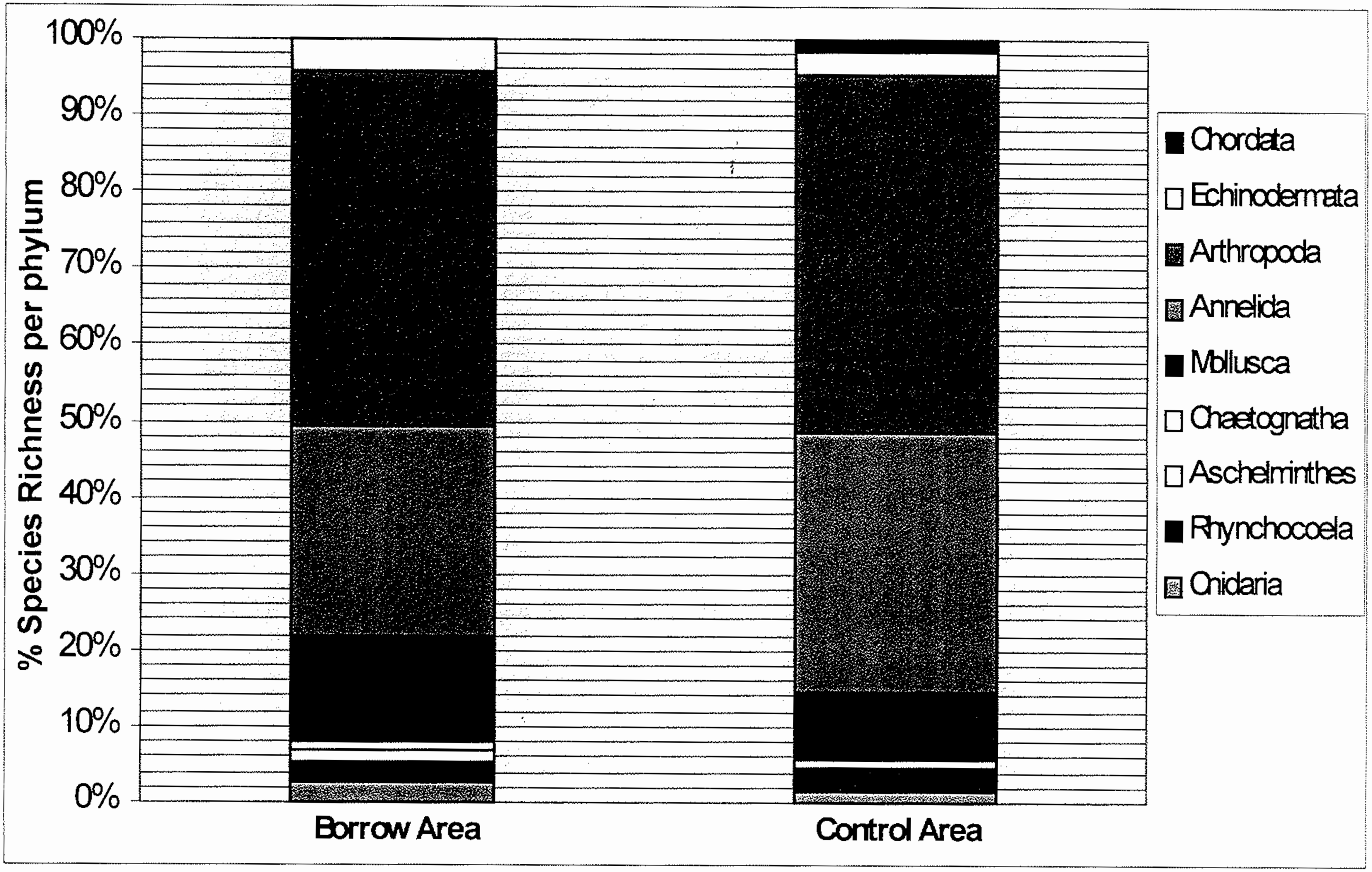
Ruppert, E.E., and R.S. Fox. 1988. Seashore animals of the southeast. Univ. of South Carolina Press. Columbia. 429 pp.

Uebelacker, J.M. and P.G. Johnson. 1984. Taxonomic Guide to the Polychaetes of the Northern Gulf of Mexico. U.S. Dept. of Interior. Seven Volumes.

Williams, A.B. 1984 Shrimps, Lobsters, and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida. Smithsonian Institution Press, Washington, D.C. 550 pp.

6.0 APPENDICES

6.1 Benthic Data



Coastal Science Associates, Inc. P.O. Box 11687 Columbia, SC 29211 Tel. (803)-256-3081 Fax (803)-256-7475	Daufuskie Island Beach Nourishment Second Post-dredge Monitoring Study. Graph indicating the percent species richness of organisms sampled in both of the sample areas.	Date: July 6, 7, and 11, 2000 Figure 1

Table 1. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Macrobenthic survey results for the Borrow Area, BA, July 6, 7, & 11, 2000.

Taxonomy	BA-1	BA-2	BA-3	BA-4	BA-5	BA-6	BA-7	BA-8	BA-9	BA-10
Phylum Cnidaria										
Anthozoa Pennatulacea *Renilla reniformis*		22		1	27	13	7	5	1	
Hydrozoa Colonial hydroid sp.		1			1		1			
Phylum Rhynchocoela										
Enopla *Enopla* sp.	15		6		2	1		7	6	1
Anopla *Anopla* sp.						2	4			
Phylum Aschelminthes										
Nematoda *Nematoda* sp.								1		
Phylum Chaetognatha										
Sagitta sp.		1			1					
Phylum Mollusca										
Gastropoda Olividae *Olivella mutica*	1	2	6	1		1	7	5	1	
Gastropoda Cerithiopsinae *Cerithiopsis emersoni*					1					
Gastropoda *Nudabranchia* sp.									1	
Gastropoda Unknown juvenile gastropod									9	
Pelecypoda Tellinidae *Tellina versicolor*		36	30	5	26	40	5	22	64	1
Pelecypoda Tellinidae *Strigilla mirabilis*			1	1	3			3	1	1
Pelecypoda Donacidae *Donax variabilis*	4									

Pelecypoda Solenidae *Solen viridis*		1							2	
Pelecypoda Corbulidae *Corbula contracta*					1					
Pelecypoda Veneridae *Chione grus*										2
Phylum Annelida										
Polychaeta Opheliidae *Ophelina acuminata*									1	
Polychaeta Lumbrineridae *Lumbrineris* sp.			1							
Polychaeta Phyllodocidae *Etone heteropoda*						1				
Polychaeta Glyceridae *Glycera* sp.				3	1	1				17
Polychaeta Glyceridae *Glycera dibranchiata*									1	
Polychaeta Spionidae *Prionospio pygmaea*					1	1		1		
Polychaeta Spionidae *Scolelepis squamata*			1							
Polychaeta Spionidae *Malacocera vanderhorsti*						1				
Polychaeta Spionidae *Spiophanes missionensis*						2		4		
Polychaeta Spionidae *Scolelepis texana*		5			1			2		
Polychaeta Orbiniidae *Leitoscoloplos fragilis*		3	2			3	2	5	2	

Polychaeta Orbiniidae *Scoloplos rubra*							2		3	
Polychaeta Magelonidae *Magelona pettiboneae*		9	5	1	4	9	3	3		
Polychaeta Magelonidae *Magelona* sp. B									1	
Polychaeta Magelonidae *Magelona* sp. G	1									
Polychaeta Nephtyidae *Nephtys picta*	4	5	3	1	2	4		6	7	
Polychaeta Nephtyidae *Aglaophamus verrilli*			6				1	8		
Polychaeta Capitellidae *Capitella capitata*									6	
Polychaeta Cirratulidae *Caulleriella* sp.		17	2		3		1		2	
Polychaeta Sabellidae *Sabellidae* sp.		4			1					
Phylum Arthropoda										
Amphipoda Haustoriidae *Protohaustorius wigleyi*	59	70	55	35	32	144	49	194	49	2
Amphipoda Haustoriidae *Parahaustorius longimerus*	42			1						
Amphipoda Haustoriidae *Neohaustorius schmitzi*	7									3
Amphipoda Haustoriidae *Amphiporeia virginana*	14	1						1		3
Amphipoda Bateidae *Batea catharinesis*	6	7			7	1	1			

Amphipoda Corophiidae *Cerapus tubularis*	1	7			3	1				
Amphipoda Phoxocephalidae *Trichophoxus floridanus*	2				1					
Amphipoda Oedicerotidae *Monoculodes edwardsi*		4	1		4	2	2	1	1	
Amphipoda Platyischnopidae *Eudevanopus honduranus*		1	1		4	3	2	3	2	
Amphipoda Ischyroceridae *Jassa falcata*		3								
Amphipoda Ampeliscidae *Ampelisca verilli*						1				
Amphipoda Gammaridae *Gammarus* sp.	1			1	1	2		1	2	
Crustacea Copepoda *Calanoida* sp.	118	26	7		6		3	8		1
Crustacea Cumacea *Oxyurostylis smithi*	3		1	1	6	1				
Crustacea Cumacea *Almyracuma proximoculi*						1				
Crustacea Stomatopoda sp. larva	2	1	1							
Crustacea Hoplocarida Pseudozoea larva		1	1							
Crustacea Unknown sp. (Juvenille)		1							2	
Isopoda Idoteidae *Chiridotea coeca*		1		2		1				6
Isopoda Sphaeromidae *Ancinus depressus*	10		1	2				3	6	12

Mysidacea Mysidae Bowmaniella portoricensis	91	18	21	21	50	43	9	10	5	5
Mysidacea Mysidae *Mysidopsis bigelowi*	3	12						3		
Decapoda Paguridae *Pagurus longicarpus*		1						1		4
Decapoda Paguridae *Pagurus pollicaris*	1									
Decapoda Pasiphaeidae *Leptochela* sp.	1									
Decapoda Sergestidae *Acetes americanus carolinae*	5		1	1	1		3	4	3	
Decapoda Sergestidae *Lucifer faxoni borradaili*	1									
Decapoda Bresiliidae *Discias atlanticus*								1		
Decapoda Penaeidae *Penaeus* sp. (Juvenile)				1						
Decapoda Brachyuran crab megalopa	66	4	6			2		16	4	3
Decapoda Brachyuran crab zoea		6			2	8	3	25	3	
Decapoda Anomuran crab zoea		1			1					
Decapoda Thalassinid shrimp larva	1	6				1	2	1	1	
Decapoda Hippidae *Emerita talpoida*	1									
Phylum Echinodermata										
Echinoidea Clypeasteroida *Mellita quinquiesperforata*	1					1				1
Holothuroidea Holothuroidea sp. (Juvenile)						2		1		

Stelleroidea Platyasterida *Luida clathra*								1		
Abundance	461	277	159	78	193	293	107	346	186	62
Species Richness	27	31	22	16	28	29	19	30	27	15
Total Species Richness	73									
Total Abundance	2,162									

Table 2. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Macrobenthic survey results for the Control Area, CA, July 6, 7, & 11, 2000.

Taxonomy	CA-1	CA-2	CA-3	CA-4	CA-5	CA-6	CA-7	CA-8	CA-9	CA-10
Phylum Cnidaria										
Anthozoa Pennatulacea *Renilla reniformis*	47	64	2							
Phylum Rhynchocoela										
Enopla *Enopla* sp.	4	6	6	3	3	2		5	4	
Anopla *Anopla* sp.								1		
Phylum Chaetognatha										
Sagitta sp.			1	2		1				
Phylum Mollusca										
Gastropoda Olividae *Olivella mutica*	3	5					1			
Gastropoda Turridae *Mangelia plicosa*		1								
Pelecypoda Tellinidae *Tellina versicolor*	22	33	8	18	5	21	34	15	24	3
Pelecypoda Tellinidae *Strigilla mirabilis*	1									
Pelecypoda Arcidae *Andara transversa*	1	2								
Pelecypoda Corbulidae *Corbula contracta*	1									
Phylum Annelida										
Polychaeta Spionidae *Spiophanes bombyx*				3	1	1	1	2	1	
Polychaeta Glyceridae *Glycera dibranchiata*					2			1		

Polychaeta Glyceridae *Glycera* sp.					18	1		1	1	
Polychaeta Spionidae *Spiophanes missionensis*	3		1							
Polychaeta Spionidae *Prionospio cirrobranchiata*				2		2	1			
Polychaeta Spionidae *Prionospio pygmaea*										2
Polychaeta Spionidae *Malacocera vanderhorsti*		1		2				3	2	15
Polychaeta Spionidae *Dispio uncinata*	1									
Polychaeta Spionidae *Scolelepis texana*			3							
Polychaeta Orbiniidae *Leitoscoloplos fragilis*	4	1	2				2		9	
Polychaeta Orbiniidae *Scoloplos rubra*		1	1	4		1	2			
Polychaeta Magelonidae *Magelona pettiboneae*	1	3	2	2		7	7		1	
Polychaeta Magelonidae *Magelona* sp. H								1		
Polychaeta Nephtyidae *Nephtys picta*	5	2	3	2			1	4	9	4
Polychaeta Nephtyidae *Aglaophamus verrilli*	2	5	3	4		2	5	1		
Polychaeta Cirratulidae *Caulleriella* sp.	6	1		5	1			2	2	
Polychaeta Lumbrineridae *Lumbrineris* sp.								1		

Polychaeta Opheliidae *Ophelia denticulata*					2					
Polychaeta Opheliidae *Ophelina cylindricaudata*	1									
Polychaeta Opheliidae *Armandia agilis*										1
Polychaeta Opheliidae *Travista hobsonae*	1									
Polychaeta Pectinariidae *Pectinaria regalis*					1					
Polychaeta Terebellidae *Terebella* sp.		1								
Phylum Arthropoda										
Amphipoda Haustoriidae *Protohaustorius wigleyi*	44	57	151	53		125	120	5	2	38
Amphipoda Haustoriidae *Parahaustorius longimerus*					1					
Amphipoda Haustoriidae *Neohaustorius schmitzi*	2	3	4	20		10	9			
Amphipoda Haustoriidae *Amphiporeia virginana*			1			1	1			
Amphipoda Bateidae *Batea catharinesis*		18		1	2					
Amphipoda Corophiidae *Cerapus tubularis*	2		2	1		1	2		1	
Amphipoda Phoxocephalidae *Trichophoxus floridanus*	2	1	4	3		4	1			
Amphipoda Oedicerotidae *Monoculodes edwardsi*	3		1	1		1	2			3

Amphipoda Platyischnopidae *Eudevanopus honduranus*	1	1	2	1		3				
Amphipoda Gammaridae *Gammarus* sp.	23		2	3	1	5				
Crustacea Copepoda *Calanoida* sp.	9	7	24	17	4	14	5	1	4	
Crustacea Cumacea *Oxyurostylis smithi*				1	1			1	1	
Crustacea Cumacea *Almyracuma proximoculi*		1	1	2	2		1			
Crustacea Stomatopoda sp. larva	1		1			1				
Crustacea Unknown larva			14	47		7	11			
Isopoda Idoteidae *Chiridotea coeca*	1	1	1	1	4					
Isopoda Unknown sp. Juvenille				1			1			
Isopoda Sphaeromidae *Ancinus depressus*	1	3	1	27	12	5	18		1	5
Tanaidacea Tanaidae *Tanais* sp.				1		2				
Mysidacea Mysidae Bowmaniella portoricensis	19	6	12	27	7	22	50	3	4	4
Mysidacea Mysidae *Mysidopsis bigelowi*	2		3	11	1	2	9	1	3	1
Decapoda Paguridae *Pagurus longicarpus*					1				1	
Decapoda Pasiphaeidae *Leptochela* sp.							1			2
Decapoda Albuneidae *Lepidopa* sp.										1

Decapoda Sergestidae *Acetes americanus carolinae*		1	2	9		9	11	1	2	6
Decapoda Sergestidae *Lucifer faxoni borradaili*	1	1	1							
Decapoda Pinnotheridae *Pinnixa* sp.					1					
Decapoda Brachyuran crab megalopa	1	12	14	5		14	8		1	
Decapoda Brachyuran crab zoea	4	1	5	5	3	2	4		2	
Decapoda Anomuran crab zoea	7	1	5	4	2	3		2	2	
Decapoda Thalassinid shrimp larva	5	7	3	6		5				
Decapoda Hippidae *Emerita talpoida*				1						
Phylum Echinodermata										
Echinoidea Clypeasteroida *Mellita quinquiesperforata*		1	1		1					
Stelleroidea *Ophiuroidea* sp. (Juvenile)		1	1	1						
Phylum Chordata										
Chordata Amphioxus *Branchiostoma caribaeum*					4					
Abundance	231	249	288	296	80	274	308	51	77	85
Species Richness	34	32	35	36	24	29	26	19	21	13
Total Species Richness	68									
Total Abundance	1,939									

6.2 Water Quality Tables

Table 1. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Results of water quality sampling for the Borrow Area, BA, July 6, 7, & 11, 2000.

Sample Station	Temperatur e	Dissolved Oxygen	pH	Conductivity	Salinity	Turbidit y
BA - 1 TOP	28.4° C	6.6 mg/L	7.75	48.6 mS/cm	30 ppm	32.9 NTU
BA - 1 BOTTOM	28.5° C	6.8 mg/L	7.78	48.4 mS/cm	33 ppm	33.5 NTU
BA - 2 TOP	28.4° C	6.8 mg/L	7.73	48.4 mS/cm	28 ppm	29.0 NTU
BA - 2 BOTTOM	28.9° C	7.0 mg/L	7.70	48.4 mS/cm	25 ppm	34.7 NTU
BA - 3 TOP	28.8° C	6.5 mg/L	6.88	48.5 mS/cm	26 ppm	35.0 NTU
BA - 3 BOTTOM	28.3° C	6.4 mg/L	7.44	48.6 mS/cm	27 ppm	37.8 NTU
BA - 4 TOP	29.6° C	7.4 mg/L	7.82	50.3 mS/cm	37 ppm	28.2 NTU
BA - 4 BOTTOM	30.0° C	7.4 mg/L	7.80	50.3 mS/cm	38 ppm	29.1 NTU
BA - 5 TOP	30.3° C	8.0 mg/L	7.85	49.1 mS/cm	39 ppm	26.8 NTU
BA - 5 BOTTOM	31.3° C	8.0 mg/L	7.82	48.4 mS/cm	39 ppm	27.7 NTU
BA - 6 TOP	31.2° C	8.2 mg/L	7.87	48.2 mS/cm	35 ppm	24.5 NTU
BA - 6 BOTTOM	30.5° C	7.2 mg/L	7.84	51.2 mS/cm	35 ppm	26.0 NTU
BA - 7 TOP	30.0° C	7.4 mg/L	7.89	50.7 mS/cm	36 ppm	25.5 NTU
BA - 7 BOTTOM	29.9° C	7.2 mg/L	7.79	51.1 mS/cm	35 ppm	27.2 NTU
BA - 8 TOP	30.1° C	7.4 mg/L	7.89	51.1 mS/cm	38 ppm	25.4 NTU
BA - 8 BOTTOM	29.9° C	7.0 mg/L	7.78	51.3 mS/cm	39 ppm	30.9 NTU
BA - 9 TOP	29.3° C	7.0 mg/L	7.83	51.1 mS/cm	32 ppm	27.8 NTU
BA - 9 BOTTOM	29.2° C	6.9 mg/L	7.77	51.1 mS/cm	33 ppm	31.9 NTU
BA - 10 TOP	29.4° C	5.8 mg/L	7.85	50.4 mS/cm	33 ppm	28.3 NTU
BA - 10 BOTTOM	29.3° C	6.3 mg/L	7.82	50.6 mS/cm	33 ppm	35.2 NTU

Table 2. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Results of water quality sampling for the Control Area, CA, July 6, 7, & 11, 2000.

Sample Station	Temperature	Dissolved Oxygen	pH	Conductivity	Salinity	Turbidity
CA - 1 TOP	28.9° C	7.1 mg/L	7.79	48.4 mS/cm	32 ppm	30.9 NTU
CA - 1 BOTTOM	28.8° C	7.0 mg/L	7.66	48.4 mS/cm	31 ppm	37.9 NTU
CA - 2 TOP	29.1° C	7.1 mg/L	7.56	48.0 mS/cm	33 ppm	31.4 NTU
CA - 2 BOTTOM	29.0° C	6.9 mg/L	7.72	41.9 mS/cm	31 ppm	51.0 NTU
CA - 3 TOP	29.0° C	7.2 mg/L	7.79	41.9 mS/cm	35 ppm	27.5 NTU
CA - 3 BOTTOM	29.1° C	6.8 mg/L	7.82	41.9 mS/cm	35 ppm	58.0 NTU
CA - 4 TOP	29.4° C	6.9 mg/L	7.92	48.0 mS/cm	33 ppm	24.1 NTU
CA - 4 BOTTOM	29.4° C	6.8 mg/L	7.70	48.4 mS/cm	35 ppm	32.4 NTU
CA - 5 TOP	29.4° C	7.1 mg/L	7.87	41.4 mS/cm	35 ppm	23.5 NTU
CA - 5 BOTTOM	29.7° C	6.9 mg/L	7.83	41.8 mS/cm	36 ppm	42.0 NTU
CA - 6 TOP	29.7° C	6.6 mg/L	7.95	47.8 mS/cm	34 ppm	22.5 NTU
CA - 6 BOTTOM	29.5° C	6.6 mg/L	7.86	48.2 mS/cm	35 ppm	37.7 NTU
CA - 7 TOP	29.8° C	7.2 mg/L	7.90	47.6 mS/cm	32 ppm	24.2 NTU
CA - 7 BOTTOM	29.6° C	7.0 mg/L	7.80	48.2 mS/cm	33 ppm	39.0 NTU
CA - 8 TOP	30.0° C	7.3 mg/L	7.96	46.7 mS/cm	35 ppm	24.6 NTU
CA - 8 BOTTOM	29.5° C	7.0 mg/L	7.90	48.0 mS/cm	35 ppm	40.0 NTU
CA - 9 TOP	28.8° C	7.0 mg/L	7.69	50.0 mS/cm	32 ppm	28.8 NTU
CA - 9 BOTTOM	29.0° C	7.0 mg/L	7.61	50.0 mS/cm	32 ppm	31.9 NTU
CA - 10 TOP	30.2° C	7.1 mg/L	7.95	47.7 mS/cm	37 ppm	27.1 NTU
CA - 10 BOTTOM	30.0° C	6.8 mg/L	7.90	47.9 mS/cm	37 ppm	34.0 NTU

6.3 Sediment Data

Table 1. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Data table showing post-dredge percent sand, percent fines, and percent shell material. Sampled on July 6, 7, & 11, 2000.

Sample Station	Percent Sand	Percent Fines	Percent Shell*
BA - 1	95.68	3.32	1
BA - 2	97.52	1.48	1
BA - 3	97.82	2.18	0
BA -4	96.49	1.51	2
BA - 5	96.84	2.16	1
BA - 6	97.09	1.91	1
BA - 7	96.00	4.00	0
BA - 8	96.21	2.79	1
BA - 9	91.70	7.30	1
BA - 10	86.27	1.73	12
CA - 1	96.90	2.10	1
CA - 2	96.01	2.99	1
CA - 3	97.12	1.88	1
CA - 4	88.42	1.58	10
CA - 5	88.06	1.94	10
CA - 6	94.35	2.65	3
CA - 7	94.38	3.62	2
CA - 8	80.48	11.52	8
CA - 9	94.14	2.86	3
CA - 10	96.87	1.13	2

Figure 1. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Graph showing post-dredge sediment sample data for the Borrow Area percent sands composition. Sampled on July 6, 7, & 11, 2000.

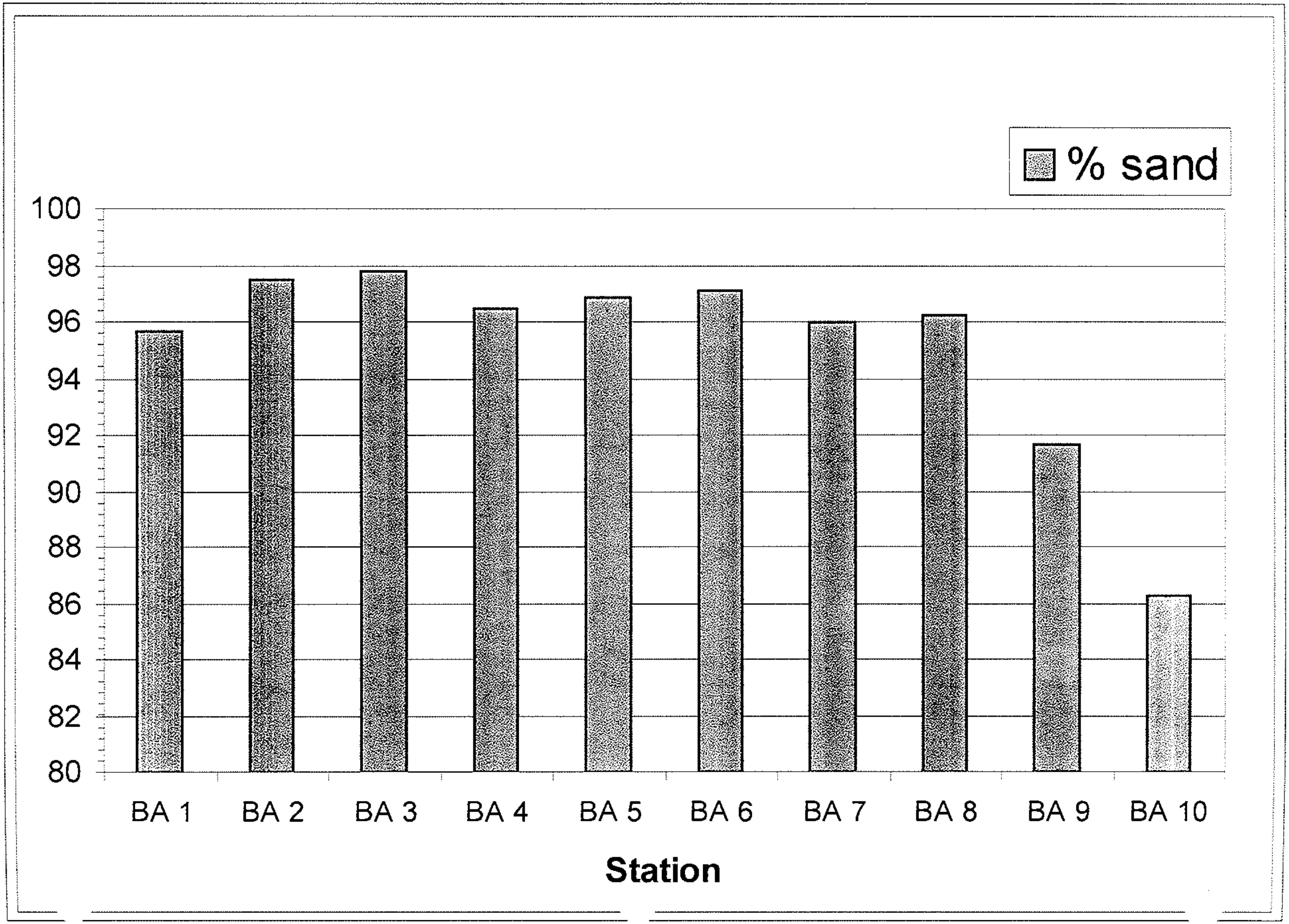


Figure . Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Graph showing post-dredge sediment sample data for the Borrow Area percent fines composition. Sampled on July 6, 7, & 11, 2000.

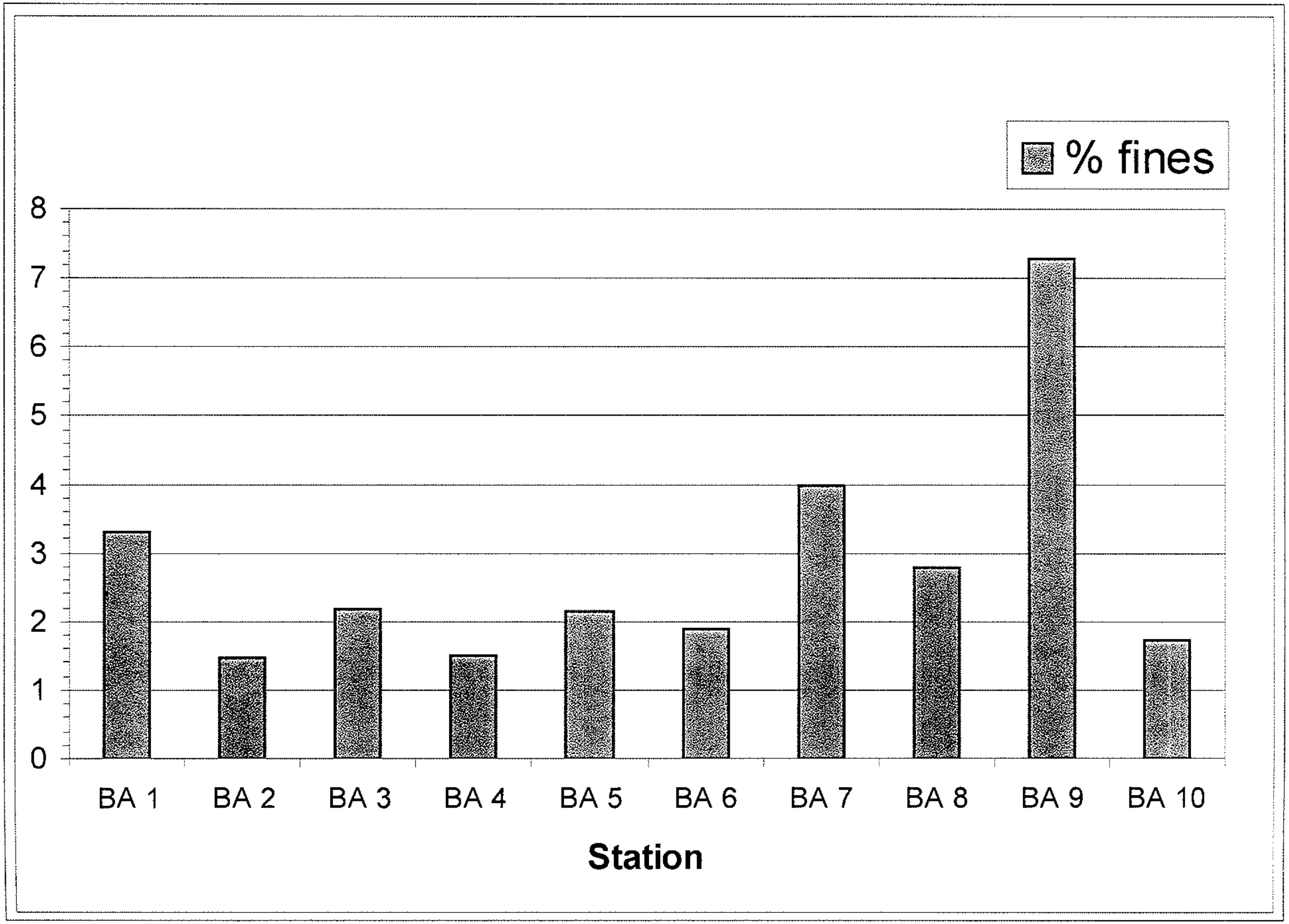


Figure 3. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Graph showing post-dredge sediment sample data for the Borrow Area percent shell composition. Sampled on July 6, 7, & 11, 2000.

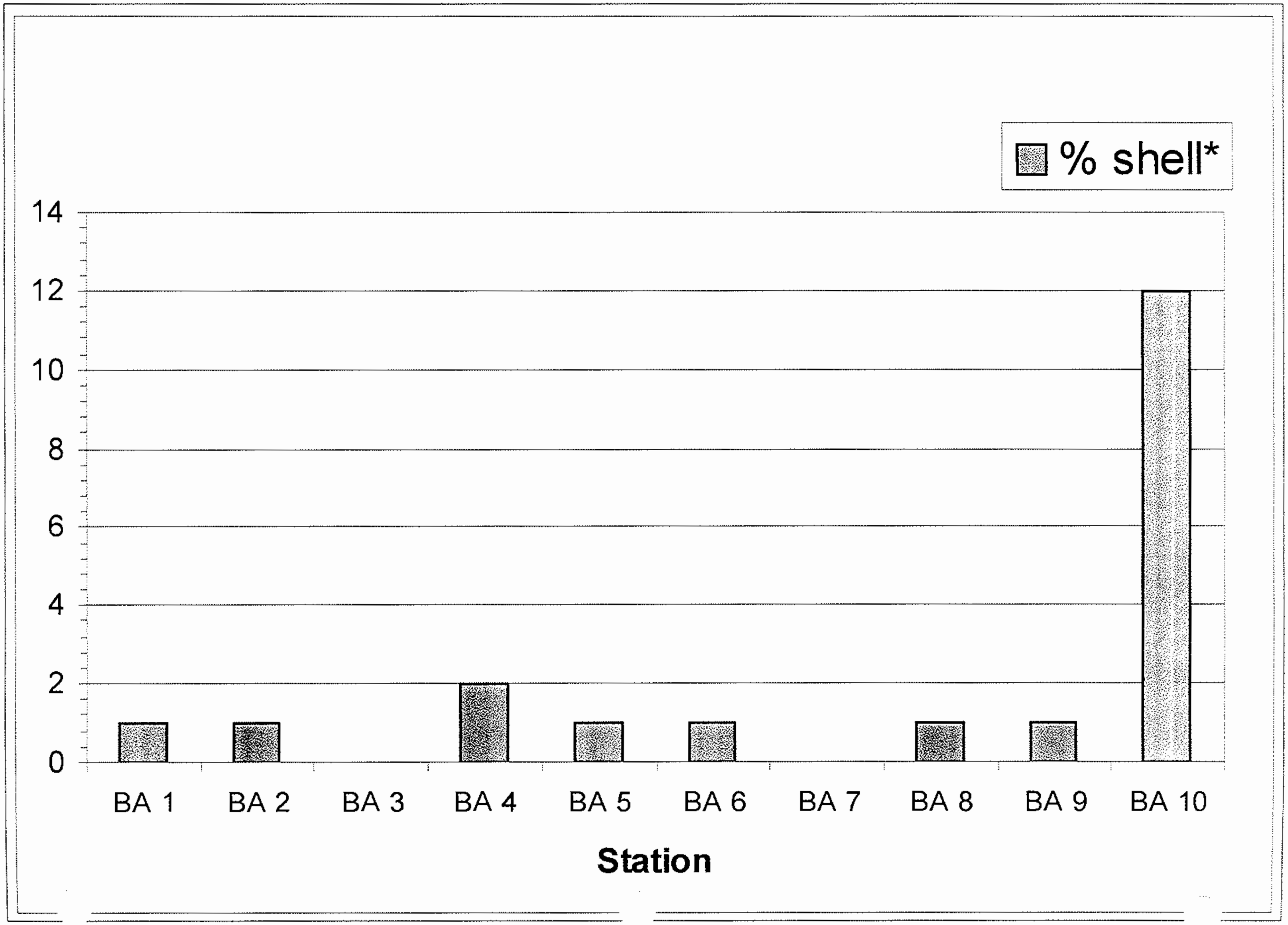


Figure ... Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Graph showing post-dredge sediment sample data for the Control Area percent sand composition. Sampled on July 6, 7, & 11, 2000.

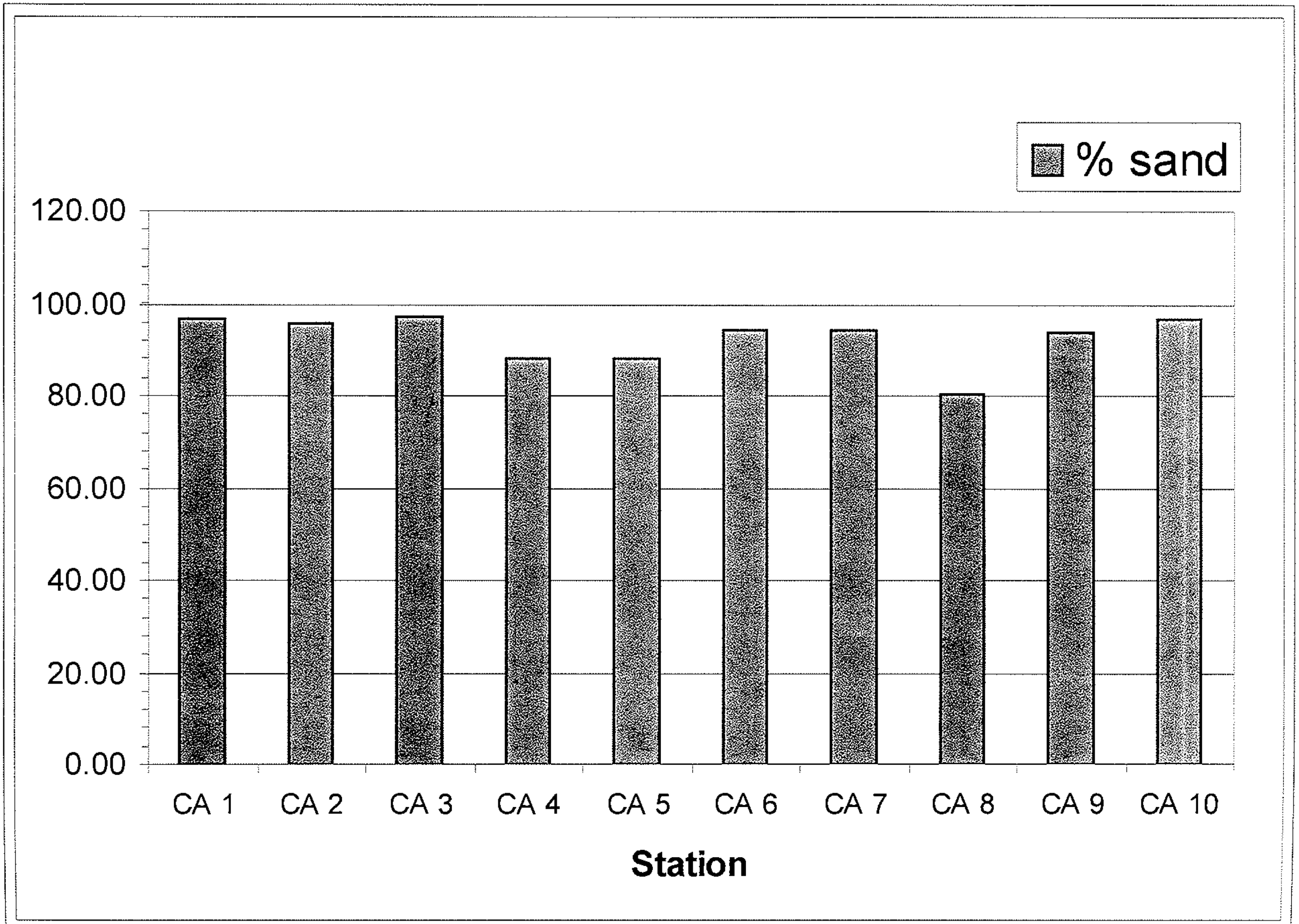


Figure 5. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Graph showing post-dredge sediment sample data for the Control Area percent fines composition. Sampled on July 6, 7, & 11, 2000.

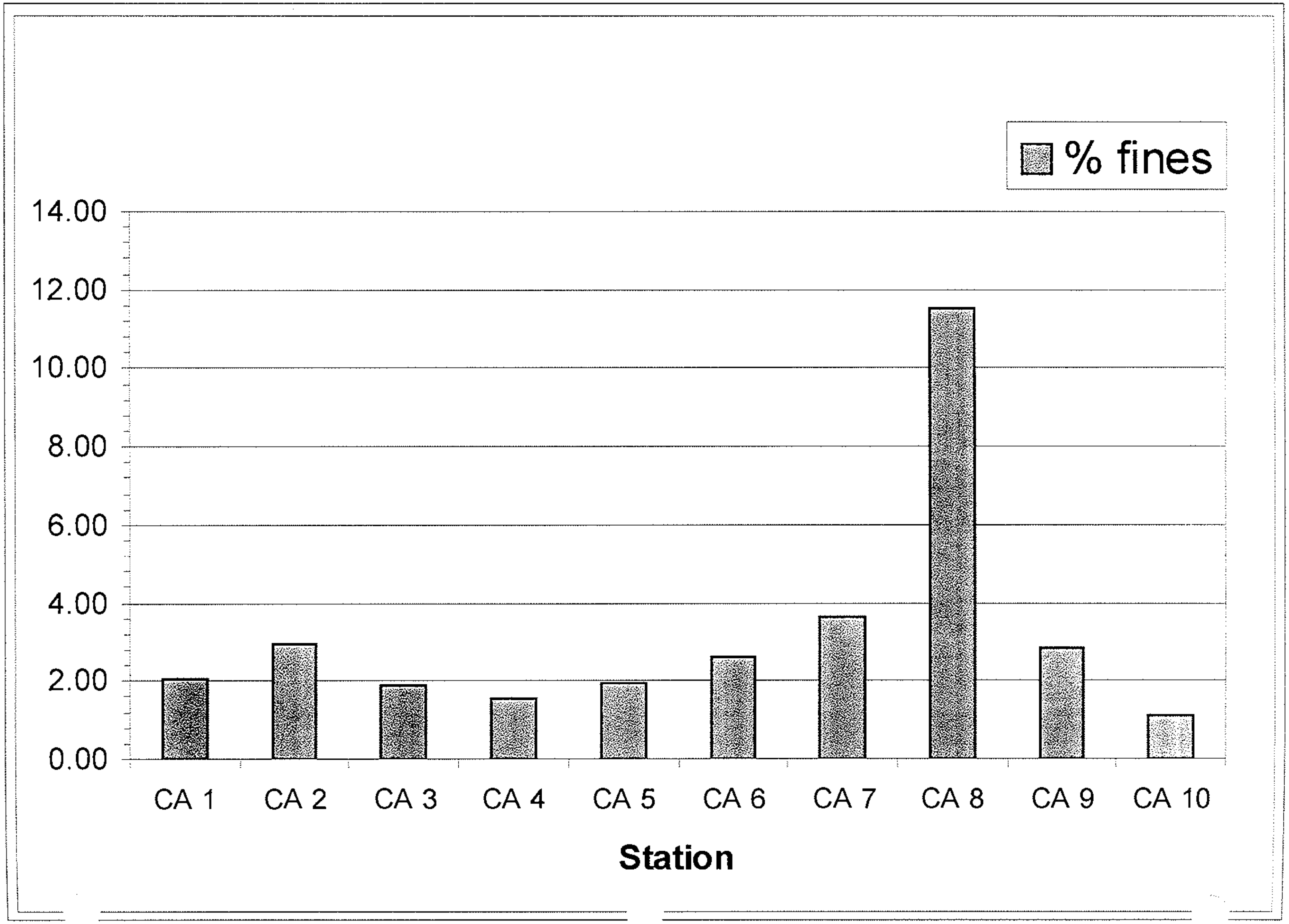
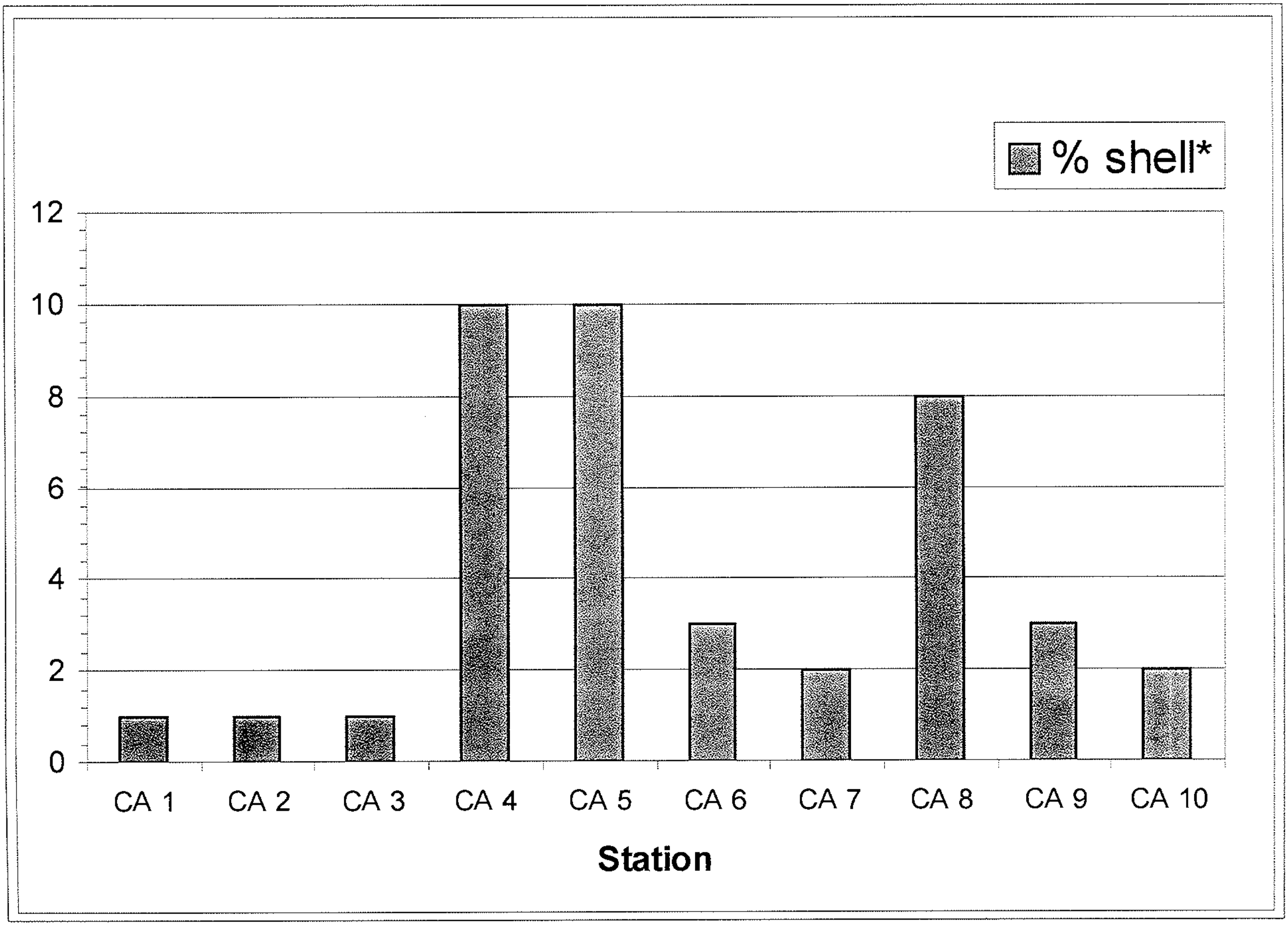


Figure [illegible]. Daufuskie Island Beach Nourishment Final Post-dredge Monitoring Study. Graph showing post-dredge sediment sample data for the Control Area percent shell composition. Sampled on July 6, 7, & 11, 2000.



APPENDIX A-5

PRELIMINARY COMPILATION OF DISPOSAL/NOURISHMENT ZONES
AND
BORROW AREAS IN RECOVERY FROM 5-YEAR RUNNING TOTAL

U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT

Prepared: February 2000 — Updated: September 2000

ATTACHMENT A-5

PRELIMINARY COMPILATION OF DISPOSAL/NOURISHMENT ZONES
U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT
Prepared: February 2000, Updated: September 2000

The information contained within the preliminary compilation has been prepared using available information. The proposed projects, extending to the year 2011, are included; however, the projected information is highly speculative and should not be used as factual data.

NAVIGATION PROJECTS

The Wilmington District performs routine maintenance dredging of navigation channels along the entire 320 miles of shoreline from the Virginia line to the north and the South Carolina to the south.

The beneficial use of dredged material that meets the criteria of greater than or equal to 90% sand (retained by #200 sieve or greater than or equal to 0.074 mm) is an integral part of the navigation program. Where possible, clean, beach quality material, removed from the navigation channels, is placed in the wave uprush zone of nearby beaches or on control-of-effluent islands used by nesting colonial waterbirds. The placement of material in this manner is consistent with Section .1100 of the Coastal Management regulations (TT15A:07M.1100).

The beneficial placement of material removed from the navigation projects back into the littoral system is performed by hydraulic pipeline dredge with the pipeline extending from the area being dredged to the approved beach disposal area. The material is placed within the wave uprush zone at the proper elevation that allows the material to be under tidal influence creating a gentle slope without escarpments. The purpose of placement of material is not to build up the beachfront dune or berm system, only to return the material to the littoral system. This is the difference between what is referred to as disposal versus beach nourishment associated with a Beach Erosion Control and Hurricane Protection Project such as Wrightsville Beach.

NOURISHMENT PROJECTS

The District currently maintains active Beach Erosion Control and Hurricane Wave Protection Projects at Wrighstville Beach, Carolina Beach and Vicinity and Carolina Beach-South (Kure Beach). The Brunswick County Beaches, Ocean Isle Portion, is proposed for construction in FY 2001. Additional studies are currently underway for Beach

Erosion Control and Hurricane Wave Protection Projects at Brunswick County Beaches, Oak Island and Caswell Beach Portion and the Holden Beach Portion, and Dare County Beaches. These three projects are currently proposed for construction, contingent upon approval, for FY 2004 and FY 2005. Nourishment is generally performed by a hydraulic pipeline dredge and includes the construction/maintenance of a dune and berm system. The compatibility of the beachfront material in relationship to the borrow source is evaluated prior to placement of material. Pending studies include the Towns of Topsail Beach, North Topsail Beach, and Surf City; Bogue Banks, and the Hatteras to Ocracoke Portion of Dare County Beaches.

SUMMARY

The placement of dredged material within the 320 miles of beachfront along the North Carolina coastline is summarized below by mileage and maintenance schedule. The summary is broken down by disposal versus nourishment events. This breakdown is necessary to delineate between material placed in the wave uprush area versus on the upper beach and dune system. The computations are made based on actual mileage used during any given disposal event. For instance, an approved 5-mile of beachfront may be designated for disposal; however, during a given event only 0.4 to 1 mile of beachfront may be impacted. Calculations were made based on a 16-year period and percentage of North Carolina Shoreline (320 miles) impacted.

DISPOSAL ACTIVITIES

- Average/year – 8.0 miles or 2.5% of total NC Shoreline (320 miles)
- Minimum for any year – 3.5 miles or 1% of total NC Shoreline
- Maximum for any given year is 22.4 miles or 7.0% of total NC Shoreline

EXISTING BEACH NOURISHMENT

- Average of 2.9 miles or 1% of NC Shoreline
- Minimum of 0 (possible that no beach nourishment in any given year)
- Maximum of 9.8 (all occur at same time) which is 3.1% of NC Shoreline

PROPOSED BEACH NOURISHMENT

- Average of 16.9 miles or 5.3% of NC Shoreline
- Minimum would be 0 (possible none occurred)
- Maximum of 85.0 miles which is 26.6% of NC Shoreline

CUMULATIVE (averaging both disposal and nourishment projects existing and future)

- Average impact from existing disposal and nourishment (8.0 + 2.9) = 11.0 miles, 3.4 % of NC Shoreline
- Maximum impact (worst case) from existing beach disposal and nourishment activities (22.4 + 9.8) = 32.2 miles, 10.1% of NC Shoreline
- Average impact from existing disposal and nourishment projects and proposed projects (8.0 + 2.9 + 16.9) = 27.8 miles, 8.7% of NC Shoreline
- Maximum impact (worst case) from existing disposal and nourishment and proposed beach nourishment (22.4 + 9.8 + 85.0) = 117.2 miles, 36.6% of NC Shoreline

TABULATION OF BEACH DISPOSAL AND NOURISHMENT PROJECTS
U.S. ARMY CORPS OF ENGINEERS – WILMINGTON DISTRICT
Prepared and Updated September 2000

USGS QUAD #	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ACTUAL DISPOSAL LIMITS	ESTIMATED QUANTITY CU. YDS	COMMENTS
Outer Banks	Avon	Begins at a point 1.15 miles south of Avon Harbor and extends north 3.1 miles	3.1 miles (16,368 lf)	0.4 miles or2,000 linear feet	<50,000 every 6 yrs	Special Use Permit Required from NPS/CHNS
	Rodanthe	Extends from rd to Rodanthe Harbor south 700' to south end of beach disposal area (straight out from existing dirt road). North end at Wildlife Refuge Boundary (PINWR)	.91 miles or 4,800 linear feet	0.4 miles or 2,000 linear feet	<100,000 every 6 yrs	Special Use Permit Required from NPS/CHNS
	Ocracoke (Ocracoke Island	Begins at a point 5,000 linear feet south of Hatteras Inlet and extends southward about 3,000 linear feet.	0.6 mile or 3,000 linear feet	0.4 mile or 2,000 linear feet	<100,000 every 2 to 3 years	Special Use Permit Required from NPS/CHNS
	Rollinson (Hatteras)	Begins at a point 0.85 miles south of Hatteras Harbor and extends north 5.85 miles to a	5.85 miles (30,888 lf)	0.4 miles or 2,000 linear	<60,000 every 2 years	Special Use Permit NPS/CHNS

USGS QUAD #	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ACTUAL DISPOSAL LIMITS	ESTIMATED QUANTITY CU. YDS	COMMENTS
Outer Banks	Silver Lake (Teaches Hole/Ocracoke)	From a point 2,000'NE of inlet and extending approximately 2,000 linear feet (0.4 miles) to the NE (Ocracoke Island)	0.4 miles or 2,000 linear ft	0.4 miles or 2,000 linear feet	<50,000 every 2 yrs	Special Use Permit NPS/CHNS
	Oregon Inlet		3 miles or 15,840 linear feet	1.5 miles or 7,920 linear feet	300,000 Annually	Special Use Permit USFWS/PINWR
Outer Banks	Drum Inlet	Core Banks. From a point 2,000 feet on either side of inlet extending for 1 mile in either direction	2 miles 10,560 linear ft	1 mile or 5,280 linear feet	298,000 initial, 100,000 maint. Unscheduled Assume 8 year cycle	SUP from NPS/CLNS (Included in analysis; however, no determination of site being reused can be made at this time.)
Beaufort (22)	Morehead City (Brandt Island)	2,000 ft west of inlet, Fort Macon and Atlantic Beach to Coral Bay Club, Pine Knoll Shores	7.3 miles 38,300 linear ft	5.2 miles or 27,800 linear feet	3.5 million every 8 yrs	Material from Ocean Bar routinely placed in nearshore berm or ODMDS on annual basis

USGS QUAD #	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ACTUAL DISPOSAL LIMITS	ESTIMATED QUANTITY CU YDS	COMMENTS
Beaufort (22)	AIWW Section I, Tangent B	Pine Knoll Shores, vicinity of Coral Bay	2 miles (10,500 lf)	0.4 miles or 2,000 linear feet	<50,000 every 5 yrs	This area is included every 8 years as part of pumpout of Brandt Island. Also included in the area under investigation for beach nourishment at Bogue Banks.
Swansboro (25)	AIWW Bogue Inlet Crossing Section I, Tangent-H through F	Approx. 2,000 feet from inlet going east to Emerald Point Villas, Emerald Isle (Bogue Banks)	1mile or 5,280 linear feet	0.4 miles or 2,000 linear feet	<100,000 annually	
Browns Inlet (27/28)	AIWW Section II, Tangents-F,G,H	Camp Lejeune, 3,000 feet west of Browns Inlet extending westward	1.58 miles or 6,000 linear feet	1 mile or 5,280 linear feet	<200,000 every 2 yrs	
New River Inlet (28)	AIWW, New River Inlet Crossing Section II, Tangents I & J, Channel to Jax. Section III, tangents 1&2	N. Topsail Beach, 3,000 feet west of inlet extending westward to Maritime Way (Galleon Bay area)	1.5 miles or 8,000 linear feet	0.8 miles or 4,000 linear feet	<200,000 annually	Two areas 2,000 linear feet on either side of disposal area are routinely used.

USGS QUAD #	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ACTUAL DISPOSAL LIMITS	ESTIMATED QUANTITY CU. YDS	COMMENTS
Hampstead (33)	AIWW, Sect. III	Topsail Island, Queens Grant	0.6 miles or 2,500 lf	0.6 miles or 2,500 lf	<50,000 every 6 yrs	
Hampstead (33)	AIWW, Topsail Inlet Crossing & Topsail Creek	Topsail Beach, from a point 2,000 feet north of Topsail Inlet	1 mile or 5,280 lf	0.4 mi or 2,000 ft	<75,000 annually	
Wrightsville Beach (35)	AIWW Sect. III,Tang 11&12 Mason Inlet Crossing	Shell Island (north end of Wrightsville Beach from a point 2,000 feet from Mason Inlet	0.4 mi. or 2,000 linear feet	0.4 mi. or 2,000 lf	<100,000 NOT SCHEDULED	Not required for past 8 years since inlet crossing closed up. If reopened will be rescheduled if needed. (Not included in analysis.)
Wrightsville Beach (35)	Masonboro Sand Bypassing	At a point 9,000 feet from jetty extending southward midway of island	1.2 miles or 6,000 lf	1 mile 5,280 lf	500,000 every 4 years	Same time as Wrightsville Beach nourishment
Carolina Beach (36)	AIWW, Section IV, Tangent 1	Southern end of Masonboro Island at a point 2,000 linear feet from Carolina Beach Inlet extending northward to Johns Bay area	1.3 miles (7,000 linear feet)	0.4 miles (2,000 linear feet)	<50,000 annually	This site is used alternately with Carolina Beach Disposal Site on North End of Island

USGS QUAD #	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ACTUAL DISPOSAL LIMITS	ESTIMATED QUANTITY CU. YDS	COMMENTS
Beachfront on eastern end of island	4.7 miles or (25,000 linear feet)			4.7 miles or (25,000 linear feet)	1.1 million every 6 years	Disposal of material from Wilmington Harbor Ocean Bar Project
Bald Head	Bald Head	Beach front on eastern and western shoreline	3.0 miles or 16,000 lf	3.0 miles or 16,000 lf	1.1 million every 2 years (Except every 6th year when it	Disposal least costly from Wilmington Harbor Ocean Bar Project
EXISTING BEACH NOURISHMENT PROJECTS						
Wrightsville Beach (35)	Wrightsville Beach Nourishment Project	From South side of Water Tower to Sand Dollar Lane to the north	3 miles of beach or 14,000 lf	3 mi 14,000 lf	1 million every 4 years	3 miles includes 2,000 lf transition area
Carolina Beach (36/37)	Carolina Beach North	500 feet north of Carolina Beach pier extending southward to town limits of Hanby Beach	3 miles or 14,000 linear feet	3 miles or 14,000 linear feet	1 million every 3 years	Renourished concurrent with Carolina Beach South. 3 mi. includes natural transition area.
Carolina Beach (36/37)	Carolina Beach South (Kure Beach)	Town Limits of Hanby Beach extending southward to a point just north of the Riggings	3.8 miles or 18,000 linear feet	3.8 miles or 18,000 linear feet	1 million every 3 years (3.3 million initial placement 97/98)	Renourished concurrent with Carolina Beach North Project. 3 mi. includes natural transition area.

USGS QUAD #	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ACTUAL DISPOSAL LIMITS	ESTIMATED QUANTITY CU. YDS	COMMENTS
		SCHEDULED BEACH NOURISHMENT/933/1135 PROJECTS AND PROPOSED STUDIES				
FY 2001 Brunswick Co. Bches	Ocean Isle Portion	Beachfront of Ocean Isle Beach	5.3 miles (28,000 lf)	5.3 miles (28,000 lf)	TBD	Pending Funding
FY 2001/2/4 Brunswick Co. Bch	Oak Island and Caswell Beach Portion	Beachfront of Oak Island and Caswell Beach	10.3 miles (54,384 lf)	10.3 miles (54,384 lf)	TBD	933 (Wilmington Harbor Project), year 2001/2; 1135 Sea Turtle Habitat Restoration Project, year 2001, both funded and approved. Brunswick County Beaches Portion, Pending approval of GRR and NEPA, 2004
FY 2005 Brunswick Co. Bches	Holden Beach Portion	Beachfront of Holden Beach	7.6 miles (40,120 lf)	7.6 miles (40,120 lf)	TBD	Pending Completion and approval of GRR/NEPA
FY 2013 North Topsail Beach	N. Topsail Beach, area outside CBRAo	Beachfront of Town of North Topsail Beach	12 mile study area (63,360 linear feet)	5 miles (26,400)	TBD	Recon Requested; no study underway. Study area will not include approx. 7 miles of beachfront witihn Coastal Barrier Resources Zone
FY 2006 Bogue Banks	Bogue Banks	Beachfront of Bogue Banks from Beaufort Inlet to Bogue Inlet	17.1 miles total miles (90,288 linear feet)	17.1 miles (90,288 lf) , 3 phases, 5.7 mi. ea. phase	TBD	Recon level Feasibility Study requested; no study underway. Project to be completed in 3 5.7 mile phases

USGS QUAD #	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ACTUAL DISPOSAL LIMITS	ESTIMATED QUANTITY CU. YDS	COMMENTS
FY 2008 Topsail Beach	Town of Topsail Beach	Beachfront of Topsail Island within Town limits of Topsail Beach	10 miles (52,800 lf)	10 miles (52,800 lf)	TBD	Pending funding of GRR/NEPA
FY 2011 Surf City	Town of Surf City	Beachfront of Topsail Island within Town limits of Surf City	5.5 miles (29,040 linear feet)	5.5 miles (29,040 linear feet)	TBD	Recon Requested; no study underway
FY 2004 Dare County Beaches	Dare County Bodie Island Portion	Beachfront of Kitty Hawk and Nags Head	14.2 miles (74,976 lf)	14.2 miles (74,976 lf)	Initial 12.3 million; Nourishment 3.9 every 3 years	Pending approval of Feasibility Study and EIS
FY 2004 Kitty Hawk North	Kitty Hawk	Beachfront of Kitty Hawk	2.2 miles (11,616 lf)	2.2 miles (11,616 lf)	TBD	Request for additional study. Not included in analysis
FY 2008 Dare County Beaches	Hatteras to Ocracoke Portion	Beachfront of Hatteras and Ocracoke Islands (HOT SPOTS)	10 miles (52,800 lf)	10 miles (52,800 lf)	TBD	Pending completion of Feasibility Study and EIS

K7eppgnw/beachmanagement/updateddispinfo0

APPENDIX B

APPENDIX B

Magnetometer Report

(TAR)

A Submerged Cultural Resources Remote Sensing Survey of Three Proposed Borrow Areas for the Bogue Banks Beach Nourishment Project in Carteret County, North Carolina

Submitted to:

CSE Baird LLC
P.O. Box 8056
Columbia, South Carolina 29202-8056

and

Stroud Engineering, P.A.
Hestron Plaza Two, Suite A
151-A Highway 24
Morehead City, North Carolina 28557

Submitted by:

Tidewater Atlantic Research, Inc.
P. O. Box 2494
Washington, North Carolina 27889

3 February 2000

Abstract

Carteret County is planning to conduct a nourishment project to rebuild the beaches along Bogue Banks. The proposed project will require borrowing sand from three areas south of Pine Knoll Shores, Salter Path and Indian Beach. In order to determine the proposed project's impact on potentially significant submerged cultural resources, Stroud Engineering, P.A. and CSE Baird LLC contracted with Tidewater Atlantic Research, Inc., (TAR) of Washington, North Carolina to conduct a systematic proton precession magnetometer and side scan sonar survey. The proposed remote sensing survey was designed to locate and identify submerged cultural resources in the study areas and generate sufficient data to make an initial assessment of each target's significance and provide insight into the necessity for avoidance or additional investigation. That survey was carried out between 7 and 13 December 1999. No magnetic or acoustic anomalies were identified in either Borrow Area A or Borrow Area B-1. In Borrow Area B-2, 10 magnetic anomalies were identified near the western end of the survey area. Seven of those targets contained signature characteristics indicative of significant submerged cultural resources. Because they could be associated with an historic shipwreck, either avoidance or additional investigation to positively identify the nature and significance of material generating the seven anomalies is recommended. If avoidance of the area is possible, no additional investigation should be necessary.

Table of Contents

List of Figures

Introduction

Stroud Engineering, P.A., is working with Carteret County on beach renourishment projects on Bogue Banks. The source material for the project has been identified as three areas south of Pine Knoll Shores, Salter Path and Indian Beach. In order to determine the proposed project's effects on potentially significant submerged cultural resources, Stroud Engineering, P.A. and CSE Baird LLC contracted with Tidewater Atlantic Research, Inc., (TAR) of Washington, North Carolina to conduct a systematic proton precession magnetometer and side scan sonar survey to locate, identify and assess the significance of any underwater cultural material in the proposed borrow areas.

The investigation conducted by TAR was designed to provide accurate and reliable identification, assessment and remote sensing documentation of submerged cultural resources in the prospective project areas in terms of the criteria established in compliance with the National Historic Preservation Act of 1966, as amended and the Archaeological and Historic Preservation Act of 1979, as amended. The results of the investigation will provide Stroud Engineering, P.A. and CSE Baird LLC with the archaeological data essential for complying with submerged cultural resource legislation and regulations.

The methodology employed by TAR combined state of the art technology, experienced personnel and an investigative technique designed to generate appropriate historical and remote sensing data. Fieldwork activities associated with the project were carried out between 7 and 13 December 1999. Analysis of the remote sensing data identified 10 anomalies within the western part of Borrow Area B2. Seven of those targets contained signature characteristics indicative of significant submerged cultural resources and were recommended for further investigation. No magnetic or acoustic anomalies were detected in Borrow Areas A or B1.

Coordination for the survey was provided by Bill Forman, Stroud Engineering, and Phil McKee, CSE Baird. The field project staff included Dr. Gordon P. Watts, Jr., the principal investigator, archaeologists Raymond Tubby and Steve Brodie and archaeological assistants Mark Padover and Mike Phillips. Data analysis, historical research and report preparation were carried out by Gordon Watts, Raymond Tubby and Robin Arnold. All members of the project staff exceed the minimum standards for archaeological personnel identified by the Department of Interior and the North Carolina Division of Archives and History.

Project Location

The three Carteret County Borrow Areas are located south of Bogue Banks between Atlantic Beach and Emerald Isle. Borrow Area A forms an "L"-shaped polygon south-southeast of Salter Path and Indian Beach. Borrow Area B-1 is a long rectangular polygon offshore of and roughly parallel to the shoreline of the west extremity of Atlantic Beach and Pine Knoll Shores. Borrow Area B-2 is a long rectangular polygon offshore of and roughly parallel to the shoreline of Salter Path, Indian Beach and eastern Emerald Isle (Figure 1).

North Carolina State Plane Coordinates, NAD 1983 for Borrow Area A are:

Point	Northing	Easting
A	331043.56	2624077.59
B	341655.89	2623855.74
C	341761.05	2628865.86
D	338728.96	2628929.75
E	338861.61	2635193.01
F	331281.44	2635354.35

North Carolina State Plane Coordinates, NAD 1983 for Borrow Area B-1 are:

Point	Northing	Easting
A	350432.77	2670926.10
B	348405.98	2656162.79
C	346614.84	2644048.87
D	344906.79	2644085.74
E	346309.33	2656016.78
F	348359.78	2670922.61

North Carolina State Plane Coordinates, NAD 1983 for Borrow Area B-2 are:

Point	Northing	Easting
A	340961.55	2610140.28
B	342151.31	2616103.44
C	345657.97	2640081.60
D	343904.64	2640269.91
E	340397.98	2616480.06
F	338957.74	2610391.36

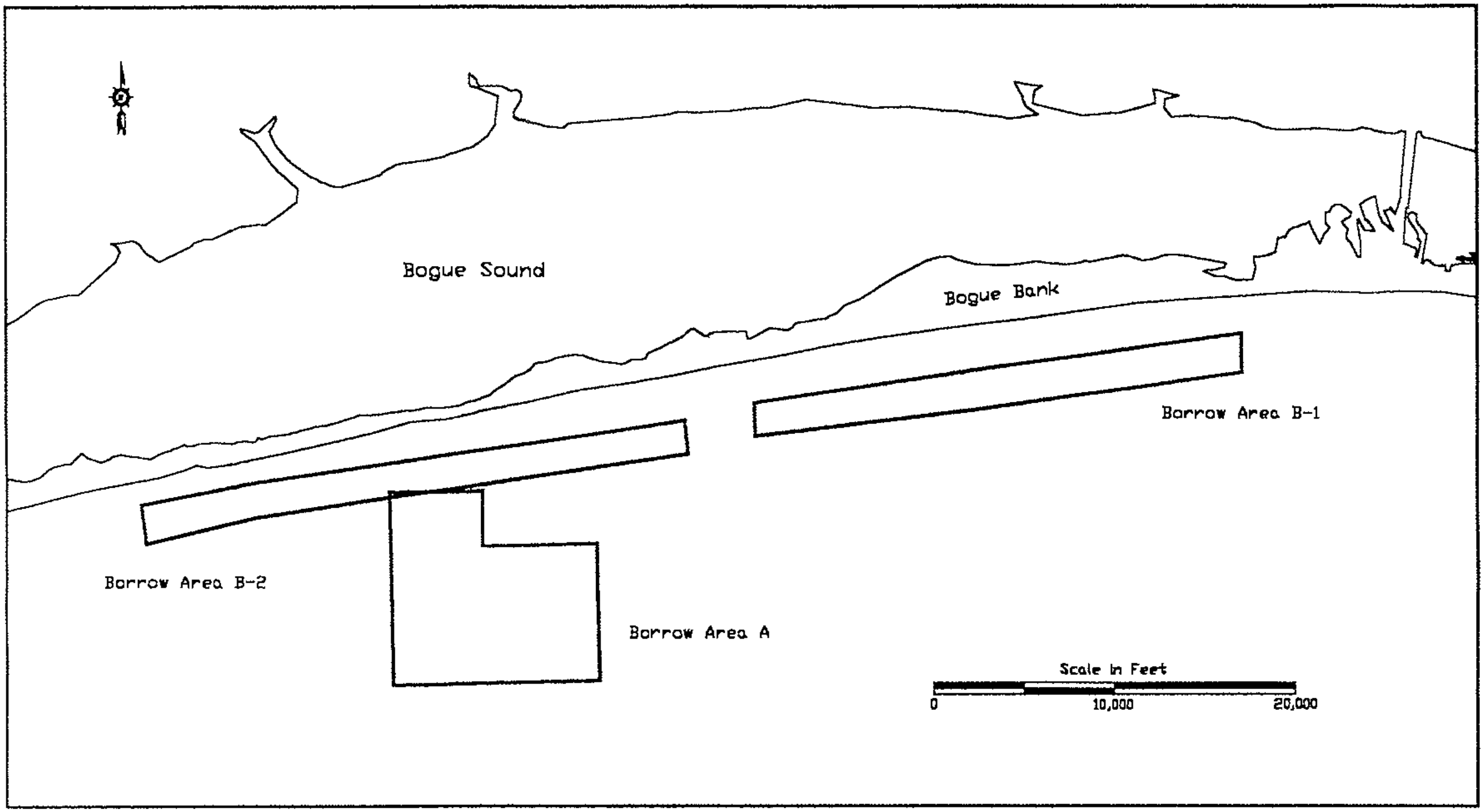


Figure 1. Project Location Map.

Project Research Objectives

The Bogue Banks Borrow Area survey was initiated in order to comply with the criteria of National Historic Preservation Act of 1966, as amended, through 1992 (36 CFR 800, Protection of Historic Properties), the Abandoned Shipwreck Act of 1987 (*Abandoned Shipwreck Act Guidelines*, National Park Service, *Federal Register*, Vol. 55, No. 3, 4, December 1990, pages 50116-50145) and the Secretary of Interior's Standards and Guidelines for Archaeology and Historic Preservation (*Federal Register* 48, No. 190, 1983). In keeping with the intent of that legislation and associated regulations Stroud Engineering and CSE Baird determined that a remote sensing survey would be necessary to assess the potential impact of proposed project activities on submerged cultural resources in the project areas. The remote sensing survey conducted by TAR was designed to identify magnetic and/or acoustic anomalies that might be generated by shipwreck resources, assess the potential significance of each one and determine the necessity for additional investigation designed to generate data to support a preliminary determination of National Register of Historic Places eligibility.

Research Methodology

Literature, Historical and Archival Research

In order to generate historical data to facilitate identification of shipwreck remains in the Beaufort/Morehead vicinity, records from a variety of repositories were examined. At the Underwater Archaeology Unit in Kure Beach, the archaeological site files were surveyed for both historic and prehistoric submerged archaeological sites in the Beaufort Inlet area. Similar surveys of site file inventories were also conducted in the Anthropology Department Research Laboratory and the Program in Maritime History and Underwater Research at East Carolina University in Greenville, North Carolina.

A literature and archival investigation was also initiated by a survey of secondary source materials associated with the historical development of eastern North Carolina. The survey focused on documentation of activities such as exploration, colonization, development, agriculture, industry, trade, shipbuilding, commerce, warfare, transportation and fishing that would have been contributing factors in the loss of vessels in the vicinity of the proposed borrow areas. In examining each of these factors special attention was devoted to activities associated with navigation in the vicinity of Beaufort Inlet.

Preliminary wreck specific information was collected from such secondary sources as: *The Encyclopedia of American Shipwrecks* (Berman 1972); *Merchant Steam Vessels of the United States 1807 - 1868* (Lytle and Holdcamper 1952); *Disasters to American Vessels, Sail and Steam, 1841-1846* (Lockhead 1954); *Shipwrecks of the Civil War, The Encyclopedia of Union and Confederate Naval Losses* (Shomette 1973); *Shipwrecks of the Western Hemisphere* (Marx 1971); *Shipwreck Encyclopedia of The Civil War: North Carolina, 1861-186* (Spence 1991) and other published materials. Additional information was also generated by a survey of selected North Carolina newspapers, the Wreck Information List of the U.S. Hydrographic Office, National Oceanic and Atmospheric Administration and maritime records associated with Beaufort and Morehead City. Select historic maps and charts preserved in the collections of the National Archives Cartographic Branch in College Park, MD and North Carolina repositories of cartographic data were also examined.

Relevant sources of shipwreck data preserved in the North Carolina Division of Archives and History in Raleigh; Underwater Archaeology Unit of the Division of Archives and History at Kure Beach; the Steamship Historical Society, Baltimore; Mystic Seaport Museum, Connecticut; the National Archives and the Mariners Museum at Newport News, Virginia were surveyed for site specific data associated with the Beaufort Inlet, Bogue Bank and Shackleford Bank areas. TAR personnel also contacted and interviewed the head of the Underwater Archaeology Unit, area archaeologists, historians and other individuals knowledgeable in maritime history and shipwreck research to solicit their assistance in generating wreck data.

Field Investigations

To reliably identify submerged cultural resources, TAR conducted a systematic remote sensing survey of the proposed borrow areas identified in the Scope of Work. TAR personnel utilized 31-foot and 25-foot vessels to conduct the survey. In order to fulfill the requirements stated in the Scope of Work, TAR employed both magnetic and acoustic remote sensing equipment. A combination of magnetic and acoustic remote sensing equipment represent the "state-of-the-art" in submerged cultural resource location technology and offers the most reliable and cost effective method of locating and identifying potentially significant targets. Data collection was controlled using a differential global positioning system (DGPS). The DGPS produces the highly accurate coordinates necessary to support a sophisticated navigation program and assure reliable target location.

Magnetic Remote Sensing

An EG&G Geometrics 866 dual channel proton precession magnetometer capable of plus or minus 0.1 gamma resolution was employed to collect magnetic data in the survey areas. To produce the most comprehensive magnetic record, data were collected on a two-second interval and the sensor was deployed and maintained in the water column at a depth of 10 to 12 feet above the bottom surface. An analog recorder provided a continuous permanent record of the magnetic background and target signatures. Because of the historical nature of the area, magnetic data were collected along transects spaced on 100-foot intervals and recorded on both an analog recorder and as a data file associated with the computer navigation system. Data from the survey were contour plotted using QuickSurf computer software to facilitate anomaly location and definition of target signature characteristics. All magnetic data were correlated with the acoustic remote sensing records.

Acoustic Remote Sensing

A 500 kHz Klein 521 high resolution side scan sonar was employed to collect acoustic data in the survey area. During the survey, the side scan sonar transducer was deployed and maintained at a 10-foot elevation above the bottom surface. Because of the historical nature of the area and the requirements for collecting magnetic data, acoustic data were also collected along transects spaced on 100-foot intervals. Sonar range scales were selected to provide a combination of 100% coverage of the survey area and high target signature definition. Acoustic data were recorded on a two channel wet-paper recorder and tied to the magnetic and positioning data by the computer navigation system event marking program.

Positioning System

A differential global positioning system (DGPS) was used to control navigation and data collection in the survey areas. The system has an accuracy of plus or minus three feet, and can be used to generate highly accurate coordinates for the computer navigation system. Differential corrections were received from the United States Coast Guard Beacon at Fort Macon, North Carolina. A Furuno GP-35 differential global positioning system was employed in conjunction with on-board IBM compatible 486-66 BSI and Pentium 233MMX ProStar computers loaded with a Coastal Oceanographics Hypack navigation and data collection software program. All magnetic and acoustic records were tied to positioning events generated by Hypack. Positioning data generated by the navigation system were tied to magnetometer records by regular annotations to facilitate target location and anomaly analysis. Annotations included lane number, date, start and end of lane, direction and target identification.

Data Analysis

To ensure reliable target identification and assessment, analysis of the magnetic and acoustic data were carried out as it was generated. Using QuickSurf contouring software, magnetic data generated during the survey were contour plotted at 10 gamma intervals for analysis and accurate location of the material generating each magnetic anomaly. Magnetic targets were isolated and analyzed in accordance with intensity, duration, areal extent and signature characteristics. Sonagram signatures associated with magnetic targets were analyzed on the basis of configuration, areal extent, target intensity and contrast with background, elevation and shadow image.

Data generated by the remote sensing equipment were developed to support an assessment of each magnetic and acoustic signature. Analysis of each target signature included consideration of magnetic and sonar signature characteristics previously demonstrated to be reliable indicators of historically significant submerged cultural resources. Assessment of each target included recommendations for additional investigation to determine the exact nature of the cultural material generating the signature and its potential National Register significance. Historical evidence was developed into a background that identified possible correlations with magnetic targets. A magnetic contour map of each survey area was produced to aid in the analysis of each target. All targets were listed and described and a map produced that showed their location within the project area.

Historical Overview of Beaufort/Morehead City Vicinity

Among the earliest residents of Shackleford Banks and Cape Lookout during the late 1600s and early 1700s were whalers, who established a series of temporary camps and shelters amid the dunes. By the 1720s, Cape Lookout and Shackleford Banks became a more permanent base of operations for New England whalers (Angley 1982:5). When Beaufort was appointed as "a port for the unloading and discharging [of] vessels," in 1722 it was clear that successful development would also depend on trade entering and clearing through Beaufort Inlet (Paul 1970:370-373; Angley 1982:8). Unlike many of the inlets along the North Carolina coast, Beaufort Inlet was relatively stable and offered a safe and deep channel for ship traffic (Stick 1958:312).

Not all of the vessels bound for Beaufort were successful in navigating the inlet. In November 1718, the pirate Blackbeard lost two vessels on or near the bar. Both the ship *Queen Anne's Revenge* and the sloop *Adventure* were run aground, perhaps deliberately. Many of the crew of the *Queen Anne's Revenge* and the *Adventure* were abandoned on Shackleford Banks while Blackbeard and a hand-picked crew sailed for Bath in the remaining sloop.

Although Beaufort remained a relatively unimportant port during the 18th century it did play a small role in Revolutionary War maritime activity. While the blockade imposed upon the American coast by the British Navy seriously impacted trade for many Colonial ports, shipping through Beaufort provided a portion of the supplies needed by the Patriots in North Carolina. In the years that followed the Revolution, North Carolina experienced an increase in the volume of maritime trade and shipbuilding. Just after the turn of the century, Beaufort Inlet was described as one of the best on the North Carolina coast, with "the channel being generally 3 1/4 to 3 1/2 fathoms" deep. Beaufort was also mentioned as having a fairly vigorous, though small, shipbuilding industry (Tatham 1806). In 1810, Jacob Henry, a former representative from Carteret County to the North Carolina House of Commons, commented upon the local shipbuilding industry at Beaufort:

> The principal trade carried on here is ship building in which they have acquired a very considerable reputation.... Live oak and Cedar are the timbers principally used but the stock is by no means so abundant as it has been. Some of the swiftest sailors and best built Vessels in the United States have been launch'd here, particularly the Ship *Minerva*, a well known Packet between Charleston and New York. There are at present five Vessels at the Stocks, two of which are ready to be launch'd (Newsome 1929:399).

The Beaufort vicinity was severely battered by a hurricane that struck the area in 1815. The storm, later described as "being one of the most violent and disastrous ever known upon the coast," brought about significant changes to the bar at Beaufort. The bar was "injured so that but 12 feet could be brought over it at low water." Fortunately, the channel eventually recovered from the storm's damage and by 1830, the depth on the bar had increased to 18 feet at mean low water. By 1854, the bar channel had decreased to a depth of 15 1/2 feet and migrated slightly to the south (United States Congress, Senate Executive Document, No. 78, 33rd Congress, pp. 3-4).

Around 1841, John Motley Morehead, governor of North Carolina, had a vision of establishing a port facility at the eastern terminus of the Atlantic and North Carolina Railroad. A decision was finally reached in 1855 to locate the proposed port and rail facility on Sheppard's Point (Konkle 1922:339-340).

The editor of the Greensboro *Patriot* described the conditions and natural advantages which he believed would benefit maritime traffic through Beaufort Inlet to the new port facility at Morehead City in September 1858:

> The inlet at Beaufort Harbor is, we understand, about three-quarters of a mile wide, extending from the point on the Shackleford banks on the east to the point at Fort Macon on the west. Ships drawing from eighteen to twenty feet can cross the bar with safety. Ships crossing the bar, enter the harbor near the Shackleford banks, then bear in a westwardly direction toward Fort Macon. From the bar at the inlet, across the Sound to Beaufort, is about three miles, this being about the widest part of the harbor. The channel is in the form of a half-moon, one horn running eastwardly along the Shackleford banks, called Core Sound, and the other westwardly by Morehead and Carolina cities, which are situated on Bogue Sound. The deepest water is along Newport river, which runs in nearly a north direction between Morehead City and Beaufort, touching the railroad wharf in the former place. The main channel is about one mile wide, so that the inside of the channel would be some two miles from Beaufort, though vessels drawing from nine to ten feet water can approach the Beaufort wharves at full tide. Running up the channel about three miles from the bar, we come to the railroad wharf at Morehead City, where vessels drawing eighteen feet can approach with ease, and unload and take in lading with the greatest safety (Konkle 1922:341-342).

Within six months, the rail and port facility at Morehead City was prospering, much to the chagrin of the people of Beaufort. Ships were continually calling at the wharfs and being loaded with cargoes directly from train cars:

> Here a steamer drawing twenty feet of water, and the locomotive weighing twenty or thirty tons, with its whole train, may be along side each other; and this, too, on each side of the wharf at the same time, while in front other vessels may be loading or discharging cargoes (Konkle 1922:360-361).

The development of Morehead City was soon disrupted by the Civil War. On 22 March 1862, Union forces occupied Morehead City. Four days later Union troops crossed the Newport River and took control of Beaufort. Fort Macon also fell into Union forces under General Ambrose E. Burnside following a fierce one-day siege (Stick 1958:148-153). Preceding the final assault on Fort Macon, a Union gunboat and one or two smaller vessels were positioned inside Beaufort Inlet, controlling the approaches and exits to Bogue and Core Sounds. On 22 April, several Union vessels anchored near Harker's Island to the east of Beaufort, including the steamer *Alice Price* that served as General Burnside's temporary headquarters. When the fall of Fort Macon was imminent, Confederate forces burned the bark *Glen* to keep it out of Union hands. On 26 April, Colonel Moses J. White, commander of Fort Macon, surrendered to Generals Parks and Burnside on Shackleford Banks (Angley 1982:34; Stick 1958:148-153).

The occupation of Fort Macon and the surrounding vicinity provided Union naval forces with access to a deep-water port and a place of rendezvous that was used to support the blockading squadron throughout the remainder of the war. During December 1864 and January 1865, fleets under Admiral David Porter massed at Beaufort Harbor in preparation for their assault on Fort Fisher in Wilmington, the last major stronghold of the Confederacy in North Carolina. During the Civil War at least five Confederate vessels were captured at sea in the Cape Lookout area: the schooners *Edwin*, *Julia*, *Revere* and *Louisa Agnes* were captured in 1861 and the steamer *Banshee* was taken on 21 November 1863 (Angley 1982:35; Price 1948). One Confederate vessel was lost in the vicinity as a result of enemy action. On 9 July 1864, the side-wheel steamer *Pevensey* was chased ashore and blown up on Bogue Banks, approximately nine miles west of Beaufort Inlet (Hill 1975:11-13). Not all of the known shipwrecks near Beaufort were a result of enemy action. On 12 June 1863, the USS *Lavender* ran aground in heavy seas near Cape Lookout Shoals while en route from the Delaware Capes to Charleston. The *Lavender* was a screw tug of 173 tons. On 20 July 1865, the 186-ton Union screw steamer *Quinnebaugh* went ashore on Beaufort bar in rough weather after her machinery failed. The *Quinnebaugh* was transporting Union troops, refugees and civilians north at the time of her loss (Shomette 1973:88-89; Berman 1972:141; Lytle and Holdcamper 1975:291).

Six years after the Civil War, the federal government began measures to reduce the severity of maritime disasters along the coast by establishing the United States Lifesaving Service. In 1874, seven stations were established along the North Carolina coast. In 1875, a similar station was authorized by Congress for Cape Lookout, though it would be another ten years before it was finally built. Over the following years three other stations were established on Core Banks, and a facility was also established near Fort Macon, just west of Beaufort Inlet (Angley 1982:35-36; Stick 1958:169-170, 310-313).

Menhaden fishing became an important source of income for the Cape Lookout-Beaufort area in the years following the Civil War. From 1865 to 1873, the state's first menhaden processing plant was in operation on Harker's Island. By the turn of the century several plants were in operation at Beaufort and at various points on Bogue and Core Sounds (Hill 1975:16-18).

Growth of Beaufort and Morehead City as ports was slow during the late-19th and early 20th centuries. In the 1880s, the federal government began work on the improvement of Beaufort Inlet in the hopes of increasing the amount of maritime trade to the port communities. The depth over the bar in the later 19th century was just over 15 feet, but it was said that "the harbor entrance was rapidly deteriorating; its width, measured from Fort Macon to Shackleford Point, having increased 500 feet between the years 1864 and 1880" (Stick 1958:312; Angley 1982:39-40). By 1880, the width of the inlet had increased an additional 900 feet. As a means to prevent further erosion, jetties were constructed from both shores into the inlet. Over the next five years, five jetties were constructed on Shackleford Point and another six on Fort Macon Point. By 1889, the deterioration of the inlet had been brought under control (Angley 1982:40; Stick 1958:312).

Between 1905 and 1907, the channel across Beaufort Inlet bar was dredged to a depth of 20 feet at mean low water. A 20-foot channel, 200 feet wide, was also provided inside the inlet to the wharves at Morehead City. A smaller channel, seven feet deep and 100 feet wide, was dredged to the wharves along the Beaufort waterfront (Angley 1982:40). The Army Corps of Engineers submitted several reports between 1907 and 1914 that indicated that both Morehead City and Beaufort were growing centers of maritime trade. The majority of vessels utilizing the two ports were fishing boats and small, shallow-draft cargo vessels (Angley 1982:41). Beaufort Inlet was described in 1907 as being limited in importance:

> The present commerce through the inlet is small, owing in a large measure to the hitherto shallow draft of not generally more than 12 feet at mean low water that could be carried across the bar.
>
> The present annual commerce of Beaufort, N. C., the principal place on the water adjacent to this harbour, amounts to about 64,000 tons annually, valued at $3,500,000, of which only about one-fourth to one-fifth passes through the inlet (United States Congress, House Document No. 1454, p. 3).

Statistics for 1912 reflect that 12 sailing and 35 gasoline powered vessels totaling 570 net tons were registered at Morehead City. For the same year, the registry at the rival port of Beaufort listed 175 sailing vessels, 240 gasoline powered vessels and 6 barges with a net registered tonnage of 6,005 (Angley 1982:42; United States Congress, House Documents No. 1022:4-11 and No. 1108:6-7).

A number of vessels travelling along the coast became victims of maritime hazards. Between 1 July 1898 and 30 June 1908, 82 vessels were reported lost off the North Carolina coast (United States Congress, House Document No. 315, pp. 5-6). Several of those shipwrecks had themselves become hazards to navigation. On 20 and 27 February 1891, notices were printed in the Wilmington *Weekly Star* that the federal government was in the process of removing wrecks that had become obstacles to other vessels:

> Masters and owners of vessels engaged in the coastwise trade will be glad to know that the commanding Officer of the USS *Yantic* has been ordered to cruise along the coast from Sandy Hook to Charleston, S. C. and to destroy, as far as practicable, all abandoned wrecks which are dangerous to navigation. There are a number of these wrecks on the coast of North Carolina and Virginia.
>
> Off the North Carolina coast the *Yantic* will find the schooner *Dudley Farlin*, twenty-four miles northwest of Bodie Island Light; the schooner *Mollie J. Saunders*, seven miles southeast of the same light; the steamer *Glenrath*, south by west of Cape Lookout Light, four or five miles further in shore, the steamer *Aberlady Bay*, and a sunken wreck eighteen miles east-northeast of Frying Pan Shoal Lightship (Wilmington *Weekly Star*, 20 and 27 February 1891).

In a 1897 Congressional report the hazards found at Cape Lookout to maritime traffic were summarized by the captain of the life-saving station at Cape Lookout:

> I ascertain that, since 1888, 19 schooners, 6 steamships, and 1 bark were disabled or ashore around Cape Lookout that would have been unharmed in all probability, if a safe harbor had been near. Two of these steamships and many of the schooners proved total losses. Unknown wrecks are occasionally discovered on or near the shoals. Nine large vessels have been anchored south of the beach at one time during northeasters. When the wind shifted they had to go to sea. Twenty-two schooners have been seen at one time laying to under the lee of Lookout Shoals during a northeast gale, and 57 vessels have been sighted passing by in one day. The locality is being frequented more and more as seafaring men learn the advantage of it. The great danger at present is being caught in the great bight with a southerly gale (United States Congress, House Document No. 25, p. 5).

To prevent vessels from wrecking near Cape Lookout a lighthouse had been in use, but mariners often complained that the light was difficult to see. As a remedy, a lightship was placed at Cape Lookout Shoals in 1904 and remained in operation until 1933 when it was removed (Holland 1968:32-35; Stick 1958:310). In addition to the lightship, a lens lantern was erected in 1900 on Cape Lookout Bight for the "large number of vessels that seek a lee under Cape Lookout" (Holland 1968:32).

During World War I, Cape Lookout Bay served as a rendezvous and staging area for convoys bound for Europe, and Morehead City was occasionally used as a distribution point for war supplies. From 1926 to 1938, the federal government made considerable improvements to the Port of Morehead City by increasing the depth of the channel through Beaufort Inlet to 30 feet (Stick 1952:237-238). In 1923, the tug *Juno* sank in the Beaufort Inlet channel causing considerable difficulty for other vessels to pass. The *Juno* was eventually dynamited to clear the entrance. This earlier event may have been a contributing factor in recognizing the need for channel improvements (*The Evening Dispatch,* 23 July 1923; Berman 1972:128).

Hostilities in the Cape Lookout vicinity were much more evident during the events of World War II. For example, on the night of 18 March 1942, German submarines sank three tankers in the Cape Lookout area: the *Papoose,* the *W. E. Hutton* and the *E. M. Clark.* Five days later another tanker, the *Naeco* was sunk in the same vicinity (Stick 1952:234). As a result of the high number of vessel losses occurring during the early stages of the war, defensive measures were put into place. Coastal communities were systematically blacked out, a more efficient convoy system was devised and additional planes and patrol vessels were put into service for the Cape Lookout area and North Carolina coast in general (Stick 1952:237-239).

In the early 1950s, improvements were once again undertaken at Morehead City. By the summer of 1954, a project to widen the 30-foot channel to 300 feet to the terminal facilities, construct a 600-foot turning basin and dredge a 12-foot channel in Bogue Sound along the city's commercial waterfront was nearly completed (Angley 1982:48). By 1954, the main shipping channel to Beaufort had also been dredged to a depth of 12 feet and a width of 100 feet. The improvements could easily accommodate sports and commercial fishing vessels and pleasure craft, but was inadequate to handle large, deep-draft cargo vessels (Angley 1982:48). Since the mid-1950s, regular maintenance dredging has been undertaken at the channels leading into the Morehead City and Beaufort harbors. Today, Morehead City continues as a major deep-water port with several large vessels arriving monthly.

Summary of Findings

Investigation of the three borrow areas off Bogue Bank identified a total of 10 magnetic anomalies. No magnetic and/or acoustic anomalies were identified during remote sensing of Borrow Area A or Borrow Area B-1 (Figures 2, 3, 4). All ten of the identified anomalies were located in the western part of Borrow Area B-2 (Figures 5, 6). Analysis of the target signatures suggest that seven of the anomalies could be associated with shipwreck remains. It is recommended that those seven targets be avoided. In the event that they cannot be avoided, additional investigation is recommended to identify the nature and assess the significance of material generating the signatures. The remaining three targets contained signature characteristics suggestive of single ferrous objects and are not recommended for additional investigation.

Borrow Area A

No magnetic and/or acoustic targets were identified in Area A.

Borrow Area B-1

No magnetic and/or acoustic targets were identified in Area B-1.

Borrow Area B-2

Target Designation: B2-01

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2611456	341287	262	6

Potential: Low

Target B2-01 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 1 and the contoured signature consisted of data from the anomaly identified as 1.2 in the magnetometer records. The detectable signature had a maximum intensity of 262 gammas and a maximum duration of 6 two-second pulses (Figure 7). The contoured dipolar signature covered an area of approximately 19,800 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, as the anomaly lies on the

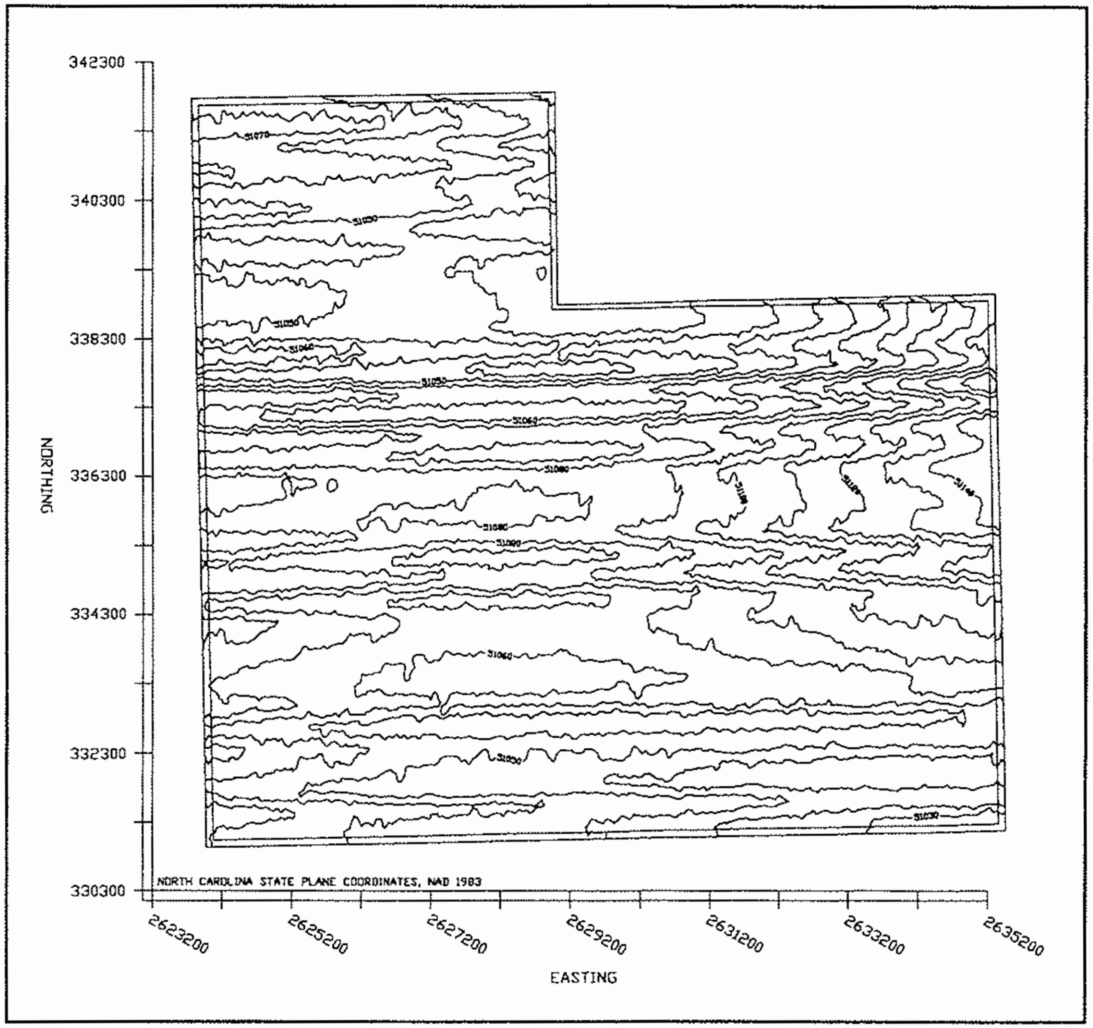


Figure 2. Magnetic contour map of Borrow Area A.

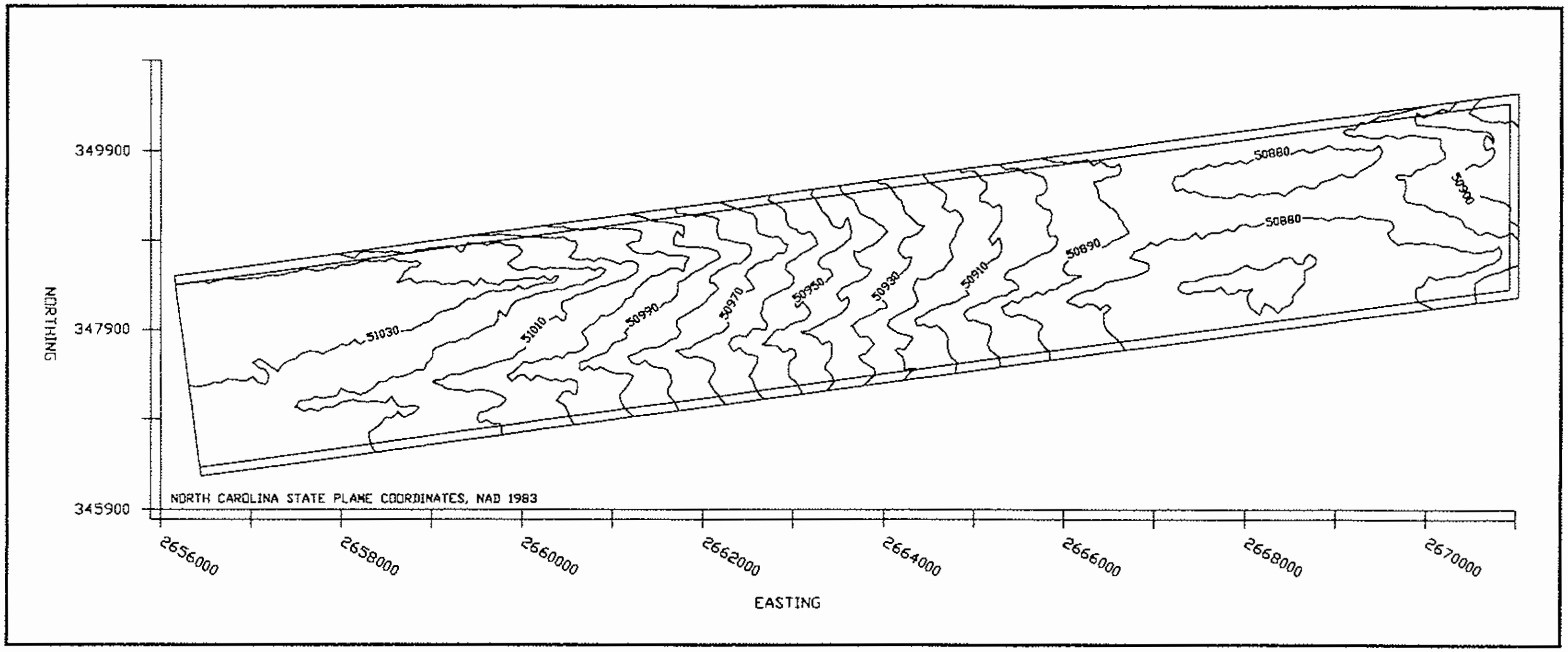


Figure 3. Magnetic contour map of Borrow Area B-1 east end.

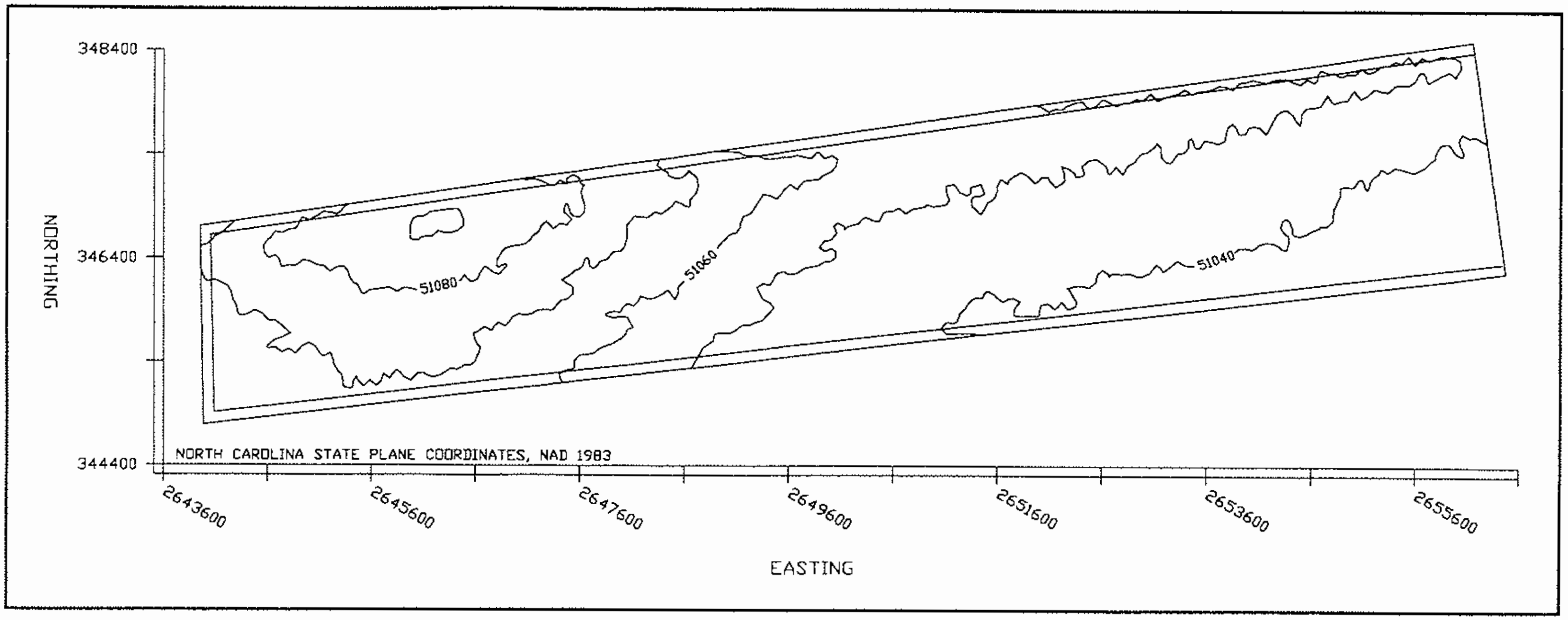


Figure 4. Magnetic contour map of Borrow Area B-1 west end.

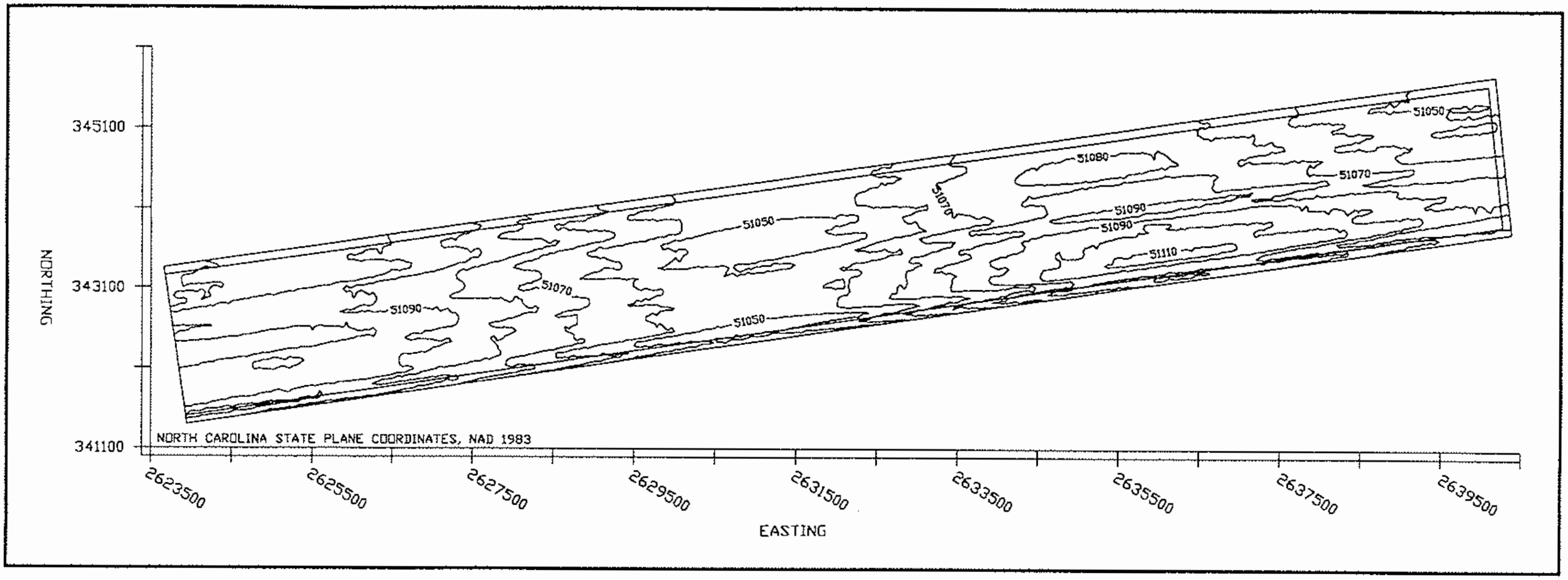


Figure 5. Magnetic contour map of Borrow Area B-2 east end.

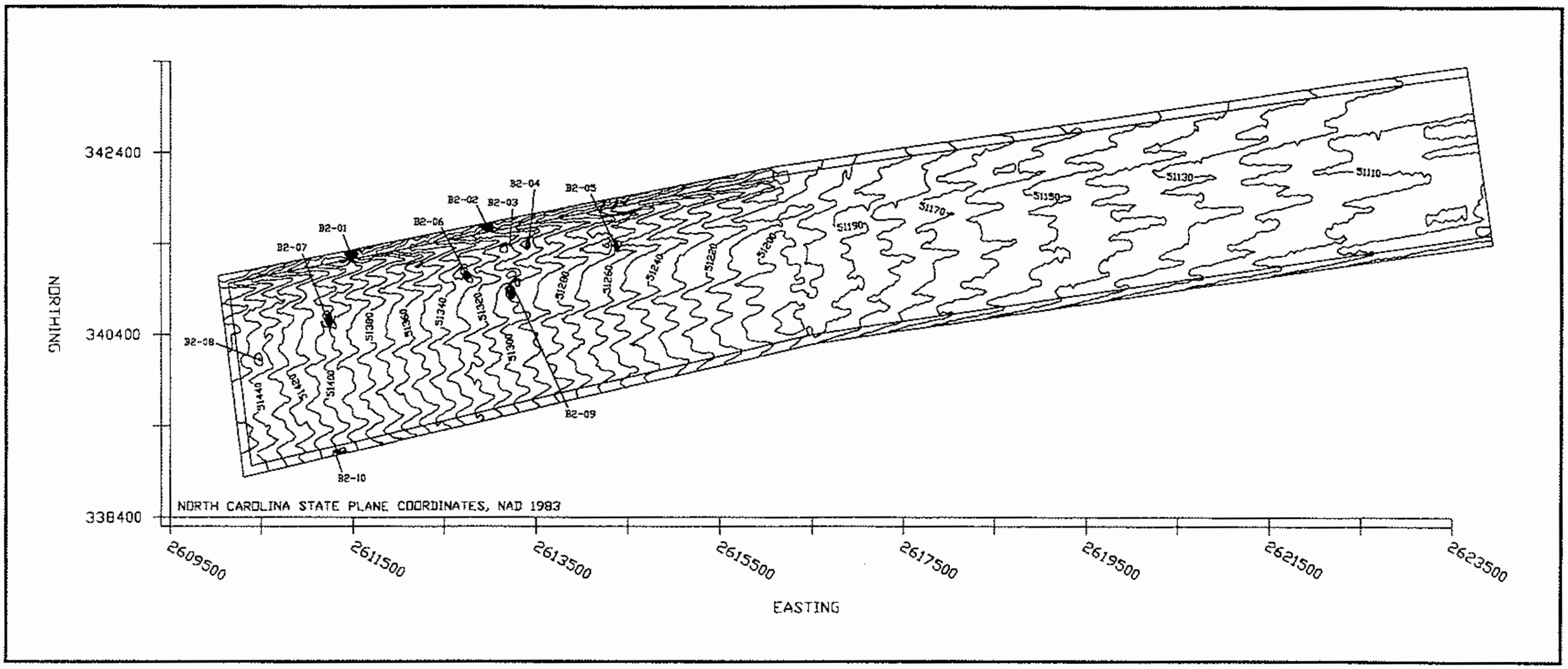


Figure 6. Magnetic contour map of Borrow Area B-2 west end.

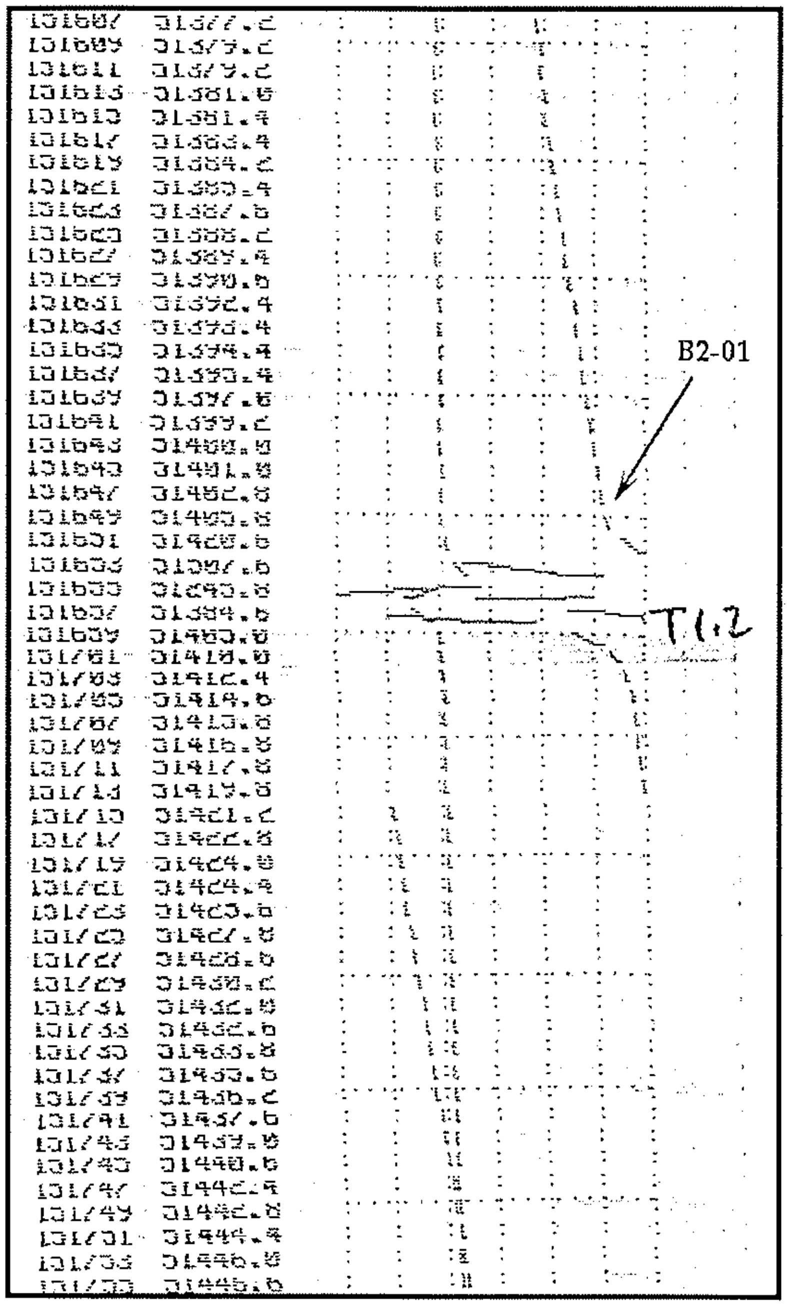


Figure 7. Magnetic Target B2-01.

edge of the survey area, it may potentially be associated with a significant cultural resource adjacent the current project area. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-02

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2612965	341596	59	5

Potential: Low

Target B2-02 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 1 and the contoured signature consisted of data from the anomaly identified as 1.1 in the magnetometer records. The detectable signature had a maximum intensity of 59 gammas and a maximum duration of 5 two-second pulses (Figure 8). The contoured dipolar signature covered an area of approximately 11,220 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-03, B2-04, B2-06 and B2-09 the target may represent scattered debris associated with a shipwreck. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-03

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2613207	341371	27	5

Potential: Low

Target B2-03 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 4 and the contoured signature consisted of data from the anomaly identified as 4.1 in the magnetometer records. The detectable signature had a maximum intensity of 27 gammas and a maximum duration of 5 two-second pulses (Figure 9). The contoured

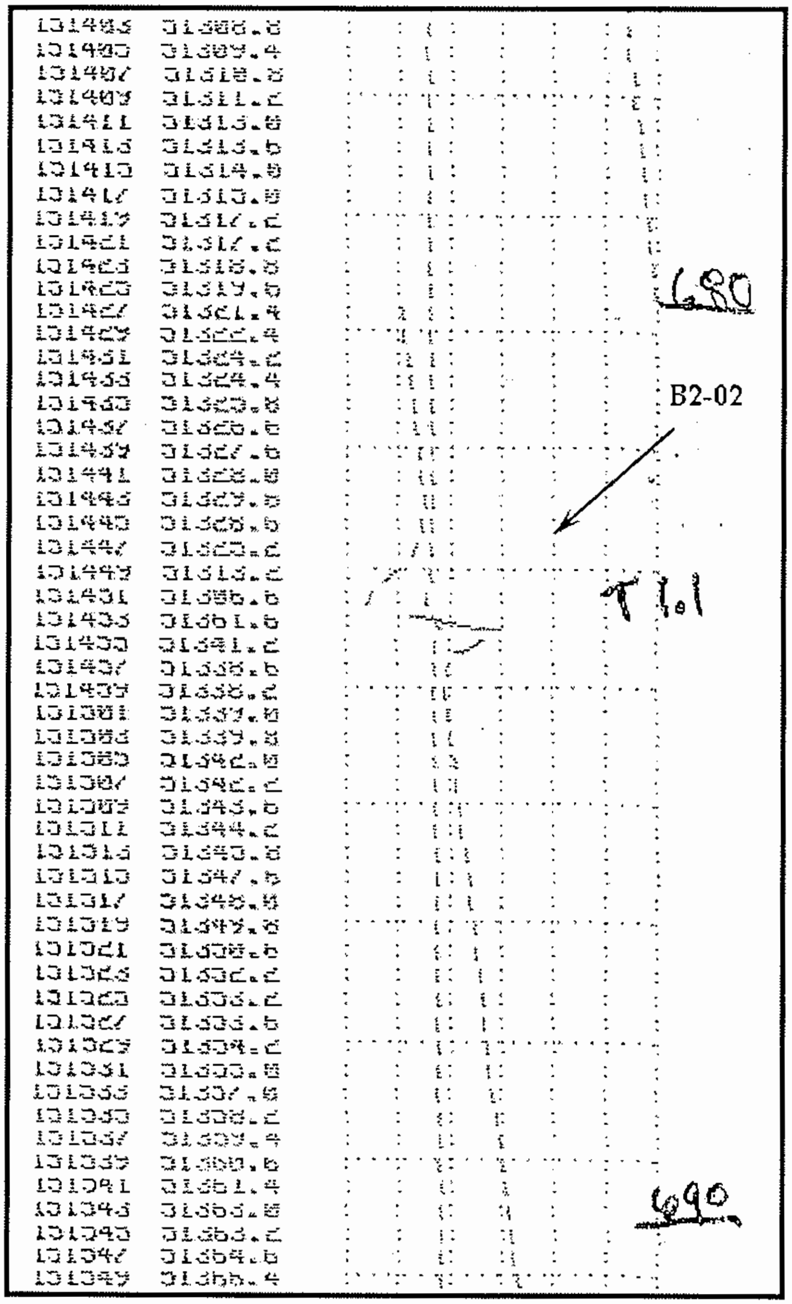


Figure 8. **Magnetic Target B2-02.**

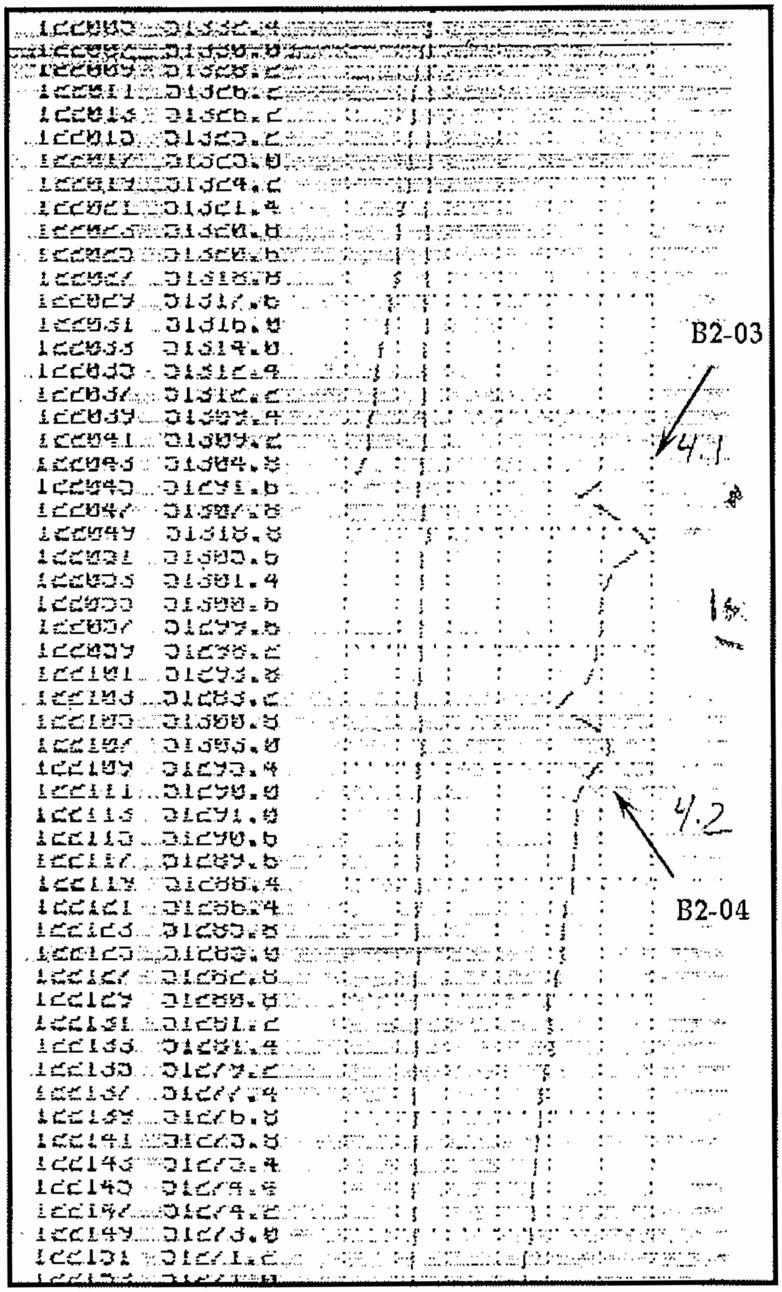


Figure 9. Magnetic Targets B2-03 and B2-04.

dipolar signature covered an area of approximately 8,800 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-02, B2-04, B2-06 and B2-09 the target may represent scattered debris associated with a shipwreck. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-04

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2613393	341404	20	6

Potential: Low

Target B2-04 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 4 and the contoured signature consisted of data from the anomaly identified as 4.2 in the magnetometer records. The detectable signature had a maximum intensity of 20 gammas and a maximum duration of 6 two-second pulses (Figure 9). The contoured dipolar signature covered an area of approximately 9,500 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-02, B2-03, B2-06 and B2-09 the target may represent scattered debris associated with a shipwreck. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-05

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2614359	341393	50	5

Potential: Low

Target B2-05 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 6 and the contoured signature consisted of data from the anomaly identified as 6.0 in the magnetometer records. The detectable signature had a maximum intensity of 50 gammas and a maximum duration of 5 two-second pulses (Figure 10). The contoured dipolar signature covered an area of approximately 8,000 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. The sharp, low intensity signature does not appear to represent the more complex types often associated with shipwreck remains. No additional investigation of the target is recommended in conjunction with the proposed project.

Target Designation: B2-06

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2612754	341037	49	7

Potential: Low

Target B2-06 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 6 and the contoured signature consisted of data from the anomaly identified as 6.1 in the magnetometer records. The detectable signature had a maximum intensity of 49 gammas and a maximum duration of 7 two-second pulses (Figure 11). The contoured dipolar signature covered an area of approximately 14,025 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-02, B2-03, B2-04 and B2-09 the target may represent scattered debris associated with a shipwreck. In the event that the proposed

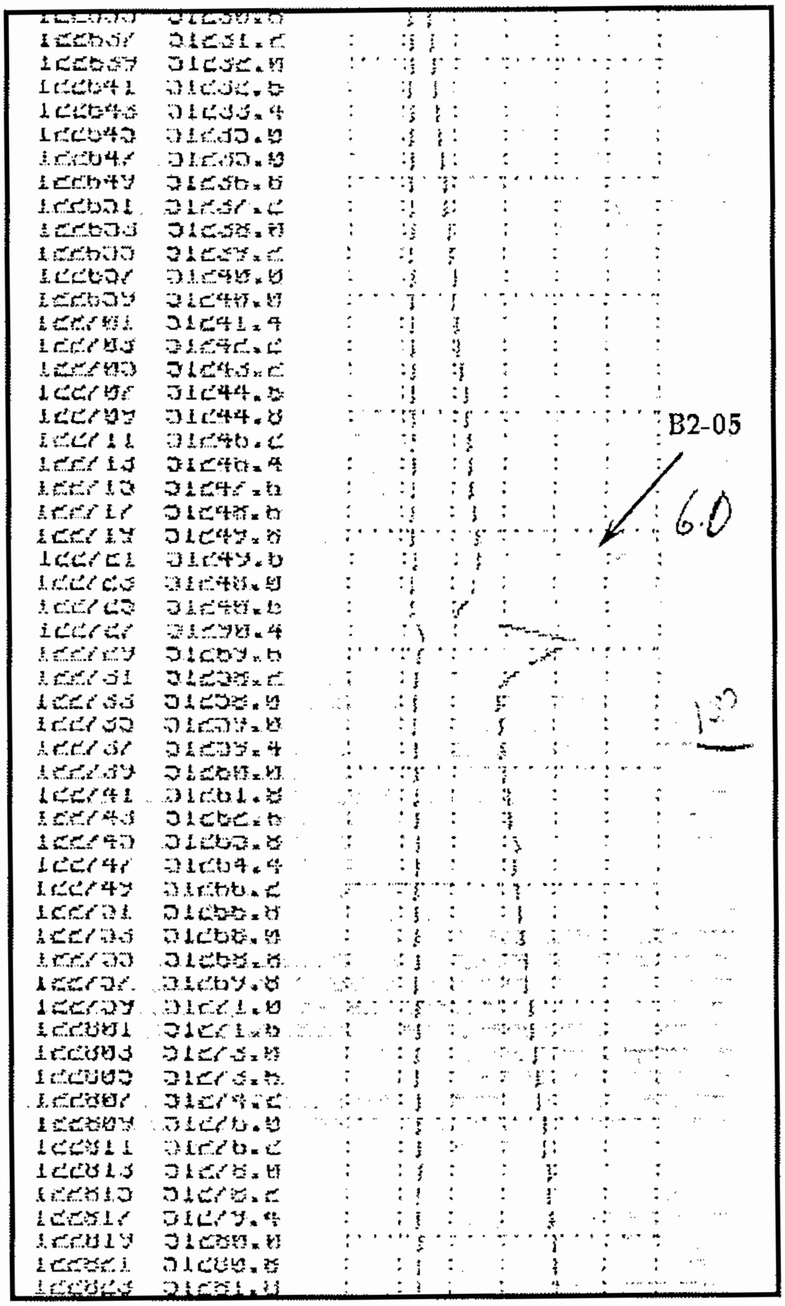


Figure 10. Magnetic Target B2-05.

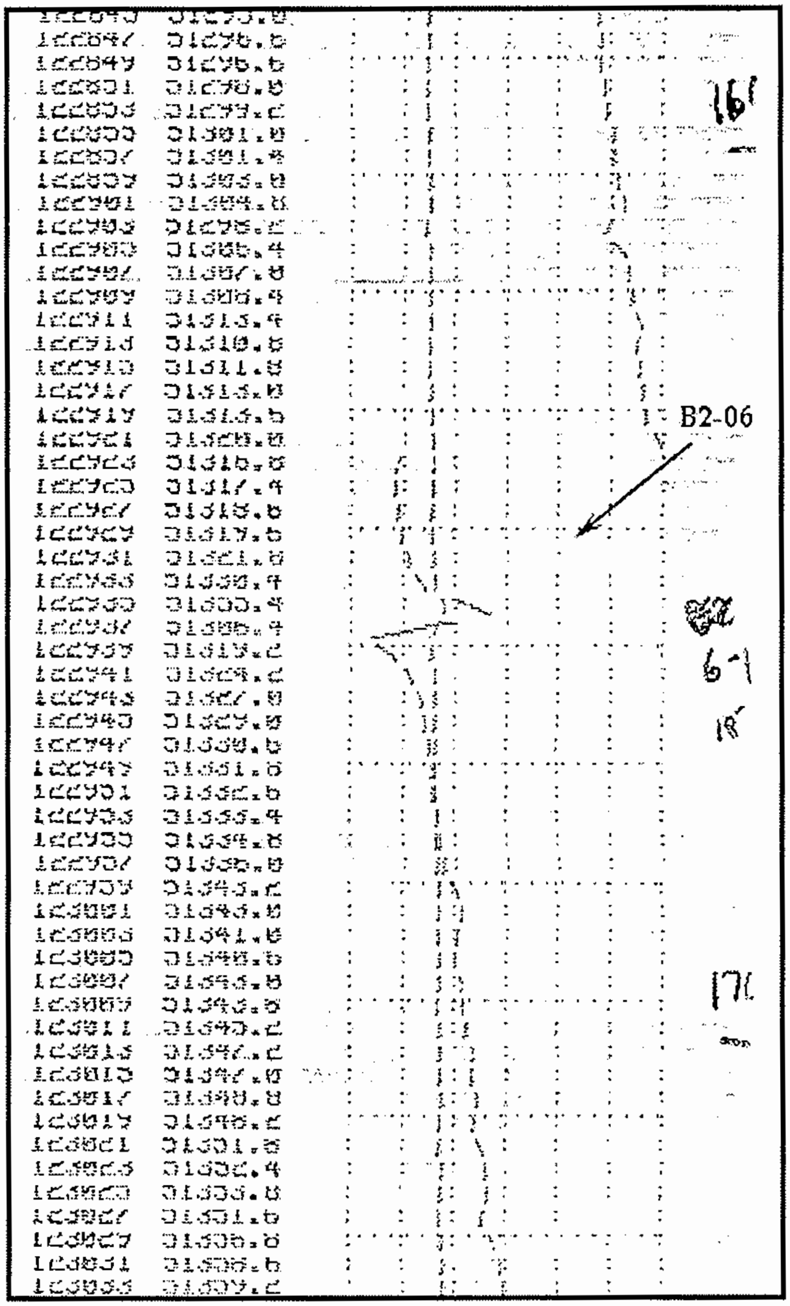


Figure 11. Magnetic Target B2-06.

project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-07

Signature Type: Positive Monopolar

State Plane	Northing	Easting	Intensity	Duration
	2611216	340557	82	5

Potential: Low

Target B2-07 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 8 and the contoured signature consisted of data from the anomaly identified as 8.1 in the magnetometer records. The detectable signature had a maximum intensity of 82 gammas and a maximum duration of 5 two-second pulses (Figure 12). The contoured positive monopolar signature covered an area of approximately 12,000 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. The sharp, moderate intensity signature does not appear to represent the more complex types often associated with shipwreck remains. No additional investigation of the target is recommended in conjunction with the proposed project.

Target Designation: B2-08

Signature Type: Dipolar

State Plane	Northing	Easting	Intensity	Duration
	2610512	340108	22	7

Potential: Low

Target B2-08 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 11 and the contoured signature consisted of data from the anomaly identified as 11.1 in the magnetometer records. The detectable signature had a maximum intensity of 22 gammas and a maximum duration of 7 two-second pulses (Figure 13). The contoured dipolar signature covered an area of approximately 11,310 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that

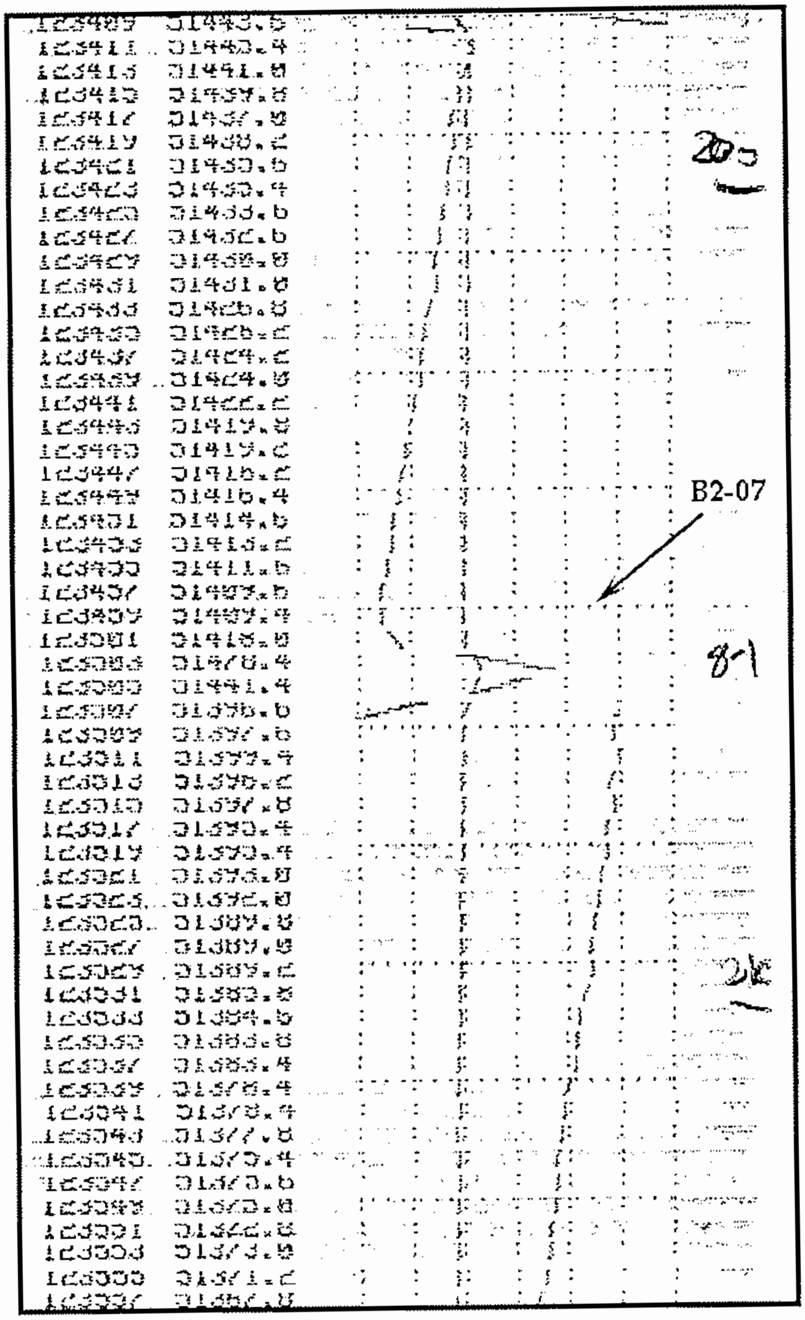


Figure 12. Magnetic Target B2-07.

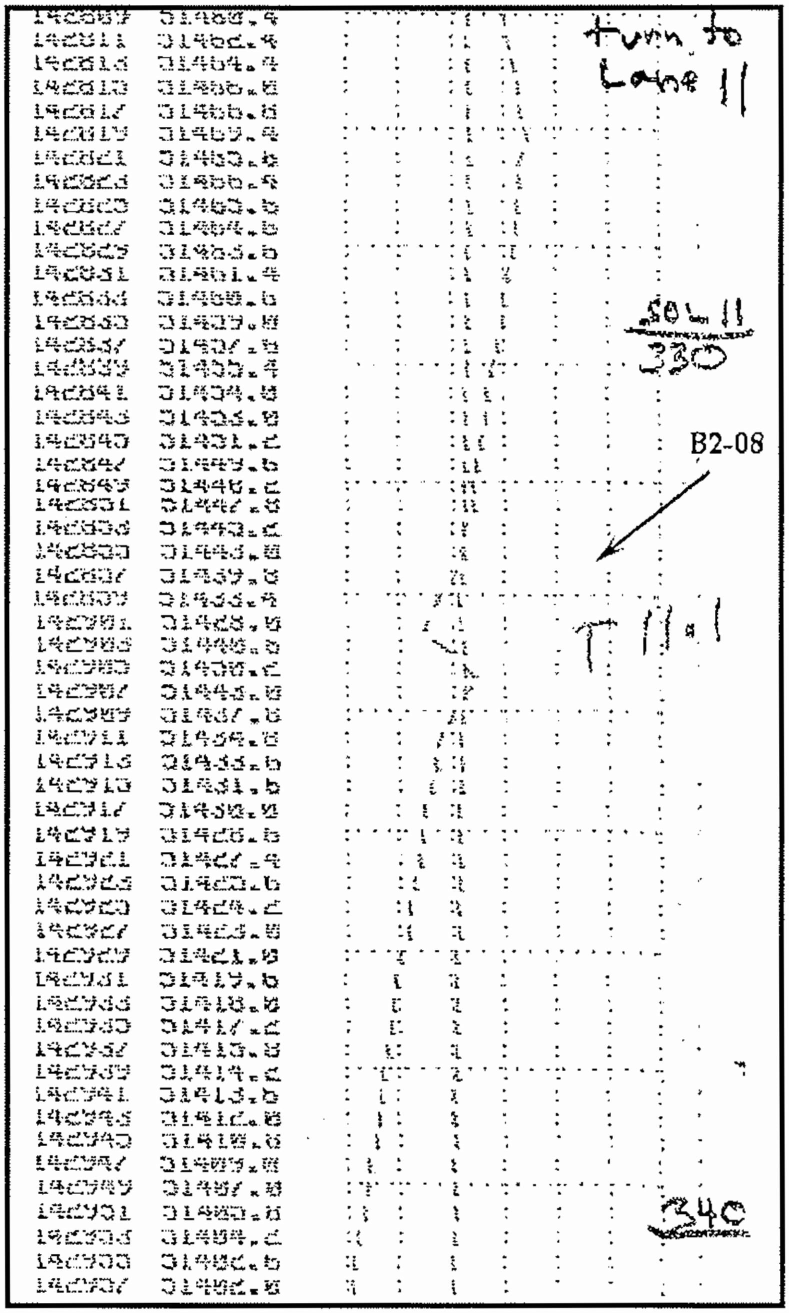


Figure 13. Magnetic Target B2-08.

material generating the anomaly could be a concentration of ferrous objects such as the fasteners of a vessel or other similar hardware. It is possible that the anomaly could be associated with the remains of a vessel as the signature characteristics are similar to those low intensity and long duration anomalies demonstrated to be associated with the remains of wooden hull vessels. In the event that the proposed project will impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

Target Designation: B2-09

Signature Type: Negative Monopolar

State Plane	**Northing**	**Easting**	**Intensity**	**Duration**
	2613222	340888	49	5

Potential: Low

Target B2-09 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lanes 8 and 9 and the contoured signature consisted of data from the anomalies identified as 8.2 and 9.1 in the magnetometer records. The detectable signature had a maximum intensity of 49 gammas and a maximum duration of 5 two-second pulses (Figure 14). The contoured negative monopolar signature covered an area of approximately 23,000 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. However, because of a possible spatial association with targets B2-02, B2-03, B2-04 and B2-06 the target may represent scattered debris associated with a shipwreck. In the event that the proposed project would impact the anomaly location, consideration should be given to identifying and assessing the potential historical significance of the material associated with the target.

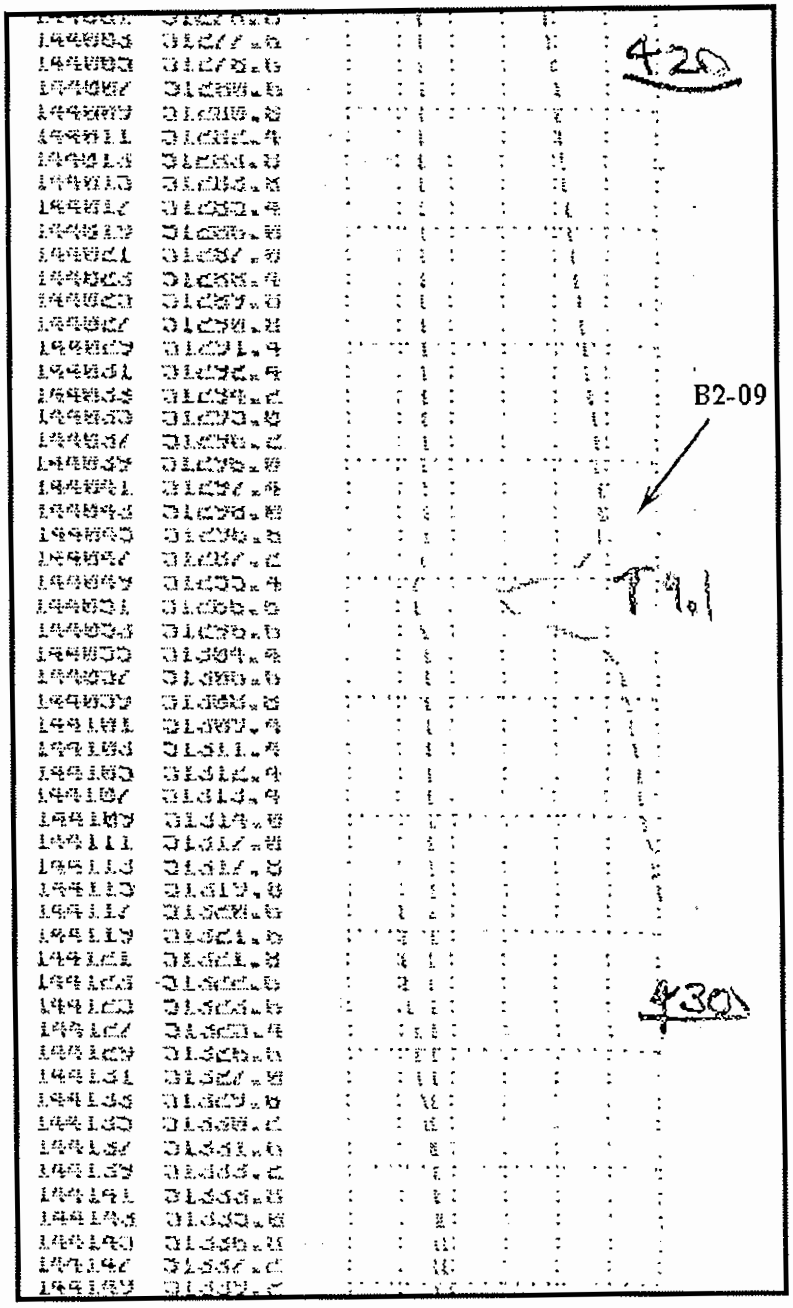


Figure 14. Magnetic Target B2-09.

Target Designation: B2-10

Signature Type: Multi-component

State Plane	Northing	Easting	Intensity	Duration
	2611288	339080	32	7

Potential: Low

Target B2-10 was located in the western end of Borrow Area B-2. The magnetic signature was identified on lane 23 and the contoured signature consisted of data from the anomaly identified as 23.1 in the magnetometer records. The detectable signature had a maximum intensity of 32 gammas and a maximum duration of 7 two-second pulses (Figure 15). The contoured multi-component signature covered an area of approximately 14,250 square feet. No sonar signature was associated with the material generating the magnetic signature. The signature characteristics, intensity and duration suggest that material generating the anomaly could be a single ferrous object such as pipe, cable, anchors or other similar debris. The sharp, low intensity signature does not appear to represent the more complex types often associated with shipwreck remains. No additional investigation of the target is recommended in conjunction with the proposed project.

Conclusions and Recommendations

A survey of historical and archaeological literature and archival background research confirmed considerable evidence of maritime activity along the southeastern North Carolina coast. That evidence suggests a high probability for submerged cultural resources in the waters around Beaufort Inlet. Discovery of what appears to be the remains of Blackbeard's *Queen Anne's Revenge* and several Civil War vessels reinforce that hypothesis. Both Beaufort and Morehead City provided early settlers with centers of transportation and trade and bases of operations to exploit the natural resources of the Carolina coast. Yet in spite of nature and the scope of maritime activity, there is only one reference to a specific vessel lost in the immediate vicinity of the proposed project. That vessel is the Civil War blockade runner *Pevensey* that was run ashore at the site of the Iron Steamer Pier. No known sites exist in the survey areas in the files of the Underwater Archaeology Unit of the Division of Archives and History.

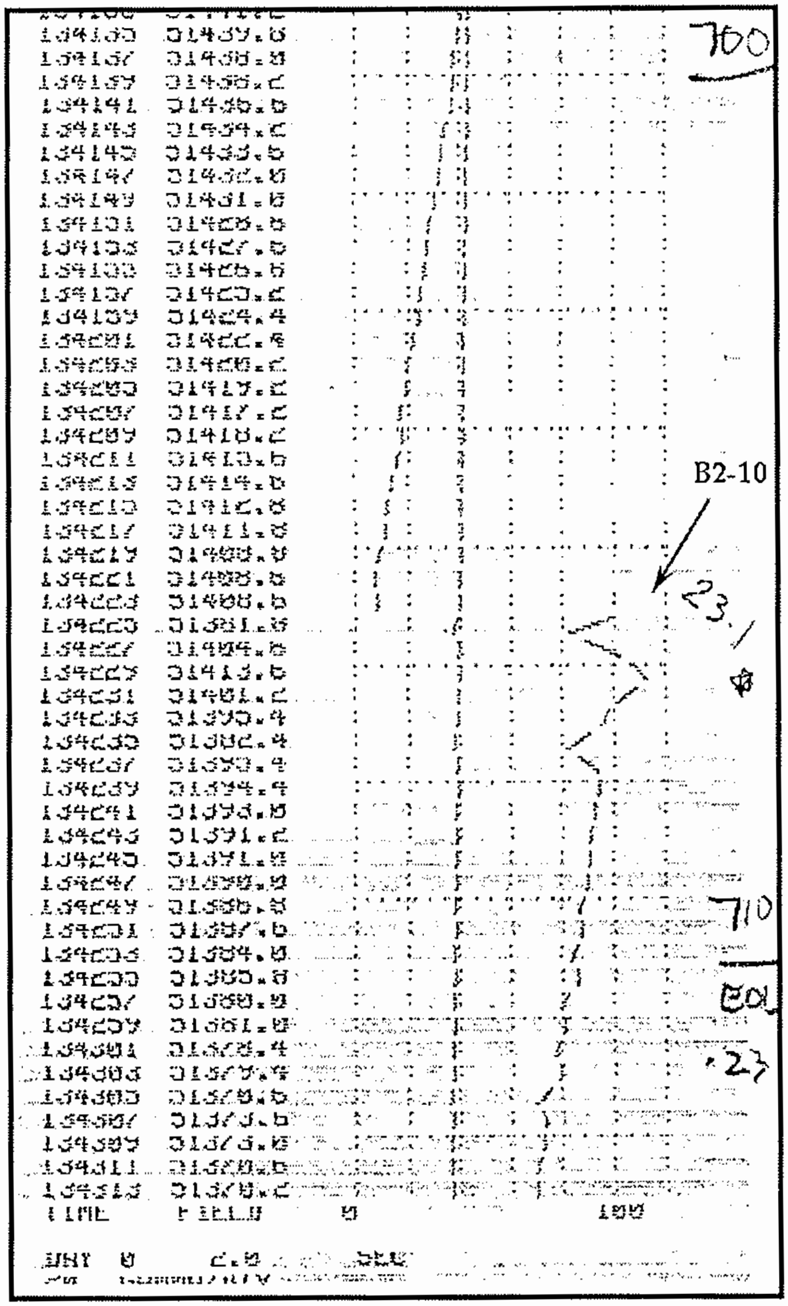


Figure 15. Magnetic Target B2-10.

Analysis of the remote sensing data revealed no magnetic and/or acoustic anomalies in either Borrow Area A or Borrow Area B-1. On the basis of that analysis, no additional investigation of the area is recommended in conjunction with the proposed project.

Analysis of the remote sensing data for Borrow Area B-2 confirmed the presence of 10 magnetic anomalies in the western part of the survey area. Seven of those targets contained signature characteristics consistent with significant submerged cultural resources. Analysis of the target signatures suggests that five of the anomalies, B2-02, B2-03, B2-04, B2-06 and B2-09, may be spatially associated and could represent scattered debris from a shipwreck. Another target, B2-08, contained signature characteristics similar to those commonly associated with wooden hull vessels. Though the final anomaly, B2-01, exhibited signature characteristics suggestive of a single ferrous object its location along the northern edge of the survey area does not rule out a possible association with a significant cultural resource lying adjacent to the project area. The remaining three targets, B2-05, B2-07 and B2-10, contained signature characteristics suggestive of single ferrous objects. With the exception of the above seven anomalies, the proposed project will have no impact on potentially significant submerged cultural resources.

In order to provide reasonable assurance that proposed dredging does not impact targets B2-01, B2-02, B2-03, B2-04, B2-06, B2-08 and B2-09, a buffer zone should be established around each anomaly location. Unfortunately, there is no concrete data regarding the establishment of an effective buffer zone around submerged cultural resource sites. In the absence of such data and due to the nature of the high energy environment off Bogue Banks, it may be appropriate to establish a buffer zone 250 feet in circumference around the center of the target coordinates. In order to assess the buffer zone effectiveness, the target environment at each site should be periodically monitored to determine what, if any, change has occurred. In the event that the target locations cannot be avoided, diver investigation of the seven anomalies is recommended to identify and assess their National Register of Historic Places eligibility.

References Cited

Angley, Wilson
1982 An Historic Overview of The Beaufort Inlet - Cape Lookout Area of North Carolina. Report on file at the Research Branch, N. C. Division of Archives and History, Raleigh.

Berman, Bruce D.
1972 *Encyclopedia of American Shipwrecks.* The Mariners Press, Boston.

Federal Register
1990 Abandoned Shipwreck Act; Final Guidelines; Notice. National Park Service, U. S. Department of Interior, Part III, 4 December.

Hill, Mrs. Fred
1975 *Historic Carteret County, North Carolina.* Carteret County Historical Research Association, Beaufort.

Holland, F. Ross
1968 A Survey History of Cape Lookout National Seashore. United States Department of the Interior, Washington, D. C.

Konkle, Burton A.
1922 *John Motley Morehead and the Development of North Carolina, 1796-1866.* Philadelphia: William J. Campbell.

Lytle, William M. and Forrest R. Holdcamper
1975 *Merchant Steam Vessels of the United States 1790 - 1868,* "The Lytle Holdcamper List." Staten Island, New York: The Steamship Historical Society of America.

Marx, Robert F.
1975 *Shipwrecks of the Western Hemisphere, 1492-1825.* David McKay and Company, New York.

National Ocean Service
1990 Automatic Wreck and Obstruction Information System. National Oceanic and Atmospheric Administration, U. S. Department of Commerce.

Newsome, A. R. (Editor)
1929 A Miscellany from the Thomas Henderson Letter Book, 1810-1811. *North Carolina Historical Review.*

Paul, Charles L.
1970 Beaufort, North Carolina: Its Development as a Colonial Town. *North Carolina Historical Review.*

Price, Marcus W.
1948 Ships that Tested the Blockade of the Carolina Ports, 1861-1865. *The American Neptune*, July.

Rush, Richard et al.
1894-
1914 *Official Records of the Union and Confederate Navies in the War of the Rebellion.* 30 vols., Government Printing Office, Washington.

Saunders, William L. (Editor)
1886-
1890 *Colonial Records of North Carolina.* 10 vols., State of North Carolina, Raleigh.

Shomette, Donald G.
1973 *Shipwrecks of the Civil War.* Donic Ltd., Washington.

Spence, E. Lee
1991 *Shipwreck Encyclopedia of The Civil War: North Carolina, 1861-1865.* Sullivan's Island, S. C.: Shipwreck Press Inc.

Stick, David
1952 *Graveyard of the Atlantic: Shipwrecks of the North Carolina Coast.* The University of North Carolina Press, Chapel Hill.

1958 *The Outer Banks of North Carolina..* The University of North Carolina Press, Chapel Hill.

Tatham, William
1806 Survey of the Coast of North Carolina from Cape Hatteras to Cape Fear, 1806. Typed copy of manuscript report. North Carolina Collection of the Louis Round Wilson Library, University of North Carolina, Chapel Hill, North Carolina.

United States Congress, Senate Executive Document, No. 78, 33rd Congress, 1st Session.

United States Congress, House Document No. 25, 55th Congress, 1st Session.

United States Congress, House Document No. 1454, 60th Congress, 2nd Session.

United States Congress, House Document No. 315, 61st Congress, 2nd Session.

Newspapers

The Evening Dispatch [Wilmington, N.C.]
Weekly Star [Wilmington, N. C.]

APPENDIX C

APPENDIX C

UNC-IMS Study

FINAL REPORT
(Revised on September11, 2000)

Bogue Banks beach renourishment project: Late fall 1999 assessment of benthic invertebrate and demersal fish resources in the offshore mining sites prior to sand mining

Prepared for

Carteret County and CSE Baird, Inc.

By

Charles H. Peterson & John T. Wells
Institute of Marine Sciences
University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, NC 28557

September 11, 2000

Charles H. Peterson

John T. Wells

TABLE OF CONTENTS

1. Introduction/Purpose

This benthic assessment was conducted under contract with Carteret County, North Carolina in anticipation of a beach renourishment project for Bogue Banks. The purpose of this report is to describe the results of a single fall 1999 sampling of the benthic invertebrates and surficial sediments at the offshore borrow areas and nearby controls and the results of three (late fall-winter-spring) sets of trawl samples for demersal fishes and invertebrates around the borrow areas. This information may ultimately be incorporated into a monitoring scheme and helps in the short term to describe the biological resources at risk in the offshore system. Benthic invertebrates are commonly used in environmental assessments because they are sedentary and show the imprint of any environmental perturbation and because they are important trophic links to higher levels on the food chain, demersal predatory fishes, birds, and crustaceans (Warwick 1993). Many of these consumers have value as targets of commercial and/or recreational fisheries or as attractive charismatic wildlife (McLachlan 1983).

There are several environmental issues relating to the benthic habitat and biological resources that arise in considering a beach renourishment project (e.g., Naqvi and Pullen 1982, Reilly and Bellis 1983, Nelson 1989, Van Dolah et al. 1992, Peterson et al. 2000). The most significant include: (1) impacts to and recovery of the benthic invertebrate community at the borrow areas; (2) potential impacts to commercially or recreationally important demersal fishes and crustaceans in part because of these effects on their benthic invertebrate prey; (3) impacts to and recovery of the benthic invertebrate community on the intertidal and shallow subtidal beach; and (4) potential impacts to commercially and recreationally important fishes in the surf zone and/or shorebirds in large part because of these effects on their benthic invertebrate prey and because of enhanced turbidity along the shoreline.

Each of these issues deserves consideration and typically requires some field monitoring before and after renourishment to evaluate the actual resulting impacts. Because the benthic invertebrate community at the offshore borrow sites changes across the seasons, it is appropriate to sample in multiple seasons (fall and spring, at a minimum, but during four seasons in most previous studies – see Van Dolah et al. 1994) both before and after the renourishment project to assess impacts and recovery. Because renourishment was originally planned for winter 2000-2001, an initial set of samples was collected in the late fall of 1999 to provide fall baseline data to characterize the benthic invertebrate community at the prospective offshore borrow sites and at nearby control sites, which were not planned to be mined, prior to any disturbance from the renourishment project. This report includes a description of results from an analysis of the fall1999 samples. We also include here a complete analysis of composition of surface sediment samples in each of the borrow sites and control sites so as to characterize the sedimentary habitat in which the invertebrates live. Sedimentary habitat is the prime factor that controls abundance and composition of soft-bottom invertebrate communities (Snelgrove and Butman 1994).

The test of the impacts of removing sand from any of the three "Borrow Areas" A, B1, and B2 (Fig. 1) requires the use of a BACI (Before-After-Control-Impact) experimental design (Green 1979, Stewart-Oaten et al. 1986). Such a design is required to separate spatial and temporal variation from impacts of the sand mining activity. In a BACI design, samples from impact (Borrow) areas would be compared with those from control (undisturbed) areas both before and after the sand is removed. Control areas would have no sand removed but would otherwise be affected by all other impacts, i.e. storms, shrimping, etc., that affect the impact area. These samples taken before the removal of the sand can be compared with identically conducted samplings made after sand mining to evaluate impacts. In addition, the design also calls for spring sampling both before and after the removal of sand to assess the seasonal component, for a minimum of 4 sampling periods to complete the assessment of impacts. This report describes only the first of those samplings and thus does not include any spring sampling of the Borrow Areas or any sampling of the intertidal beaches.

Assessment of the significance of the offshore mining of sands for the renourishment also involves evaluation of potential impacts on demersal fishes and crustaceans at the Borrow Area (e.g., Van Dolah et al. 1992). Impacts could occur directly during sand mining and indirectly through modification of the prey community. This effect on prey could last for some unknown time. The fish and crustacean community also changes seasonally so sampling is needed to document presence and relative abundance of demersal fish and crustaceans and to describe their utilization of benthic invertebrate prey. This report describes results of trawl sampling on three dates, late fall, winter, and spring.

No sampling has yet taken place to serve explicitly as the before-renourishment monitoring data for the intertidal invertebrates of Bogue Banks beaches or for sea turtles. The invertebrate community of the intertidal beaches is so strongly seasonal and dynamic within the warm season that sampling to provide baseline information should most appropriately occur throughout the warm season, with subsequent identically designed sampling to assess potential impacts and recovery but after the project has been completed. The complete design for such beach monitoring would include "before and after" (BACI) sampling of control beaches where no renourishment occurs (Green 1979, Stewart-Oaten 1986).

2. Description of Sampling and Analytic Methodologies

A. Benthic Invertebrate Resources

Core sampling was conducted during late fall 1999 from 20 sites, 10 of which were inside and 10 of which outside the three potential borrow areas (Fig. 1). This sampling produced a total of two hundred core samples to characterize the invertebrate macrofauna at all three prospective borrow sites and at control sites near each borrow site (Fig. 1). Ten replicate core samples were taken at each of six sites in Borrow Area A and at each of two sites from Borrow Area B-1 and Borrow Area B-2. Ten replicate cores were also taken at each of ten control sites: six around Borrow Area A and two near each Borrow Area B site. Exact locations of each site were determined using a handheld GPS with differential receiver (Table 1). Water depths ranged from 35 feet at the inshore sites to 47-49 feet at the offshore sites. Cores were taken by divers using a cylindrical corer 9.9 cm in internal diameter (each covering a surface area of 76.4 cm^2) with 500-µm mesh across the top to prevent loss of surface animals. Replicates were haphazardly positioned at each systematically distributed (see Fig. 1) sample station within a 3-m^2 area. All core samples were taken to a depth of 10 cm. After being transported to the boat, the contents were emptied from the core tubes into plastic bags, labeled, and sealed. Immediately upon returning to the lab, the material from the cores was sieved through a 500-µm mesh. Material retained on the sieve was preserved in a 5% aqueous solution of buffered formalin. Rose Bengal vital stain was added to the samples to facilitate sorting. After a week, the formalin was drained off through a 500-µm sieve and replaced with 70% ethanol. Subsequently, animals were separated from detritus by hand picking and identified to family. Several benthic impact studies including especially those by Warwick (1988) of IMER in Plymouth, England have demonstrated that analysis of response at the level of family preserves all the information about community patterns without the high costs of proceeding to species level.

At the same time that the macrofaunal cores were taken, divers collected three 2.65cm-diameter cores to a depth of 2 cm at each site to sample the meiofauna (fauna smaller than 0.5mm and greater than 0.063mm). These samples were iced onboard ship, preserved in the lab with a 5% aqueous solution of formalin, and archived for possible analysis, if required.

Benthic sled sampling was used to collect belt transect samples of larger, more sparsely distributed animals such as hermit crabs and sand dollars. The sled has matching steel blades on both the top and the bottom so that it functions properly no matter how it lands on the bottom. To produce a belt transect, the sled (25 cm tall with a 63 cm wide blade) was towed 15.8 m along the bottom by a line extending to the boat and sampled the top 6 cm of sediment. Sediment passes through the 6 mm mesh and larger organisms are retained. A taut-line buoy attached to the sled allowed for accurate positioning along the marked course. We sampled only on a flat-calm day (9 December 1999) at sea to prevent the sled from bouncing and to control its positioning. Using this sled, we took 40 belt transect samples of 10 m^2 each. This design yielded two replicate belt transect samples at each of the 20 sampling sites (Fig. 1). Animals found in the sled samples were identified, counted, and recorded. Species not immediately identifiable in the field were collected and returned to the lab for identification.

B. Demersal Fish and Crustaceans

In order to provide a semi-quantitative characterization of demersal fishes and crustaceans, including commercially or recreationally important species, that occupy the potential borrow areas and may conceivably be impacted directly by dredging operations or indirectly by loss of their benthic invertebrate prey, we sampled the demersal species of the three borrow areas. This sampling design is similar to that conducted by Van Dolah et al. (1994) in assessing impacts of sand mining on demersal fishes and invertebrates for beach renourishment at Folly Beach, South Carolina. Replicate trawl samples were taken on 29 November 1999, on 4 February 2000, and on 11 May 2000 from the R/V Capricorn using timed 20-minute otter-trawl tows at 4.02k/hr with a 12.3-m otter trawl. Thus the trawl would cover 16,492 m^2 of bottom area if there were no currents. The actual bottom area covered varied according to wind and tidal currents during any specific tow, which is why tows were standardized by time and speed rather than distance covered. These trawl samples were distributed as follows: 4 in Borrow Area A and 2 in each of Borrow Areas B-1 and B-2. The contents of each tow were identified to species, counted, and recorded. In addition, stomachs of up to 20 replicate individual fish of the most abundant species were removed, and preserved by formalin injection onboard ship. Stomach contents for up to twenty of the eight most common fish species from the November trawl survey were identified (when possible) and divided into major taxonomic group (e.g. polychaete, decapod, bivalve, etc.). Fish guts were examined from both inshore areas and offshore areas when possible. The divided categories were then weighed to the nearest 0.0001 g. Detailed inspection of some of the diet remains allowed identification to the family, genus or species level of some of the gut contents.

C. Sediments

At each site where macrofaunal cores were collected, divers also took core samples for grain-size analysis of sediments. Composite bottom samples were obtained at each of the ten Borrow Area sites and each of the ten control sites. Using PVC sampling tubes (16.5 cm [6.5 in] long and 2.5 cm [1 in] wide), divers collected 3 replicate samples of the upper 2 cm of the bottom within a 3-m^2 area at each of the twenty sites. Sample tubes were tightly capped, then brought to the surface and returned to the laboratory for analysis. Loss of fine-grained material, which can occur with conventional grab samplers, is minimized by using diver collections. Samples were assumed to be representative of the surficial material in which most of the macrofauna live.

In the laboratory, the replicate sediment samples were combined in a single container, then washed three times to remove salts and placed in a drying oven. After recording the bulk sample weight, a Calgon dispersant was added and the fine-grained (mud) component (by definition less than 0.063 mm diameter) was rinsed through a #230 mesh wet sieve. The remaining material (sand + gravel/coarse shell) was reweighed and prepared for sieve analysis. Prior to sieving the sand-sized fraction, the gravel/coarse shell fraction (by definition more than 2 mm in diameter) was removed with a #10 mesh sieve and weighed. A Tyler mechanical splitter was used to obtain a 25 g subsample of the remaining material (sand) which was then sieved at ¼ phi intervals (Carver 1971).

Each sieve stack was placed in a mechanical ro-tap for 20 minutes. Individual sieve fractions were weighed and recorded. Small amounts of fine-grained sediment that had not previously washed through the wet sieve were collected in a pan at the bottom of the sieve stack and, for computational purposes, were included with the wet-sieved material. Percentages of gravel/coarse shell, sand, and fine-grained sediment were computed from the bulk sample weights, and percentages of each size fraction in the sand range were computed from the 25 g splits that were sieved. Mean and standard deviation were computed using Excel software and mean phi values were converted to millimeters using the standard conversion, phi = $-\log_2$(mm), where mm corresponds to the intermediate diameter in mm (Folk 1974).

3. Results

A. Benthic Invertebrate Resources

Table 2 (2a for per-core results and 2b normalized to per square meter) presents the results of analyses of the 200 core samples taken to describe the benthic macrofauna at the three Borrow Areas and the surrounding Controls for each. Total macrofaunal densities were slightly greater at the offshore sites (14.1 invertebrates per core at Borrow Area A and 9.3 per core averaged over nearby Control sites) than at the inshore sites (9.7 invertebrates per core averaged over Borrow Areas B-1 and B-2 and 6.6 per core averaged over nearby Control sites). Results suggest slightly higher macrofaunal abundances in the Borrow Areas than in their respective Control Areas (Fig. 2). To test whether these possible differences are the consequence of differences in surficial sediments, we regressed average invertebrate density in cores against mean phi for each sampling site, conducting a separate analysis for the offshore and inshore sites. The inshore sites revealed no significant relationship (Fig. 3a) with a p-value of 0.28. The analogous regression for the offshore sites (Fig. 3b) was statistically significant at $p< 0.0001$, but the direction of the effect was reversed from normal expectation. Benthic infaunal abundance might normally be expected to be lower where sediments are coarser except when fine sediments are organically rich enough to create local reducing conditions and generate toxic hydrogen sulfide. However, here the two anomalous treatment sites in the offshore area with high shell content and low phi values had the highest densities of infaunal invertebrates (Fig. 3b). This relationship may be the indirect consequence of surficial shell inhibiting fish and invertebrate predation on infauna.

The higher taxonomic composition of the benthic infauna sampled in cores did not vary greatly over the sample sites. Over all sites polychaetes accounted for 65 % to 75 % of the total macrofauna in these late-fall 1999 samples. Because of the dominance by polychaetes, they exhibited the same patterns across depth and treatment (Fig. 4) as the total macrofauna (Fig. 2). Other common groups in order of abundance were bivalves (Fig. 5), nemerteans, small crustaceans, echinoderms, and gastropods (Fig. 6). The Appendix presents all the raw data.

Table 3 (3a for per-belt transect results and 3b normalized to per square meter) describes the results of analysis of all 40 belt transects for larger benthic invertebrates. The inshore sites revealed higher numbers of these larger invertebrates than the offshore sites. Borrow Area A contained 3.1 larger invertebrates per $10m^2$ belt transect and its nearby Control sites averaged 2.8, as compared to the average of Borrow Areas B-1 and B-2, which was 0.7 and their nearby control sites of 1.2 (Table 3). No consistent difference appeared between Borrow and Control Areas in this data set (Fig. 7). Gastropods were the most common taxon represented in these samples (Fig. 8), followed by echinoderms (Fig. 9).

B. Demersal Fish and Crustaceans

Trawl sampling detected relatively large numbers of demersal fishes occupying the seafloor habitat during late fall, declining by early February, and increasing again by early May (Table 4 presents the results of trawling for fishes and crustaceans on 29 November 1999; Table 5 presents the 4 February 2000 results; and Table 6 presents the 11 May 2000 results). Fish and mobile crustaceans caught in the trawls showed site averages ranging from 16,531 to 37,149 per km^2 in November, from 1,087 to 9,882 per km^2 in February, and 488 to 120,536 per km^2 in May (Tables 4-6).

In November, offshore areas were dominated by spot, which accounted for more than 50% of total catch and was sufficiently abundant there to create a pattern of slightly higher fish densities offshore than inshore. In addition to spot, pinfish, pigfish, and croaker were the most common species offshore (Table 4a). Inshore fishes were dominated by croaker, silver perch, silversides, pinfish, and sea mullet (Table 4b).

The abundance of most fish species had decreased by 4 February. This February sampling took place after a 3-week cold spell, the first prolonged cold weather of the winter of 1999-2000. The contents of these February 2000 samples (Table 5a,b) contrasted with those of November 1999 (Table 4a,b), showing an average reduction in catch by 81%. Catch in February from inshore stations was 41% and of offshore stations 3.7% of the corresponding catches in November. The abundances of two commercially and recreationally important species, spot and croaker, which made up 51% of the fall catch, dropped by 98.9% and 99.8% respectively. In February, pinfish, menhaden, and silversides made up 96.4% of the total catch. Spot, croaker, pigfish, sea mullet, and silver perch all showed large declines from November to February in both inshore and offshore areas. Pinfish catch in offshore areas was greatly reduced in February compared to November; however, inshore catches of pinfish were similar across dates. Two species of fish, menhaden and southern flounder (both found only in the inshore area), were more abundant in February than in November.

Our sampling on 11 May 2000 revealed higher total abundance of fishes in the inshore areas than we observed in either of our earlier samplings, but total fish abundance in the offshore borrow areas was intermediate between the December and February counts (Table 6a,b). Catch in May from the inshore stations was 1200% higher (Table 6a) than in February, largely due to increases in Atlantic silversides and Atlantic thread herring. In the offshore stations, catch in May was 1600% greater (Table 6b) than observed in February. Pigfish and scup largely accounted for this enhancement in total fish abundance in the offshore.

Examination of the stomach contents of the eight most abundant fish (croaker, gray trout, pinfish, pigfish, sea mullet, silver perch, silversides, and spot) taken from the November 1999 sampling demonstrated that many of the benthic invertebrates found in core samples and belt transects were major diet items of these fish (Table 7). Only about half of all stomachs examined were empty, with some variation among species. Major prey species for croaker and pinfish included polychaete worms, bivalves, and occasionally small shrimp (primarily grass shrimp, *Palaemonetes* sp.) and crabs (primarily pinnotherid crabs). Shrimp (both *Palaemonetes* sp. and penaeids) and to a lesser degree portunid crabs were the primary prey species found in the stomachs of gray trout. Sea mullet prey items were dominated by pinnotherid and portunid crabs and large polychaete worms. Small grass shrimp and other bottom-dwelling crustaceans (amphipods and isopods) were the dominant prey found in silver perch stomachs. Pigfish stomachs contained primarily polychaetes with an occasional grass shrimp present. Some polychaetes and small crustaceans (isopods, cumaceans, and amphipods) were found in the stomachs of spot, but stomachs were relatively empty compared to other species. Finally, silversides fed primarily on harpacticoid (benthic dwelling) and calanoid (planktonic) copepods.

Comparisons between stomach contents of fish collected from inshore and offshore locations were possible for six of the eight species that were caught in abundance in both areas (croaker, gray trout, pinfish, silver perch, silversides, and spot). Examination of the data revealed no consistent pattern in either the proportion of empty stomachs or major prey items between the two areas.

C. Sediments

Data are summarized in Table 8; individual size frequency curves and histograms are provided in Figure 10. With the exception of two treatment sites in Borrow Area A, sands comprised at least 90% of the bottom sediment by weight. In all cases, muds comprised less than 4% of the sediment by weight. Visual inspection of the samples revealed that the coarse fraction, typically less than 8% by weight, was comprised primarily of coarse shell fragments. Using the Wentworth size scale (Folk 1974), mean grain size in 80% of the samples was classified as fine sand and 20% as either medium or coarse sand. Values for standard deviation showed that 85% of the samples were moderately or moderately well sorted. Reed and Wells (2000) found similar sediment distribution patterns off Fort Macon, Atlantic Beach and Pine Knoll Shores, NC, in samples taken at 36 locations during each of two sampling periods, fall 1996 and spring 1997. Their samples showed muddier sediments occurring in the offshore areas but no significant seasonal variations in mean size or sorting.

Comparison of the grain size distributions taken in conjunction with the invertebrate coring and the analysis of grain sizes from the CSE Baird and Athena Technologies cores indicates finer sizes in the cores associated with the invertebrate sampling. This difference can be attributed to several factors: (1) the cores taken in association with invertebrate sampling covered only the uppermost surface layer only (2 cm), which is often covered by a thin mud drape; (2) this set of cores included Control locations outside the Borrow Areas, which were selected for their sand deposits, whereas the controls do not always match this level of coarseness; and (3) the cores associated with invertebrate sampling were collected by hand by divers in a fashion that involved minimal loss of fines during the sampling process.

4. Discussion

The benthic invertebrates occupying the bottom in both the inshore and offshore Borrow Areas represent species that are indeed being consumed by demersal fishes, such as spot, croaker, pinfish, pigfish, and sea mullets. Our gut examinations revealed that feeding was active and intense enough on the benthos in late November to yield gut contents in fishes with gut passage times of 6-12 hours. Compared to other gut data that we have taken from demersal fishes in the Neuse River and the Newport River in summer (pers. obs.), the percentages of empty stomachs in this data set are quite low. The densities of benthic invertebrates (6-16 individuals per 76.4-cm^2 core) are similar to those found occupying sandy bottoms in the Beaufort Inlet in December 1994 (Peterson et al. 1999), which were around 10 individuals per 76.4 cm^2 core (the same used in this study). The Beaufort Inlet samples were taken at a depth of 26-36 feet, similar to the inshore sites sampled in this study. Both surveys showed a general dominance by polychaetes. No other sampling of benthic invertebrates is truly comparable to these because of differences in sieve mesh size, water depth, reef proximity, geography, or sedimentology. Nevertheless, we present some benthic macrofauna data in Tables 9 (total macrofauna) and 10 (major taxa) from these other studies for contrast. Densities of benthic infauna in cores at the Borrow Areas in late November during our sampling period and in the earlier Beaufort Inlet study are lower than those observed near hard-bottom reefs off Wrightsville Beach (Posey and Ambrose 1994) and those observed by Van Dolah (1994) in finer sediments off Hilton Head, South Carolina (Table 8). For those taxa reported in Posey and Ambrose (1994), bivalves, gastropods, scaphopods, amphipods, isopods, polychaetes, and echinoderms, densities were higher than in our sampling of the Borrow Areas (Table 9).

Belt transects for larger invertebrates revealed a similar dominance by gastropod molluscs in our new data set from the Borrow Areas and in our earlier Beaufort Inlet study. These larger invertebrates were slightly more common in the Beaufort Inlet than in the study areas sampled here (Table 11). Greater echinoderm (sand dollar) densities occurred in the vicinity of the Beaufort Inlet. The only other analogous data set on larger invertebrates comes from Dahlgren et al. (1994), although they report only some taxa from belt transects near hard-bottom reefs off Wrightsville Beach. Dahlgren et al. (1994) reported belt transect data (Table 11) for several classes of echinoderms near the same reefs studies by Posey and Ambrose (1994). Dahlgren et al. (1994) observed higher densities of holothuroids (sea cucumbers) than we document in the Borrow Areas but similar densities of echinoids (sand dollars) and stelleroids (sea stars) (Table 11). The difference in sea cucumber densities is likely also a consequence of the finer sediments in the site studied by Dahlgren et al. (1994).

Our fish sampling revealed densities of many fishes as high in December as we routinely find during all the warm months in the vicinity of Beaufort Inlet immediately outside the estuary and as high as Van Dolah et al. (1994) found in the Folly River. The fish assemblage at the proposed borrow sites for the Bogue Banks project was dominated by species of substantial value to commercial and recreational fisheries of North Carolina and neighboring states. These fishes were actively feeding on the benthic macrofauna. Shrimp catches were low, although commercial shrimp trawling was being conducted in the immediate vicinity of all the Borrow Areas at the time of our sampling in late fall 1999. Many species of demersal fish of the estuaries of North Carolina and the Southeast generally are known to exit the sounds and estuaries in the fall on route to offshore sites for overwintering. The precise locations of these overwintering sites are not completely described, but our sampling indicates that this area off Bogue Banks is utilized in abundance during late fall by spot, croaker, pigfish, pinfish, silver perch, and sea mullet. Subsequent sampling during early February revealed emigration of these fishes to unknown locations as the weather became cooler. The only other conceivably comparable data on fish and crustacean abundances from trawl sampling come from Van Dolah et al. (1994). They reported average densities in the Folly River, South Carolina ranging across site and season from about 7,000 to 55,000 per km^2. These densities are similar to our average densities ranging from 500 up to 120,536 per km^2. The densities that we observed around the borrow areas in late November 1999 were judged by our boat captain, who has operated this trawl routinely for 25 years, to be similar to densities in spring, summer, and fall around Beaufort Inlet (J. Purifoy, pers. com.).

Dredging could impact the demersal fishes and crustaceans by direct removal and mortality during dredging, by causing emigration to other areas, where crowding could reduce growth and production, and by creating some unknown period of time when benthic prey abundances had not yet recovered and so growth and production were reduced. If sediment character in the borrow areas changes after sand mining, the new community of benthic invertebrates could differ dramatically from the existing community and could provide less of more food resources for demersal fishes and crustaceans. Van Dolah et al. (1994) demonstrated an effect of sand mining at the borrow area on species richness of demersal fishes and crustaceans that persisted through the first spring and fall after the cessation of the winter project; however, no effect was detected on total fish abundance.

Our sampling was designed to serve as the fall baseline data set for the Borrow Areas in contemplation of a monitoring scheme to assess impacts of and recovery from the sand mining for beach renourishment. This includes not only the benthic macrofauna and demersal fishes but also the sediments on the sea floor. Unfortunately, two sites in the offshore borrow area (A) possesses sediments that are much coarser with much higher shell content than any of the controls (Fig. 3b), so that we have no adequate control for this portion of the borrow area. Unless one of these sites is mined and one is not, any subsequent assessment of impacts of sand mining will be compromised by this sedimentological anomaly. Because the macrofauna is so closely tied to sediment character, the evaluation of any changes in surface sediment character after mining is critical to interpreting the impacts on and recovery of benthic invertebrates and probably also fishes. The limited amount of past literature on impacts of sand mining at borrow sites on the nearshore shelf gives mixed indications of whether recovery of benthic invertebrates will occur rapidly or slowly. Borrow areas in which sedimentation has not dramatically reduced the average size of surficial sediments have tended to show recovery of total benthic abundances in about a year, whereas borrow areas that experienced deposition of fine sediments exhibited recolonization by dramatically different benthic organisms and did not converge to reference or pre-dredge composition even after multiple (3 or more) years (Saloman 1974, Taylor Biological Company 1978, Van Dolah et al. 1992, 1994). There has been no definitive analysis of the conditions that lead to mud deposition in some but not other borrow areas, so no confident predictions can be generated for this specific Bogue Banks project. Presumably, rate of supply of suspended fine sediments and bottom shear stress help determine the degree of deposition of fine sediments.

Baseline sampling of the nourishment sites and control sites on the beach itself would also need to be conducted prior to sand mining, but during the warm months when the intertidal beach is used by macrofauna. We already possess a substantial amount of data on abundances of intertidal beach invertebrates from all along Bogue Banks from 1997-1999 from studies conducted by L. Manning (unpubl.: see Table 11 for an example data set). This information could conceivably be incorporated into an assessment design to evaluate the potential consequences of the renourishment on the beach system, allowing contrasts between the multiple summers before renourishment and the summer or summers afterwards as one means of assessing impact and rate of recovery. This previous sampling was not conducted in a design intended for evaluation of the Bogue Banks renourishment project, so it is unclear whether sufficient sites were sampled throughout the biologically active (warm) seasons in sufficient places to provide a set of replicated reference and treatment (renourished) sites sufficient to achieve adequately powerful tests of impacts on intertidal invertebrates. A review of past studies of the response of beach invertebrates to renourishment projects (Nelson 1989, 1993, Peterson et al. 2000) suggests that return of macroinvertebrates will be rapid if renourishment is restricted to months when invertebrates are largely absent from the intertidal beach and if a good match exists between grain size distributions of the natural beach and the new sands that are added. Finer particles are detrimental to suspension feeders, especially mole crabs (Bowman and Dolan 1985), and slow their recovery. In analyzing short-term effects of renourishment in Pine Knoll Shores on Bogue Banks, North Carolina, Peterson et al. (2000) documented virtual failure to initiate the recovery process by mole crabs and coquina clams, the biomass dominants of the Bogue Banks intertidal beaches, by mid July, 5-10 weeks after termination of the project. This renourishment grossly modified the beach sedimentology, changing average phi from 2.33 to 3.67 (Peterson et al. 2000). A previous renourishment project on Bogue Banks at Fort Macon studied by Reilly and Bellis (1983) documented a similar failure of coquina clams to return to the beach by the first July after project completion, but mole crabs did return with only a one-month time lag relative to the seasonal cycle at control beaches. No information on quantitative sedimentology is provided in that report, although there is a claim of a good match in grain size, which could explain why mole crabs were able to initiate recovery sooner than in the Pine Knoll Shores project studied by Peterson et al. (2000). Manning (unpub. data) also has shown that enhancing shell content on the intertidal beach has a strong negative effect on coquina clams by inhibiting normal rates of burrowing, thereby exposing them to transport off the beach into unfavorable and potentially inhospitable environments.

5. Conclusions and Recommendations

(1) Based on our benthic invertebrate sampling, fish trawling, and observations of fish guts, we conclude that demersal fishes of commercial and recreational value are using the invertebrates on the seafloor at the Borrow Areas as food during the late fall (and presumably also winter and spring). We recommend a targeted evaluation of the degree to which these fishes are food-limited during late fall through spring and the degree to which they rely in all seasons on the prospective Borrow Areas for feeding as compared to nearby bottom habitats and sites, so as to evaluate the significance of reduced abundances of benthic invertebrates in Borrow Areas. It is presently unclear in the absence of sampling other shelf habitats and sites whether the sand bodies proposed for dredging are preferred feeding grounds, relatively low-use feeding grounds, or used in proportion to the bottom area that they occupy.

(2) We conclude that demersal fishes are sufficiently abundant at the Borrow Areas to justify additional sampling at other seasons and in other habitats offshore so as to be able to quantify the importance of the Borrow Areas to the total fish populations.

(3) We conclude that benthic invertebrates are common enough during late fall in the Borrow Areas and important enough as food for demersal fishes as to justify benthic monitoring in other seasons of the year prior to and after mining activities to assess impact and recovery.

(4) We conclude that sampling of intertidal beach invertebrates is necessary to provide the baseline for impact assessment after the renourishment. Such baseline information could conceivably come from historical data, but only if a sufficiently powerful design can be created, based on knowledge of spatial and temporal fluctuations and the project plan.

(5) A review of limited information on recovery rates of sediments and benthic invertebrate resources in offshore borrow areas from other studies suggests that recovery rate is unpredictable, requiring times ranging from a year to indefinite (undetermined) numbers of years.

(6) Results of the most applicable and recent study of impacts of renourishment on beach invertebrates imply effects that could last throughout the warm season if sediments used in renourishment do not match those of the natural beach. We recommend that renourishment occur in winter (the period of low intertidal abundances of beach invertebrates, which is December through March) and that sands used in renourishment be treated to remove shell that exceeds the average on the untreated beach and be selected to avoid deposition of mud balls and silts and clays to minimize duration of negative impacts. It seems that enhancement of the phi size to 3.67 was inadequate to allow rapid recolonization in a previous renourishment of Bogue Banks, but what phi increase is possible without impact on recovery rates of beach invertebrates is unclear.

(7) We conclude that inadequate information exists to recommend one proposed Borrow Area over any other for this project. Sampling of benthic invertebrate resources on only a single date does not provide sufficient seasonal coverage to rank the proposed Borrow Areas by importance as prey for demersal fishes and crustaceans.

(8) We conclude that the Bogue Banks renourishment project could be conducted with minimal adverse ecological damage (a) if the borrow sites were dredged in a way that avoided complete excavation of the sand body and avoided changes in sedimentation processes, thus preventing their transformation into depositional muddy areas, (b) if the dredging were confined to periods of low abundance of demersal fishes and shrimps at the borrow areas (as determined by in situ monitoring prior to dredging), and (c) if the sands deposited on the intertidal beach matched the size distribution of natural sands on the beach with minimal muds and minimal shell and were deposited during the winter (December through March) when these invertebrates are largely absent. These requirements present technical uncertainties because (a) it is not clear that we understand the potential sources of fine sediments and the processes of deposition of fine sediments at the Borrow Areas well enough to have confidence in designing the sand mining in a way that will avoid transformation into muddy bottoms; (b) the costs of placing the dredge on hold while awaiting departure of demersal fishes in late fall may preclude using monitoring to determine exactly when fish impacts will be minimized; and (c) costs of providing a sand resource that matches the sedimentology of the natural beach may be high.

6. Literature Cited

Bowman, M.L., and R. Dolan. 1985. The relationship of Emerita talpoida to beach charactersitics. J. Coastal Res. 1:151-163.

Carver, R.E., 1971. Procedures in Sedimentary Petrology. Wiley-Interscience, New York. pp. 49-127.

Dahlgren, C.P., M.H. Posey, and A.W. Hulbert. 1999. The effects of bioturbation on the infaunal community adjacent to an offshore hardbottom reef. Bull. Mar. Sci. 64:21-34.

Day, J.H., J.G. Field, and M.P. Montgomery. 1971. The use of numerical methods to determine the distribution of the benthic fauna across the continental shelf of North Carolina. J. Anim. Ecol. 40:93-125.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill, Austin, TX.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. Wiley, New York, NY.

McLachlan, A. 1983. Sandy beach ecology: a review. In: McLachlan, A. , and Erasmus, T. (eds.) Sandy beaches as ecosystems, W. Junk, The Hague, pp. 321-380.

Naqvi, S.M., and E.J. Pullen. 1982. Effects of beach nourishment and borrowing on marine organisms. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Misc. Rept. 82-14.

Nelson, W.G. 1989. An overview of the effects of beach nourishment on the sand beach fauna. In: Tait, L.S. (ed.) Beach preservation technology '88: problems and advances in beach nourishment. Tallahassee, FL: Florida Shore and Beach Preservation Association, pp. 295-310.

Nelson, W.G. 1993.Beach restoration in the southeastern US: environmental effects and biological monitoring. Ocean Coastal Manage. 19:157-182.

Peterson, C.H., H.C. Summerson, H.S. Lenihan, J. Grabowski, S.P. Powers, and G.W. Safrit, Jr. 1999. Beaufort Inlet Benthic Resources Survey. Report to the U.S. Army Corps of Engineers, Wilmington District Office, NC.

Peterson, C.H., D.H.M. Hickerson, and G.Grissom Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. J. Coastal Res. 16:368-378.

Posey, M.H. and W.G Ambrose, Jr. 1994. Effects of proximity to an offshore hard-bottom reef on infaunal abundances. Mar. Biol. 118:745-753.

Reed, A.J. and J.T. Wells. 2000. Sediment distribution patterns offshore of a renourished beach: Atlantic Beach and Fort Macon, North Carolina. Journal of Coastal Research (in press).

Reilly, F.J., and V.J Bellis. 1983. The ecological impacts of beach nourishment with dredged materials on the intertidal zone at Bogue Banks, North Carolina. Misc. Rept. 83-3, U.S. Army Corps of Engineers, CERC, Springfield, VA.

Saloman, C.H. 1974. Physical, chemical, and biological characteristics of nearshore zone of sandy key, Florida, prior to beach restoration. Final Report, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Snelgrove, P.V., and C.A Butman. 1994. Animal-sediment relationships revisited: cause versus effect. Oceanogr. Mar. Biol. Ann. Rev. 32:111-177.

Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker. 1986. Environmental impact assessment: pseudoreplication in time? Ecology 60:1225-1240.

Taylor Biological Company. 1978. Ecological comparison of beaches, offshore borrow sites and adjacent bottom at Anna Maria Island and Treasure Island, Florida. Contract No. DACW17-78-M-1410, U.S. Army Engineer District, Jacksonville, Jacksonville, FL.

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levinsen, and W.A. Roumillat. 1992. A physical and biological monitoring study of the Hilton Head beach nourishment project. Report to the Town of Hilton Head Island, Hilton Head Island, SC, and the South Carolina Coastal Council, Charleston, SC.

Van Dolah, R.F. R.M. Martore, A.E. Lynch, P.H. Wendt, M.V. Levisen, D.J. Whitaker, and W.D. Anderson. 1994. Environmental evaluation of the Folly Beach nourishment project. Report to the U.S. Army Corps of Engineers, Charleston, SC.

Warwick, R.M. 1988. The level of taxonomic discrimination required to detect pollution effects on marine benthic communities. Mar. Poll. Bull. 19:259-268.

Warwick, R.M. 1993. Environmental impact studies in marine communities: pragmatical considerations. Aust. J. Ecol. 18:63-80.

7. List of Figures

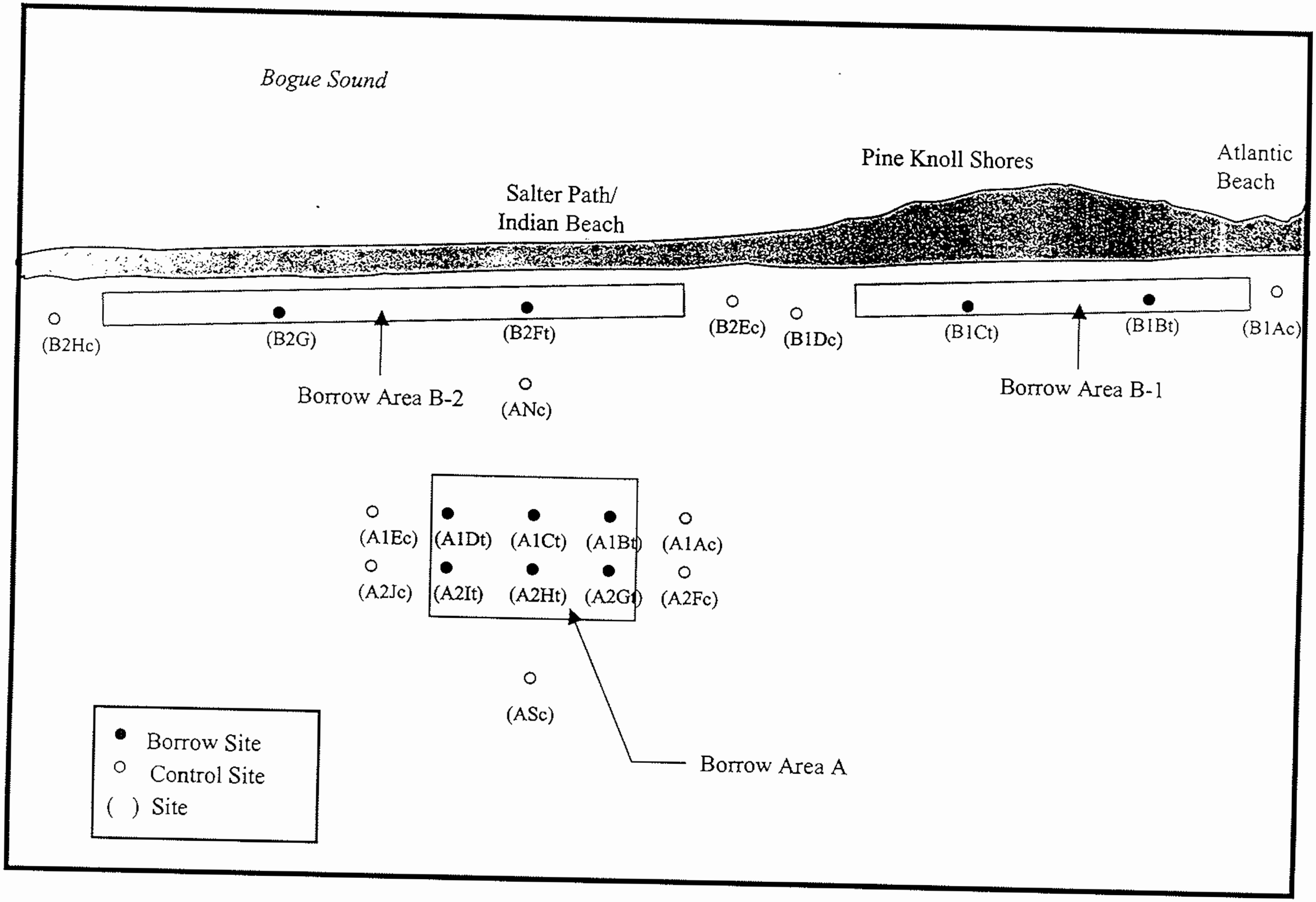


Figure 1. Schematic representation of sampling sites (see Table 1 for precise coordinates of each site).

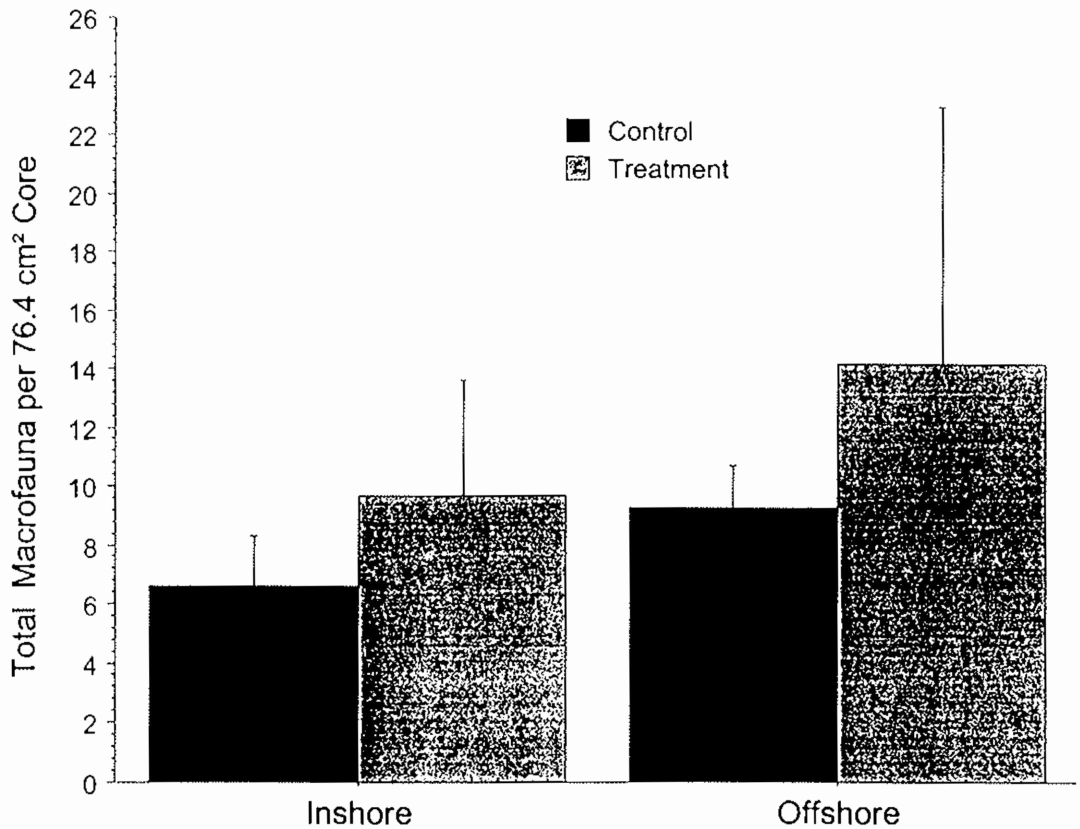


Figure 2. Mean (+standard deviation) abundances of macrofauna from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

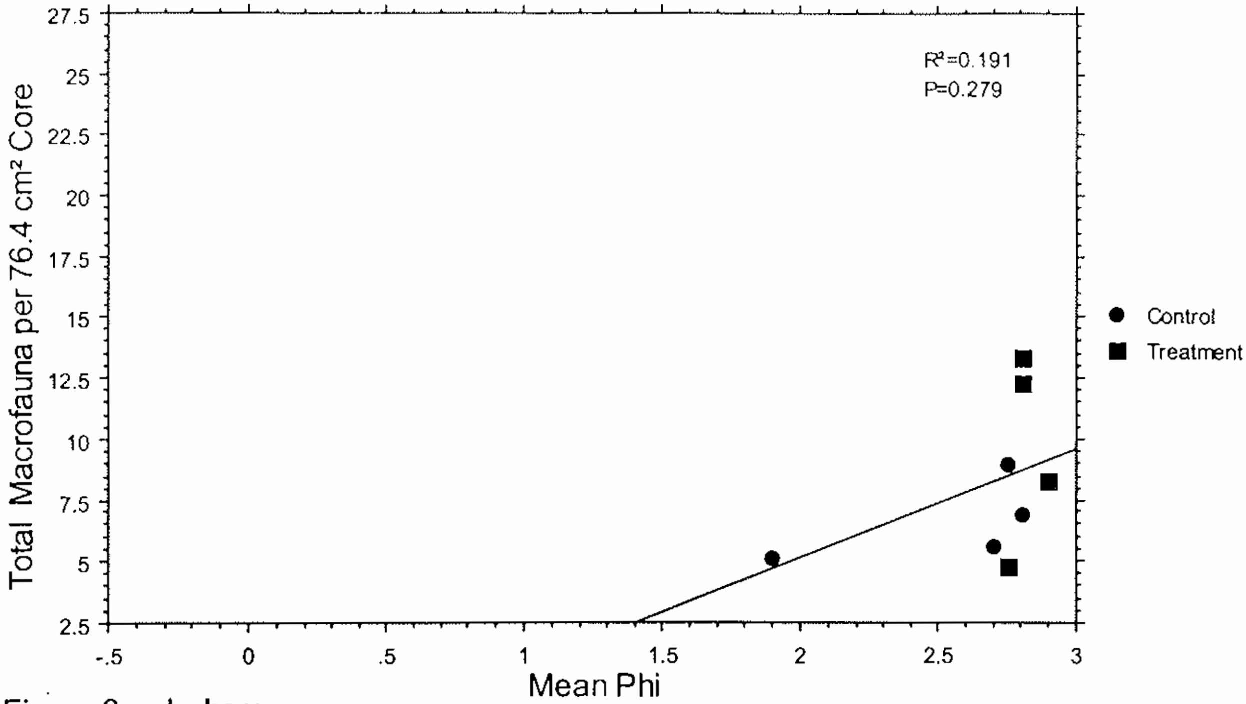


Figure 3a - Inshore

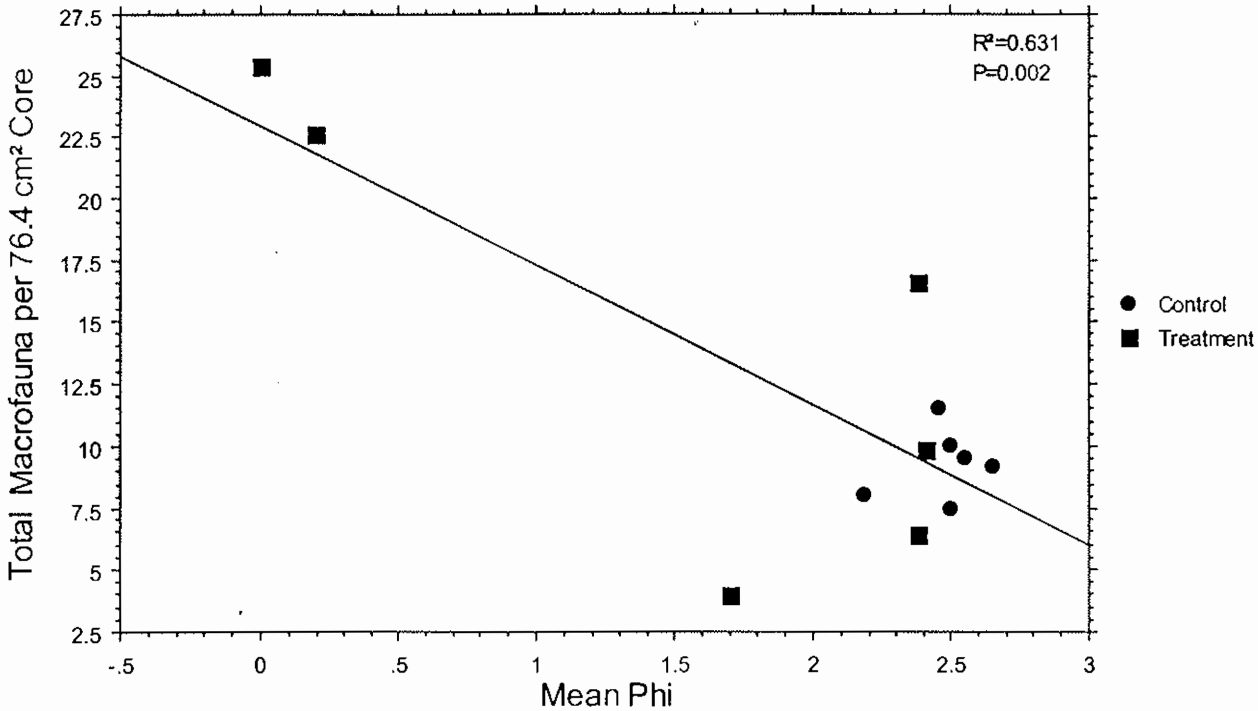


Figure 3b - Offshore

Figure 3. Regressions of mean abundances of macrofauna against sediment mean phi grain size from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore (3a) and offshore (3b). Mean values average ten 76.4 cm^2 cores per site.

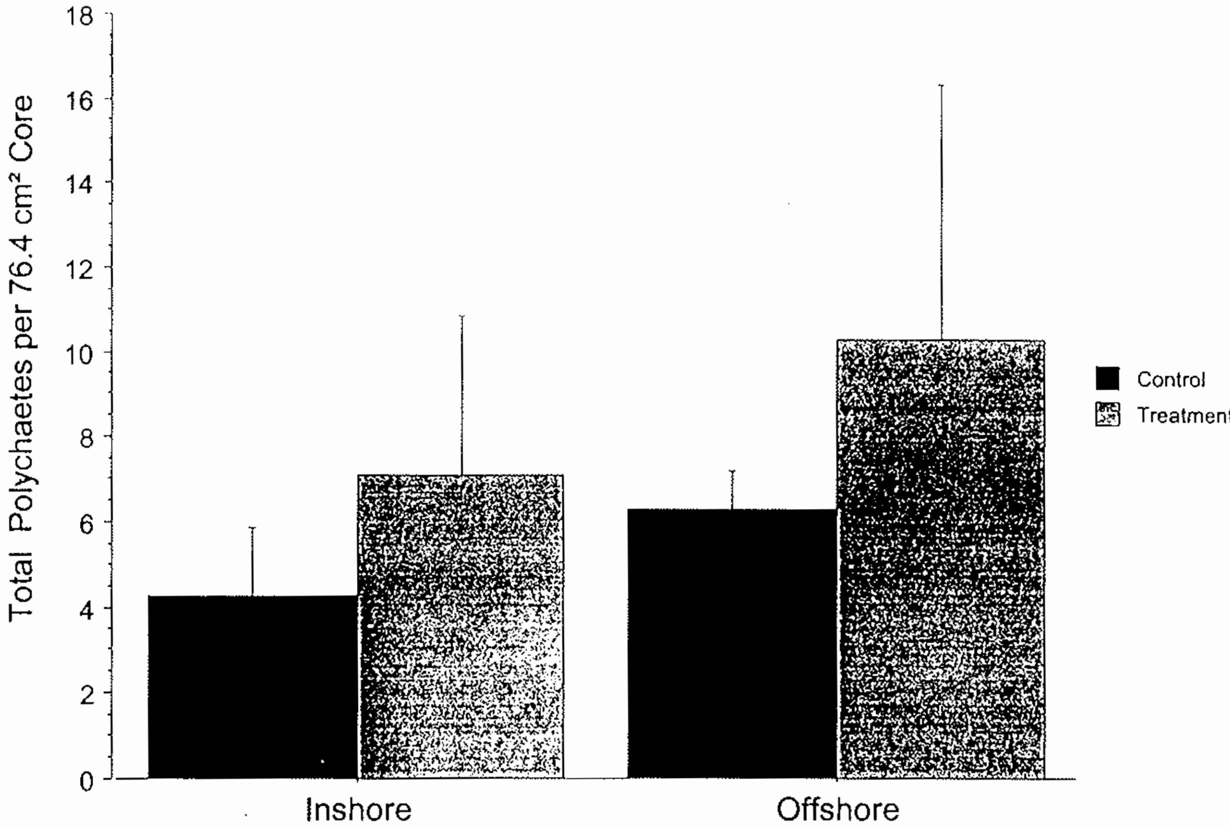


Figure 4. Mean (+standard deviation) abundances of polychaetes from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

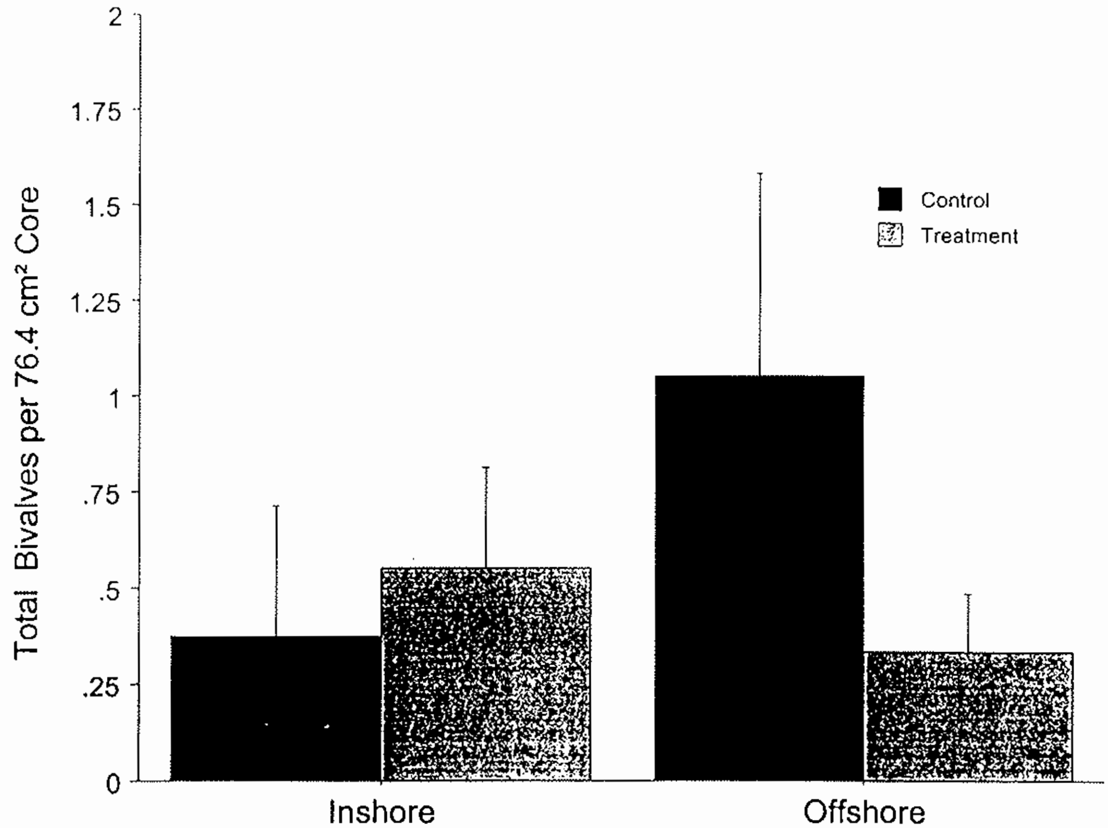


Figure 5. Mean (+standard deviation) abundances of bivalves from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

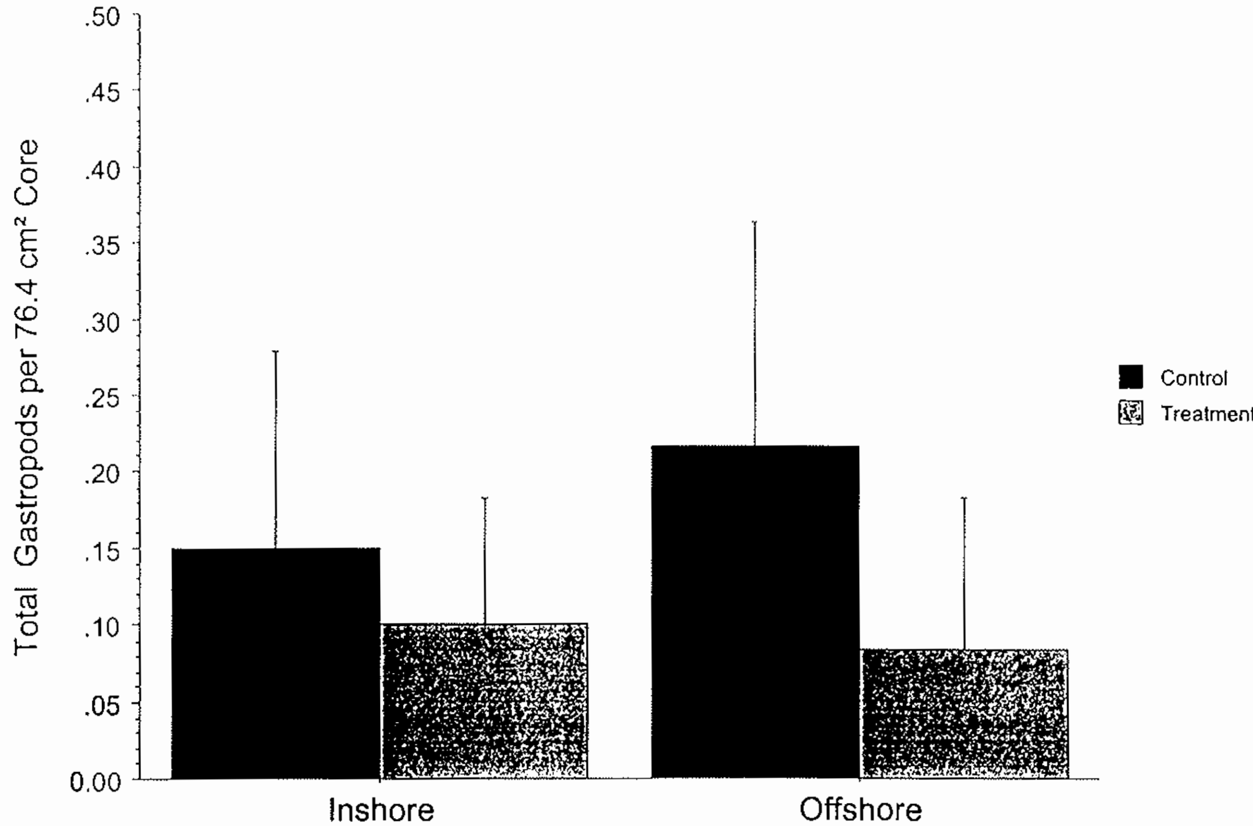


Figure 6. Mean (+standard deviation) abundances of gastropods from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average ten 76.4 cm^2 cores per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

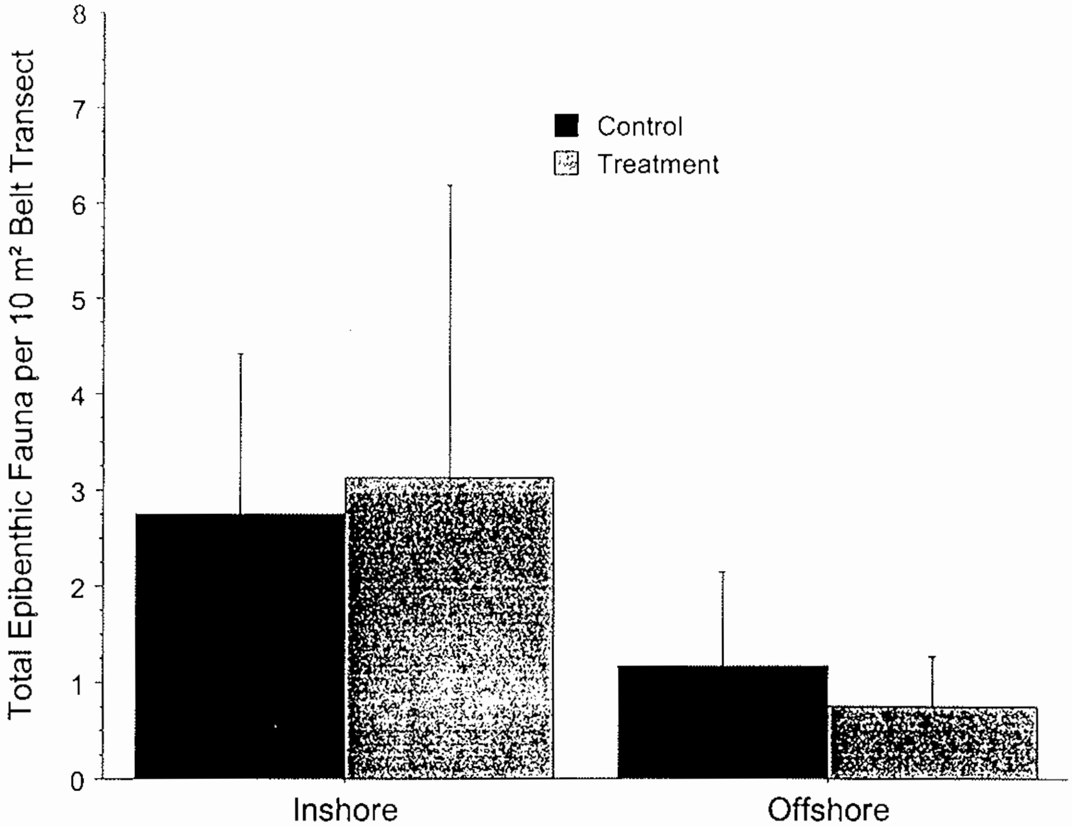


Figure 7. Mean (+standard deviation) abundances of epibenthic fauna from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average two10 m^2 belt transects per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

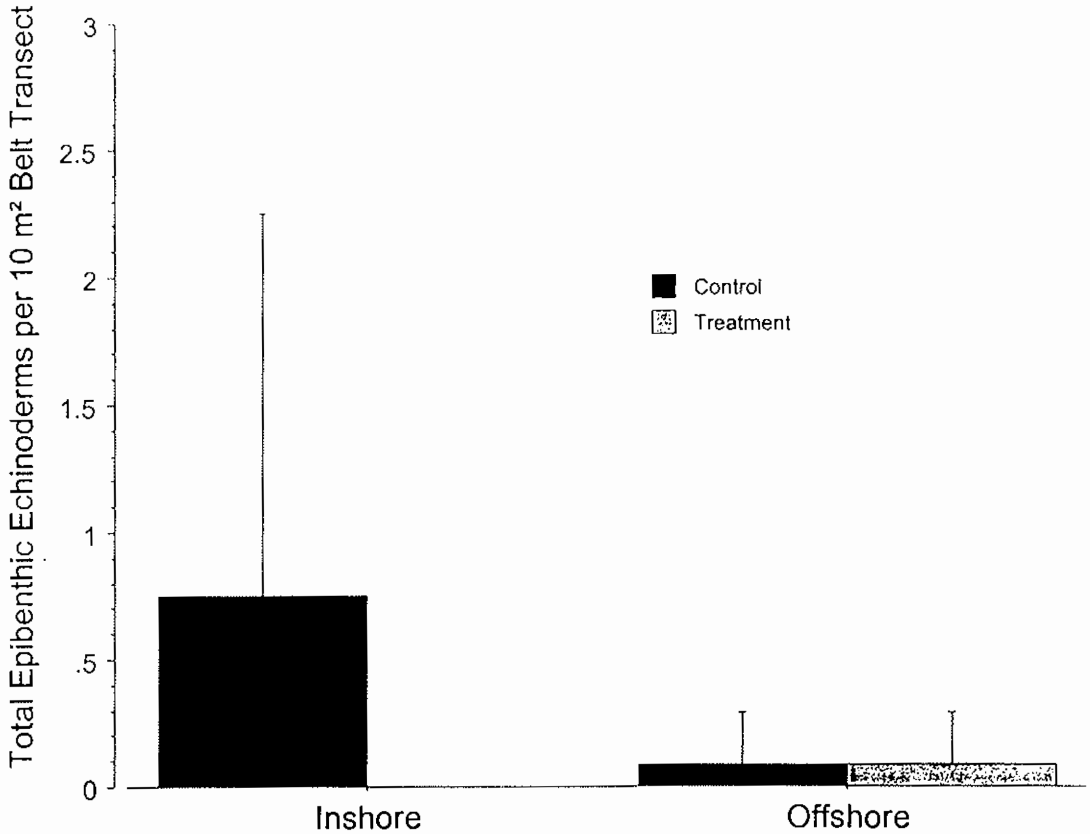


Figure 8. Mean (+standard deviation) abundances of epibenthic echinoderms from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average two10 m^2 belt transects per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

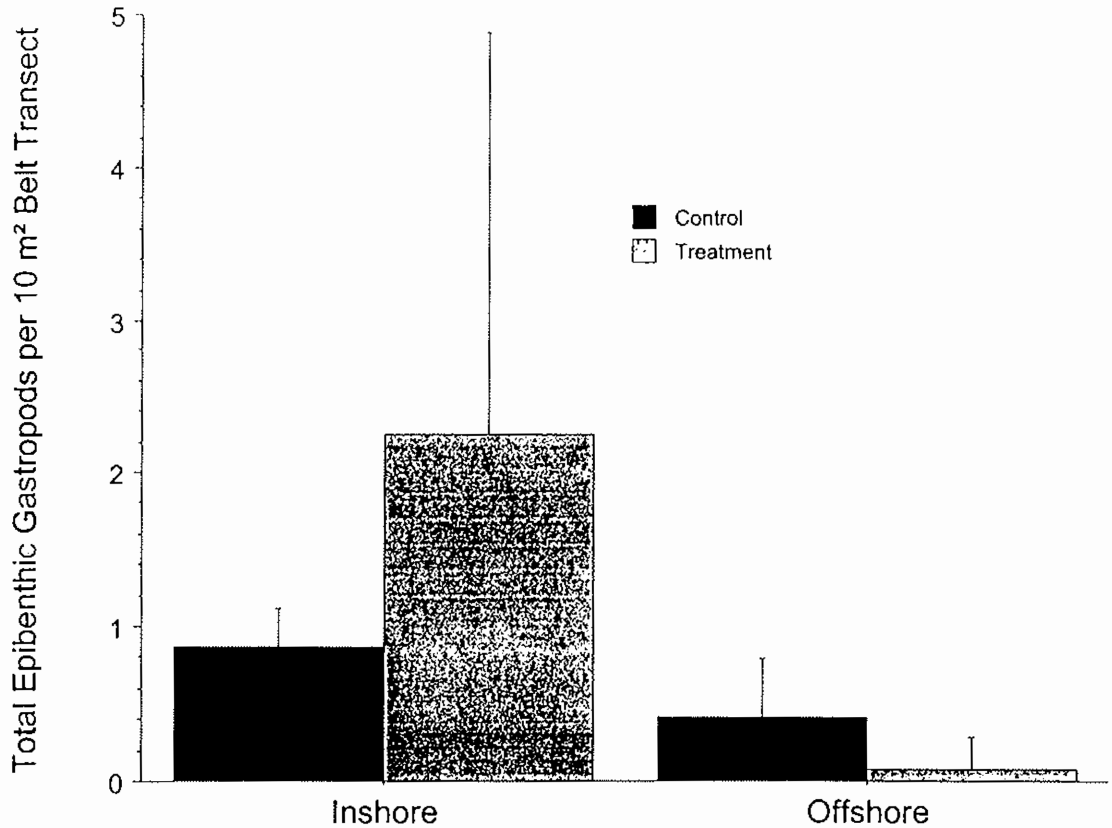
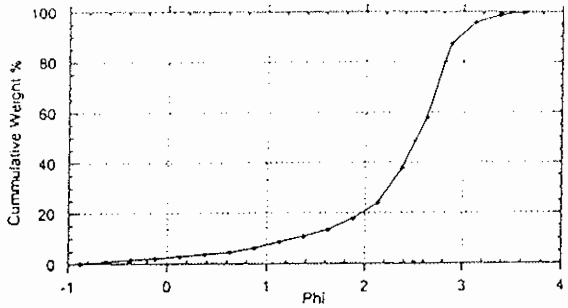


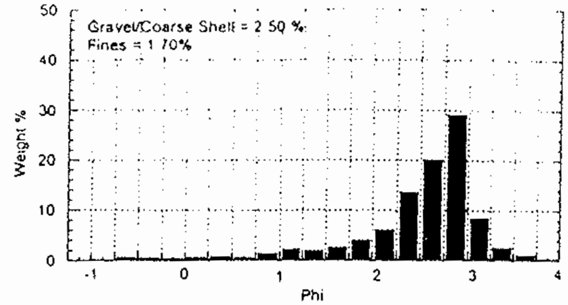
Figure 9. Mean (+standard deviation) abundances of epibenthic gastropods from within the proposed sand borrow areas (treatment) and from nearby areas surrounding the borrow areas (control) both inshore and offshore. Mean values average two10 m^2 belt transects per site. Six sites were sampled from both within and around the offshore area and four sites each from within and around the inshore area.

Figure 10. Size frequency curves and histograms of composite bottom samples taken at treatment and control sites in Borrow Areas A, B-1, and B-2.

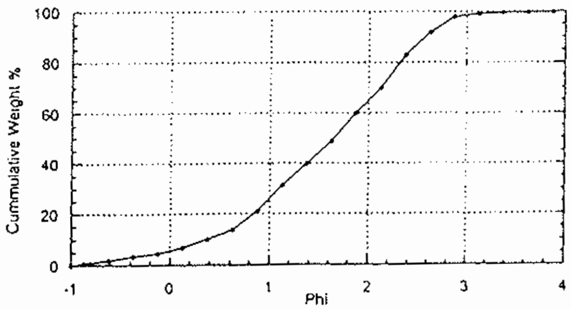
A1Ac



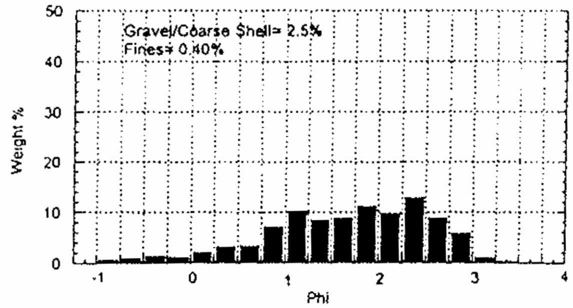
A1Ac



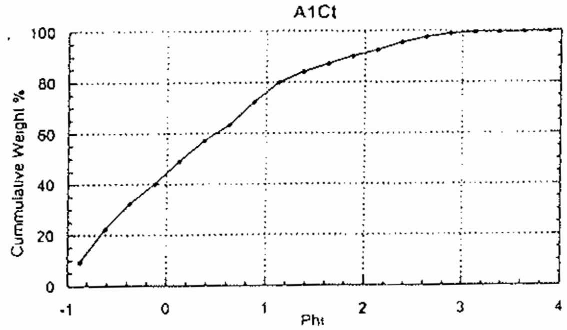
A1Bt



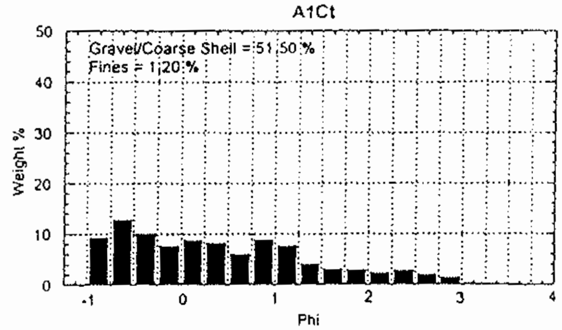
A1Bt



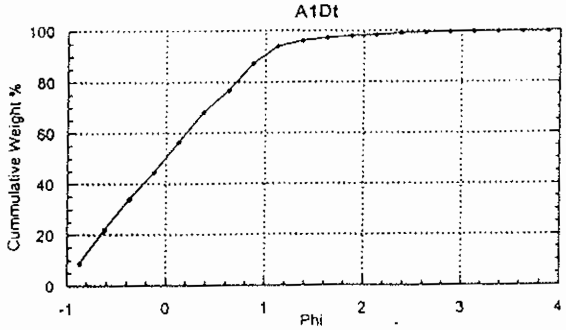
A1Ct



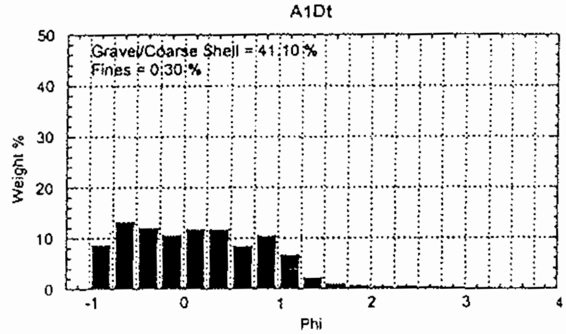
A1Ct



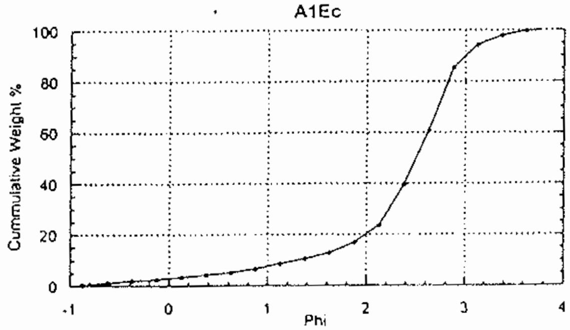
A1Dt



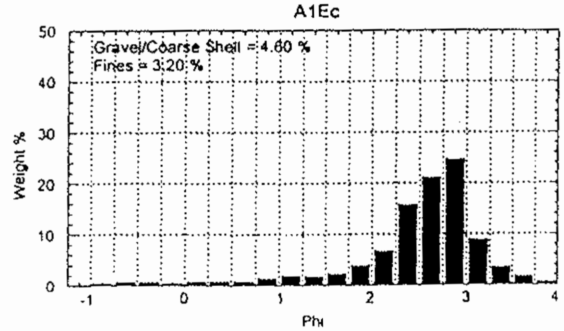
A1Dt

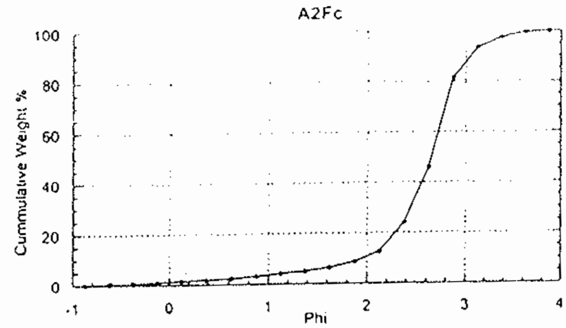


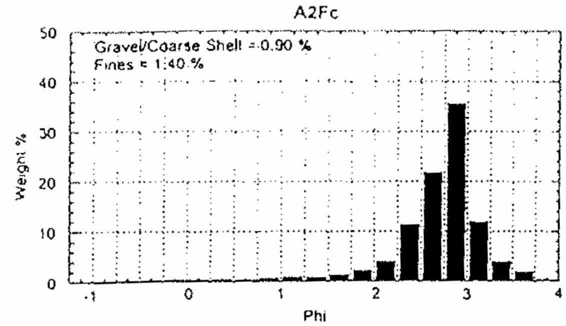
A1Ec

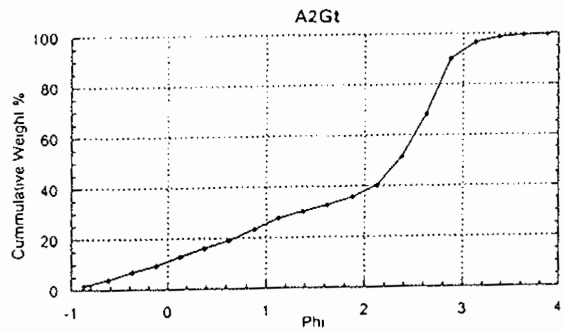


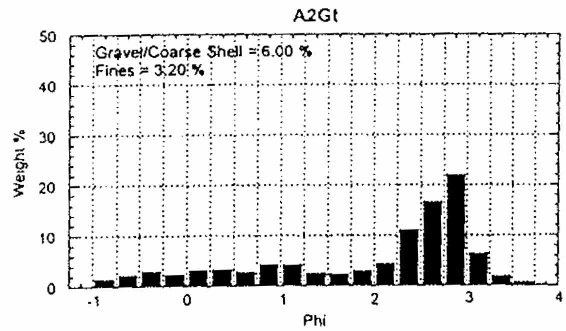
A1Ec

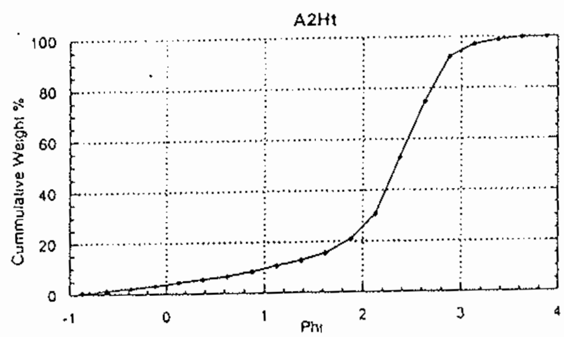


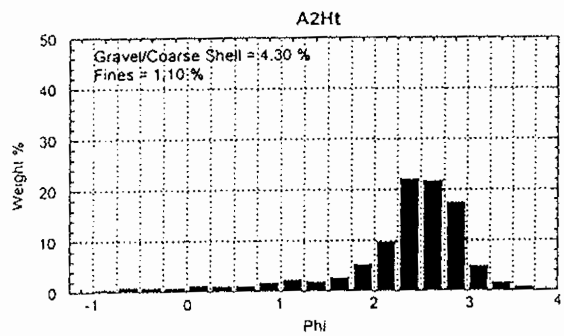

A2Fc
Cummulative Weight %
Phi

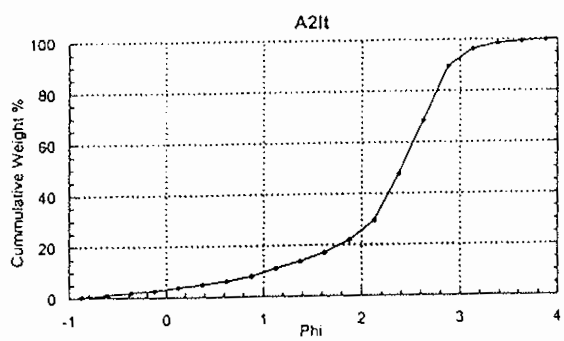

A2Fc
Gravel/Coarse Shell = 0.90 %
Fines = 1.40 %
Weight %
Phi

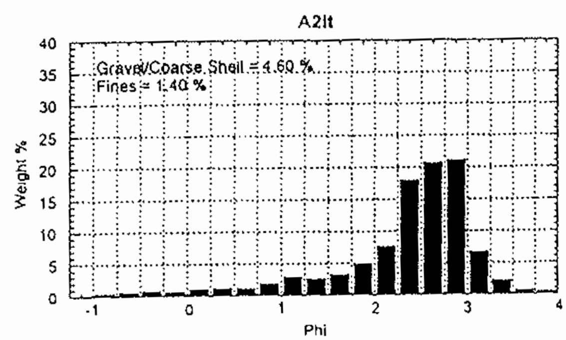

A2Gt
Cummulative Weight %
Phi

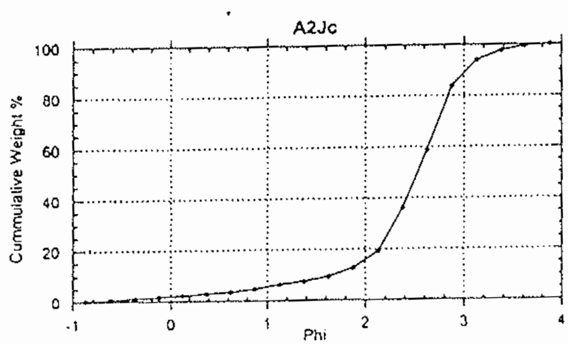

A2Gt
Gravel/Coarse Shell = 6.00 %
Fines = 3.20 %
Weight %
Phi

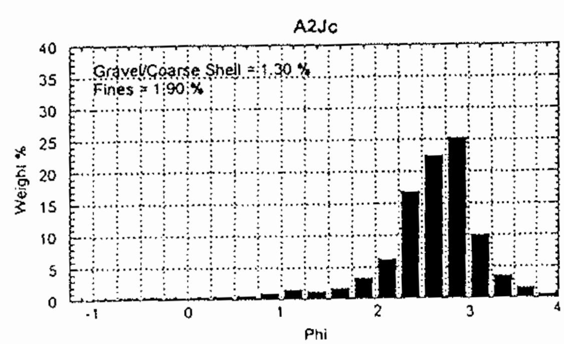

A2Ht
Cummulative Weight %
Phi

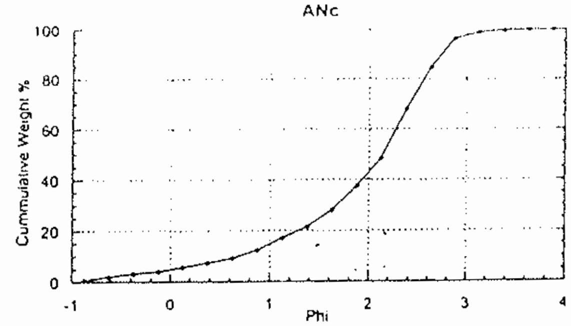

A2Ht
Gravel/Coarse Shell = 4.30 %
Fines = 1.10 %
Weight %
Phi

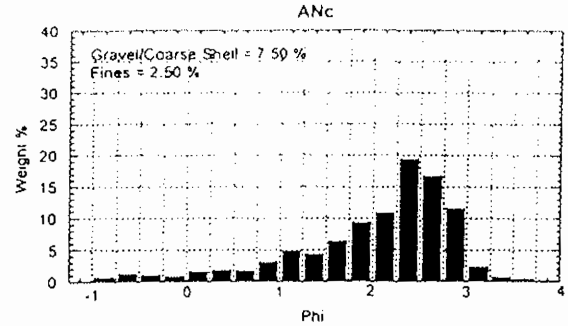

A2It
Cummulative Weight %
Phi

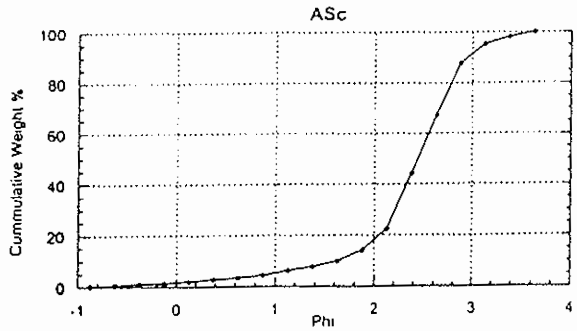

A2It
Gravel/Coarse Shell = 4.60 %
Fines = 1.40 %
Weight %
Phi

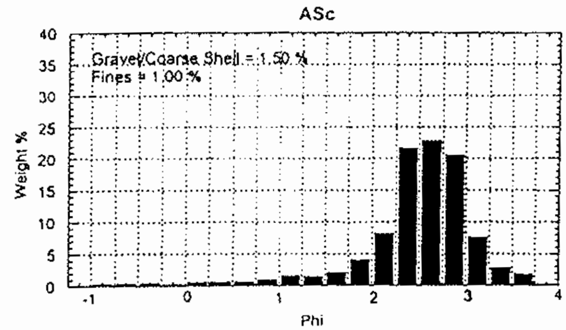

A2Jc
Cummulative Weight %
Phi

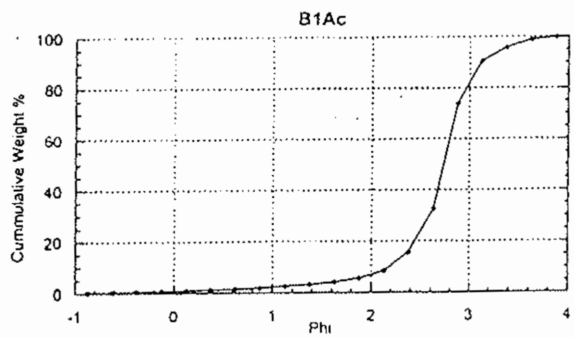

A2Jc
Gravel/Coarse Shell = 1.30 %
Fines = 1.90 %
Weight %
Phi

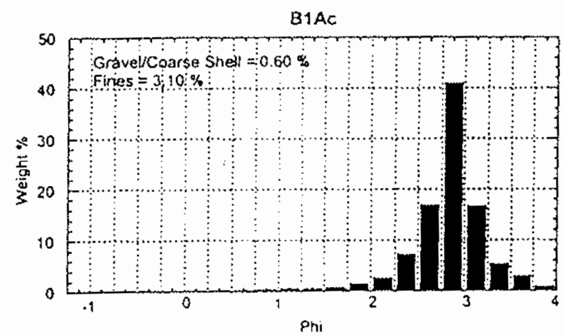

ANc
Cummulative Weight %
Phi

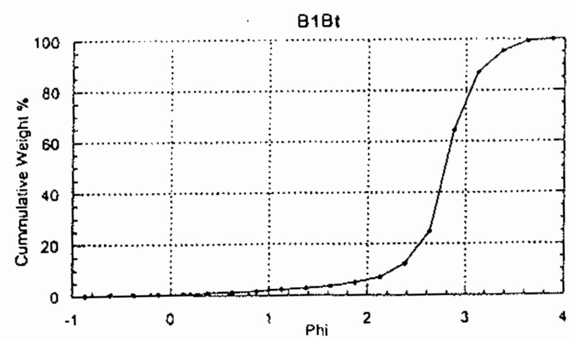

ANc
Gravel/Coarse Shell = 7.50 %
Fines = 2.50 %
Weight %
Phi

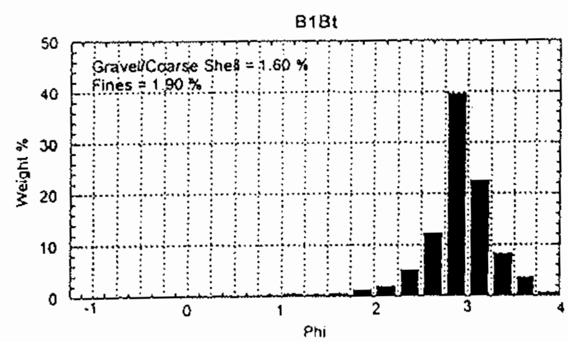

ASc
Cummulative Weight %
Phi

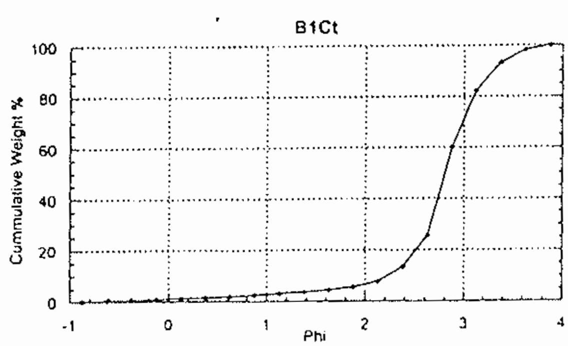

ASc
Gravel/Coarse Shell = 1.50 %
Fines = 1.00 %
Weight %
Phi

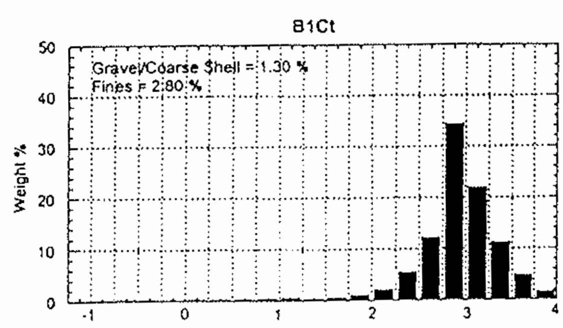

B1Ac
Cummulative Weight %
Phi


B1Ac
Gravel/Coarse Shell = 0.60 %
Fines = 3.10 %
Weight %
Phi

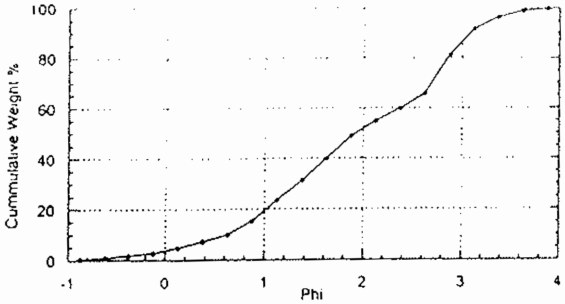

B1Bt
Cummulative Weight %
Phi


B1Bt
Gravel/Coarse Shell = 1.60 %
Fines = 1.90 %
Weight %
Phi

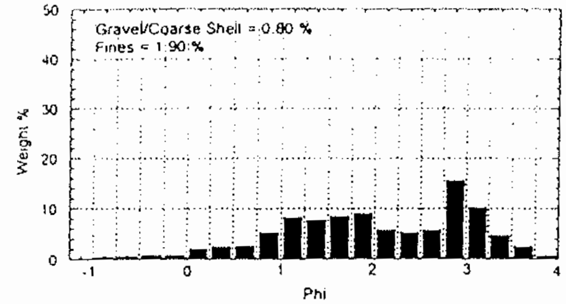

B1Ct
Cummulative Weight %
Phi


B1Ct
Gravel/Coarse Shell = 1.30 %
Fines = 2.80 %
Weight %
Phi

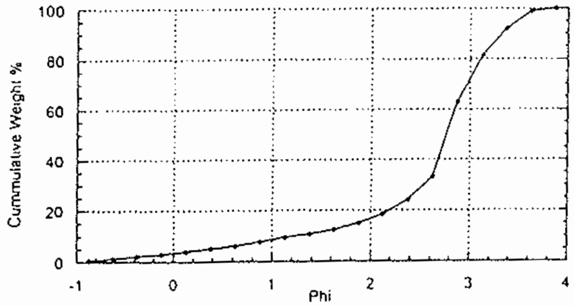
B1Dc



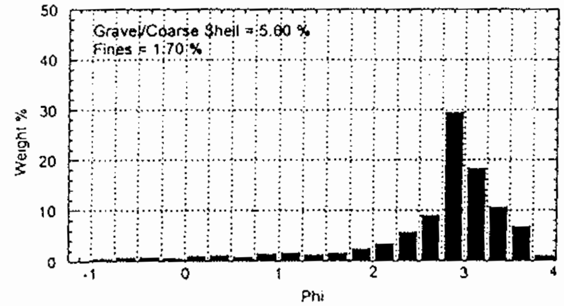
B1Dc



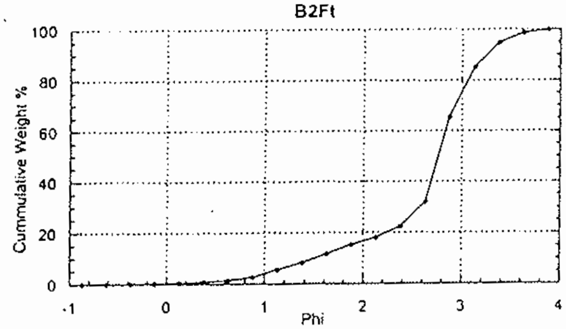
B2Ec



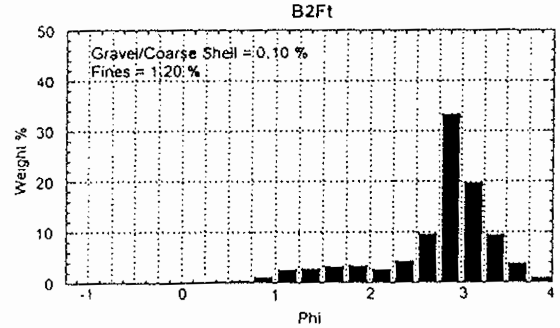
B2Ec



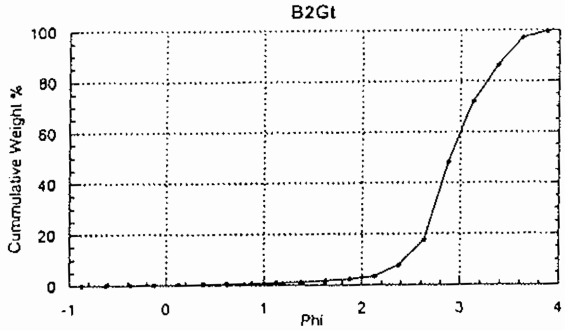
B2Ft



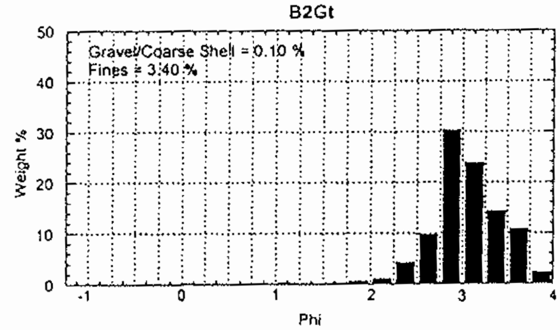
B2Ft



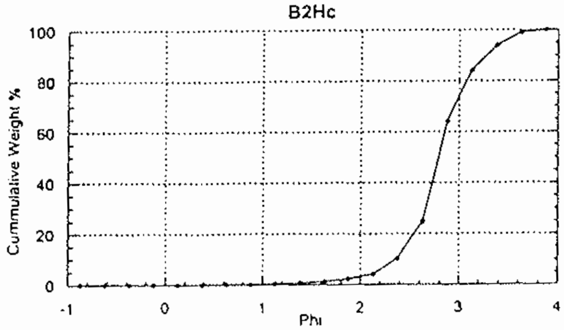
B2Gt



B2Gt



B2Hc



B2Hc

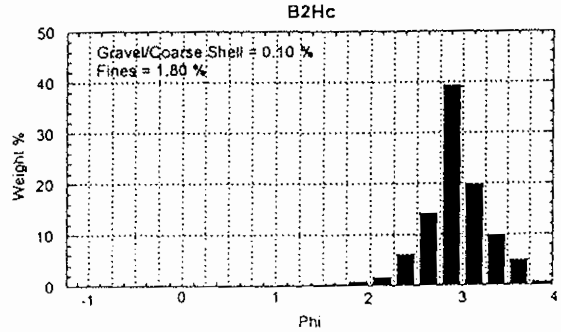


Table 1. Actual coordinates (in degrees - decimal minutes) of sites sampled in and adjacent to proposed sand Borrow Areas off Bogue Banks, NC. Sites are plotted on Figure 1.

Borrow Area 1		**Control**	
A1Bt		**A1Ac**	
N 34° 39.333'	W 76° 53.625'	N 34° 39.333'	W 76° 52.875'
A1Ct		**A1Ec**	
N 34° 39.333'	W 76° 54.375'	N 34° 39.333'	W 76° 55.875'
A1Dt		**A2Fc**	
N 34° 39.333'	W 76° 55.125'	N 34° 38.917'	W 76° 52.875'
A2Gt		**A2Jc**	
N 34° 38.917'	W 76° 53.625'	N 34° 38.917'	W 76° 55.875'
A2Ht		**ANc**	
N 34° 38.917'	W 76° 54.375'	N 34° 40.067'	W 76° 54.175'
A2It		**ASc**	
N 34° 38.917'	W 76° 55.125'	N 34° 38.183'	W 76° 54.375'
Borrow Area B-1*		**Control**	
B1Ct		**B1Ac**	
N 34° 41.06'	W 76° 49.652'	N 34° 41.261'	W 76° 45.706'
B1Bt		**B1Dc**	
N 34° 41.227'	W 76° 47.841'	N 34° 40.862'	W 76° 51.819'
Borrow Area B-2*		**Control**	
B2Ft		**B2Ec**	
N 34° 40.545'	W 76° 54.374'	N 34° 40.797'	W 76° 52.187'
B2Gt		**B2Hc**	
N 34° 40.245'	W 76° 56.44'	N 34° 39.891'	W 76° 58.752'

* sampled at 35' contour determined by standardizing for 37' at 34°41.023'N 34°49.702'W

Table 2a. Mean (SD = standard deviation) of abundance of individuals by taxonomic family found in 76.4cm² core samples taken at sites in (Treatment) and adjacent (Control) to inshore and offshore proposed sand borrow areas for the Bogue Banks beach renourshment. Statistics are calculated from the average of 10 cores taken from each of 6 sites sampled both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

			Inshore				Offshore			
			Treatment (n=4)		Control (n=4)		Treatment (n=6)		Control (n=6)	
		Family	mean	SD	mean	SD	mean	SD	mean	SD
Mollusc	Bivalve	juv	0.05	(0.058)	0.2	(0.141)	0.033	(0.052)	0.133	(0.197)
		Arcid	0.05	(0.058)	0	(0)	0	(0)	0.017	(0.041)
		Corbulid	0	(0)	0	(0)	0.017	(0.041)	0	(0)
		Crassatellid	0	(0)	0	(0)	0.033	(0.082)	0	(0)
		Cuspidariid	0	(0)	0	(0)	0	(0)	0.017	(0.041)
		Diplodontid	0	(0)	0.025	(0.05)	0	(0)	0	(0)
		Lucinid	0.225	(0.15)	0.075	(0.096)	0.117	(0.16)	0.667	(0.497)
		Mactrid	0.1	(0.2)	0.025	(0.05)	0.017	(0.041)	0.067	(0.082)
		Mesodesmatid	0	(0)	0	(0)	0	(0)	0.017	(0.041)
		Pandorid	0	(0)	0	(0)	0	(0)	0.017	(0.041)
		Solecurtid	0.05	(0.1)	0	(0)	0.017	(0.041)	0.033	(0.082)
		Tellinid	0.025	(0.05)	0.025	(0.05)	0.067	(0.082)	0.05	(0.084)
		Venerid	0.05	(0.058)	0.025	(0.05)	0.033	(0.052)	0.033	(0.052)
	Total	Bivalve	0.55	(0.265)	0.375	(0.34)	0.333	(0.151)	1.05	(0.532)
	Gastropod	Acteocinid	0	(0)	0	(0)	0.017	(0.041)	0	(0)
		Columbellid	0.025	(0.05)	0	(0)	0.05	(0.084)	0.083	(0.117)
		Nassariid	0	(0)	0.025	(0.05)	0	(0)	0	(0)
		Naticid	0.025	(0.05)	0.025	(0.05)	0	(0)	0.05	(0.084)
		Olivid	0.025	(0.05)	0.05	(0.1)	0.017	(0.041)	0.067	(0.082)
		Terebrid	0.025	(0.05)	0.05	(0.1)	0	(0)	0.017	(0.041)
	Total	Gastropod	0.1	(0.082)	0.15	(0.129)	0.083	(0.098)	0.217	(0.147)
	Opistobranch	Haminoeid	0.025	(0.05)	0	(0)	0.017	(0.041)	0.033	(0.052)
	Scaphopod		0	(0)	0	(0)	0.017	(0.041)	0.033	(0.052)
	Total	Mollusc	0.675	(0.33)	0.525	(0.32)	0.45	(0.176)	1.333	(0.427)

Table 2a cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
Crustacea	Amphipod	unident.	0 (0)	0.025 (0.05)	0 (0)	0.067 (0.121)
		Ampeliscid	0 (0)	0 (0)	0.017 (0.041)	0.05 (0.055)
		Aorid	0.025 (0.05)	0.025 (0.05)	0.017 (0.041)	0.017 (0.041)
		Caprellid	0 (0)	0 (0)	0.033 (0.052)	0 (0)
		Corophiid	0 (0)	0 (0)	0.017 (0.041)	0 (0)
		Gammerid	0.075 (0.05)	0.05 (0.1)	0.05 (0.122)	0.05 (0.055)
		Haustoriid	0.125 (0.096)	0.1 (0.141)	0.017 (0.041)	0.05 (0.084)
		Liljeborgiid	0.025 (0.05)	0.1 (0.141)	0.083 (0.117)	0.067 (0.103)
		Melitid	0 (0)	0.025 (0.05)	0.183 (0.402)	0 (0)
		Oedicerotid	0.175 (0.222)	0.2 (0.183)	0.05 (0.122)	0.033 (0.052)
		Phoxocephalid	0 (0)	0.025 (0.05)	0.017 (0.041)	0 (0)
		Stenothoid	0 (0)	0 (0)	0 (0)	0.017 (0.041)
	Total	Amphipod	0.425 (0.206)	0.55 (0.443)	0.483 (0.449)	0.35 (0.138)
	Copepoda		0 (0)	0 (0)	0.017 (0.041)	0 (0)
	Cumacean		0.075 (0.05)	0.075 (0.096)	0.083 (0.098)	0.05 (0.084)
	Decapod	unident.	0.025 (0.05)	0 (0)	0.017 (0.041)	0 (0)
		Pagurid	0 (0)	0.15 (0.238)	0.017 (0.041)	0.017 (0.041)
		Penaeid	0.025 (0.05)	0 (0)	0 (0)	0.017 (0.041)
		Pinnotherid	0.1 (0.082)	0.075 (0.15)	0.083 (0.16)	0.233 (0.333)
		Sergestid	0.025 (0.05)	0 (0)	0 (0)	0.017 (0.041)
		Xanthid	0 (0)	0.025 (0.05)	0 (0)	0 (0)
	Isopod	Idoteid	0.05 (0.058)	0.025 (0.05)	0 (0)	0.05 (0.122)
		Sphaeromatid	0 (0)	0.025 (0.05)	0 (0)	0 (0)
	Isopod	total	0.05 (0.058)	0.05 (0.058)	0 (0)	0.05 (0.122)
	Mysid		0 (0)	0.1 (0.141)	0 (0)	0 (0)
	Ostracod		0 (0)	0.025 (0.05)	0 (0)	0.017 (0.041)
	Tanaid		0 (0)	0 (0)	0.017 (0.041)	0.017 (0.041)
	Total	Crustacea	0.725 (0.299)	1.05 (0.42)	0.717 (0.564)	0.767 (0.301)

Table 2a cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
Annelid	Polychaete	unident.	0 (0)	0 (0)	0.017 (0.041)	0 (0)
		Acrocirrid	0 (0)	0 (0)	0.017 (0.041)	0 (0)
		Ampharetid	0.05 (0.1)	0 (0)	0.05 (0.084)	0.05 (0.084)
		Aphroditid	0 (0)	0.025 (0.05)	1.583 (2.402)	0.05 (0.122)
		Arabellid	0 (0)	0 (0)	0.033 (0.052)	0.033 (0.052)
		Capitellid	1.7 (1.417)	1.25 (0.839)	3.333 (2.856)	1.617 (0.717)
		Cerratulid	0 (0)	0.025 (0.05)	0.217 (0.325)	0.05 (0.084)
		Chaetopterid	0.05 (0.058)	0 (0)	0 (0)	0.117 (0.117)
		Dorvilleid	0 (0)	0 (0)	0.067 (0.103)	0.017 (0.041)
		Eunicid	0.1 (0.115)	0 (0)	0.1 (0.11)	0.017 (0.041)
		Glycerid	0.15 (0.129)	0.15 (0.1)	0.567 (0.656)	0.217 (0.194)
		Goniadid	0.5 (0.327)	0.625 (0.377)	0.733 (0.776)	0.717 (0.412)
		Hesionid	0.025 (0.05)	0.025 (0.05)	0.133 (0.197)	0.117 (0.147)
		Lumbrinerid	0 (0)	0 (0)	0.033 (0.052)	0.083 (0.098)
		Magelonid	0.575 (0.754)	0.3 (0.294)	0.05 (0.055)	0.35 (0.226)
		Maldanid	0.025 (0.05)	0.025 (0.05)	0.083 (0.16)	0.033 (0.052)
		Nephtyid	0.1 (0.082)	0.125 (0.05)	0.35 (0.493)	0.283 (0.133)
		Nereid	0 (0)	0.025 (0.05)	0.333 (0.28)	0.15 (0.152)
		Onuphid	0.175 (0.236)	0.125 (0.126)	0.067 (0.082)	0.2 (0.141)
		Opheliid	0.025 (0.05)	0.1 (0)	0.183 (0.16)	0.083 (0.204)
		Orbiniid	0.125 (0.05)	0.175 (0.096)	0.067 (0.121)	0.083 (0.16)
		Oweniid	0.025 (0.05)	0.05 (0.1)	0 (0)	0.233 (0.339)
		Paraonid	0.05 (0.1)	0 (0)	0.267 (0.378)	0.067 (0.082)
		Pectinarid	0.025 (0.05)	0 (0)	0 (0)	0.017 (0.041)
		Phyllodocid	0.025 (0.05)	0.025 (0.05)	0.183 (0.299)	0.017 (0.041)
		Pilargid	0 (0)	0 (0)	0.017 (0.041)	0 (0)
		Pisionid	0 (0)	0 (0)	0.067 (0.163)	0 (0)
		Polydontid	0 (0)	0 (0)	0.033 (0.082)	0 (0)
		Spionid	3.35 (3.018)	1.1 (0.688)	1.017 (0.527)	1.617 (0.527)
		Syllid	0.025 (0.05)	0.125 (0.189)	0.583 (0.791)	0.067 (0.121)
		Terebellid	0 (0)	0 (0)	0.067 (0.163)	0.017 (0.041)
	Total	Polychaetae	7.1 (3.746)	4.275 (1.603)	10.25 (6.078)	6.3 (0.863)

Table 2a cont.

			Inshore				Offshore			
			Treatment		Control		Treatment		Control	
		Family	mean	SD	mean	SD	mean	SD	mean	SD
	Oligochaete		0	(0)	0	(0)	0.583	(0.861)	0	(0)
Aschelminthes	Nematode		0.125	(0.096)	0.125	(0.189)	0.433	(0.659)	0.15	(0.055)
Nemertean			0.325	(0.275)	0.4	(0.2)	0.683	(0.838)	0.25	(0.084)
Platyhelminthes	Polycladid		0.05	(0.1)	0.025	(0.05)	0.133	(0.207)	0	(0)
Echinoderm	Echiniod	Mellitid	0.025	(0.05)	0	(0)	0	(0)	0	(0)
		Schizasterid	0	(0)	0	(0)	0.033	(0.082)	0	(0)
	Echiniod	total	0.025	(0.05)	0	(0)	0.033	(0.082)	0	(0)
	Ophiuroid	Amphiurid	0.15	(0.058)	0.075	(0.05)	0.6	(0.906)	0.067	(0.082)
		unident.	0	(0)	0	(0)	0.017	(0.041)	0	(0)
	Ophiuroid	total	0.15	(0.058)	0.075	(0.05)	0.617	(0.926)	0.067	(0.082)
	Holothuroid	Cucumariid	0	(0)	0	(0)	0.017	(0.041)	0.017	(0.041)
		Synaptid	0.025	(0.05)	0	(0)	0.017	(0.041)	0.017	(0.041)
	Total	Echinoderm	0.2	(0.082)	0.075	(0.05)	0.683	(0.877)	0.1	(0.089)
Cnidaria	Actiniaria	Edwardsiid	0.125	(0.25)	0	(0)	0.017	(0.041)	0.05	(0.084)
		Halaclavid	0.05	(0.1)	0.025	(0.05)	0.05	(0.084)	0.033	(0.052)
		unident.	0	(0)	0	(0)	0	(0)	0.033	(0.082)
	Hydroid		0.05	(0.058)	0	(0)	0	(0)	0.033	(0.052)
Kamptozoa	(colonial)		0	(0)	0	(0)	0	(0)	0.05	(0.055)
Sipuncula		Golfingiid	0.025	(0.05)	0.025	(0.05)	0.017	(0.041)	0.05	(0.084)
		Sipunculid	0.05	(0.058)	0.025	(0.05)	0.05	(0.084)	0.05	(0.122)
	Sipuncula	total	0.075	(0.096)	0.05	(0.058)	0.067	(0.082)	0.1	(0.126)
Echiurida			0.075	(0.096)	0.025	(0.05)	0.033	(0.052)	0.05	(0.084)
Phoronida			0	(0)	0.025	(0.05)	0	(0)	0.017	(0.041)
Bryozoa	Ectoproct	Bugulid	0	(0)	0	(0)	0.017	(0.041)	0	(0)
Tunicate			0	(0)	0	(0)	0	(0)	0.017	(0.041)
Chaetognath			0.1	(0.141)	0.025	(0.05)	0	(0)	0	(0)
Amphioxis			0	(0)	0	(0)	0.017	(0.041)	0	(0)
		TOTAL	9.675	(3.902)	6.625	(1.696)	14.133	(8.786)	9.283	(1.436)

Table 2b. Mean (SD = standard deviation) abundance expressed as number m^{-2} of individuals by taxonomic family found in $76.4cm^2$ core samples taken within (Treatment) and adjacent (Control) to inshore and offshore proposed sand borrow areas for the Bogue Banks beach renourshment. Statistics are calculated from the average of 10 cores taken from each of 6 sites sampled both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

			Inshore		Offshore	
			Treatment (n=4)	Control (n=4)	Treatment (n=6)	Control (n=6)
		Family	mean SD	mean SD	mean SD	mean SD
Mollusc	Bivalve	juv	6.54 (7.59)	26.18 (18.46)	4.32 (6.81)	17.41 (25.79)
		Arcid	6.54 (7.59)	0 (0)	0 (0)	2.23 (5.37)
		Corbulid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Crassatellid	0 (0)	0 (0)	4.32 (10.73)	0 (0)
		Cuspidariid	0 (0)	0 (0)	0 (0)	2.23 (5.37)
		Diplodontid	0 (0)	3.27 (6.54)	0 (0)	0 (0)
		Lucinid	29.45 (19.63)	9.82 (12.57)	15.31 (20.94)	87.3 (65.05)
		Mactrid	13.09 (26.18)	3.27 (6.54)	2.23 (5.37)	8.77 (10.73)
		Mesodesmatid	0 (0)	0 (0)	0 (0)	2.23 (5.37)
		Pandorid	0 (0)	0 (0)	0 (0)	2.23 (5.37)
		Solecurtid	6.54 (13.09)	0 (0)	2.23 (5.37)	4.32 (10.73)
		Tellinid	3.27 (6.54)	3.27 (6.54)	8.77 (10.73)	6.54 (10.99)
		Venerid	6.54 (7.59)	3.27 (6.54)	4.32 (6.81)	4.32 (6.81)
	Total	Bivalve	71.99 (34.69)	49.08 (44.5)	43.59 (19.76)	137.43 (69.63)
	Gastropod	Acteocinid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Columbellid	3.27 (6.54)	0 (0)	6.54 (10.99)	10.86 (15.31)
		Nassariid	0 (0)	3.27 (6.54)	0 (0)	0 (0)
		Naticid	3.27 (6.54)	3.27 (6.54)	0 (0)	6.54 (10.99)
		Olivid	3.27 (6.54)	6.54 (13.09)	2.23 (5.37)	8.77 (10.73)
		Terebrid	3.27 (6.54)	6.54 (13.09)	0 (0)	2.23 (5.37)
	Total	Gastropod	13.09 (10.73)	19.63 (16.88)	10.86 (12.83)	28.4 (19.24)
	Opistobranch	Haminoeid	3.27 (6.54)	0 (0)	2.23 (5.37)	4.32 (6.81)
	Scaphopod		0 (0)	0 (0)	2.23 (5.37)	4.32 (6.81)
	Total	Mollusc	88.35 (43.19)	68.72 (41.88)	58.9 (23.04)	174.48 (55.89)

Table 2b cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
Crustacea	Amphipod	unident.	0 (0)	3.27 (6.54)	0 (0)	8.77 (15.84)
		Ampeliscid	0 (0)	0 (0)	2.23 (5.37)	6.54 (7.2)
		Aorid	3.27 (6.54)	3.27 (6.54)	2.23 (5.37)	2.23 (5.37)
		Caprellid	0 (0)	0 (0)	4.32 (6.81)	0 (0)
		Corophiid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Gammerid	9.82 (6.54)	6.54 (13.09)	6.54 (15.97)	6.54 (7.2)
		Haustoriid	16.36 (12.57)	13.09 (18.46)	2.23 (5.37)	6.54 (10.99)
		Liljeborgiid	3.27 (6.54)	13.09 (18.46)	10.86 (15.31)	8.77 (13.48)
		Melitid	0 (0)	3.27 (6.54)	23.95 (52.62)	0 (0)
		Ocdicerotid	22.91 (29.06)	26.18 (23.95)	6.54 (15.97)	4.32 (6.81)
		Phoxocephalid	0 (0)	3.27 (6.54)	2.23 (5.37)	0 (0)
		Stenothoid	0 (0)	0 (0)	0 (0)	2.23 (5.37)
	Total	Amphipod	55.63 (26.96)	71.99 (57.98)	63.22 (58.77)	45.81 (18.06)
	Copepoda		0 (0)	0 (0)	2.23 (5.37)	0 (0)
	Cumacean		9.82 (6.54)	9.82 (12.57)	10.86 (12.83)	6.54 (10.99)
	Decapod	unident.	3.27 (6.54)	0 (0)	2.23 (5.37)	0 (0)
		Pagurid	0 (0)	19.63 (31.15)	2.23 (5.37)	2.23 (5.37)
		Penaeid	3.27 (6.54)	0 (0)	0 (0)	2.23 (5.37)
		Pinnotherid	13.09 (10.73)	9.82 (19.63)	10.86 (20.94)	30.5 (43.59)
		Sergestid	3.27 (6.54)	0 (0)	0 (0)	2.23 (5.37)
		Xanthid	0 (0)	3.27 (6.54)	0 (0)	0 (0)
	Isopod	Idoteid	6.54 (7.59)	3.27 (6.54)	0 (0)	6.54 (15.97)
		Sphaeromatid	0 (0)	3.27 (6.54)	0 (0)	0 (0)
	Isopod	total	6.54 (7.59)	6.54 (7.59)	0 (0)	6.54 (15.97)
	Mysid		0 (0)	13.09 (18.46)	0 (0)	0 (0)
	Ostracod		0 (0)	3.27 (6.54)	0 (0)	2.23 (5.37)
	Tanaid		0 (0)	0 (0)	2.23 (5.37)	2.23 (5.37)
	Total	Crustacea	94.9 (39.14)	137.43 (54.97)	93.85 (73.82)	100.39 (39.4)

Table 2b cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
Annelid	Polychaete	unident.	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Acrocirrid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Ampharetid	6.54 (13.09)	0 (0)	6.54 (10.99)	6.54 (10.99)
		Aphroditid	0 (0)	3.27 (6.54)	207.2 (314.4)	6.54 (15.97)
		Arabellid	0 (0)	0 (0)	4.32 (6.81)	4.32 (6.81)
		Capitellid	222.51 (185.47)	163.61 (109.82)	436.26 (373.82)	211.65 (93.85)
		Cerratulid	0 (0)	3.27 (6.54)	28.4 (42.54)	6.54 (10.99)
		Chaetopterid	6.54 (7.59)	0 (0)	0 (0)	15.31 (15.31)
		Dorvilleid	0 (0)	0 (0)	8.77 (13.48)	2.23 (5.37)
		Eunicid	13.09 (15.05)	0 (0)	13.09 (14.4)	2.23 (5.37)
		Glycerid	19.63 (16.88)	19.63 (13.09)	74.21 (85.86)	28.4 (25.39)
		Goniadid	65.45 (42.8)	81.81 (49.35)	95.94 (101.57)	93.85 (53.93)
		Hesionid	3.27 (6.54)	3.27 (6.54)	17.41 (25.79)	15.31 (19.24)
		Lumbrinerid	0 (0)	0 (0)	4.32 (6.81)	10.86 (12.83)
		Magelonid	75.26 (98.69)	39.27 (38.48)	6.54 (7.2)	45.81 (29.58)
		Maldanid	3.27 (6.54)	3.27 (6.54)	10.86 (20.94)	4.32 (6.81)
		Nephtyid	13.09 (10.73)	16.36 (6.54)	45.81 (64.53)	37.04 (17.41)
		Nereid	0 (0)	3.27 (6.54)	43.59 (36.65)	19.63 (19.9)
		Onuphid	22.91 (30.89)	16.36 (16.49)	8.77 (10.73)	26.18 (18.46)
		Opheliid	3.27 (6.54)	13.09 (0)	23.95 (20.94)	10.86 (26.7)
		Orbiniid	16.36 (6.54)	22.91 (12.57)	8.77 (15.84)	10.86 (20.94)
		Oweniid	3.27 (6.54)	6.54 (13.09)	0 (0)	30.5 (44.37)
		Paraonid	6.54 (13.09)	0 (0)	34.95 (49.48)	8.77 (10.73)
		Pectinarid	3.27 (6.54)	0 (0)	0 (0)	2.23 (5.37)
		Phyllodocid	3.27 (6.54)	3.27 (6.54)	23.95 (39.14)	2.23 (5.37)
		Pilargid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
		Pisionid	0 (0)	0 (0)	8.77 (21.34)	0 (0)
		Polydontid	0 (0)	0 (0)	4.32 (10.73)	0 (0)
		Spionid	438.48 (395.03)	143.98 (90.05)	133.12 (68.98)	211.65 (68.98)
		Syllid	3.27 (6.54)	16.36 (24.74)	76.31 (103.53)	8.77 (15.84)
		Terebellid	0 (0)	0 (0)	8.77 (21.34)	2.23 (5.37)
	Total	Polychaetae	929.32 (490.31)	559.55 (209.82)	1341.62 (795.55)	824.61 (112.96)

Table 2b cont.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
	Oligochaete		0 (0)	0 (0)	76.31 (112.7)	0 (0)
Aschelminthes	Nematode		16.36 (12.57)	16.36 (24.74)	56.68 (86.26)	19.63 (7.2)
Nemertean			42.54 (35.99)	52.36 (26.18)	89.4 (109.69)	32.72 (10.99)
Platyhelminthes	Polycladid		6.54 (13.09)	3.27 (6.54)	17.41 (27.09)	0 (0)
Echinoderm	Echiniod	Mellitid	3.27 (6.54)	0 (0)	0 (0)	0 (0)
		Schizasterid	0 (0)	0 (0)	4.32 (10.73)	0 (0)
	Echiniod	total	3.27 (6.54)	0 (0)	4.32 (10.73)	0 (0)
	Ophiuroid	Amphiurid	19.63 (7.59)	9.82 (6.54)	78.53 (118.59)	8.77 (10.73)
		unident.	0 (0)	0 (0)	2.23 (5.37)	0 (0)
	Ophiuroid	total	19.63 (7.59)	9.82 (6.54)	80.76 (121.2)	8.77 (10.73)
	Holothuroid	Cucumariid	0 (0)	0 (0)	2.23 (5.37)	2.23 (5.37)
		Synaptid	3.27 (6.54)	0 (0)	2.23 (5.37)	2.23 (5.37)
	Total	Echinoderm	26.18 (10.73)	9.82 (6.54)	89.4 (114.79)	13.09 (11.65)
Cnidaria	Actiniaria	Edwardsiid	16.36 (32.72)	0 (0)	2.23 (5.37)	6.54 (10.99)
		Halaclavid	6.54 (13.09)	3.27 (6.54)	6.54 (10.99)	4.32 (6.81)
		unident.	0 (0)	0 (0)	0 (0)	4.32 (10.73)
	Hydroid		6.54 (7.59)	0 (0)	0 (0)	4.32 (6.81)
Kamptozoa	(colonial)		0 (0)	0 (0)	0 (0)	6.54 (7.2)
Sipuncula		Golfingiid	3.27 (6.54)	3.27 (6.54)	2.23 (5.37)	6.54 (10.99)
		Sipunculid	6.54 (7.59)	3.27 (6.54)	6.54 (10.99)	6.54 (15.97)
	Sipuncula	total	9.82 (12.57)	6.54 (7.59)	8.77 (10.73)	13.09 (16.49)
Echiurida			9.82 (12.57)	3.27 (6.54)	4.32 (6.81)	6.54 (10.99)
Phoronida			0 (0)	3.27 (6.54)	0 (0)	2.23 (5.37)
Bryozoa	Ectoproct	Bugulid	0 (0)	0 (0)	2.23 (5.37)	0 (0)
Tunicate			0 (0)	0 (0)	0 (0)	2.23 (5.37)
Chaetognath			13.09 (18.46)	3.27 (6.54)	0 (0)	0 (0)
Amphioxis			0 (0)	0 (0)	2.23 (5.37)	0 (0)
		TOTAL	1266.36 (510.73)	867.15 (221.99)	1849.87 (1150)	1215.05 (187.96)

Table 3a. Mean (SD = standard deviation) abundance of animals by family captured in a $10 m^2$ tow of a benthic sled at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment. Statistics are calculated from the average of 2 samples taken from each of 6 sites both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

			Inshore		Offshore	
			Treatment	Control	Treatment	Control
		Family	mean SD	mean SD	mean SD	mean SD
Mollusc	Bivalve	Mactrid	0 (0)	0.25 (0.289)	0 (0)	0 (0)
		Venerid	0 (0)	0.125 (0.25)	0 (0)	0 (0)
	Gastropod	Terebrid	2.25 (2.63)	0.875 (0.25)	0.0833333 (0.204)	0.4166667 (0.376)
	Scaphopod		0 (0)	0 (0)	0 (0)	0.0833333 (0.204)
Crustacea	Decapod	Calappid	0 (0)	0.125 (0.25)	0.0833333 (0.204)	0.0833333 (0.204)
		Pagurid	0.375 (0.25)	0.5 (0.408)	0.3333333 (0.408)	0.1666667 (0.258)
	offshore	Hippolythid	0 (0)	0 (0)	0 (0)	0.0833333 (0.204)
		Portunid	0.125 (0.25)	0.125 (0.25)	0 (0)	0 (0)
		Xanthid	0.125 (0.25)	0 (0)	0 (0)	0 (0)
Annelid	Polychaete	Glycerid	0 (0)	0 (0)	0.0833333 (0.204)	0.0833333 (0.204)
		Maldanid	0 (0)	0 (0)	0 (0)	0.0833333 (0.204)
		Onuphid	0.125 (0.25)	0 (0)	0.0833333 (0.204)	0 (0)
Echinoderm	Asteriod	Astropectinid	0 (0)	0 (0)	0.0833333 (0.204)	0.0833333 (0.204)
	Echinoid	Mellitid	0 (0)	0.75 (1.5)	0 (0)	0 (0)
Cnidaria	Anthozoa	Renillid	0.125 (0.25)	0 (0)	0 (0)	0 (0)
Sipuncula		Golfingiid	0 (0)	0 (0)	0 (0)	0.0833333 (0.204)
		TOTAL	3.125 (3.065)	2.75 (1.658)	0.75 (0.524)	1.1666667 (0.983)

Table 3b. Mean (SD = standard deviation) abundance expressed as number m^{-2} of animals by family captured in a $10m^2$ tow of a benthic sled at sites within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment. Statistics are calculated from the average of 2 samples taken from each of 6 sites both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

			Inshore				Offshore			
			Treatment		Control		Treatment		Control	
		Family	mean	SD	mean	SD	mean	SD	mean	SD
Mollusc	Bivalve	Mactrid	0	(0)	0.025	(0.029)	0	(0)	0	(0)
		Venerid	0	(0)	0.013	(0.025)	0	(0)	0	(0)
	Gastropod	Terebrid	0.225	(0.263)	0.088	(0.025)	0.008	(0.02)	0.042	(0.038)
	Scaphopod		0	(0)	0	(0)	0	(0)	0.008	(0.02)
Crustacea	Decapod	Calappid	0	(0)	0.013	(0.025)	0.008	(0.02)	0.008	(0.02)
		Pagurid	0.038	(0.025)	0.05	(0.041)	0.033	(0.041)	0.017	(0.026)
		Hippolythid	0	(0)	0	(0)	0	(0)	0.008	(0.02)
		Portunid	0.013	(0.025)	0.013	(0.025)	0	(0)	0	(0)
		Xanthid	0.013	(0.025)	0	(0)	0	(0)	0	(0)
Annelid	Polychaete	Glycerid	0	(0)	0	(0)	0.008	(0.02)	0.008	(0.02)
		Maldanid	0	(0)	0	(0)	0	(0)	0.008	(0.02)
		Onuphid	0.013	(0.025)	0	(0)	0.008	(0.02)	0	(0)
Echinoderm	Asteriod	Astropectinid	0	(0)	0	(0)	0.008	(0.02)	0.008	(0.02)
	Echinoid	Mellitid	0	(0)	0.075	(0.15)	0	(0)	0	(0)
Cnidaria	Anthozoa	Renillid	0.013	(0.025)	0	(0)	0	(0)	0	(0)
Sipuncula		Golfingiid	0	(0)	0	(0)	0	(0)	0.008	(0.02)
		TOTAL	0.313	(0.307)	0.275	(0.166)	0.075	(0.052)	0.117	(0.098)

Table 4a. Mean (SD = standard deviation) (n=2) abundances of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 11 November 1999.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	58.5	(70.004)	172	(237.588)	48	(53.74)	28.5	(2.121)
Atlantic cutlassfish	*Trichiurus lepturus*	8	(11.314)	15.5	(3.536)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	1	(1.414)	1.5	(2.121)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	40.5	(57.276)	84	(39.598)	23.5	(17.678)	39	(38.184)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	0	(0)	42	(59.397)	0	(0)	0	(0)
banded drum	*Larimus fasciatus*	0	(0)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0	(0)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	0	(0)
blackcheek tonguefish	*Symphurus plagiusa*	3	(4.243)	5	(7.071)	0	(0)	0	(0)
blackwing searobbin	*Prionotus rubio*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
bluefish	*Pomatomus saltatrix*	1.5	(2.121)	3	(1.414)	0	(0)	2	(2.828)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	2	(2.828)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	4.5	(3.536)	0.5	(0.707)	1	(1.414)	25	(32.527)
clearnose skate	*Raja ocellata*	3	(4.243)	7	(9.899)	0	(0)	0	(0)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	0	(0)	0	(0)	1.5	(2.121)	0	(0)
gray trout (weakfish)	*Cynoscion regalis*	14	(14.142)	3.5	(4.95)	1.5	(2.121)	0	(0)
harvestfish	*Peprilus alepidotus*	0	(0)	0	(0)	0	(0)	0	(0)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	1	(1.414)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0	(0)	0	(0)
lookdown	*Selene vomer*	6	(1.414)	5	(4.243)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	0	(0)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	21	(16.971)	15	(21.213)	0	(0)	8.5	(12.021)
northern puffer	*Sphoeroides maculatus*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
ocellated flounder	*Ancylopsetta quadrocellata*	0	(0)	0	(0)	0	(0)	0	(0)

Table 4a cont.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	9	(2.828)	1.5	(2.121)	42.5	(38.891)	27.5	(28.991)
pinfish	*Lagodon rhomboides*	34.5	(43.134)	26	(36.77)	68.5	(78.489)	189	(134.35)
planehead filefish	*Monacanthus hispidus*	0	(0)	0	(0)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	0	(0)	0	(0)	0	(0)	0	(0)
round herring	*Etrumeus teres*	0	(0)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0	(0)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	0	(0)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	0	(0)
silver perch	*Bairdiella chrysoura*	47	(14.142)	56	(62.225)	1	(1.414)	0	(0)
silver seatrout	*Cynoscion nothus*	0	(0)	0	(0)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	0	(0)	0	(0)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0.5	(0.707)	0	(0)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	0	(0)	0	(0)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	0	(0)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	0	(0)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	0	(0)
spiny box fish	*Lactophrys trigonus*	0.5	(0.707)	1.5	(2.121)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	18.5	(12.021)	13	(16.971)	302	(87.681)	290	(108.894)
spotted hake	*Urophycis regia*	0	(0)	0	(0)	0	(0)	0	(0)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0	(0)	0	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	0	(0)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0.5	(0.707)	0.5	(0.707)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	0	(0)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	3.5	(4.95)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	0	(0)	0	(0)	0	(0)	0	(0)
Average Abundance (n)		271.50	(183.14)	459.50	(392.44)	490.50	(127.99)	609.50	(290.62)
Average Species Diversity (H′)		1.99	(0.06)	1.57	(0.22)	1.13	(0.12)	1.31	(0.02)
Average Species Richness (S)		13.50	(3.54)	15.00	(9.90)	7.50	(2.12)	7.00	(1.41)

Table 4b. Mean (SD = standard deviation) (n=2) abundances expressed as number km-2 of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 11 November 1999.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	3547.17	(4244.72)	10429.3	(14406.26)	2910.5	(3258.55)	1728.11	(128.61)
Atlantic cutlassfish	*Trichiurus lepturus*	485.08	(686.03)	939.85	(214.41)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	60.64	(85.74)	90.95	(128.61)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	2455.74	(3472.96)	5093.38	(2401.04)	1424.93	(1071.91)	2364.78	(2315.3)
Atlantic stingray	*Dasyatis sabina*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	0	(0)	2546.69	(3601.56)	0	(0)	0	(0)
banded drum	*Larimus fasciatus*	0	(0)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0	(0)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	0	(0)
blackcheek tonguefish	*Symphurus plagiusa*	181.91	(257.28)	303.18	(428.75)	0	(0)	0	(0)
blackwing searobbin	*Prionotus rubio*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
bluefish	*Pomatomus saltatrix*	90.95	(128.61)	181.91	(85.74)	0	(0)	121.27	(171.48)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	272.86	(214.41)	30.32	(42.87)	60.64	(85.74)	1515.89	(1972.29)
clearnose skate	*Raja ocellata*	181.91	(257.28)	424.45	(600.23)	0	(0)	0	(0)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	0	(0)	0	(0)	90.95	(128.61)	0	(0)
gray trout (weakfish)	*Cynoscion regalis*	848.9	(857.51)	212.22	(300.15)	90.95	(128.61)	0	(0)
harvestfish	*Peprilus alepidotus*	0	(0)	0	(0)	0	(0)	0	(0)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	60.64	(85.74)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0	(0)	0	(0)
lookdown	*Selene vomer*	363.81	(85.74)	303.18	(257.28)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	0	(0)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	1273.34	(1029.04)	909.53	(1286.26)	0	(0)	515.4	(728.9)
northern puffer	*Sphoeroides maculatus*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
ocellated flounder	*Ancylopsetta quadrocellata*	0	(0)	0	(0)	0	(0)	0	(0)

Table 4b cont.

Species		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	545.72	(171.48)	90.95	(128.61)	2577.01	(2358.17)	1667.48	(1757.88)
pinfish	*Lagodon rhomboides*	2091.92	(2615.45)	1576.52	(2229.57)	4153.53	(4759.22)	11460.1	(8146.37)
planehead filefish	*Monacanthus hispidus*	0	(0)	0	(0)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	0	(0)	0	(0)	0	(0)	0	(0)
round herring	*Etrumeus teres*	0	(0)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0	(0)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	0	(0)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	0	(0)
silver perch	*Bairdiella chrysoura*	2849.87	(857.51)	3395.59	(3773.04)	60.64	(85.74)	0	(0)
silver seatrout	*Cynoscion nothus*	0	(0)	0	(0)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	0	(0)	0	(0)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	0	(0)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	30.32	(42.87)	0	(0)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	0	(0)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	0	(0)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	0	(0)
spiny box fish	*Lactophrys trigonus*	30.32	(42.87)	90.95	(128.61)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	1121.76	(728.9)	788.26	(1029.04)	18311.91	(5316.58)	17584.28	(6602.84)
spotted hake	*Urophycis regia*	0	(0)	0	(0)	0	(0)	0	(0)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0	(0)	0	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	0	(0)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	30.32	(42.87)	30.32	(42.87)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	0	(0)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	212.22	(300.15)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	0	(0)	0	(0)	0	(0)	0	(0)
Average Abundance (n)		16462.53	(11104.84)	27861.99	(23796.04)	29741.69	(7760.51)	36957.31	(17621.93)
Average Species Diversity (H′)		1.99	(0.06)	1.57	(0.22)	1.13	(0.12)	1.31	(0.02)
Average Species Richness (S)		13.50	(3.54)	15.00	(9.90)	7.50	(2.12)	7.00	(1.41)

Table 5a. Mean (SD = standard deviation) (n=2) abundances of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms^{-1} (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control).the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 4 February 2000 .

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
Atlantic cutlassfish	*Trichiurus lepturus*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	47	(18.385)	58	(77.782)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	56	(59.397)	43	(60.811)	16.5	(21.92)	4.5	(6.364)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	0.5	(0.707)	0	(0)	0	(0)	0	(0)
banded drum	*Larimus fasciatus*	0	(0)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0.5	(0.707)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	0	(0)
blackcheek tonguefish	*Symphurus plagiusa*	2	(1.414)	2	(1.414)	0	(0)	0	(0)
blackwing searobbin	*Prionotus rubio*	0	(0)	1.5	(2.121)	0	(0)	0	(0)
bluefish	*Pomatomus saltatrix*	0	(0)	0	(0)	0	(0)	0	(0)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	0	(0)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	0	(0)	0	(0)	0	(0)	0.5	(0.707)
clearnose skate	*Raja ocellata*	0	(0)	0	(0)	0.5	(0.707)	1.5	(0.707)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	0	(0)	0.5	(0.707)	0	(0)	0.5	(0.707)
gray trout (weakfish)	*Cynoscion regalis*	0	(0)	1	(1.414)	0.5	(0.707)	0	(0)
harvestfish	*Peprilus alepidotus*	0	(0)	0	(0)	0	(0)	0	(0)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	0	(0)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0.5	(0.707)	0	(0)
lookdown	*Selene vomer*	0	(0)	0	(0)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	0	(0)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	1	(1.414)	0.5	(0.707)	0	(0)	0	(0)
northern puffer	*Sphoeroides maculatus*	0	(0)	0	(0)	0	(0)	0	(0)
ocellated flounder	*Ancylopsetta quadrocellata*	0.5	(0.707)	0.5	(0.707)	0	(0)	0	(0)

Table 5a cont.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	0	(0)	0	(0)	0	(0)	0	(0)
pinfish	*Lagodon rhomboides*	38.5	(24.749)	15	(21.213)	3.5	(2.121)	9	(9.899)
planehead filefish	*Monacanthus hispidus*	0	(0)	0	(0)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	0	(0)	0	(0)	0	(0)	0	(0)
round herring	*Etrumeus teres*	0	(0)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0.5	(0.707)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	0	(0)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	0	(0)
silver perch	*Bairdiella chrysoura*	0	(0)	0	(0)	0	(0)	0	(0)
silver seatrout	*Cynoscion nothus*	0	(0)	0	(0)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	0	(0)	0	(0)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	0	(0)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	3	(4.243)	5	(7.071)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	0	(0)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	2.5	(3.536)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	0	(0)
spiny box fish	*Lactophrys trigonus*	0	(0)	0	(0)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	3	(2.828)	4	(5.657)	0	(0)	0	(0)
spotted hake	*Urophycis regia*	11	(1.414)	4	(5.657)	0.5	(0.707)	0.5	(0.707)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0.5	(0.707)	1	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	0	(0)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0	(0)	0	(0)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	0	(0)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	1	(1.414)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	0	(0)	0	(0)	0	(0)	0	(0)
Average Abundance (n)		162.50	(67.18)	139.50	(191.63)	22.50	(24.75)	18.00	(7.07)
Average Species Diversity (H′)		1.39	(0.02)	1.10	(0.76)	1.02	(0.44)	1.04	(0.15)
Average Species Richness (S)		8.00	(1.41)	9.00	(9.90)	4.50	(0.71)	5.50	(2.12)

Table 5b. Mean (SD = standard deviation) (n=2) abundances expressed as number km-2 of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 4 February 2000 .

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
Atlantic cutlassfish	*Trichiurus lepturus*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	2849.87	(1114.78)	3516.86	(4716.35)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	3395.59	(3601.56)	2607.32	(3687.3)	1000.49	(1329.13)	272.86	(385.88)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	30.32	(42.87)	0	(0)	0	(0)	0	(0)
banded drum	*Larimus fasciatus*	0	(0)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	30.32	(42.87)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	0	(0)
blackcheek tonguefish	*Symphurus plagiusa*	121.27	(85.74)	121.27	(85.74)	0	(0)	0	(0)
blackwing searobbin	*Prionotus rubio*	0	(0)	90.95	(128.61)	0	(0)	0	(0)
bluefish	*Pomatomus saltatrix*	0	(0)	0	(0)	0	(0)	0	(0)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	0	(0)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	0	(0)	0	(0)	0	(0)	30.32	(42.87)
clearnose skate	*Raja ocellata*	0	(0)	0	(0)	30.32	(42.87)	90.95	(42.87)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	0	(0)	30.32	(42.87)	0	(0)	30.32	(42.87)
gray trout (weakfish)	*Cynoscion regalis*	0	(0)	60.64	(85.74)	30.32	(42.87)	0	(0)
harvestfish	*Peprilus alepidotus*	0	(0)	0	(0)	0	(0)	0	(0)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	0	(0)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	30.32	(42.87)	0	(0)
lookdown	*Selene vomer*	0	(0)	0	(0)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	0	(0)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	60.64	(85.74)	30.32	(42.87)	0	(0)	0	(0)
northern puffer	*Sphoeroides maculatus*	0	(0)	0	(0)	0	(0)	0	(0)
ocellated flounder	*Ancylopsetta quadrocellata*	30.32	(42.87)	30.32	(42.87)	0	(0)	0	(0)

Table 5b cont.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	0	(0)	0	(0)	0	(0)	0	(0)
pinfish	*Lagodon rhomboides*	2334.47	(1500.67)	909.53	(1286.26)	212.22	(128.61)	545.72	(600.23)
planehead filefish	*Monacanthus hispidus*	0	(0)	0	(0)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	0	(0)	0	(0)	0	(0)	0	(0)
round herring	*Etrumeus teres*	0	(0)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	30.32	(42.87)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	0	(0)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	0	(0)
silver perch	*Bairdiella chrysoura*	0	(0)	0	(0)	0	(0)	0	(0)
silver seatrout	*Cynoscion nothus*	0	(0)	0	(0)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	0	(0)	0	(0)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	0	(0)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	181.91	(257.28)	303.18	(428.75)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	0	(0)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	151.59	(214.41)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	0	(0)
spiny box fish	*Lactophrys trigonus*	0	(0)	0	(0)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	181.91	(171.48)	242.54	(343.01)	0	(0)	0	(0)
spotted hake	*Urophycis regia*	666.99	(85.74)	242.54	(343.01)	30.32	(42.87)	30.32	(42.87)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	30.32	(42.87)	60.64	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	0	(0)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0	(0)	0	(0)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	0	(0)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	60.64	(85.74)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	0	(0)	0	(0)	0	(0)	0	(0)
Average Abundance (n)		9853.26	(4073.2)	8458.65	(11619.33)	1364.3	(1500.65)	1091.44	(428.76)
Average Species Diversity (H′)		1.39	(0.02)	1.10	(0.76)	1.02	(0.44)	1.04	(0.15)
Average Species Richness (S)		8.00	(1.41)	9.00	(9.90)	4.50	(0.71)	5.50	(2.12)

Table 6a. Mean (SD = standard deviation) (n=2) abundances of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 11 May 2000 .

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	0	(0)	0	(0)	0	(0)	2	(2.828)
Atlantic cutlassfish	*Trichiurus lepturus*	0	(0)	12	(11.314)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	0	(0)	2	(2.828)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	556	(50.912)	1422	(347.897)	0	(0)	0	(0)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	748	(452.548)	284	(248.902)	0	(0)	2	(2.828)
banded drum	*Larimus fasciatus*	4	(5.657)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0	(0)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	2	(2.828)
blackcheek tonguefish	*Symphurus plagiusa*	4	(5.657)	16	(22.627)	0	(0)	2	(2.828)
blackwing searobbin	*Prionotus rubio*	358	(500.632)	464	(650.538)	0	(0)	8	(0)
bluefish	*Pomatomus saltatrix*	10	(2.828)	4	(0)	0	(0)	0	(0)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	0	(0)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	4	(5.657)	20	(16.971)	0	(0)	0	(0)
clearnose skate	*Raja ocellata*	10	(14.142)	24	(33.941)	0	(0)	2	(2.828)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	8	(11.314)	0	(0)	0	(0)	0	(0)
gray trout (weakfish)	*Cynoscion regalis*	0	(0)	0	(0)	0	(0)	0	(0)
harvestfish	*Peprilus alepidotus*	56	(79.196)	10	(14.142)	0	(0)	24	(33.941)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	0	(0)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0	(0)	0	(0)
lookdown	*Selene vomer*	0	(0)	0	(0)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	2	(2.828)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	12	(16.971)	20	(28.284)	0	(0)	0	(0)
northern puffer	*Sphoeroides maculatus*	2	(2.828)	2	(2.828)	0	(0)	2	(2.828)
ocellated flounder	*Ancylopsetta quadrocellata*	12	(16.971)	6	(2.828)	0	(0)	36	(50.912)

Table 6a cont.

species		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	38	(48.083)	0	(0)	0	(0)	394	(557.2)
pinfish	*Lagodon rhomboides*	0	(0)	18	(25.456)	0	(0)	0	(0)
planehead filefish	*Monacanthus hispidus*	0	(0)	2	(2.828)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	10	(14.142)	30	(36.77)	8	(5.657)	6	(8.485)
round herring	*Etrumeus teres*	2	(2.828)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0	(0)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	144	(203.647)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	2	(2.828)
silver perch	*Bairdiella chrysoura*	0	(0)	0	(0)	0	(0)	0	(0)
silver seatrout	*Cynoscion nothus*	20	(28.284)	52	(73.539)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	6	(8.485)	2	(2.828)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	2	(2.828)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	0	(0)	2	(2.828)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	4	(5.657)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	0	(0)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	2	(2.828)
spiny box fish	*Lactophrys trigonus*	0	(0)	0	(0)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	12	(11.314)	42	(14.142)	0	(0)	4	(5.657)
spotted hake	*Urophycis regia*	32	(39.598)	60	(79.196)	0	(0)	0	(0)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0	(0)	0	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	2	(2.828)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0	(0)	0	(0)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	2	(2.828)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	0	(0)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	68	(96.167)	40	(56.569)	0	(0)	0	(0)
Average Abundance (n)		1976.00	(203.65)	2542.00	(1632.00)	8.00	(5.66)	632.00	(848.53)
Average Species Diversity (H′)		1.44	(0.59)	1.19	(0.72)	0.00	0.00	1.29	(0.30)
Average Species Richness (S)		14.50	(4.95)	18.00	(8.49)	1.00	0.00	8.00	(4.24)

Table 6b. Mean (SD = standard deviation) (n=2) abundances expressed as number km-2 of species captured per 12.3m otter trawl towed for 20 minutes at a speed of 1.1 ms-1 (2.5mph) and covering an estimated 0.016 km2 at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 11 May 2000.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
Atlantic croaker	*Micropogonias undulatus*	0	(0)	0	(0)	0	(0)	121.27	(171.48)
Atlantic cutlassfish	*Trichiurus lepturus*	0	(0)	727.63	(686.03)	0	(0)	0	(0)
Atlantic menhaden	*Brevoortia tyrannus*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
Atlantic silverside	*Menidia menidia*	33713.32	(3087.07)	86223.62	(21094.89)	0	(0)	0	(0)
Atlantic stingray	*Dasyatis sabina*	0	(0)	0	(0)	0	(0)	0	(0)
Atlantic thread herring	*Opisthonema oglinum*	45355.32	(27440.46)	17220.47	(15092.29)	0	(0)	121.27	(171.48)
banded drum	*Larimus fasciatus*	242.54	(343.01)	0	(0)	0	(0)	0	(0)
black drum	*Pogonias cromis*	0	(0)	0	(0)	0	(0)	0	(0)
black sea bass	*Centropristis striata*	0	(0)	0	(0)	0	(0)	121.27	(171.48)
blackcheek tonguefish	*Symphurus plagiusa*	242.54	(343.01)	970.17	(1372)	0	(0)	121.27	(171.48)
blackwing searobbin	*Prionotus rubio*	21707.49	(30356.05)	28134.85	(39445.67)	0	(0)	485.08	(0)
bluefish	*Pomatomus saltatrix*	606.35	(171.48)	242.54	(0)	0	(0)	0	(0)
brown shrimp	*Farfantepenaeus aztecus*	0	(0)	0	(0)	0	(0)	0	(0)
butterfish	*Peprilus triacanthus*	242.54	(343.01)	1212.71	(1029.04)	0	(0)	0	(0)
clearnose skate	*Raja ocellata*	606.35	(857.51)	1455.25	(2058.03)	0	(0)	121.27	(171.48)
cownose ray	*Rhinoptera bonasus*	0	(0)	0	(0)	0	(0)	0	(0)
fringed flounder	*Etropus crossotus*	485.08	(686.03)	0	(0)	0	(0)	0	(0)
gray trout (weakfish)	*Cynoscion regalis*	0	(0)	0	(0)	0	(0)	0	(0)
harvestfish	*Peprilus alepidotus*	3395.59	(4802.09)	606.35	(857.51)	0	(0)	1455.25	(2058.03)
inshore lizardfish	*Synodus foetens*	0	(0)	0	(0)	0	(0)	0	(0)
longfin squid	*Loligo pealeii*	0	(0)	0	(0)	0	(0)	0	(0)
lookdown	*Selene vomer*	0	(0)	0	(0)	0	(0)	0	(0)
manta shrimp	*Squilla empusa*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
northern kingfish	*Menticirrhus saxatilis*	727.63	(1029.04)	1212.71	(1715.01)	0	(0)	0	(0)
northern puffer	*Sphoeroides maculatus*	121.27	(171.48)	121.27	(171.48)	0	(0)	121.27	(171.48)
ocellated flounder	*Ancylopsetta quadrocellata*	727.63	(1029.04)	363.81	(171.48)	0	(0)	2182.88	(3087.07)

Table 6b cont.

		Nearshore				Offshore			
		Treatment		Control		Treatment		Control	
Species		mean	SD	mean	SD	mean	SD	mean	SD
pigfish	*Orthopristis chrysoptera*	2304.15	(2915.53)	0	(0)	0	(0)	23890.37	(33786.08)
pinfish	*Lagodon rhomboides*	0	(0)	1091.44	(1543.54)	0	(0)	0	(0)
planehead filefish	*Monacanthus hispidus*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
portunid crab	*Portunus gibbesii*	606.35	(857.51)	1819.06	(2229.57)	485.08	(343.01)	363.81	(514.49)
round herring	*Etrumeus teres*	121.27	(171.48)	0	(0)	0	(0)	0	(0)
sand seatrout	*Cynoscion arenarius*	0	(0)	0	(0)	0	(0)	0	(0)
scup	*Stenotomus chrysops*	0	(0)	0	(0)	0	(0)	8731.51	(12348.23)
sheepshead	*Archosargus probatocephalus*	0	(0)	0	(0)	0	(0)	121.27	(171.48)
silver perch	*Bairdiella chrysoura*	0	(0)	0	(0)	0	(0)	0	(0)
silver seatrout	*Cynoscion nothus*	1212.71	(1715.01)	3153.04	(4459.07)	0	(0)	0	(0)
smooth butterfly ray	*Gymnura altavela*	363.81	(514.49)	121.27	(171.48)	0	(0)	0	(0)
smooth dogfish	*Mustelus canis*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
southern flounder	*Paralichthys lethostigma*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
spadefish	*Chaetodipterus faber*	242.54	(343.01)	0	(0)	0	(0)	0	(0)
speckled crab	*Arenaeus cribrarius*	0	(0)	0	(0)	0	(0)	0	(0)
spider crab	*Libinia dubia*	0	(0)	0	(0)	0	(0)	121.27	(171.48)
spiny box fish	*Lactophrys trigonus*	0	(0)	0	(0)	0	(0)	0	(0)
spot	*Leiostomus xanthurus*	727.63	(686.03)	2546.69	(857.51)	0	(0)	242.54	(343.01)
spotted hake	*Urophycis regia*	1940.33	(2401.04)	3638.13	(4802.09)	0	(0)	0	(0)
spotted whiff	*Citharichthys macropos*	0	(0)	0	(0)	0	(0)	0	(0)
striped burrfish	*Chilomycterus schoepfi*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
striped cusk-eel	*Ophidion marginatum*	0	(0)	0	(0)	0	(0)	0	(0)
summer flounder	*Paralichthys dentatus*	0	(0)	121.27	(171.48)	0	(0)	0	(0)
white shrimp	*Litopenaeus setiferus*	0	(0)	0	(0)	0	(0)	0	(0)
windowpane	*Scopthalmus aquosus*	4123.21	(5831.13)	2425.42	(3430.09)	0	(0)	0	(0)
Average Abundance (n)		119815.67	(12348.21)	154135.34	(98957.22)	485.08	(343.01)	38321.61	(51450.89)
Average Species Diversity (H′)		1.44	(0.59)	1.19	(0.72)	0.00	0.00	1.29	(0.30)
Average Species Richness (S)		14.50	(4.95)	18.00	(8.49)	1.00	0.00	8.00	(4.24)

Table 7. Results of gut content analysis for eight species of fish caught in trawl surveys conducted in November 1999.

Species	Location	% of fish stomachs empty *	Average weight of stomach contents	% clam**	% polychaete	% crab	% shrimp	% fish	% small crustaceans	% echindoerms
Croaker	Nearshore	50%	0.004	0%	0%	0%	70%	20%	10%	0%
Croaker	Offshore	40%	0.008	20%	25%	4%	10%	5%	1%	1%
Gray Trout	Nearshore	0%	0.006	0%	0%	0%	100%	0%	0%	0%
Gray Trout	Offshore	0%	0.107	0%	0%	5%	90%	5%	0%	0%
Pigfish	Offshore	33%	0.040	0%	90%	0%	5%	0%	5%	0%
Pinfish	Nearshore	20%	0.061	0%	50%	2%	20%	25%	1%	0%
Pinfish	Offshore	40%	0.019	0%	55%	3%	10%	25%	5%	0%
Sea Mullet	Offshore	40%	0.240	1%	37%	61%	1%	0%	0%	0%
Silver Perch	Nearshore	66%	0.002	0%	0%	0%	95%	0%	5%	0%
Silver Perch	Offshore	10%	0.005	0%	0%	0%	61%	0%	38%	0%
Silversides	Nearshore	nd	nd	0%	0%	0%	0%	0%	100%	0%
Silversides	Offshore	nd	nd	0%	0%	0%	0%	0%	100%	0%
Spot	Nearshore	56%	0.007	55%	20%	0%	0%	0%	20%	5%
Spot	Offshore	50%	0.010	5%	10%	0%	0%	65%	10%	0%

* Percentage calculated by dividing the number of fish examined whose stomach contents weighed 0.000 g by the number of fish examined.

** Percent of total diet made up by each group was calculated by summing the total stomach contents weights in that category of all fish examined and dividing that weight by the total wet weight of identifiable stomach contents off all fish within that species.

nd = not determined, stomach contents do not weigh enough to make a reasonable evaluation.

Table 8. Results of Sediment Analysis.

Sample Number	%Gravel	%Sand	%Fines	Mean	Std.Dev.	Mean (mm)	Description	Sorting
A1Ac	2.50	95.80	1.70	2.45	0.76	0.18	Fine Sand	Mod.Sorted
A1Bt	2.50	97.10	0.40	1.66	0.86	0.31	Medium Sand	Mod.Sorted
A1Ct	51.50	47.30	1.20	0.43	1.01	0.74	Coarse Sand	Poorly Sorted
A1Dt	41.10	58.60	0.30	0.16	0.73	0.90	Coarse Sand	Mod.Sorted
A1Ec	4.60	92.20	3.20	2.45	0.79	0.18	Fine Sand	Mod.Sorted
A2Fc	0.90	97.70	1.40	2.65	0.61	0.16	Fine Sand	Mod.Well Sorted
A2Gt	6.00	90.80	3.20	1.95	1.16	0.26	Medium Sand	Poorly Sorted
A2Ht	4.30	94.60	1.10	2.28	0.80	0.21	Fine Sand	Mod.Sorted
A2It	4.60	94.00	1.40	2.31	0.81	0.20	Fine Sand	Mod.Sorted
A2Jc	1.30	96.80	1.90	2.52	0.69	0.17	Fine Sand	Mod.Well Sorted
Anc	7.50	90.00	2.50	2.01	0.86	0.25	Fine Sand	Mod. Sorted
ASc	1.50	97.50	1.00	2.46	0.68	0.18	Fine Sand	Mod.Well Sorted
B1Ac	0.60	96.30	3.10	2.77	0.56	0.15	Fine Sand	Mod.Well Sorted
B1Bt	1.60	96.50	1.90	2.85	0.53	0.14	Fine Sand	Mod.Well Sorted
B1Ct	1.30	95.90	2.80	2.86	0.61	0.14	Fine Sand	Mod.Well Sorted
B1Dc	0.80	97.30	1.90	2.02	0.99	0.25	Fine Sand	Mod.Sorted
B2Ec	5.60	92.70	1.70	2.65	0.89	0.16	Fine Sand	Mod.Sorted
B2Ft	0.10	98.70	1.20	2.71	0.68	0.15	Fine Sand	Mod.Well Sorted
B2Gt	0.10	96.50	3.40	2.99	0.63	0.13	Fine Sand	Mod.Well Sorted
B2Hc	0.10	98.10	1.80	2.90	0.40	0.13	Fine Sand	Well Sorted

Table 9. Mean (SD = standard deviation) abundance m^{-2} of total infauna from this study compared with infauna abundances found in other studies from nearby locations.

Study			TOTAL INFAUNA m^{-2} mean SD
This study	Inshore Nov. 1999	Treatment	1266 (510.73)
	Inshore Nov. 1999	Control	867 (221.99)
	Offshore Nov. 1999	Treatment	1850 (1150)
	Offshore Nov. 1999	Control	1215 (187.96)
Day et al. (1971)[a]	Apr. 1965 - Jan. 1966	10m site	1005
	Apr. 1965 - Jan. 1966	20m site	936
Peterson et al. (1999)[b]	Dec. 1994	East Site	1597 (959)
		West Site	1170 (592)
Posey & Ambrose (1994)[c]	Jul.1990		3680 (900)
	Apr. 1991(1)		11030 (1281)
	Apr. 1991(2)		6880 (917)
Van Dolah et al. (1994)[d]	Winter 1990	Control site	2755
	Fall 1990	Control site	3527

[a] Day et al. (1971) took samples with a $0.2m^2$ van Veen grab and sieved them through a 1mm sieve. Infaunal abundances from samples taken from sites along a transect off Cape Lookout NC, were averaged over 5 sampling dates from Apr 1965 to Jan 1966. The two sites with depths closest to those of this study are presented.

[b] Peterson et al. (1999) present abundances of infauna (> 0.5mm) from 9.9cm diameter cores taken at sites about 1km SE (East Site) and SW (West Site) of Beaufort Inlet, Beaufort NC prior to any experimental disturbance. Replicate cores were taken from each of 9 stations on each side of the inlet.

[c] Posey and Ambrose (1994) present abundances of infauna (> 0.5mm) from 12cm diameter cores taken 12cm deep from stations along transects (1 & 2) perpendicular to "23 Mile Reef" 43.5km from Wilmington, NC. The 32m deep stations presented here are the stations 75m from the reef and least affected by the presence of the reef and associated fauna.

[d] Abundances of infauna (> 0.5mm) from 7.6cm diameter core samples 15cm deep taken by Van Dolah et al. (1994) are from an undisturbed control site 3km from Hilton Head I.

Table 10. Mean (SD = standard deviation) abundance expressed as number m^{-2} of infauna from major taxanomic groups from this study compared with abundances found in studies from nearby locations.

		Nearshore		Offshore		Day et al. (1971)[a]		Posey & Ambrose (1994)[b]			
		Treatment	Control	Treatment	Control	10m	20m	Jul.1990		Apr. 1991	
		mean SD	mean SD	mean SD	mean SD	mean	mean	mean	SD	mean	SD
Mollusc	Bivalve	71.99 (34.69)	49.08 (44.5)	43.59 (19.76)	137.43 (69.63)	10.5	85	1220	(398.37)	1040	(519.62)
	Gastropod	13.09 (10.73)	19.63 (16.88)	10.86 (12.83)	28.4 (19.24)	16	6	0	(0)	110	(259.81)
	Scaphopod	0 (0)	0 (0)	2.23 (5.37)	4.32 (6.81)	0	0	150	(138.56)	0	(0)
Crustacea	Amphipod	55.63 (26.96)	71.99 (57.98)	63.22 (58.77)	45.81 (18.06)	336.5	113	70	(51.96)	340	(173.21)
	Isopod	6.54 (7.59)	6.54 (7.59)	0 (0)	6.54 (15.97)	-	-	700	(346.41)	560	(173.21)
Annelid	Polychaete (1)	929.32 (490.31)	559.55 (209.82)	1341.62 (795.55)	824.61 (112.96)	387	643	1230	(225.17)	8050	(1299.04)
	(2)							1000	(103.92)	4000	(398.37)
Echinoderm	Echiniod	3.27 (6.54)	0 (0)	4.32 (10.73)	0 (0)	66	4.5	100	(86.6)	-	-
	Ophiuroid	19.63 (7.59)	9.82 (6.54)	80.76 (121.2)	8.77 (10.73)	0	0	30	(34.64)	-	-
Sipuncula		9.82 (12.57)	6.54 (7.59)	8.77 (10.73)	13.09 (16.49)	4.5	13	-	-	-	-

[a] Day et al. (1971) took samples with a $0.2m^2$ van Veen grab and sieved them through a 1mm sieve. Infaunal abundances from samples taken from sites along a transect off Cape Lookout NC, were averaged over 5 sampling dates from Apr 1965 to Jan 1966. The two sites with depths closest to those of this study are presented.

[b] Posey and Ambrose (1994) present abundances of infauna (> 0.5mm) from 12cm diameter cores taken 12cm deep from stations along a transect (transects 1 & 2 for polychaetes) perpendicular to "23 Mile Reef" 43.5km from Wilmington, NC. The 32m deep stations presented here are the stations 75m from the reef and least affected by the presence of the reef and associated fauna.

Table 11. Mean (SD=standard deviation) abundance m^{-2} of echinoderms captured in a $10m^2$ belt transect (tow of a benthic sled) at stations within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project compared with similar samples from other studies from nearby locations.

			This study								Dahlgren et al. (1994)[a]				Peterson et al (1999)[b]			
			Inshore				Offshore								December 1994			
			Treatment		Control		Treatment		Control		Spring 1993		Fall 1993		West Site		East Site	
			mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Mollusc	Bivalve		0	(0)	0.038	(0.048)	0	(0)	0	(0)	-	-	-	-	0.011	(0.047)	0	(0)
	Gastropod		0.225	(0.263)	0.088	(0.025)	0.008	(0.02)	0.042	(0.038)	-	-	-	-	0.072	(0.075)	0.65	(0.6)
	Scaphopod		0	(0)	0	(0)	0	(0)	0.008	(0.02)	-	-	-	-	0	(0)	0	(0)
Crustacea	Decapod	Pagurid	0.038	(0.025)	0.05	(0.041)	0.033	(0.041)	0.017	(0.026)	-	-	-	-	0.567	(0.49)	0.089	(0.132)
		total	0.063	(0.048)	0.075	(0.065)	0.042	(0.038)	0.033	(0.041)	-	-	-	-	0.617	(0.488)	0.1	(0.146)
Annelid	Polychaete		0.013	(0.025)	0	(0)	0.017	(0.041)	0.017	(0.026)	-	-	-	-	0	(0)	0.017	(0.038)
Echinoderm	Asteriod		0	(0)	0	(0)	0.008	(0.02)	0.008	(0.02)	0.053	(0.101)	0.007	(0.014)	0.017	(0.051)	0.006	(0.024)
	Echinoid		0	(0)	0.075	(0.15)	0	(0)	0	(0)	0.043	(0.048)	0.026	(0.055)	1.606	(1.273)	0.036	(0.094)
	Holothuroid		0	(0)	0	(0)	0	(0)	0	(0)	0.644	(0.948)	0.505	(0.728)	0.006	(0.024)	0.017	(0.038)
Cnidaria	Anthozoa	Renillid	0.013	(0.025)	0	(0)	0	(0)	0	(0)	-	-	-	-	0.017	(0.071)	0.006	(0.024)

[a] Dahlgren et al. (1994) present abundances of benthic fauna (> 1.5cm) from $10m^2$ belt transects taken by divers from 32m deep stations along a transect perpendicular to "23 Mile Reef" 43.5km from Wilmington, NC. The means presented here average samples from 1, 10, 25, 50, and 75 m from the reef. Tests among the transect stations showed no statistical difference in abundances relative to reef proximity.

[b] Peterson et al. (1999) present abundances of benthic fauna from (> 1.5cm) from $10m^2$ belt transects taken at sites about 1km SE (East Site) and SW (West Site) of Beaufort Inlet, Beaufort NC prior to any experimental disturbance. At the West Site transect were sampled by divers using visual and manual examination. Visibility was insufficient at the East Site for diver counts thus samples were taken using a benthic sled.

Table 12. Mean counts (standard error) of major taxa per transect for sampling conducted at six sites along Bogue Banks, NC. Sampling at each site was conducted along three transects oriented perpendicular to shore and spaced 50 m apart. Organisms were collected using a hand-operated aluminum corer with an internal diameter of 10.2 cm taken to a depth of 20 cm. Two cores were taken, seived on 1 mm mesh and pooled to form a single sample. Cores were collected every three meters along each transect and extended from just landward of mean high water to approximately 1 m deep in the surf zone. All sampling was conducted in the Spring and does not reflect relative abundances that may occur in other seasons.

SITE, DATE	**Ghost Crabs** *(Ocypode quadrata)*	**Donax spp.** *(D.variabilis, D. parvula)*	**Polychaetes** *(Scolelepis squamata)*	**Amphipods** (Talitridae, Haustoriidae)	**Mole Crab** *(Emerita talpoida)*
Emerald Isle Point, 5/30/97	7 (2.52)	89.7 (25.64)	172.3 (59.80)	36.3 (2.73)	0.3 (0.33)
Emerald Isle, 5/29/97	0	393.3 (161.99)	202.3 (56.68)	23 (8.14)	6.7 (3.33)
Salter Path, 5/27/97	6 (3.46)	219 (12.86)	179.3 (50.86)	17 (5.29)	7.3 (4.37)
Pine Knoll Shores, 5/28/97	0.3 (0.33)	269.7 (59.03)	171.7 (27.38)	66.7 (14.17)	0.6 (0.67)
Atlantic Beach, 5/20/97	0.3 (0.33)	68.7 (20.18)	141.3 (40.96)	18.7 (8.21)	0.6 (0.67)
Fort Macon, 5/22/97	1 (1.00)	14 (5.86)	239 (72.70)	10.3 (3.18)	1.7 (0.67)

APPENDICES

Appendix 1. Number of individuals by taxonomic family found in 76.4cm2 core samples taken at sites in (Treatment) and adjacent (Control) to inshore and offshore proposed sand borrow areas for the Bogue Banks beach renourishment. Ten cores were taken from each of 6 sites sampled both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

Year	Area	Treatment	sample number	Mollusc Bivalve juv	Arcid	Corbulid	Crassatellid	Cuspidarid	Diplodontid	Lucinid	Mactrid	Mesodesmatid	Pandorid
Nov-99	Offshore	Control	A1Ac-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ac-2	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A1Ac-3	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A1Ac-4	0	0	0	0	0	0	1	1	0	0
Nov-99	Offshore	Control	A1Ac-6	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A1Ac-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ac-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ac-11	0	0	0	0	0	0	3	0	0	0
Nov-99	Offshore	Control	A1Ac-12	0	0	0	0	0	0	1	1	0	0
Nov-99	Offshore	Control	A1Ac-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-8	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-8	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A1Ct-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-3	0	0	0	1	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-6	0	0	0	1	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-8	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-1	2	0	0	0	1	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-5	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A1Ec-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ec-14	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-1	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	A2Fc-2	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A2Fc-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-4	3	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-5	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-7	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	A2Fc-8	0	0	0	0	0	0	2	1	0	0
Nov-99	Offshore	Control	A2Fc-9	0	0	0	0	0	0	3	0	1	0
Nov-99	Offshore	Control	A2Fc-10	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-11	0	0	1	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-3	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Bivalve cont. Solecurtid	Tellinid	Venerid	Total Bivalve	Gastropod Acteocinid	Columbellid	Nassariid	Naticid	Olivid	Terebrid	Total Gastropod	Opistobranch Haminoeid	Scaphopod	Total Mollusc
A1Ac-1	0	1	1	2	0	0	0	0	0	0	0	0	0	2
A1Ac-2	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Ac-3	0	0	0	1	0	0	0	1	1	0	2	0	0	3
A1Ac-4	0	0	0	2	0	1	0	0	0	0	1	0	0	3
A1Ac-6	0	0	0	1	0	0	0	0	1	0	1	0	0	2
A1Ac-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-11	0	0	0	3	0	0	0	0	0	0	0	0	0	3
A1Ac-12	0	0	0	2	0	0	0	0	0	0	0	0	0	2
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-4	0	1	0	1	0	0	0	0	0	0	0	0	0	1
A1Bt-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	1	1	0	0	0	0	0	0	0	0	0	1
A1Bt-8	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-8	0	0	1	2	1	0	0	0	0	0	1	0	0	3
A1Ct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Dt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-6	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Dt-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-8	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Dt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-1	0	0	0	3	0	0	0	0	0	0	0	0	0	3
A1Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	1	0	0	2	0	2	0	0	0	0	2	0	0	4
A1Ec-6	1	0	0	1	0	0	0	0	0	0	0	0	0	1
A1Ec-7	0	0	0	0	0	1	0	0	0	0	1	0	0	1
A1Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	2	0	0	0	0	0	0	0	0	0	2
A2Fc-2	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Fc-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-4	0	0	0	3	0	0	0	0	0	0	0	0	0	3
A2Fc-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	2	0	0	0	0	0	0	0	0	0	2
A2Fc-8	0	0	0	3	0	0	0	0	0	0	0	0	0	3
A2Fc-9	0	0	0	4	0	0	0	0	0	0	0	0	0	4
A2Fc-10	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	1	0	0	1	0	2	0	0	0	0	2	0	0	3
A2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0	1	0	1
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-11	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Amphipod unident.	Ampeliscid	Aorid	Caprellid	Corophiid	Gammarid	Haustoriid	Liljeborgiid	Melitid	Oedicerotid	Phoxocephalid	Stenothoid
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-3	0	0	0	0	0	1	0	0	0	0	0	0
A1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-8	0	1	0	0	0	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-11	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-12	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-5	0	0	0	0	0	0	0	1	0	0	0	0
A1Bt-6	0	1	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	0	0	0	0	0	0	1	0	0	0	0	0
A1Bt-13	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	1	0	0	0	0	0	0	0	0
A1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-10	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	0	0	1	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-6	0	0	0	0	0	0	0	1	0	0	0	0
A1Dt-7	0	0	0	1	0	0	0	0	0	0	0	0
A1Dt-8	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-9	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-10	0	0	0	0	0	0	0	0	4	0	0	0
A1Dt-12	0	0	0	0	0	0	0	0	6	0	0	0
A1Ec-1	0	0	0	0	0	0	0	1	0	0	0	0
A1Ec-2	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-8	0	0	0	0	0	0	0	1	0	0	0	0
A1Ec-9	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	0	1	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-2	0	1	0	0	0	0	0	0	0	0	0	0
A2Fc-3	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-4	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-5	1	0	0	0	0	0	0	0	0	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-8	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-9	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-10	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	1	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	0	0	3	0	0	0	0
A2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-11	0	0	0	0	0	0	0	0	0	0	1	0
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	1	0	0	0	0	0	0
A2Ht-3	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Total Amphipod	Copepoda	Cumacean	Decapod unident	Pagurid	Penaeid	Pinnotherid	Sergestid	Xanthid	Isopod Idoteid	Sphaeromatid	Mysid	Ostracod	Tanaid
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-3	1	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Ac-4	0	0	0	0	0	0	2	0	0	0	0	0	0	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-4	0	0	0	0	0	0	1	0	0	0	0	0	0	1
A1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Dt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-9	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Dt-10	4	1	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-12	6	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-8	1	0	0	0	0	0	1	0	0	0	0	0	0	0
A1Ec-9	0	0	0	0	0	0	6	0	0	0	0	0	1	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-2	1	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Fc-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-8	0	0	0	0	1	0	0	0	0	0	0	0	0	1
A2Fc-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	2	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	0	0	0	1	1	0	0	0	0	0	0	0	0	0
A2Gt-11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	2	0	0	0	0	0	0	0
A2Ht-2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Total	Annelid Polychaete unident.	Polychaete cont. Acrocirrid	Ampharetid	Aphroditid	Arabellid	Capitellid	Cirratulid	Chaetopteridae	Dorvilleid	Eunicid	Glycerid	Goniadid
A1Ac-1	0	0	0	0	0	0	1	0	0	0	0	1	0
A1Ac-2	0	0	0	0	0	0	6	0	0	0	0	0	0
A1Ac-3	2	0	0	0	0	0	4	1	0	0	0	0	0
A1Ac-4	2	0	0	0	0	0	5	0	0	0	0	1	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Ac-8	1	0	0	0	0	0	0	1	0	0	0	0	1
A1Ac-9	0	0	0	0	0	0	1	0	0	0	0	0	2
A1Ac-11	0	0	0	0	0	0	3	0	0	0	0	0	2
A1Ac-12	0	0	0	0	0	0	0	0	1	0	0	1	0
A1Ac-13	0	0	0	0	0	0	1	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	1	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	1	0	0	0	0	0	1
A1Bt-5	1	1	0	0	0	0	0	0	0	0	0	0	2
A1Bt-6	1	0	0	0	0	0	1	0	0	0	0	0	1
A1Bt-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	3	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	1	0	0	0	0	0	2
A1Bt-11	1	0	0	0	0	0	0	0	0	0	0	0	1
A1Bt-13	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	1	0	0	0	1	0	1	0	0	0	0	0	0
A1Ct-3	0	0	0	0	8	1	8	0	0	1	0	3	0
A1Ct-4	2	0	1	0	8	0	4	0	0	0	1	1	0
A1Ct-5	0	0	0	0	9	0	2	0	0	0	0	0	0
A1Ct-6	0	0	0	0	3	0	1	0	0	0	0	0	0
A1Ct-7	0	0	0	0	7	0	0	0	0	0	0	0	0
A1Ct-8	0	0	0	1	5	0	2	1	0	0	1	2	0
A1Ct-10	0	0	0	0	1	0	1	0	0	0	0	0	0
A1Ct-11	0	0	0	0	10	0	3	0	0	1	0	0	0
A1Ct-12	0	0	0	0	0	0	4	0	0	0	0	7	0
A1Dt-1	1	0	0	0	0	0	0	0	0	1	0	3	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	1	0	0	0	3	0	4	3	0	0	0	0	0
A1Dt-4	0	0	0	0	2	0	9	0	0	0	0	2	0
A1Dt-6	1	0	0	0	3	0	0	0	0	0	0	0	0
A1Dt-7	1	0	0	0	2	0	0	3	0	0	0	0	0
A1Dt-8	0	0	0	0	4	0	8	1	0	0	0	4	1
A1Dt-9	1	0	0	0	4	0	13	1	0	0	0	4	0
A1Dt-10	5	0	0	0	4	0	12	0	0	0	0	0	1
A1Dt-12	6	0	0	0	19	0	4	0	0	1	0	2	0
A1Ec-1	1	0	0	0	0	0	1	0	0	0	0	0	1
A1Ec-2	1	0	0	0	0	0	2	0	1	0	0	0	0
A1Ec-4	0	0	0	0	0	0	2	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	1	0	0	0	0	0	1	0	1	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-8	2	0	0	0	0	0	0	0	0	0	0	0	1
A1Ec-9	7	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	1	0	0	0	1
A1Ec-14	1	0	0	0	0	0	2	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	1	2	0	0	0	0	0	0
A2Fc-2	2	0	0	0	0	0	0	0	0	0	0	0	3
A2Fc-3	0	0	0	0	0	0	1	0	0	0	0	0	1
A2Fc-4	0	0	0	0	0	0	2	0	0	0	0	0	0
A2Fc-5	1	0	0	0	0	0	4	0	0	0	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	3	0	0	0	0	0	3
A2Fc-8	2	0	0	0	0	0	0	0	0	0	0	1	0
A2Fc-9	0	0	0	1	0	0	1	0	0	0	0	0	2
A2Fc-10	0	0	0	0	0	0	7	0	0	0	0	1	0
A2Gt-1	1	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	3	0	0	0	0	0	2	0	0	0	0	0	1
A2Gt-4	0	0	0	0	0	0	1	0	0	0	0	1	0
A2Gt-5	0	0	0	0	0	0	1	0	0	0	0	0	0
A2Gt-6	2	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	2	0	0	0	0	0	2	0	0	0	0	0	2
A2Gt-11	1	0	0	0	0	0	2	0	0	0	0	0	0
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	2	0	0	0	0	0	1	0	0	0	0	0	0
A2Ht-2	1	0	0	0	0	0	11	0	0	0	1	0	1
A2Ht-3	0	0	0	0	0	0	6	0	0	0	0	0	4

Appendix 1 cont.

sample number	Polychaete cont. Hesionid	Lumbrinerid	Magelonid	Maldanid	Nephtyid	Nereid	Onuphid	Ophelid	Orbiniid	Oweniid	Paraonid	Pectinarid	Phyllodocid	Pilargid
A1Ac-1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-3	0	0	0	0	1	0	1	0	0	0	0	0	0	0
A1Ac-4	0	0	0	0	0	1	0	0	0	1	0	0	0	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-8	0	0	3	0	0	0	1	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-11	0	0	1	0	0	1	0	0	0	1	0	0	0	0
A1Ac-12	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	1	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	0	2	0	0	0	0	0	0
A1Bt-5	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-13	0	0	0	0	11	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-3	3	0	0	0	0	1	0	0	0	0	0	0	0	0
A1Ct-4	1	0	0	0	0	1	0	0	0	0	3	0	0	0
A1Ct-5	0	0	0	0	0	0	0	0	0	0	5	0	1	0
A1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-8	1	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Ct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-11	0	1	0	0	0	0	0	0	0	0	0	0	1	0
A1Ct-12	0	0	0	1	0	1	0	0	0	0	0	0	1	0
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Dt-4	0	0	0	0	0	0	0	1	0	0	1	0	0	0
A1Dt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-7	0	0	0	0	0	0	0	1	0	0	0	0	1	0
A1Dt-8	0	0	0	0	1	0	0	1	0	0	1	0	1	0
A1Dt-9	0	0	0	3	0	0	0	0	0	0	1	0	1	0
A1Dt-10	0	0	0	0	0	2	0	1	0	0	4	0	2	0
A1Dt-12	0	0	0	1	0	0	0	0	0	0	0	0	1	0
A1Ec-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
A1Ec-2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-9	0	0	0	0	3	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	0	0	3	1	0	0	1	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-3	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Fc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-5	0	0	0	0	0	0	0	0	0	1	1	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	1	0	0	0	0	0	0	0	0	0	0
A2Fc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-9	1	1	0	0	1	0	0	0	0	0	0	0	0	0
A2Fc-10	0	1	0	0	0	1	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
A2Gt-4	0	0	0	0	0	2	1	0	0	0	0	0	0	0
A2Gt-5	2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	1	0	0	1	0	0	0	0	0
A2Gt-9	0	0	0	0	0	1	0	0	0	0	1	0	0	0
A2Gt-11	0	0	0	0	0	1	0	0	0	0	0	0	0	1
A2Gt-12	0	0	0	0	0	1	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Ht-3	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Polychaeta cont. Pisionid	Polydontid	Spionid	Syllid	Terebellid	Polychaetae Total	Oligochaete	Aschelminthes Nematode	Nemertean	Platyhelminthes Polycladid	Echinoderm Echiniodes Mellitid
A1Ac-1	0	0	3	0	0	6	0	0	0	0	0
A1Ac-2	0	0	7	0	0	13	0	0	0	0	0
A1Ac-3	0	0	0	0	0	7	0	0	0	0	0
A1Ac-4	0	0	1	0	0	9	0	0	2	0	0
A1Ac-6	0	0	0	0	0	1	0	0	0	0	0
A1Ac-8	0	0	1	0	0	7	0	1	0	0	0
A1Ac-9	0	0	0	0	0	3	0	0	0	0	0
A1Ac-11	0	0	6	0	0	14	0	0	0	0	0
A1Ac-12	0	0	3	0	0	6	0	0	0	0	0
A1Ac-13	0	0	0	0	0	2	0	1	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	0	0	1	0	0	2	0	0	0	0	0
A1Bt-4	0	0	0	0	0	4	0	0	0	0	0
A1Bt-5	0	0	0	0	0	4	0	0	0	0	0
A1Bt-6	0	0	0	0	0	2	0	0	0	0	0
A1Bt-7	0	0	0	0	0	1	0	0	0	0	0
A1Bt-8	0	0	0	0	0	3	0	0	0	0	0
A1Bt-9	0	0	0	0	0	3	0	0	0	0	0
A1Bt-11	0	0	0	0	0	1	0	0	0	0	0
A1Bt-13	0	0	0	0	0	11	0	0	0	0	0
A1Ct-1	0	0	5	0	0	7	1	1	0	0	0
A1Ct-3	0	0	0	2	0	27	7	0	0	0	0
A1Ct-4	0	0	0	4	2	26	0	1	11	1	0
A1Ct-5	0	0	1	0	0	18	7	0	4	1	0
A1Ct-6	0	0	1	0	0	5	0	1	2	0	0
A1Ct-7	0	0	0	0	0	7	0	0	0	0	0
A1Ct-8	0	0	0	1	1	16	7	1	1	2	0
A1Ct-10	0	0	0	0	0	2	0	0	0	0	0
A1Ct-11	0	0	0	9	0	25	0	0	1	0	0
A1Ct-12	0	0	1	0	1	16	0	0	2	0	0
A1Dt-1	0	0	0	0	0	4	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	0	1	1	0	13	0	2	1	0	0
A1Dt-4	0	0	0	2	0	17	0	0	1	0	0
A1Dt-6	0	0	0	4	0	7	0	1	1	0	0
A1Dt-7	0	0	1	7	0	15	0	0	0	1	0
A1Dt-8	0	0	0	1	0	23	0	1	0	0	0
A1Dt-9	0	2	4	0	0	33	3	8	3	0	0
A1Dt-10	0	0	2	0	0	28	0	4	6	1	0
A1Dt-12	4	0	3	1	0	36	0	1	1	2	0
A1Ec-1	0	0	0	0	0	3	0	0	1	0	0
A1Ec-2	0	0	0	0	0	4	0	0	0	0	0
A1Ec-4	0	0	14	0	0	16	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	1	0	0
A1Ec-6	0	0	2	0	0	4	0	0	0	0	0
A1Ec-7	0	0	4	0	0	5	0	0	0	0	0
A1Ec-8	0	0	1	0	0	2	0	1	0	0	0
A1Ec-9	0	0	2	0	0	5	0	0	1	0	0
A1Ec-12	0	0	0	0	0	2	0	0	0	0	0
A1Ec-14	0	0	1	0	0	8	0	0	0	0	0
A2Fc-1	0	0	0	2	0	6	0	1	0	0	0
A2Fc-2	0	0	6	0	0	9	0	0	0	0	0
A2Fc-3	0	0	1	0	0	4	0	0	0	0	0
A2Fc-4	0	0	3	0	0	5	0	0	0	0	0
A2Fc-5	0	0	1	0	0	7	0	0	1	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	1	0	0	8	0	0	0	0	0
A2Fc-8	0	0	0	0	0	1	0	0	0	0	0
A2Fc-9	0	0	2	1	0	10	0	0	0	0	0
A2Fc-10	0	0	2	0	0	12	0	0	0	0	0
A2Gt-1	0	0	3	0	0	3	0	0	0	0	0
A2Gt-2	0	0	6	0	0	11	0	0	0	0	0
A2Gt-4	0	0	0	0	0	5	0	0	1	0	0
A2Gt-5	0	0	0	0	0	3	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	2	0	0	4	1	0	0	0	0
A2Gt-9	0	0	4	0	0	10	0	0	0	0	0
A2Gt-11	0	0	0	0	0	4	0	0	0	0	0
A2Gt-12	0	0	1	2	0	4	0	0	0	0	0
A2Gt-13	0	0	0	0	0	1	0	0	0	0	0
A2Ht-2	0	0	6	1	0	21	0	0	0	0	0
A2Ht-3	0	0	1	0	0	12	0	0	0	0	0

Appendix 1 cont.

sample number	Echinoderm cont. Schizasterid	Ophiuroid Amphiurid	unident	Holothuroid Cucumariid	Synaptid	Echinoderm Total	Cnidaria Actiniaria Edwardsiid	Halaclavid	unident	Hydroid	Kamptozoa (colonial)	Sipuncula Golfingiid	Sipuncula
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-3	0	0	0	0	0	0	1	0	0	0	0	0	0
A1Ac-4	0	0	0	0	0	0	0	0	0	0	0	1	0
A1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-9	0	0	0	0	0	0	1	0	0	0	0	0	0
A1Ac-11	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-12	0	0	0	1	0	1	0	0	0	1	0	1	0
A1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-3	1	0	0	0	0	1	0	0	0	0	0	0	0
A1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-13	1	0	0	0	0	1	0	0	0	0	0	0	0
A1Ct-1	0	1	0	0	0	1	0	0	0	0	0	0	0
A1Ct-3	0	4	0	0	0	4	0	0	0	0	0	0	0
A1Ct-4	0	2	0	0	0	2	0	1	0	0	0	0	0
A1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-6	0	1	0	0	0	1	0	0	0	0	0	0	0
A1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	1
A1Ct-8	0	5	1	0	0	6	0	0	0	0	0	0	0
A1Ct-10	0	1	0	0	0	1	0	0	0	0	0	0	0
A1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-12	0	1	0	0	0	1	0	0	0	0	0	0	1
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-3	0	2	0	0	0	2	0	0	0	0	0	0	0
A1Dt-4	0	1	0	0	0	1	0	0	0	0	0	0	0
A1Dt-6	0	2	0	0	0	2	0	0	0	0	0	0	0
A1Dt-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-8	0	4	0	0	0	4	0	0	0	0	0	0	0
A1Dt-9	0	5	0	0	0	5	1	0	0	0	0	0	0
A1Dt-10	0	3	0	0	0	3	0	0	0	0	0	0	0
A1Dt-12	0	3	0	0	0	3	0	0	0	0	0	1	0
A1Ec-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ec-14	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	1	0
A2Fc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-5	0	1	0	0	0	1	0	0	0	0	0	0	0
A2Fc-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-8	0	1	0	0	0	1	0	1	0	0	0	0	0
A2Fc-9	0	0	0	0	0	0	0	0	0	0	1	0	0
A2Fc-10	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-9	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-11	0	0	0	1	0	1	0	0	0	0	0	0	0
A2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-13	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-3	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Echiurida	Phoronida	Bryozoa Ectoproct Bugulid	Tunicata	Chaetognath	Amphioxus	TOTAL
A1Ac-1	0	0	0	0	0	0	8
A1Ac-2	0	0	0	0	0	0	14
A1Ac-3	0	0	0	0	0	0	13
A1Ac-4	0	0	0	0	0	0	17
A1Ac-6	0	0	0	0	0	0	3
A1Ac-8	0	1	0	0	0	0	10
A1Ac-9	0	0	0	0	0	0	4
A1Ac-11	0	0	0	0	0	0	17
A1Ac-12	0	0	0	0	0	0	11
A1Ac-13	0	0	0	0	0	0	3
A1Bt-2	0	0	0	0	0	0	0
A1Bt-3	0	0	0	0	0	0	4
A1Bt-4	0	0	0	0	0	0	5
A1Bt-5	0	0	0	0	0	0	5
A1Bt-6	0	0	0	0	0	0	3
A1Bt-7	0	0	0	0	0	0	2
A1Bt-8	0	0	0	0	0	0	4
A1Bt-9	0	0	0	0	0	0	3
A1Bt-11	0	0	0	0	0	0	2
A1Bt-13	0	0	0	0	0	0	12
A1Ct-1	0	0	0	0	0	0	11
A1Ct-3	0	0	0	0	0	0	38
A1Ct-4	0	0	0	0	0	0	44
A1Ct-5	0	0	0	0	0	0	30
A1Ct-6	0	0	0	0	0	0	9
A1Ct-7	0	0	0	0	0	0	8
A1Ct-8	0	0	0	0	0	0	36
A1Ct-10	0	0	0	0	0	0	3
A1Ct-11	0	0	0	0	0	0	26
A1Ct-12	0	0	0	0	0	1	21
A1Dt-1	0	0	0	0	0	0	5
A1Dt-2	0	0	0	0	0	0	0
A1Dt-3	0	0	0	0	0	0	20
A1Dt-4	0	0	0	0	0	0	19
A1Dt-6	0	0	0	0	0	0	13
A1Dt-7	0	0	0	0	0	0	17
A1Dt-8	0	0	0	0	0	0	29
A1Dt-9	0	0	0	0	0	0	54
A1Dt-10	0	0	0	0	0	0	47
A1Dt-12	0	0	0	0	0	0	50
A1Ec-1	0	0	0	0	0	0	8
A1Ec-2	0	0	0	0	0	0	5
A1Ec-4	0	0	0	0	0	0	16
A1Ec-5	0	0	0	0	0	0	5
A1Ec-6	0	0	0	0	0	0	6
A1Ec-7	0	0	0	0	0	0	6
A1Ec-8	0	0	0	0	0	0	5
A1Ec-9	0	0	0	0	0	0	13
A1Ec-12	0	0	0	0	0	0	2
A1Ec-14	0	0	0	0	0	0	9
A2Fc-1	0	0	0	0	0	0	9
A2Fc-2	0	0	0	0	0	0	13
A2Fc-3	0	0	0	0	0	0	4
A2Fc-4	1	0	0	0	0	0	9
A2Fc-5	0	0	0	0	0	0	11
A2Fc-6	0	0	0	0	0	0	0
A2Fc-7	0	0	0	0	0	0	10
A2Fc-8	0	0	0	0	0	0	8
A2Fc-9	0	0	0	0	0	0	15
A2Fc-10	0	0	0	0	0	0	13
A2Gt-1	0	0	0	0	0	0	4
A2Gt-2	0	0	0	0	0	0	17
A2Gt-4	0	0	0	0	0	0	6
A2Gt-5	0	0	0	0	0	0	3
A2Gt-6	0	0	0	0	0	0	3
A2Gt-8	0	0	0	0	0	0	5
A2Gt-9	0	0	0	0	0	0	12
A2Gt-11	0	0	0	0	0	0	7
A2Gt-12	0	0	0	0	0	0	4
A2Gt-13	0	0	0	0	0	0	3
A2Ht-2	1	0	0	0	0	0	23
A2Ht-3	0	0	1	0	0	0	13

Appendix 1 cont

Year	Area	Treatment	sample number	Mollusc Bivalve juv	Arcid	Corbulid	Crassatellid	Cuspidariid	Diplodontid	Lucinid	Mactrid	Mesodesmatid	Pandorid
Nov-99	Offshore	Treatment	A2Ht-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-5	0	0	0	0	0	0	0	1	0	0
Nov-99	Offshore	Treatment	A2Ht-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-7	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A2Ht-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-11	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Treatment	A2Ht-13	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A2It-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-4	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A2It-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-7	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Treatment	A2It-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2It-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-1	0	0	0	0	0	0	1	1	0	0
Nov-99	Offshore	Control	A2Jc-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-3	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A2Jc-4	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A2Jc-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-7	0	0	0	0	0	0	4	0	0	0
Nov-99	Offshore	Control	A2Jc-8	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	A2Jc-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-12	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	ANc-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-3	1	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-5	0	0	0	0	0	0	0	0	0	1
Nov-99	Offshore	Control	ANc-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ASc-1	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	ASc-2	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	ASc-4	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	ASc-5	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	ASc-7	0	1	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ASc-9	0	0	0	0	0	0	3	0	0	0
Nov-99	Offshore	Control	ASc-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ASc-12	0	0	0	0	0	0	1	0	0	0
Nov-99	Offshore	Control	ASc-14	0	0	0	0	0	0	2	0	0	0
Nov-99	Offshore	Control	ASc-15	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-5	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-8	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Control	B1Ac-13	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-14	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-1	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B1Bt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-4	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B1Bt-6	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B1Bt-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-5	0	1	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-8	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Solecurtid	Bivalve cont. Tellinid	Venerid	Total Bivalve	Gastropod Acteocinid	Columbellid	Nassariid	Naticid	Olivid	Terebrid	Total Gastropod	Opisthobranch Haminoeid	Scaphopod	Total Mollusc
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Ht-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-7	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Ht-8	0	1	0	1	0	0	0	0	0	0	0	0	0	1
A2Ht-9	0	0	0	0	0	0	0	0	0	0	0	0	1	1
A2Ht-11	0	0	0	2	0	0	0	0	0	0	0	0	0	2
A2Ht-13	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2It-1	0	0	0	0	0	0	0	0	1	0	1	0	0	1
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	1	0	2	0	0	0	0	0	0	0	0	0	2
A2It-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-7	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	1	0	1	0	0	0	0	0	0	0	0	0	1
A2It-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	1	0	0	0	0	1	0	0	1
A2Jc-1	0	0	0	2	0	0	0	0	0	0	0	1	0	3
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-3	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Jc-4	0	0	0	1	0	0	0	0	0	0	0	0	0	1
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	0	0	0	4	0	0	0	0	0	0	0	0	0	4
A2Jc-8	0	0	0	1	0	0	0	0	1	0	1	0	0	2
A2Jc-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-12	0	0	0	1	0	0	0	0	0	0	0	0	0	1
ANc-2	0	0	1	1	0	0	0	0	0	0	0	0	0	1
ANc-3	0	0	0	1	0	0	0	1	0	0	1	0	0	2
ANc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
ANc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-9	0	0	0	0	0	1	0	0	0	0	1	0	0	1
ANc-11	0	0	0	0	0	0	0	1	0	0	1	0	0	1
ANc-12	0	0	0	0	0	0	0	0	0	0	0	1	1	2
ANc-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
ASc-2	0	0	0	2	0	0	0	0	0	0	0	0	0	2
ASc-4	0	1	0	3	0	0	0	0	0	1	1	0	0	4
ASc-5	0	0	0	1	0	0	0	0	0	0	0	0	1	2
ASc-7	0	1	0	2	0	0	0	0	0	0	0	0	0	2
ASc-9	0	0	0	3	0	0	0	0	1	0	1	0	0	4
ASc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-12	0	0	0	1	0	0	0	0	0	0	0	0	0	1
ASc-14	0	0	0	2	0	0	0	0	0	0	0	0	0	2
ASc-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	1	1	0	0	1
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	1	1	0	0	0	0	0	0	0	0	0	1
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-7	0	1	0	1	0	0	0	0	0	0	0	0	0	1
B1Ac-8	0	0	0	1	0	0	0	0	0	1	1	0	0	2
B1Ac-13	0	0	0	1	0	0	1	0	0	0	1	0	0	2
B1Ac-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-4	0	0	0	1	0	0	0	0	0	1	1	0	0	2
B1Bt-6	0	0	1	2	0	0	0	0	0	0	0	0	0	2
B1Bt-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-11	0	1	0	1	0	0	0	0	0	0	0	0	0	1
B1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-5	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Amphipod unident.	Amphipod cont. Ampeliscid	Aorid	Caprellid	Corophiid	Gammerid	Haustorid	Liljeborgiid	Melitid	Oedicerotid	Phoxocephalid	Stenothoid
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-6	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-7	0	0	0	0	0	1	0	0	0	0	0	0
A2Ht-8	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-9	0	0	0	0	0	1	0	0	0	0	0	0
A2Ht-11	0	0	0	0	0	0	0	0	0	3	0	0
A2Ht-13	0	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	0	0	0	0	0	0	0	0	0	0	0
A2It-6	0	0	0	0	0	0	0	0	1	0	0	0
A2It-7	0	0	0	0	0	0	0	0	0	0	0	0
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	0	0	0	0	0	0	0	0	0	0	0
A2It-11	0	0	0	0	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-3	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-4	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	3	0	0	0	0	0	0	0	0	0	0	0
A2Jc-8	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-9	0	0	0	0	0	1	0	0	0	0	0	0
A2Jc-12	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0
ANc-3	0	0	0	0	0	0	1	1	0	0	0	1
ANc-4	0	0	0	0	0	0	0	0	0	0	0	0
ANc-5	0	0	0	0	0	0	0	0	0	0	0	0
ANc-7	0	0	0	0	0	0	0	0	0	1	0	0
ANc-8	0	0	0	0	0	0	0	0	0	0	0	0
ANc-9	0	0	0	0	0	0	0	0	0	0	0	0
ANc-11	0	0	0	0	0	0	0	0	0	0	0	0
ANc-12	0	0	0	0	0	0	0	1	0	0	0	0
ANc-13	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	0	0	0	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0
ASc-4	0	0	0	0	0	0	0	0	0	0	0	0
ASc-5	0	0	0	0	0	0	0	0	0	0	0	0
ASc-7	0	0	0	0	0	0	0	0	0	0	0	0
ASc-9	0	0	1	0	0	0	0	0	0	0	0	0
ASc-11	0	0	0	0	0	0	0	0	0	0	0	0
ASc-12	0	0	0	0	0	0	1	0	0	0	0	0
ASc-14	0	0	0	0	0	0	1	0	0	1	0	0
ASc-15	0	0	0	0	0	1	0	0	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-7	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-8	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-14	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-3	0	0	0	0	0	0	0	0	0	1	0	0
B1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-7	0	0	0	0	0	1	0	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-6	0	0	0	0	0	0	0	0	0	1	0	0
B1Ct-7	0	0	0	0	0	0	0	0	0	2	0	0
B1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Total Amphipod	Copepoda	Cumacean	Decapod unident.	Pagurid	Penaeid	Pinnotherid	Sergestid	Xanthid	Isopod Idoteid	Sphaeromatid	Mysid	Ostracod	Tanaid
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-7	1	0	1	0	0	0	0	0	0	0	0	0	0	0
A2Ht-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-9	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-11	3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-13	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-3	0	0	2	0	0	0	0	0	0	0	0	0	0	0
A2Jc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-9	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-5	0	0	0	0	0	0	0	0	0	2	0	0	0	0
ANc-7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-9	0	0	0	0	0	0	1	0	0	0	0	0	0	0
ANc-11	0	0	0	0	0	0	0	0	0	1	0	0	0	0
ANc-12	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-9	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-12	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-14	2	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-15	1	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ac-1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	0	0	0	0	0	0	0	0	0	1	0	0
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
B1Ac-6	0	0	0	0	0	0	0	0	0	1	0	0	0	0
B1Ac-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-8	0	0	0	0	0	0	0	0	0	0	0	2	0	0
B1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea	Annelid	Polychaeta cont.										
	Total	Polychaeta unident.	Acrocirrid	Ampharetid	Aphroditid	Arabellid	Capitellid	Cerratulid	Chaetopteridae	Dorvilleid	Eunicid	Glycerid	Goniadid
A2Ht-4	0	0	0	0	0	0	7	0	0	0	0	1	2
A2Ht-5	0	0	0	0	0	0	14	0	0	0	0	0	1
A2Ht-6	0	0	0	0	0	0	12	2	0	0	1	0	1
A2Ht-7	2	0	0	0	0	0	13	2	0	0	0	0	3
A2Ht-8	0	0	0	0	0	0	8	0	0	0	0	0	2
A2Ht-9	1	0	0	0	0	0	6	0	0	0	0	0	4
A2Ht-11	3	0	0	0	0	1	0	0	0	0	0	0	2
A2Ht-13	1	0	0	0	0	0	5	0	0	0	0	1	1
A2It-1	0	0	0	2	0	0	3	0	0	0	0	1	1
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	2	0	0	0	0	0	1
A2It-4	0	0	0	0	1	0	3	0	0	0	0	0	3
A2It-6	1	0	0	0	0	0	4	0	0	0	1	0	1
A2It-7	0	0	0	0	1	0	3	0	0	0	0	0	1
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	2
A2It-9	0	0	0	0	0	0	8	0	0	0	1	0	0
A2It-11	0	0	0	0	0	0	0	0	0	0	0	1	1
A2It-12	0	0	0	0	0	0	4	0	0	0	0	1	1
A2Jc-1	1	0	0	0	0	0	2	0	1	0	0	0	1
A2Jc-2	0	0	0	0	0	0	1	0	0	0	0	0	0
A2Jc-3	2	0	0	0	0	0	1	0	1	0	0	0	1
A2Jc-4	0	0	0	0	0	0	2	0	0	0	0	0	2
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	1
A2Jc-6	0	0	0	0	0	0	6	0	0	0	0	0	2
A2Jc-7	3	0	0	0	0	0	2	0	0	0	0	1	2
A2Jc-8	0	0	0	0	0	0	3	0	0	0	0	0	2
A2Jc-9	1	0	0	0	0	0	5	0	0	0	0	0	2
A2Jc-12	0	0	0	0	0	0	4	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	3	0	0	0	0	0	0
ANc-3	3	0	0	0	1	0	0	0	1	0	0	0	2
ANc-4	0	0	0	0	0	0	0	0	0	0	0	1	0
ANc-5	2	0	0	0	0	0	2	0	0	1	0	0	1
ANc-7	1	0	0	0	2	0	1	0	0	0	0	0	2
ANc-8	0	0	0	0	0	0	0	0	0	0	1	0	1
ANc-9	1	0	0	0	0	0	3	0	0	0	0	0	0
ANc-11	1	0	0	0	0	0	0	0	0	0	0	0	1
ANc-12	1	0	0	0	0	0	1	0	0	0	0	0	2
ANc-13	0	0	0	0	0	0	2	0	0	0	0	0	1
ASc-1	1	0	0	0	0	0	1	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	3	0	0	0	0	1	1
ASc-4	0	0	0	0	0	0	2	0	0	0	0	1	1
ASc-5	0	0	0	0	0	0	0	0	0	0	0	0	1
ASc-7	0	0	0	0	0	0	2	0	0	0	0	0	0
ASc-9	1	0	0	2	0	0	2	0	0	0	0	0	0
ASc-11	0	0	0	0	0	0	0	0	0	0	0	1	0
ASc-12	1	0	0	0	0	1	0	0	0	0	0	1	0
ASc-14	2	0	0	0	0	0	0	0	0	0	0	0	0
ASc-15	2	0	0	0	0	0	0	1	0	0	0	1	0
B1Ac-1	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	1	0
B1Ac-3	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-4	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ac-5	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-6	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-7	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Ac-8	2	0	0	0	0	0	2	0	0	0	0	0	0
B1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	1
B1Ac-14	0	0	0	0	0	0	4	0	0	0	0	0	1
B1Bt-1	0	0	0	0	0	0	1	0	0	0	2	0	0
B1Bt-2	0	0	0	0	0	0	5	0	0	0	0	0	0
B1Bt-3	1	0	0	0	0	0	7	0	0	0	0	0	0
B1Bt-4	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-6	0	0	0	2	0	0	5	0	0	0	0	0	0
B1Bt-7	1	0	0	0	0	0	5	0	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	5	0	0	0	0	0	1
B1Bt-9	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	7	0	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-3	0	0	0	0	0	0	1	0	0	0	0	0	1
B1Ct-4	0	0	0	0	0	0	2	0	0	0	0	0	1
B1Ct-5	0	0	0	0	0	0	2	0	1	0	0	0	1
B1Ct-6	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	2	0	0	0	0	0	6	0	0	0	0	0	0
B1Ct-8	0	0	0	0	0	0	1	0	0	0	0	1	2

Appendix 1 cont.

sample number	Hesionid	Lumbrinerid	Magelonid	Maldanid	Nephtyid	Nereid	Onuphid	Ophelid	Orbiniid	Oweniid	Paraonid	Pectinariid	Phyllodocid	Pilargid
	Polychaete cont.													
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	0	0	0	0	0	2	0	0	0	0	0
A2Ht-6	0	0	0	0	0	0	0	0	1	0	0	0	0	0
A2Ht-7	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A2Ht-8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-9	0	0	1	0	2	2	0	2	0	0	0	0	0	0
A2Ht-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-13	0	0	0	0	0	0	0	1	0	0	0	0	0	0
A2It-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A2It-3	0	1	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	0	0	0	1	1	0	0	0	0	0	0	0	0
A2It-6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2It-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	0	0	0	1	2	0	2	0	0	0	0	0	0
A2It-11	0	0	1	0	0	1	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-3	0	0	1	0	1	0	0	0	0	0	0	0	0	0
A2Jc-4	0	0	4	0	0	0	0	0	0	0	0	0	0	0
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	1	0	0	0	0	0	0	0	0	1	0	0	0	0
A2Jc-8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-9	1	0	0	0	1	0	0	0	1	1	0	0	0	0
A2Jc-12	0	0	2	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-3	0	0	1	0	0	0	2	0	0	0	0	0	0	0
ANc-4	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ANc-5	0	1	0	0	1	0	0	0	0	0	0	0	0	0
ANc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-8	0	0	0	0	1	0	0	0	1	0	0	0	0	0
ANc-9	0	0	1	0	0	0	1	0	0	0	0	0	0	0
ANc-11	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ANc-12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
ANc-13	0	0	0	0	1	0	0	0	3	0	0	0	0	0
ASc-1	0	0	0	0	1	0	0	0	0	0	1	0	0	0
ASc-2	1	0	0	0	2	0	1	0	0	0	0	0	0	0
ASc-4	0	0	1	0	0	0	0	0	0	0	0	0	0	0
ASc-5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
ASc-7	0	1	1	0	0	0	0	1	0	0	0	0	0	0
ASc-9	0	0	0	0	0	4	2	0	0	3	0	0	0	0
ASc-11	0	0	1	0	1	0	0	0	0	3	0	0	0	0
ASc-12	1	0	1	0	0	0	0	3	0	2	0	0	0	0
ASc-14	1	0	0	0	1	0	0	0	0	0	0	0	0	0
ASc-15	0	1	0	0	0	0	1	0	0	1	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	1	0	0	0	0	0	1	0	0	0	0	0
B1Ac-6	0	0	0	0	0	0	0	0	0	1	0	0	0	0
B1Ac-7	0	0	0	0	0	1	0	0	0	1	0	0	0	0
B1Ac-8	0	0	2	0	0	0	0	0	0	0	0	0	0	0
B1Ac-13	0	0	0	0	2	0	0	0	0	0	0	0	0	0
B1Ac-14	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Bt-1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	1	0	1	0	0	0
B1Bt-3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Bt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-7	0	0	0	0	1	0	0	0	0	0	0	0	0	0
B1Bt-8	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-10	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-3	0	0	1	0	0	0	1	0	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Ct-5	0	0	0	1	0	0	0	0	0	0	0	0	0	0
B1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Ct-8	0	0	0	0	0	0	1	1	1	0	0	0	0	0

Appendix 1 cont.

sample number	Polychaete cont. Pisionid	Polydontid	Spionid	Syllid	Terebellid	Polychaetae Total	Oligochaete	Aschelminthes Nematode	Nemertean	Platyhelminthes Polycladid	Echinoderm Echinodea Mellitid
A2Ht-4	0	0	0	0	0	10	0	0	0	0	0
A2Ht-5	0	0	1	0	0	18	0	0	0	0	0
A2Ht-6	0	0	0	0	0	17	0	0	0	0	0
A2Ht-7	0	0	2	0	0	21	0	0	0	0	0
A2Ht-8	0	0	0	0	0	11	0	0	2	0	0
A2Ht-9	0	0	2	0	0	19	0	0	0	0	0
A2Ht-11	0	0	1	0	0	4	0	0	0	0	0
A2Ht-13	0	0	1	0	0	9	0	0	0	0	0
A2It-1	0	0	1	0	0	9	6	0	1	0	0
A2It-2	0	0	3	0	0	4	0	0	0	0	0
A2It-3	0	0	0	0	0	4	0	0	0	0	0
A2It-4	0	0	3	0	0	12	0	0	0	0	0
A2It-6	0	0	2	0	0	9	0	0	0	0	0
A2It-7	0	0	0	0	0	5	0	0	0	0	0
A2It-8	0	0	0	0	0	2	0	0	1	0	0
A2It-9	0	0	1	0	0	15	1	0	1	0	0
A2It-11	0	0	0	0	0	4	0	0	0	0	0
A2It-12	0	0	1	0	0	8	2	5	1	0	0
A2Jc-1	0	0	2	0	0	6	0	1	0	0	0
A2Jc-2	0	0	0	0	0	1	0	0	0	0	0
A2Jc-3	0	0	2	0	0	7	0	0	1	0	0
A2Jc-4	0	0	0	0	0	8	0	0	0	0	0
A2Jc-5	0	0	0	0	0	1	0	0	0	0	0
A2Jc-6	0	0	2	0	0	10	0	0	0	0	0
A2Jc-7	0	0	1	0	0	8	0	0	1	0	0
A2Jc-8	0	0	1	0	0	7	0	1	0	0	0
A2Jc-9	0	0	1	0	0	12	0	0	1	0	0
A2Jc-12	0	0	2	0	0	8	0	0	0	0	0
ANc-2	0	0	3	0	0	6	0	1	1	0	0
ANc-3	0	0	0	0	0	7	0	0	1	0	0
ANc-4	0	0	1	0	0	3	0	0	0	0	0
ANc-5	0	0	1	0	0	7	0	0	0	0	0
ANc-7	0	0	0	0	0	5	0	0	0	0	0
ANc-8	0	0	3	0	0	7	0	0	0	0	0
ANc-9	0	0	2	0	0	7	0	0	1	0	0
ANc-11	0	0	2	0	0	4	0	0	0	0	0
ANc-12	0	0	0	0	0	4	0	0	0	0	0
ANc-13	0	0	0	1	0	8	0	0	0	0	0
ASc-1	0	0	0	0	0	3	0	0	0	0	0
ASc-2	0	0	0	0	0	9	0	0	0	0	0
ASc-4	0	0	6	0	0	11	0	0	0	0	0
ASc-5	0	0	0	0	0	2	0	0	0	0	0
ASc-7	0	0	1	0	0	6	0	0	1	0	0
ASc-9	0	0	3	0	1	17	0	0	0	0	0
ASc-11	0	0	0	0	0	6	0	0	1	0	0
ASc-12	0	0	2	0	0	11	0	0	0	0	0
ASc-14	0	0	0	0	0	2	0	0	1	0	0
ASc-15	0	0	1	0	0	6	0	2	0	0	0
B1Ac-1	0	0	1	0	0	1	0	0	0	0	0
B1Ac-2	0	0	0	0	0	1	0	1	0	0	0
B1Ac-3	0	0	0	0	0	1	0	0	2	0	0
B1Ac-4	0	0	1	0	0	2	0	0	0	0	0
B1Ac-5	0	0	4	0	0	3	0	0	0	0	0
B1Ac-6	0	0	1	0	0	2	0	0	0	0	0
B1Ac-7	0	0	0	4	0	7	0	1	0	0	0
B1Ac-8	0	0	1	0	0	5	0	0	1	0	0
B1Ac-13	0	0	0	0	0	3	0	2	0	0	0
B1Ac-14	0	0	1	0	0	7	0	0	0	0	0
B1Bt-1	0	0	11	0	0	16	0	0	1	0	0
B1Bt-2	0	0	3	0	0	10	0	0	1	0	0
B1Bt-3	0	0	2	0	0	10	0	0	1	0	0
B1Bt-4	0	0	9	0	0	9	0	1	0	0	1
B1Bt-6	0	0	9	0	0	16	0	0	0	0	0
B1Bt-7	0	0	9	0	0	15	0	1	1	0	0
B1Bt-8	0	0	4	0	0	11	0	0	0	0	0
B1Bt-9	0	0	1	0	0	2	0	0	0	0	0
B1Bt-10	0	0	6	0	0	14	0	0	1	0	0
B1Bt-11	0	0	4	0	0	5	0	0	0	0	0
B1Ct-3	0	0	0	1	0	5	0	0	0	0	0
B1Ct-4	0	0	4	0	0	8	0	0	0	0	0
B1Ct-5	0	0	6	0	0	11	0	0	0	0	0
B1Ct-6	0	0	13	0	0	13	0	0	0	0	0
B1Ct-7	0	0	7	0	0	14	0	0	0	0	0
B1Ct-8	0	0	8	0	0	15	0	0	0	0	0

Appendix 1 cont.

sample number	Schizasterid	Ophiuroid Amphiurid	unident.	Holothuroid Cucumariid	Synaptid	Echinoderm Total	Cnidaria Actiniaria Edwardsiid	Halaclavid	unident.	Hydroid	Kamptozoa (colonial)	Sipuncula Golfingiid	Sipuncula
A2Ht-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-7	0	1	0	0	0	1	0	1	0	0	0	0	0
A2Ht-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-9	0	0	0	0	1	1	0	0	0	0	0	0	1
A2Ht-11	0	0	0	0	0	0	0	1	0	0	0	0	0
A2Ht-13	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-9	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-11	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-12	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	1	0	0
A2Jc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-5	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-6	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-7	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-8	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-9	0	1	0	0	0	1	0	0	0	0	0	0	0
A2Jc-12	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-5	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-7	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-8	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-9	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-11	0	0	0	0	0	0	0	0	0	0	1	0	0
ANc-12	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-13	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	0	1	1	0	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-4	0	0	0	0	0	0	0	0	0	0	0	0	1
ASc-5	0	0	0	0	0	0	0	0	0	0	0	0	1
ASc-7	0	0	0	0	0	0	1	0	0	0	0	0	1
ASc-9	0	1	0	0	0	1	0	0	2	0	0	0	0
ASc-11	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-12	0	0	0	0	0	0	0	1	0	0	0	0	0
ASc-14	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-15	0	0	0	0	0	0	0	0	0	1	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-5	0	0	0	0	0	0	0	0	0	0	0	1	0
B1Ac-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-7	0	1	0	0	0	1	0	0	0	0	0	0	0
B1Ac-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-13	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-14	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	1	0	0	1	2	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-4	0	0	0	0	0	1	0	0	0	0	0	0	0
B1Bt-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-7	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Bt-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-9	0	0	0	0	0	0	0	0	0	0	0	0	1
B1Bt-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-11	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Ct-3	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-5	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-7	0	2	0	0	0	2	0	0	0	1	0	0	0
B1Ct-8	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Echiurida	Phoronida	Bryozoa Ectoproct Bugulid	Tunicate	Chaetognath	Amphioxus	TOTAL
A2Ht-4	0	0	0	0	0	0	10
A2Ht-5	0	0	0	0	0	0	19
A2Ht-6	0	0	0	0	0	0	17
A2Ht-7	0	0	0	0	0	0	26
A2Ht-8	0	0	0	0	0	0	14
A2Ht-9	0	0	0	0	0	0	23
A2Ht-11	0	0	0	0	0	0	10
A2Ht-13	0	0	0	0	0	0	11
A2It-1	0	0	0	0	0	0	17
A2It-2	0	0	0	0	0	0	4
A2It-3	0	0	0	0	0	0	4
A2It-4	0	0	0	0	0	0	14
A2It-6	0	0	0	0	0	0	10
A2It-7	0	0	0	0	0	0	6
A2It-8	0	0	0	0	0	0	3
A2It-9	0	0	0	0	0	0	18
A2It-11	0	0	0	0	0	0	4
A2It-12	1	0	0	0	0	0	18
A2Jc-1	0	0	0	0	0	0	11
A2Jc-2	0	0	0	0	0	0	2
A2Jc-3	0	0	0	0	0	0	11
A2Jc-4	0	0	0	0	0	0	9
A2Jc-5	0	0	0	0	0	0	1
A2Jc-6	0	0	0	0	0	0	10
A2Jc-7	0	0	0	0	0	0	16
A2Jc-8	0	0	0	0	0	0	10
A2Jc-9	0	0	0	1	0	0	16
A2Jc-12	0	0	0	0	0	0	9
ANc-2	0	0	0	0	0	0	9
ANc-3	0	0	0	0	0	0	13
ANc-4	0	0	0	0	0	0	3
ANc-5	0	0	0	0	0	0	10
ANc-7	0	0	0	0	0	0	6
ANc-8	0	0	0	0	0	0	7
ANc-9	0	0	0	0	0	0	10
ANc-11	0	0	0	0	0	0	7
ANc-12	0	0	0	0	0	0	7
ANc-13	0	0	0	0	0	0	8
ASc-1	0	0	0	0	0	0	6
ASc-2	0	0	0	0	0	0	11
ASc-4	0	0	0	0	0	0	16
ASc-5	0	0	0	0	0	0	5
ASc-7	0	0	0	0	0	0	11
ASc-9	0	0	0	0	0	0	25
ASc-11	0	0	0	0	0	0	7
ASc-12	2	0	0	0	0	0	16
ASc-14	0	0	0	0	0	0	7
ASc-15	0	0	0	0	0	0	11
B1Ac-1	0	0	0	0	0	0	3
B1Ac-2	0	0	0	0	0	0	2
B1Ac-3	0	0	0	0	0	0	5
B1Ac-4	0	0	0	0	0	0	2
B1Ac-5	0	0	0	0	0	0	6
B1Ac-6	0	0	0	0	0	0	3
B1Ac-7	0	0	0	0	1	0	11
B1Ac-8	0	0	0	0	0	0	10
B1Ac-13	0	0	0	0	0	0	7
B1Ac-14	0	0	0	0	0	0	7
B1Bt-1	0	0	0	0	0	0	20
B1Bt-2	0	0	0	0	0	0	11
B1Bt-3	0	0	0	0	0	0	12
B1Bt-4	0	0	0	0	0	0	14
B1Bt-6	1	0	0	0	0	0	19
B1Bt-7	0	0	0	0	0	0	19
B1Bt-8	0	0	0	0	1	0	12
B1Bt-9	0	0	0	0	0	0	3
B1Bt-10	1	0	0	0	0	0	16
B1Bt-11	0	0	0	0	0	0	7
B1Ct-3	0	0	0	0	0	0	6
B1Ct-4	0	0	0	0	0	0	8
B1Ct-5	0	0	0	0	0	0	12
B1Ct-6	0	0	0	0	1	0	15
B1Ct-7	0	0	0	0	0	0	19
B1Ct-8	1	0	0	0	0	0	16

Appendix I cont.

Year	Area	Treatment	sample number	Mollusc Bivalve juv	Arcid	Corbulid	Crassatellid	Cuspidariid	Diplodontid	Lucinid	Mactrid	Mesodesmatid	Pandorid
Nov-99	Inshore	Treatment	B1Ct-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-12	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-3	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-3	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-6	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-11	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Ec-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-6	0	1	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-7	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B2Ft-8	1	0	0	0	0	0	2	0	0	0
Nov-99	Inshore	Treatment	B2Ft-9	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-13	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-1	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-2	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-3	0	0	0	0	0	0	2	0	0	0
Nov-99	Inshore	Treatment	B2Gt-4	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-5	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-6	0	0	0	0	0	0	0	1	0	0
Nov-99	Inshore	Treatment	B2Gt-9	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Treatment	B2Gt-10	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Gt-11	0	0	0	0	0	0	0	3	0	0
Nov-99	Inshore	Treatment	B2Gt-12	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-1	2	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-2	0	0	0	0	0	0	0	1	0	0
Nov-99	Inshore	Control	B2Hc-3	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-4	0	0	0	0	0	0	1	0	0	0
Nov-99	Inshore	Control	B2Hc-6	0	0	0	0	0	1	1	0	0	0
Nov-99	Inshore	Control	B2Hc-7	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-8	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-10	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-11	1	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B2Hc-12	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Solecurtid	Bivalve cont. Tellinid	Venerid	Total Bivalve	Gastropod Acteocinid	Columbellid	Nassariid	Naticid	Olivid	Terebrid	Total Gastropod	Opistobranch Haminoeid	Scaphopod	Total Mollusc
B1Ct-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-10	0	0	0	0	0	0	0	0	1	0	1	0	0	1
B1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-12	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-3	0	0	0	1	0	0	0	0	1	0	1	0	0	2
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	1	0	1	0	0	1
B1Dc-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	1	0	0	1	0	0	1
B2Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	1	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Ft-6	1	0	0	2	0	0	0	0	0	0	0	0	0	2
B2Ft-7	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Ft-8	0	0	0	3	0	0	0	0	0	0	0	0	0	3
B2Ft-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-2	0	0	1	1	0	0	0	0	0	0	0	0	0	1
B2Gt-3	0	0	0	2	0	0	0	0	0	0	0	0	0	2
B2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-5	0	0	0	0	0	0	0	1	0	0	1	0	0	1
B2Gt-6	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Gt-9	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Gt-10	0	0	0	0	0	1	0	0	0	0	1	0	0	1
B2Gt-11	0	0	0	3	0	0	0	0	0	0	0	0	0	3
B2Gt-12	0	0	0	0	0	0	0	0	0	0	0	1	0	1
B2Hc-1	0	0	0	2	0	0	0	0	0	0	0	0	0	2
B2Hc-2	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Hc-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-4	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Hc-6	0	0	0	2	0	0	0	0	0	0	0	0	0	2
B2Hc-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-10	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Hc-11	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Crustacea Amphipod unident.	Amphipod cont. Ampeliscid	Aorid	Caprellid	Corophiid	Gammarid	Haustoriid	Liljeborgiid	Melitid	Oedicerotid	Phoxocephalid	Stenothoid
B1Ct-9	0	0	0	0	0	0	0	0	0	1	0	0
B1Ct-10	0	0	0	0	0	1	1	0	0	0	0	0
B1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-12	0	0	0	0	0	0	0	0	0	1	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	1	0	0	0	0	0	0	0	0	1	0	0
B1Dc-3	0	0	0	0	0	0	0	1	0	0	1	0
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	0	0	0	0	0	2	0	0	0	1	0	0
B2Ec-10	0	0	0	0	0	0	2	0	0	2	0	0
B2Ec-11	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-12	0	0	0	0	0	0	1	0	0	0	0	0
B2Ec-13	0	0	1	0	0	0	0	0	0	1	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	0	0	0	0	0	0	0	1	0	0	0	0
B2Ft-6	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-7	0	0	0	0	0	0	2	0	0	0	0	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-9	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	0	0	0	0	0	0	0	0	0	1	0	0
B2Gt-1	0	0	0	0	0	1	0	0	0	0	0	0
B2Gt-2	0	0	1	0	0	0	0	0	0	0	0	0
B2Gt-3	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-5	0	0	0	0	0	0	1	0	0	0	0	0
B2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-9	0	0	0	0	0	0	1	0	0	0	0	0
B2Gt-10	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-11	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-12	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-3	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-6	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-7	0	0	0	0	0	0	1	3	1	2	0	0
B2Hc-8	0	0	0	0	0	0	0	0	0	1	0	0
B2Hc-10	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-11	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Total Amphipod	Copepoda	Cumacean	Decapod unident.	Pagurid	Penaeid	Pinnotherid	Sergestid	Xanthid	Isopod Idoteid	Sphaeromatid	Mysid	Ostracod	Tanaid
B1Ct-9	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-10	2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-11	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Ct-12	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	1	0	1	0	0	0	0	0	0	0
B1Dc-2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-3	2	0	0	0	0	0	2	0	1	0	0	0	0	0
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	3	0	0	0	0	0	0	0	1	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	1	0	0	0
B1Dc-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-12	0	0	0	0	1	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	3	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-10	4	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ec-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-12	1	0	1	0	0	0	0	0	0	0	0	1	0	0
B2Ec-13	2	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	1	0	0	0	0	0	1	0	0	0	0	0	0	0
B2Ft-6	0	0	0	1	0	1	0	0	0	1	0	0	0	0
B2Ft-7	2	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-9	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
B2Gt-2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-9	1	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Gt-10	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B2Gt-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-7	7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont

sample number	Crustacea Total	Annelid Polychaete unident.	Polychaete cont. Acrocirrid	Ampharetid	Aphroditid	Arabellid	Capitellid	Cirratulid	Chaetopteridae	Dorvilleid	Eunicid	Glycerid	Goniadid
B1Ct-9	1	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-10	2	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-11	1	0	0	0	0	0	3	0	0	0	0	0	0
B1Ct-12	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	2	0	0	0	0	0	0	0	0	0	0	0	1
B1Dc-2	2	0	0	0	0	0	0	0	0	0	0	1	0
B1Dc-3	5	0	0	0	0	0	1	0	0	0	0	0	0
B1Dc-4	0	0	0	0	0	0	1	0	0	0	0	0	1
B1Dc-5	4	0	0	0	0	0	0	0	0	0	0	0	3
B1Dc-8	0	0	0	0	0	0	5	0	0	0	0	0	2
B1Dc-9	1	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Dc-12	1	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	2	0	0	0	0	0	0
B2Ec-3	0	0	0	0	0	0	0	0	0	0	0	1	1
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	3	0	0	0	1	0	2	0	0	0	0	0	1
B2Ec-10	5	0	0	0	0	0	0	0	0	0	0	0	1
B2Ec-11	0	0	0	0	0	0	3	0	0	0	0	0	1
B2Ec-12	3	0	0	0	0	0	2	0	0	0	0	0	0
B2Ec-13	2	0	0	0	0	0	0	0	0	0	0	0	1
B2Ft-1	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	3	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0	3
B2Ft-4	2	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-6	3	0	0	0	0	0	0	0	0	0	0	0	1
B2Ft-7	3	0	0	0	0	0	1	0	0	0	0	0	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0	1
B2Ft-9	1	0	0	0	0	0	0	0	0	0	0	0	2
B2Ft-10	0	0	0	0	0	0	2	0	0	0	0	2	2
B2Ft-13	1	0	0	0	0	0	1	0	0	0	0	0	0
B2Gt-1	2	0	0	0	0	0	0	0	0	0	0	2	0
B2Gt-2	1	0	0	0	0	0	1	0	0	0	0	0	1
B2Gt-3	0	0	0	0	0	0	0	0	1	0	0	0	0
B2Gt-4	0	0	0	0	0	0	0	0	0	0	0	1	0
B2Gt-5	1	0	0	0	0	0	0	0	0	0	1	0	1
B2Gt-6	0	0	0	0	0	0	0	0	0	0	0	0	1
B2Gt-9	2	0	0	0	0	0	3	0	0	0	0	0	1
B2Gt-10	1	0	0	0	0	0	0	0	0	0	1	0	0
B2Gt-11	0	0	0	0	0	0	2	0	0	0	0	0	0
B2Gt-12	1	0	0	0	0	0	0	0	0	0	0	0	1
B2Hc-1	0	0	0	0	0	0	4	0	0	0	0	0	1
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0	1
B2Hc-3	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Hc-6	0	0	0	0	0	0	3	0	0	0	0	0	6
B2Hc-7	7	0	0	0	0	0	0	0	0	0	0	0	1
B2Hc-8	1	0	0	0	0	0	5	0	0	0	0	0	1
B2Hc-10	0	0	0	0	0	0	5	0	0	0	0	3	0
B2Hc-11	0	0	0	0	0	0	4	0	0	0	0	0	1
B2Hc-12	0	0	0	0	0	0	2	0	0	0	0	0	0

Appendix 1 cont.

sample number	Hesionid	Lumbrinerid	Polychaete cont. Magelonid	Maldanid	Nephtyid	Nereid	Onuphid	Opheliid	Orbiniid	Oweniid	Paraonid	Pectinarid	Phyllodocid	Pilargid
B1Ct-9	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B1Ct-10	0	0	1	0	0	0	1	0	0	0	0	0	0	0
B1Ct-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-3	0	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	0	0	1	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	2	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-10	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ec-11	0	0	0	1	0	0	1	1	1	0	0	0	0	0
B2Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-13	0	0	0	0	1	0	0	0	2	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	1	0	0	0	1	0	0	0	0	0
B2Ft-3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-6	0	0	0	0	1	0	1	0	0	0	0	0	0	0
B2Ft-7	0	0	0	0	0	0	1	0	0	0	0	0	1	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	1	0	0	0	0	0	0	1	0	0	0	0
B2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-3	0	0	1	0	0	0	0	0	0	0	0	1	0	0
B2Gt-4	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Gt-5	0	0	2	0	0	0	0	0	0	0	0	0	0	0
B2Gt-6	0	0	2	0	0	0	0	0	0	0	0	0	0	0
B2Gt-9	0	0	2	0	1	0	0	0	0	0	0	0	0	0
B2Gt-10	0	0	4	0	0	0	0	0	1	0	0	0	0	0
B2Gt-11	0	0	3	0	0	0	0	0	0	0	0	0	0	0
B2Gt-12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	1	0	0	0	0	0	0
B2Hc-3	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
B2Hc-7	0	0	3	0	1	0	0	0	0	0	0	0	0	0
B2Hc-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-10	0	0	4	0	0	0	0	0	0	0	0	0	1	0
B2Hc-11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix I cont.

sample number	Polychaete cont. Pisionid	Polydontid	Spionid	Syllid	Terebellid	Polychaetae Total	Oligochaete	Aschelminthes Nematode	Nemertean	Platyhelminthes Polycladid	Echinoderm Echiniodea Mellitid
B1Ct-9	0	0	1	0	0	3	0	0	0	0	0
B1Ct-10	0	0	5	0	0	8	0	0	1	0	0
B1Ct-11	0	0	11	0	0	14	0	1	1	0	0
B1Ct-12	0	0	6	0	0	6	0	0	0	0	0
B1Dc-1	0	0	0	0	0	1	0	0	0	0	0
B1Dc-2	0	0	2	0	0	3	0	0	0	0	0
B1Dc-3	0	0	2	0	0	4	0	1	2	1	0
B1Dc-4	0	0	0	0	0	2	0	0	0	0	0
B1Dc-5	0	0	0	0	0	4	0	0	0	0	0
B1Dc-8	0	0	1	0	0	8	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	1	0	0	3	0	0	1	0	0
B1Dc-11	0	0	1	0	0	3	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	1	0	0	4	0	0	0	0	0
B2Ec-3	0	0	1	0	0	3	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	4	0	0	6	0	0	0	0	0
B2Ec-8	0	0	1	0	0	1	0	0	0	0	0
B2Ec-9	0	0	6	0	0	10	0	0	0	0	0
B2Ec-10	0	0	3	0	0	5	0	0	3	0	0
B2Ec-11	0	0	2	0	0	10	0	0	0	0	0
B2Ec-12	0	0	0	0	0	2	0	0	0	0	0
B2Ec-13	0	0	3	0	0	7	0	0	0	0	0
B2Ft-1	0	0	0	0	0	1	0	0	0	0	0
B2Ft-2	0	0	1	0	0	6	0	0	0	0	0
B2Ft-3	0	0	0	0	0	4	0	0	0	0	0
B2Ft-4	0	0	1	0	0	1	0	0	0	0	0
B2Ft-6	0	0	0	0	0	3	0	0	0	0	0
B2Ft-7	0	0	0	0	0	3	0	0	0	0	0
B2Ft-8	0	0	1	0	0	2	0	0	0	0	0
B2Ft-9	0	0	0	0	0	2	0	0	0	0	0
B2Ft-10	0	0	1	0	0	7	0	0	0	0	0
B2Ft-13	0	0	0	0	0	1	0	0	0	0	0
B2Gt-1	0	0	1	0	0	5	0	0	2	0	0
B2Gt-2	0	0	0	0	0	2	0	1	1	0	0
B2Gt-3	0	0	0	0	0	3	0	0	0	1	0
B2Gt-4	0	0	0	0	0	2	0	0	0	0	0
B2Gt-5	0	0	1	0	0	5	0	0	0	0	0
B2Gt-6	0	0	0	0	0	3	0	0	0	0	0
B2Gt-9	0	0	2	0	0	9	0	1	0	0	0
B2Gt-10	0	0	3	0	0	9	0	0	0	0	0
B2Gt-11	0	0	3	0	0	8	0	0	0	0	0
B2Gt-12	0	0	1	0	0	3	0	0	3	1	0
B2Hc-1	0	0	3	0	0	8	0	0	0	0	0
B2Hc-2	0	0	0	1	0	3	0	0	1	0	0
B2Hc-3	0	0	0	0	0	2	0	0	2	0	0
B2Hc-4	0	0	0	0	0	1	0	0	1	0	0
B2Hc-6	0	0	1	0	0	11	0	0	0	0	0
B2Hc-7	0	0	2	0	0	7	0	0	0	0	0
B2Hc-8	0	0	1	0	0	7	0	0	1	0	0
B2Hc-10	0	0	2	0	0	15	0	0	1	0	0
B2Hc-11	0	0	0	0	0	6	0	0	1	0	0
B2Hc-12	0	0	1	0	0	3	0	0	0	0	0

Appendix 1 cont.

sample number	Schizasterid	Ophiuroid Amphiurid	unident.	Holothuroid Cucumariid	Synaptid	Echinoderm Total	Cnidaria Actiniaria Edwardsiid	Halacarid	unident.	Hydroid	Kamptozoa (colonial)	Sipuncula Golfingiid	Sipuncula
B1Ct-9	0	0	0	0	0	0	2	0	0	0	0	0	0
B1Ct-10	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-11	0	0	0	0	0	0	1	0	0	0	0	0	0
B1Ct-12	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-5	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-9	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-11	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-12	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-3	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Ec-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-9	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-11	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-12	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-13	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Ft-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-6	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-8	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-9	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-13	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-4	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Gt-5	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-6	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Gt-9	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-11	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-12	0	0	0	0	0	0	0	0	0	1	0	1	1
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-3	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-4	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-6	0	1	0	0	0	1	0	0	0	0	0	0	0
B2Hc-7	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-8	0	0	0	0	0	0	0	0	0	0	0	0	1
B2Hc-10	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-11	0	0	0	0	0	0	0	1	0	0	0	0	0
B2Hc-12	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont.

sample number	Echiurida	Phoronida	Bryozoa Ectoproct Bugulid	Tunicate	Chaetognath	Amphioxus	TOTAL
B1Ct-9	0	0	0	0	0	0	6
B1Ct-10	0	0	0	0	0	0	13
B1Ct-11	0	0	0	0	1	0	19
B1Ct-12	0	0	0	0	1	0	9
B1Dc-1	0	0	0	0	0	0	3
B1Dc-2	0	0	0	0	0	0	5
B1Dc-3	0	0	0	0	0	0	15
B1Dc-4	0	0	0	0	0	0	2
B1Dc-5	0	0	0	0	0	0	8
B1Dc-8	0	0	0	0	0	0	8
B1Dc-9	0	0	0	0	0	0	2
B1Dc-10	0	0	0	0	0	0	4
B1Dc-11	0	0	0	0	0	0	3
B1Dc-12	0	0	0	0	0	0	1
B2Ec-2	1	0	0	0	0	0	5
B2Ec-3	0	0	0	0	0	0	5
B2Ec-6	0	0	0	0	0	0	0
B2Ec-7	0	0	0	0	0	0	6
B2Ec-8	0	0	0	0	0	0	2
B2Ec-9	0	0	0	0	0	0	13
B2Ec-10	0	1	0	0	0	0	14
B2Ec-11	0	0	0	0	0	0	10
B2Ec-12	0	0	0	0	0	0	5
B2Ec-13	0	0	0	0	0	0	9
B2Ft-1	0	0	0	0	0	0	1
B2Ft-2	0	0	0	0	0	0	7
B2Ft-3	0	0	0	0	0	0	4
B2Ft-4	0	0	0	0	0	0	4
B2Ft-6	0	0	0	0	0	0	8
B2Ft-7	0	0	0	0	0	0	7
B2Ft-8	0	0	0	0	0	0	5
B2Ft-9	0	0	0	0	0	0	3
B2Ft-10	0	0	0	0	0	0	7
B2Ft-13	0	0	0	0	0	0	2
B2Gt-1	0	0	0	0	0	0	9
B2Gt-2	0	0	0	0	0	0	6
B2Gt-3	0	0	0	0	0	0	6
B2Gt-4	0	0	0	0	0	0	3
B2Gt-5	0	0	0	0	0	0	7
B2Gt-6	0	0	0	0	0	0	5
B2Gt-9	0	0	0	0	0	0	13
B2Gt-10	0	0	0	0	0	0	11
B2Gt-11	0	0	0	0	0	0	11
B2Gt-12	0	0	0	0	0	0	12
B2Hc-1	0	0	0	0	0	0	10
B2Hc-2	0	0	0	0	0	0	5
B2Hc-3	0	0	0	0	0	0	4
B2Hc-4	0	0	0	0	0	0	3
B2Hc-6	0	0	0	0	0	0	14
B2Hc-7	0	0	0	0	0	0	14
B2Hc-8	0	0	0	0	0	0	10
B2Hc-10	0	0	0	0	0	0	17
B2Hc-11	0	0	0	0	0	0	9
B2Hc-12	0	0	0	0	0	0	3

Appendix 2. Number of individuals by taxonomic family captured in a 10m² tow of a benthic sled at sites in (Treatment) and adjacent (Control) to inshore and offshore proposed sand borrow areas for the Bogue Banks beach renourishment. Two tows were taken from each of 6 sites sampled both within and around the offshore area and 4 sites sampled both within and around the inshore areas.

			sample	Mollusc Bivalve							Gastropod						Crustacea Decapod		
Year	Area	Treatment	number	Cardiid	Corbulid	Diplodontid	Lucinid	Mactrid	Tellinid	Venerid	Cerithid	Columbellid	Naticid	Olivid	Terebrid	scaphopod	Callianassid	Pagurid	Penaeid
Nov-99	Offshore	Control	A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Nov-99	Offshore	Treatment	A1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Ct-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nov-99	Offshore	Treatment	A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nov-99	Offshore	Control	A1Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A1Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Nov-99	Offshore	Control	A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Nov-99	Offshore	Treatment	A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Treatment	A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Nov-99	Offshore	Treatment	A2It-1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Offshore	Treatment	A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Offshore	Control	A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Offshore	Control	ASc-1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Offshore	Control	ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0
Nov-99	Inshore	Control	B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B1Ct-2	0	0	0	0	0	0	0	0	0	0	0	10	0	0	1	0
Nov-99	Inshore	Control	B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Control	B1Dc-2	0	0	0	0	1	0	1	0	0	0	0	1	0	0	2	0
Nov-99	Inshore	Control	B2Ec-1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Inshore	Control	B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-99	Inshore	Treatment	B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nov-99	Inshore	Treatment	B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0
Nov-99	Inshore	Treatment	B2Gt-2	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
Nov-99	Inshore	Control	B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nov-99	Inshore	Control	B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

Appendix 2 cont.

sample number	Pinnotherid	Sergestid	Calappid	Hippolythid	Portunid	Xanthid	Annelid Polychaete Chaetopteridae	Cossurid	Glycerid	Goniadid	Hesionid	Maldanid	Nephtyid	Nereid	Onuphid	Pilargid	Sabellariid	Terebellid
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
A1Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
ASc-1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
B2Hc-1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2 cont.

sample number	Echinoderm Echiniodea Arbaciid	Mellitid	Schizasterid	Ophiuroid Amphiurid	Ophiothricid	unident.	Holothuroid Cucumariid	Synaptid	Stelleroidea Astropectinid	Cnidaria Actiniaria Edwardsiid	Halaclavid	Anthozoa Renillid	Sipuncula Golfingiid	Bryozoa Ectoproct Bugulid
A1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Ct-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Dt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Fc-1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
A2Fc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Gt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Ht-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2It-1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
A2It-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2Jc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASc-1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ASc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ac-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Bt-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Ct-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1Dc-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ec-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Ft-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Gt-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
B2Hc-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2Hc-2	0	6	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3. Numbers of individuals of species captured 12.3m^{-1} otter trawl towed for 20 minutes at a speed of 1.1 ms^{-1} (2.5mph) and covering an estimated 0.016 km^2 at estimated 0.016 km^2 at sites within (Treatment) and near (Control) the proposed inshore and offshore Borrow Areas for the Bogue Banks beach renourishment project on 29 November 1999, 4 February 2000, and 11 May 2000.

				Atlantic croaker	Atlantic cutlassfish	Atlantic menhaden	Atlantic silverside	Atlantic stingray	Atlantic thread herring	banded drum	black drum	black sea bass	blackcheek tonguefish
Date	Area	Treatment	Trawl	*Micropogonias undulatus*	*Trichiurus lepturus*	*Brevoortia tyrannus*	*Menidia menidia*	*Dasyatis sabina*	*Opisthonema oglinum*	*Larimus fasciatus*	*Pogonias cromis*	*Centropristis striata*	*Symphurus plagiusa*
29-Nov-99	Offshore	Control	A1c	27	0	0	66	0	0	0	0	0	0
29-Nov-99	Offshore	Control	A2c	30	0	0	12	0	0	0	0	0	0
29-Nov-99	Offshore	Treatment	A1t	86	0	0	36	0	0	0	0	0	0
29-Nov-99	Offshore	Treatment	A2t	10	0	0	11	0	0	0	0	0	0
29-Nov-99	Inshore	Control	B1c	340	18	3	112	1	0	0	0	0	10
29-Nov-99	Inshore	Control	B2c	4	13	0	56	0	84	0	0	0	0
29-Nov-99	Inshore	Treatment	B1t	108	16	2	81	0	0	0	0	0	0
29-Nov-99	Inshore	Treatment	B2t	9	0	0	0	0	0	0	0	0	6
4-Feb-00	Offshore	Control	A1c	0	0	0	9	0	0	0	0	0	0
4-Feb-00	Offshore	Control	A2c	0	0	0	0	0	0	0	0	0	0
4-Feb-00	Offshore	Treatment	A1t	0	0	0	32	0	0	0	0	0	0
4-Feb-00	Offshore	Treatment	A2t	0	0	0	1	0	0	0	0	0	0
4-Feb-00	Inshore	Control	B1c	1	0	113	86	0	0	0	1	0	3
4-Feb-00	Inshore	Control	B2c	0	0	3	0	0	0	0	0	0	1
4-Feb-00	Inshore	Treatment	B1t	0	0	34	98	0	1	0	0	0	4
4-Feb-00	Inshore	Treatment	B2t	0	0	60	14	0	0	0	0	0	0
11-May-00	Offshore	Control	A1c	0	0	0	0	0	4	0	0	0	4
11-May-00	Offshore	Control	A2c	4	0	0	0	0	0	0	0	4	0
11-May-00	Offshore	Treatment	A1t	0	0	0	0	0	0	0	0	0	0
11-May-00	Offshore	Treatment	A2t	0	0	0	0	0	0	0	0	0	0
11-May-00	Inshore	Control	B1c	0	4	4	1668	0	460	0	0	0	32
11-May-00	Inshore	Control	B2c	0	20	0	1176	0	108	0	0	0	0
11-May-00	Inshore	Treatment	B1t	0	0	0	520	0	428	8	0	0	8
11-May-00	Inshore	Treatment	B2t	0	0	0	592	0	1068	0	0	0	0

Appendix 3 cont.

Date	Trawl	blackwing searobbin *Prionotus rubio*	bluefish *Pomatomus saltatrix*	brown shrimp *Farfantepenaeus aztecus*	butterfish *Peprilus triacanthus*	clearnose skate *Raja ocellata*	cownose ray *Rhinoptera bonasus*	fringed flounder *Etropus crossotus*	gray trout (weakfish) *Cynoscion regalis*	harvestfish *Peprilus alepidotus*	inshore lizardfish *Synodus foetens*	longfin squid *Loligo pealeii*	lookdown *Selene vomer*
29-Nov-99	A1c	0	4	0	2	0	0	0	0	0	0	0	0
29-Nov-99	A2c	0	0	0	48	0	0	3	0	0	0	0	0
29-Nov-99	A1t	0	0	0	2	0	0	0	3	0	0	0	0
29-Nov-99	A2t	0	0	0	0	0	0	0	0	0	2	0	0
29-Nov-99	B1c	1	2	4	1	14	0	0	7	0	0	0	2
29-Nov-99	B2c	0	4	0	0	6	0	0	0	0	0	0	8
29-Nov-99	B1t	0	3	0	2	0	0	0	4	0	0	0	5
29-Nov-99	B2t	0	0	0	7	0	0	0	24	0	0	0	7
4-Feb-00	A1c	0	0	0	0	1	0	0	0	0	0	0	0
4-Feb-00	A2c	0	0	0	1	2	0	0	0	0	0	0	0
4-Feb-00	A1t	0	0	0	0	1	0	0	1	0	0	0	0
4-Feb-00	A2t	0	0	0	0	0	0	0	0	0	0	1	0
4-Feb-00	B1c	3	0	0	0	0	0	1	2	0	0	0	0
4-Feb-00	B2c	0	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B1t	0	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B2t	0	0	0	0	0	0	0	0	0	0	0	0
11-May-00	A1c	8	0	0	0	0	0	0	0	0	0	0	0
11-May-00	A2c	8	4	0	0	0	4	0	0	0	48	0	0
11-May-00	A1t	0	0	0	0	0	0	0	0	0	0	0	0
11-May-00	A2t	0	0	0	0	0	0	0	0	0	0	0	0
11-May-00	B1c	924	4	0	32	48	0	0	0	0	0	0	0
11-May-00	B2c	4	4	0	8	0	0	0	0	20	0	0	0
11-May-00	B1t	712	8	0	0	20	0	16	0	0	0	0	0
11-May-00	B2t	4	12	0	8	0	0	0	0	112	0	0	0

Appendix 3 cont.

Date	Trawl	mantis shrimp *Squilla empusa*	northern kingfish *Menticirrhus saxatilis*	northern puffer *Sphoeroides maculatus*	ocellated flounder *Ancylopsetta quadrocellata*	pigfish *Orthopristis chrysoptera*	pinfish *Lagodon rhomboides*	planehead filefish *Monacanthus hispidus*	portunid crab *Portunus gibbesii*	round herring *Etrumeus teres*	sand seatrout *Cynoscion arenarius*
29-Nov-99	A1c	0	17	0	0	48	284	0	0	0	0
29-Nov-99	A2c	0	0	0	0	7	94	0	0	0	0
29-Nov-99	A1t	0	0	0	0	15	13	0	0	0	0
29-Nov-99	A2t	0	0	0	0	70	124	0	0	0	0
29-Nov-99	B1c	0	30	1	0	3	52	0	0	0	0
29-Nov-99	B2c	0	0	0	0	0	0	0	0	0	0
29-Nov-99	B1t	0	33	0	0	7	65	0	0	0	0
29-Nov-99	B2t	0	9	0	0	11	4	0	0	0	0
4-Feb-00	A1c	0	0	0	0	0	2	0	0	0	0
4-Feb-00	A2c	0	0	0	0	0	16	0	0	0	1
4-Feb-00	A1t	0	0	0	0	0	5	0	0	0	0
4-Feb-00	A2t	0	0	0	0	0	2	0	0	0	0
4-Feb-00	B1c	0	1	0	1	0	30	0	0	0	0
4-Feb-00	B2c	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B1t	0	2	0	1	0	56	0	0	0	0
4-Feb-00	B2t	0	0	0	0	0	21	0	0	0	0
11-May-00	A1c	0	0	0	0	0	0	0	12	0	0
11-May-00	A2c	0	0	0	0	72	788	0	0	0	0
11-May-00	A1t	0	0	0	0	0	0	0	12	0	0
11-May-00	A2t	0	0	0	0	0	0	0	4	0	0
11-May-00	B1c	4	40	4	8	0	36	4	56	0	0
11-May-00	B2c	0	0	0	4	0	0	0	4	0	0
11-May-00	B1t	0	24	4	24	72	0	0	0	0	0
11-May-00	B2t	0	0	0	0	4	0	0	20	4	0

Appendix 3 cont.

Date	Trawl	scup *Stenotomus chrysops*	sheepshead *Archosargus probatocephalus*	silver perch *Bairdiella chrysoura*	silver seatrout *Cynoscion nothus*	smooth butterfly ray *Gymnura altavela*	smooth dogfish *Mustelus canis*	southern flounder *Paralichthys lethostigma*	spadefish *Chaetodipterus faber*	speckled crab *Arenaeus cribrarius*	spider crab *Libinia dubia*	spiny box fish *Lactophrys trigonus*
29-Nov-99	A1c	0	0	0	0	0	0	0	0	0	0	0
29-Nov-99	A2c	0	0	0	0	0	0	0	0	0	0	0
29-Nov-99	A1t	0	0	2	0	0	0	0	0	0	0	0
29-Nov-99	A2t	0	0	0	0	0	0	0	0	0	0	0
29-Nov-99	B1c	0	0	100	0	0	0	0	0	0	0	3
29-Nov-99	B2c	0	0	12	0	0	0	0	0	0	0	0
29-Nov-99	B1t	0	0	57	0	0	0	0	0	0	0	1
29-Nov-99	B2t	0	0	37	0	0	0	1	0	0	0	0
4-Feb-00	A1c	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	A2c	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	A1t	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	A2t	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B1c	0	0	0	0	0	0	10	0	5	0	0
4-Feb-00	B2c	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B1t	0	0	0	0	0	0	0	0	0	0	0
4-Feb-00	B2t	0	0	0	0	0	0	6	0	0	0	0
11-May-00	A1c	0	0	0	0	0	0	0	0	0	4	0
11-May-00	A2c	288	4	0	0	0	0	0	0	0	0	0
11-May-00	A1t	0	0	0	0	0	0	0	0	0	0	0
11-May-00	A2t	0	0	0	0	0	0	0	0	0	0	0
11-May-00	B1c	0	0	0	104	4	4	4	0	0	0	0
11-May-00	B2c	0	0	0	0	0	0	0	0	0	0	0
11-May-00	B1t	0	0	0	40	12	0	0	8	0	0	0
11-May-00	B2t	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 cont.

		spot	spotted hake	spotted whiff	striped burrfish	striped cusk-eel	summer flounder	white shrimp	windowpane
Date	Trawl	*Leiostomus xanthurus*	*Urophycis regia*	*Citharichthys macropos*	*Chilomycterus schoepfi*	*Ophidion marginatum*	*Paralichthys dentatus*	*Litopenaeus setiferus*	*Scopthalmus aquosus*
29-Nov-99	A1c	367	-0	0	0	0	0	0	0
29-Nov-99	A2c	213	0	0	0	0	0	0	0
29-Nov-99	A1t	240	0	0	0	0	0	0	0
29-Nov-99	A2t	364	0	0	0	0	0	0	0
29-Nov-99	B1c	25	0	0	0	1	0	5	0
29-Nov-99	B2c	1	0	0	0	0	0	0	0
29-Nov-99	B1t	10	0	0	0	1	0	0	0
29-Nov-99	B2t	27	0	0	0	0	0	0	0
4-Feb-00	A1c	0	0	1	0	0	0	0	0
4-Feb-00	A2c	0	1	1	0	1	0	0	0
4-Feb-00	A1t	0	1	0	0	0	0	0	0
4-Feb-00	A2t	0	0	1	0	0	0	0	0
4-Feb-00	B1c	8	8	0	0	0	0	2	0
4-Feb-00	B2c	0	0	0	0	0	0	0	0
4-Feb-00	B1t	5	12	0	0	0	0	0	0
4-Feb-00	B2t	1	10	0	0	0	0	0	0
11-May-00	A1c	0	0	0	0	0	0	0	0
11-May-00	A2c	8	0	0	0	0	0	0	0
11-May-00	A1t	0	0	0	0	0	0	0	0
11-May-00	A2t	0	0	0	0	0	0	0	0
11-May-00	B1c	52	116	0	0	0	4	0	80
11-May-00	B2c	32	4	0	4	0	0	0	0
11-May-00	B1t	20	60	0	0	0	0	0	136
11-May-00	B2t	4	4	0	0	0	0	0	0

APPENDIX D

APPENDIX D

EFH Assessment

Bogue Banks Beach Restoration Plan

Draft Essential Fish Habitat Assessment

May 10, 2001

1.1 Introduction

The Fishery Management Plan amendments of the South Atlantic Fishery Management Council identify a number of Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC), which are listed in Table 1.1. While all of the habitat categories occur in the southeastern United States, many are absent from the potential impact areas of the Bogue Banks beach nourishment project. Those absent include estuarine scrub/shrub mangroves, which require a much more tropical environment; and several areas that are much removed from the impact areas associated with the project including Hoyt Hills, located in the Blake Plateau in water depths of 300 to 600 meters, the sandy shoals of Capes Hatteras and Fear and New River. There are no Council Designated Artificial Reef Special Management Zones, Intertidal Flats, Oyster Reefs and Shell Banks, Aquatic Beds, Wetlands or Seagrass Beds or estuarine EFH's in or adjacent to the potential impact areas of the project. Impacts on habitat categories potentially present in the project area are addressed in Section 2.0 of this report.

Table 1.2 list by life stages 81 fish species which may occur in the vicinity of Bogue Banks Beaches, and which are managed under MSFCMA. These fish species and habitats require special consideration to promote their viability and sustainability.

1.2 Project Description

The proposed beach nourishment project will consist of placing the equivalent of ~4.5 million cubic yards of beach-quality sediment along ~16.8 miles of Bogue Banks from the Atlantic Beach/Pine Knoll Shores town line to ~Shipwreck Lane along western Emerald Isle (Fig. 1.1). Nourishment sand will be excavated from three borrow areas by hopper dredge or hydraulic dredge and placed along as many as six contiguous reaches. (CSE Baird-Stroud, 1999, Shoreline assessment and preliminary beach restoration plan, Bogue Banks, NC. Executive Summary Report, 38 pp.)

Three potential borrow areas (A, B1, and B2) have been identified, sampled and delineated offshore of the project area. Sediment quality in each borrow area was compared with native beach sediment quality to determine compatibility indices (R_A, after the method of James, 1975). Twenty samples from the dune, berm, beach face, and low-tide terrace were used to determine the "native" sediment characteristics. The mean grain size computed from 20 samples was ~0.30 mm [versus 0.17 mm used by USACE (1976) for planning along Atlantic Beach].

Borrow area A (revised) had the lowest R_A value (1.16), meaning that ~85 percent of the deposit would be stable as beach fill. Borrow area B1 yielded an R_A value of 2.19; B2 yielded an R_A value of 1.97; and C yielded an R_A value of 1.57. The R_A factors predict how many cubic yards of nourishment material will be required to perform as 1.0 cy of native beach sediment. Variations in R_A factors were used to adjust the required (base) nourishment volume for a particular borrow area. Borrow areas with higher R_A will require proportionately higher excavation volumes to achieve the same performance as native beach sand.

Final selection of borrow area(s) will be based on several factors, including sediment quality, dredging and transportation economics/environmental impacts, and cultural resource impacts. Borrow area A is tentatively identified as the optimal sand source. It extends from ~0.5 to 2.5 miles offshore, centered near the Emerald Isle/Indian Beach town line. Sediments have been confirmed over an ~4.5 square-mile area to a section thickness averaging ~2.25 ft. This yields potentially 10 million cubic yards of beach quality sediment. Only a portion of borrow area A will be required to satisfy the nourishment volume requirements of the project (~5.1 million cubic yards after factoring in the overfill ratio). The average water depth in borrow area A is ~46 ft. The anticipated optimal equipment for excavations will be ocean-certified, self-contained hopper dredges. Such equipment typically excavates shallow trenches (~2 ft of section) in each pass (leaving narrow undisturbed areas at the margin of each cut), then travels to a buoyed pipeline anchored close to shore. Discharge to the beach is via submerged pipeline across the surf zone, then by way of shore-based pipe positioned along the dry beach.

The project will be built in ~1-2 mile sections, optimizing the disposition of pipeline. Sections will be pumped into place with the aid of temporary dikes pushed up by bulldozer in the surf zone. Daily operations will directly impact ~ 500-1000 ft of shoreline as work progresses in either direction from the submerged pipeline. Upon completion of a section, the submerged pipe and beach-building equipment will be shifted to the next section.

The project will add an average of ~50 cy per linear foot along the recreational beach between the base of the foredune and the outer bar. It will displace the shoreline ~75-100 ft seaward after fill adjustment. The backbeach grade for the project will be set close to the existing grade of the dry beach (~+7 ft NGVD). The fill will be sloped in the seaward direction to maintain proper drainage. Where oceanfront development exists at elevations nearly equaling the native dry beach, a low protective dune will be pushed up along the backbeach to prevent the slurry from draining toward buildings.

Under normal circumstances, using a single dredge, the project will require 180-300 days to construct (at 15,000-25,000 cy per day average production). The applicant desires to perform construction during winter months to avoid the tourist season, turtle-nesting season, and periods of highest biological productivity. Alternatives involving use of more than one dredge (to shorten the construction period) or splitting construction over two winter seasons are being investigated.

As construction progresses, sections will be graded to final contours, dressed to eliminate low areas, and opened for use by the community. Support equipment will be shifted out of completed sections as soon as practicable, such that construction activities in a given reach will disrupt normal beach use for only a month or so at any locality.

Table 1.1 Catagories of Essential Fish Habitat and Habitiat Areas of Particular Concern in Southeast States 1

Essential Fish Habitat	Geographically Defined Habitat Areas of Particular Concern
Estuarine Areas	**South Atlantic**
Aquatic Beds	Council Designated Artficial Reef
Estuarine Emergent Wetlands	Special Habitat Management Zones
Estuarine Scrub / Shrub Mangroves	Hermatypic (reef-forming) Coral Habitat & Reefs
Submerged Aquatic Vegetation	Hard Bottoms
Oyster Reefs & Shell Banks	Hoyt Hills
Intertidal Flats	*Sargassum* Habitat
Palustrine Emergent & Forested Wetlands	State Designated Areas of Importance to Managed Species
Estuarine Water Column	Submerged Aquatic Vegetation
Marine Areas	**North Carolina**
Artificial / Manmade Reefs	Big Rock
Coral & Coral Reefs	Bogue Sound
Live / Live Hardbottoms	Pamlico Sound at Hatteras/Ocracoke Inlets
Sargassum	Capes Fear, Lookout, & Hatteras (sandy shoals)
Water Column	New River
	The Ten Fathom Ledge
	The Point

1 Areas shown are identified in Fishery Management Plan amendments of South Atlantic Fishery Management Council and are included in Essential Fish Habitat: New Marine Fish Habitat Mandate for Federal Agencies, February 1999 (rev. 10/00, Appendices 6 and 7)

Table 1.2 Project Area Fish Species Managed Under Magnuson-Stevens Fishery Conservation and Management Act

Fish Species	Beaufort Inlet	Bogue Inlet	Atlantic Ocean South of Cape Hatteras
Red Drum	ELJA	ELJA	A
Bluefish	ELJA	ELJA	JA
Summer Flounder	LJA	LJA	ELJA
Gag grouper	JA	JA	ELJA
Gray snapper	JA	JA	ELJA
Dolphin	N/A	N/A	ELJA
Cobia	ELJA	ELJA	JA
King mackeral	JA	JA	ELJA
Spanish mackeral	LJA	LJA	ELJA
Black sea bass	LJA	LJA	ELJA
Spiny dogfish	JA	JA	ELJA
Brown shrimp	ELJA	ELJA	ELJA
Pink shrimp	ELJA	ELJA	ELJA
White shrimp	ELJA	ELJA	ELJA
Atlantic bigeye tuna	N/A	N/A	N/A
Atlantic bluefin tuna	N/A	N/A	N/A
Skipjack tuna	N/A	N/A	N/A
Longbill spearfish	N/A	N/A	N/A
Shortfin mack shark	N/A	N/A	N/A
Blue shark	N/A	N/A	N/A
Spinner shark	N/A	N/A	ELJA
Sword shark	N/A	N/A	ELJA
Yellowfin tuna	N/A	N/A	ELJA
Blue marlin	N/A	N/A	ELJA
White marlin	N/A	N/A	ELJA
Sail fish	N/A	N/A	ELJA
Calico scallop	N/A	N/A	ELJA

Notes:

E - Eggs L - Larval J - Juvenile A - Adult N/A - Not Found

Table 1.2 Project area Fish Species Managed under Magnuson-Stevens Fishery Conservation and Management Act (continued)

Fish Species	Beaufort Inlet	Bogue Inlet	Atlantic Ocean South of Cape Hatteras
Scalloped hammerhead shark	N/A	N/A	JA
Big nosed shark	N/A	N/A	JA
Black tip shark	N/A	N/A	JA
Dusky shark	N/A	N/A	JA
Night shark	N/A	N/A	JA
Sandbar shark	N/A	N/A	JA
Silky shark	N/A	N/A	JA
Tiger shark	N/A	N/A	JA
Atlantic sharpnose shark	N/A	N/A	JA
Longfin mako shark	N/A	N/A	JA
Whitetip shark	N/A	N/A	JA
Thrasher shark	N/A	N/A	JA
Gray triggerfish	N/A	N/A	ELJA
Yellow jack	N/A	N/A	ELJA
Blue runner	N/A	N/A	ELJA
Crevalle jack	N/A	N/A	ELJA
Bar jack	N/A	N/A	ELJA
Greater amberjack	N/A	N/A	ELJA
Almaco jack	N/A	N/A	ELJA
Banded rudderfish	N/A	N/A	ELJA
Spade fish	N/A	N/A	ELJA
White grunt	N/A	N/A	ELJA
Hogfish	N/A	N/A	ELJA
Puddingwife	N/A	N/A	ELJA
Red snapper	N/A	N/A	ELJA
Cubera snapper	N/A	N/A	ELJA
Silk snapper	N/A	N/A	ELJA

Notes:

E - Eggs L - Larval J - Juvenile A - Adult N/A - Not Found

Table 1.2 Project area Fish Species Managed under Magnuson-Stevens Fishery Conservation and Management Act (continued)

Fish Species	Beaufort Inlet	Bogue Inlet	Atlantic Ocean South of Cape Hatteras
Vermillon snapper	N/A	N/A	ELJA
Blueline tilefish	N/A	N/A	ELJA
Sand tilefish	N/A	N/A	ELJA
Bank sea bass	N/A	N/A	ELJA
Rock sea abss	N/A	N/A	ELJA
Graysby	N/A	N/A	ELJA
Speckled hind	N/A	N/A	ELJA
Yellowedge grouper	N/A	N/A	ELJA
Coney	N/A	N/A	ELJA
Red hind	N/A	N/A	ELJA
Jewfish	N/A	N/A	ELJA
Red grouper	N/A	N/A	ELJA
Misty grouper	N/A	N/A	ELJA
Snowy grouper	N/A	N/A	ELJA
Sheepshead	N/A	N/A	ELJA
Red porgy	N/A	N/A	ELJA
Scup	N/A	N/A	ELJA
Little tunny	N/A	N/A	ELJA

Notes:

E - Eggs L - Larval J - Juvenile A - Adult N/A - Not Found

2.0 Impacts to Essential Fish Habitat Areas and Habitat Areas of Particular Concern.

2.1 Impacts to Cape Lookout Shoals, Big Rock and Ten Fathom Ledge off of Cape Lookout.

A North Carolina HAPC is the sandy Shoals of Cape Lookout and the Big Rock off of Cape Lookout. These sites are over 15 miles from the borrow and disposal areas and will not be impacted by the project.

2.2 Impacts on *Sargassum*

Sargassum is a pelagic brown algae which occurs in large floating mats in the waters of the continental shelf, in the Sargasso Sea and in the Gulf Stream. It is a major source of biological productivity in nutrient-poor regions of the ocean. Masses of *Sargassum* provide extremely valuable habitat for a diverse assemblage of marine life including juvenile sea turtles, sea birds, and over 100 species of fish. Unregulated commercial harvest of *Sargassum* for fertilizer and livestock feed has prompted concerns over the potential loss of this important resource. There have been instances of relatively small masses of Sargassum washing ashore or into the project area under certain wind conditions. Since Sargassum occurs in the upper few feet of the water column and is not commonly found in the project area, it is not subject to impacts from dredging or disposal associated with the project.

2.3 Impacts to Artificial Reefs

The North Carolina Division of Marine Fisheries lists three artificial reef sites in the vicinity of offshore of Bogue Banks. The closest sites are AR-315, AR-320 and AR-342 and are shown on Figure 2.1. All of the sites are located 1.7 to 6.7 miles from the borrow areas and 2.4 to 2.2 miles from the closest beach deposition areas of the project.

No adverse impacts would be expected to the artificial reef areas since dredging conducted as part of the project will not be done in close proximity to the reefs. Disposal of the sand on the beaches of Bogue Banks will involve discharge of high quality sand material (sand content greater than 95 percent) onto the upper beach and will have no affect on the reefs.

Temporary increases in turbidity are associated with both dredging operations and the washing of fine sediments by waves on the nourished beach. The applicable standard required for Section 401 Water Quality Certification quoted here from WQC#2949 issued for a Corps dredging and disposal operation for the nearshore berm off of Atlantic Beach is "that the activity be conducted in such a manner as to prevent significant increase in turbidity outside the area of construction or construction related discharge . . . 25 NTUs in all saltwater classes . . ." .

Published measurements of turbidity during beach nourishments are rare. Reference (USACE, 1993, p. 6) is made to turbidity measurements for pipeline discharge of nourishment sediment on Atlantic Beach. Turbidity was a function of distance from the discharge pipe. Measurements ranged up to 250 NTUs in the vicinity of the pipe, but decreased rapidly with distance. That sediment pumped from Brandt Island had a much higher overfill ratio and mud percentage than the borrow areas proposed for this project, so turbidity must necessarily be lower for this project. A fairly comprehensive set of measurements was made for another project with mud percentages more similar to the one proposed here by Hanes (1994). Table 5 in that publication lists measured turbidities for times during and after nourishment and for both the project area and a control site uninfluenced by the nourishment. Turbidities were not measured in the immediate vicinity of the discharge pipe, but rather seaward of the breakers along the nourished stretch of beach. Values are listed for surface, mid-depth, and near bottom in the water column. The control site must have had slightly different conditions, because the after-nourishment numbers showed an average ratio of 0.6 of nourishment site to control site. (The nourished area had less turbidity than the control site well after construction.) But the numerical values were low for this post-construction period: 2.8 to 4.4 NTUs for the nourished area and 4.4 to 9.2 for the control site.

The artificial reef sites located within close proximity to the project borrow or deposition areas will be identified on the project plan sheets as sensitive areas to be avoided during dredging operations. The proposed project will not significantly impact any artificial NCDMF artificial reef sites.

2.4 Impacts on Hard Bottom

Figure E1 taken from the Final EIS, Appendix E shows Tertiary (hard bottom) outcrops and estimated Quaternary layer thickness (of unconsolidated sediments) based on Hine and Snider (1985, Figure 6). Infilled paleochannels comprise the thickest deposits but have limited extent. Additionally, in the process of sampling bottom sediments in the offshore of Bogue Banks by CSE (Final EIS, Appendix E1, Figure E5, reproduced in this assessment as figure 2.2) live hard bottom was observed in the sample locations C18a1and C18a2. These sample locations occurred in water depths of 45 feet. Project borrow areas A, B1 and B2 are superimposed on the figure to illustrate proximity of the borrow and deposition areas to the known hardbottom areas.

The closest outcropping of hard bottom is ~6500 ft from borrow areas A and B2. This distance is ~four times greater than from the expected maximum radius of sediment plumes around the dredge or around the discharge point. The nearest outcrop of hard bottom off the project area occurs about 1600 ft seaward of the bar near transect 11 (Emerald Isle, west reach) and transect 25 (Emerald Isle, central reach). There are no inlets or channelized discharges between the preferred borrow area and adjacent hard bottom areas that could direct a concentrated plume of fine-grained sediments into these habitats.

Hine and Snider (1985) documented no hard bottoms near the outer bar along Bogue Banks. The documented hard bottom areas are beyond the closure depths for the project as estimated by CSE Stroud (Final EIS, 2001 Appendix G). It is estimated that sediment located below a depth of 30 feet MLW will not receive fine sediments deposited on the beach.

The locations of exposed hard bottoms will be shown on the project construction drawings so that the areas will be avoided and protected from physical impacts due to anchoring or pipe and equipment mobilization.

2.5 Impacts on State-Designated Areas Important for Managed Species

Primary nursery areas (PNA's) are designated by the North Carolina Division of Marine Fisheries and are identified by the State as tidal saltwater which provide essential habitat for the early development of commercially important fish and shellfish. The locations of PNA's are identified in 15 NC Administrative Code 3R. 0100. There are no primary nursery areas designated by the Division of Marine Fisheries in the Atlantic Ocean. The designated areas are in Bogue Sound and the adjacent creeks and tributaries. The project will not impact primary nursery areas.

2.6 Impacts to the Marine Water Column

Dredging and disposal activities conducted during project construction may cause impacts in the marine water column in the immediate areas of the borrow and deposition sites that could potentially impact nearshore and intertidal resources. These impacts may include minor and short term suspended solids sediment plumes and related turbidity as well as the release of trace constituents from the sediment. During dredging turbidity increases outside the immediate area of dredging should be less than the N. C. Division of Water Quality standard of 25 NTU's and are considered insignificant. In case of overflowing hopper, dredges sediment from the overflow will be from sediment with more than 95 percent sand and is not likely to produce significant turbidity or other water quality impacts. Living marine and estuarine resources dependent upon good water quality are not expected to experience significant impacts.

Scientific data are limited with regard to the effects of beach disposal on fishery resources. The impacts associated with this project may be similar, on a smaller scale, to the effects of storms. Storm effects may include increased turbidity and suspended sediment load in the water column and, in some cases, changes in fish community structure (Hackney et. al.,1996). Severe storms have been documented to create conditions of fish kills, but such situations are not associated with beach disposal of dredged sand.

In a 1999 Environmental Report on the use of Federal offshore sand resources for beach and coastal restoration, U. S. Department of Interior, Minerals Management Service provide the following assessment:

In order to assess if turbidity causes an impact to the ecosystem, it is essential that the predicted turbidity levels be evaluated in light of conditions such as during storms. Storms on the Mid-Atlantic shelf may generate suspended matter concentrations of several hundred mg/L (E.G. Styles and Glenn, 1999). Concentrations of plums decrease rapidly during dispersion. Neff (1981, 1985) reported that solids concentrations of 1000 ppm two minutes after discharge decreased to 10 ppm within one hour. Poopetch (1982) showed that the initial concentration in the hopper overflow of 3,500 mg/l decreased rapidly to 500 mg/l with in 50 meters. For this reason, the impact of settling particles from the turbidity plume is expected to be minimal beyond the immediate zone of dredging.

Beach disposal of dredged sediments can affect fishery resources and EFH through increases in turbidity and burial of beach resources. These impacts may create localized stressful habitat conditions and may result in the temporary displacement of fish and other biota. However, the sand proposed for disposal on the Bogue Banks beaches will average 95 percent or more sand (4 percent or less mud). Because of the low mud content in the sediment, turbidity induced water column impacts are expected to be localized, short term, and minor.

There are several environmental issues relating to the benthic habitat and resources that arise in considering a beach renourishment project. The most significant include: (1) impacts to and recovery of the benthic invertebrate community at the borrow sites; (2) potential impacts to commercially or recreationally important demersal fishes and crustaceans in part because of these effects on their benthic invertebrate prey; (3) impacts to and recovery of the benthic invertebrate community on the intertidal and shallow subtidal beach; and (4) potential impacts to commercially and recreationally important fishes in the surf zone and/or shorebirds in large part because of these effects on their benthic invertebrate prey and because of enhanced turbidity along the shoreline. The biological monitoring program outlined in The Draft Environmental Monitoring Plan for Phase 1 – Towns of Pine knoll Shores and Indian Beach, dated April 25, 2001 is intended to address these issues. That monitoring plan is provided in appendix A of this Assessment..

2.6.1 Impacts to Offshore Resources

Monitoring studies of post-construction borrow areas in the southeast indicate that borrow areas fill in and return to near predredging conditions when there is adequate transport of sediment under the influence of strong currents in the area (Bowen and Marsh, 1988). This project's offshore borrow areas are in depths between 30 and 40 ft MLW (borrow area B) and 40 and 50 ft (borrow area A). Divers at these sites have not observed currents of sufficient magnitude to move sediment. However, most coastal areas in these depths have some rare events (e.g., hurricanes) that generate sufficient flows to move sediment. Thus the conclusion is that sediment levels in borrow areas will return to predredging conditions only during such rare events.

2.6.1.1 Impacts to Offshore Vertebrates - Fish, plankton, and other mobile animals in the vicinity of the borrow area during dredging are least likely to be affected during dredging, because of their ability to avoid the disturbed areas. Fish species have been observed to leave the area temporarily during dredging operations and return when dredging ceases (Pullen and Naqvi, 1983). A study of nearshore borrow areas after dredging offshore of South Carolina revealed no long-term impacts to fisheries, both fish and planktonic organisms, as a result of the dredging (Van Dolah et al., 1992). Creation of new habitat and the uncovering and suspension of food that attract fish during dredging have been attributed to dredging offshore borrow areas (Naqvi and Pullen, 1982). Dredging of the bottom sediments in the borrow areas can be expected to attract fish (after the dredge leaves) as a result of suspension of bottom material

2.6.1.2 Impacts to Offshore Invertebrates - Benthic organisms in the immediate area being dredged will be largely eliminated during dredging. However, initial recolonization of the dredged areas by opportunistic species is expected to occur soon after cessation of any dredging activities. Further recovery is expected from recolonization from migration of benthic organisms from adjacent areas and by larval transport. Monitoring studies of post-dredging effects and recovery rates of borrow areas indicate that most borrow sites show significant recovery by benthic organisms approximately one year after dredging (Naqvi and Pullen, 1982; Bowen and Marsh, 1988; Van Dolah et al., 1992). To encourage recolonization by organisms from undisturbed substrates, the borrow areas will not be "swept clean." Furrows of undredged materials will remain.

The monitoring plan will include collection and evaluation of bottom sediment samples from impact (borrow) areas. Benthic populations in the samples will be compared with those from control (undisturbed) areas both before and after the sand is removed. [Control areas would have no sand removed, but would otherwise be affected by all other impacts (i.e., storms, shrimping, etc., that affect the impact area).] These samples taken before the removal of the sand will be compared with identical samplings made after the nourishment to evaluate impacts. In addition, the design also calls for spring sampling both before and after the removal of sand to assess the seasonal component, for a total of four sampling periods to complete the assessment of impacts.

2.6.2 Impacts to Nearshore Resources

Nourishment sediment will be placed on the upper part of the beach, but flow down into the surf-zone region. The placed sediments are a close match in size to the sandy beach sediments, but with higher carbonate content, and a few percent mud (Appendix E, Final EIS).

There are three direct impacts from nourishment projects:

- Very short-lived substantial increases in turbidity during the placement operation (a few days at each location) alter the water column conditions sufficiently that it causes mobile species to leave the area. Return is rapid. Studies have found that speed of return of mobile species is more dependent on the return rate of their prey than on the rapid return of normal turbidity levels.

- Burial of bottom-dwelling organisms essentially destroys the community present, but Reilly and Bellis (1983) found that larval recruitment is rapid, and recovery occurs in one or two seasons.

- Alteration of sediment type necessarily results in changes in type and densities of species. Numerous monitoring studies recommend that the key to minimizing impact is to match the sediment types as closely as possible.

2.6.3 Impacts to Intertidal Resources

During project construction there will be an increase in the turbidity of the surf zone in the immediate area of sand deposition. Most of the fine material in the beach fill is expected to be washed seaward into the surf during construction. This increase in fine material may cause the temporary displacement of various species of sport fish, causing a negative impact to surf and pier fishing in the area of deposition. A study done by the National Marine Fisheries Service on the effects of beach nourishment on nearshore macroinfauna concluded that beach nourishment projects using offshore dredged material have no harmful effects, provided that the sediments are similar to those where they are placed (Saloman and Naughton, 1984).

2.6.3.1 Impacts to Intertidal Vertebrates - In view of the high mobility of fish, it is expected that fish will leave the areas under active construction. Impact on fishing resources in the intertidal zone will be minimized simply by the fact that sand-placement operations will take place at any one location for only a few days and then move further along the beach. Quantitative impacts on fish will be judged from offshore tow counts.

2.6.3.1 Impacts to Intertidal Invertebrates - Impacts on intertidal microfauna in the immediate vicinity of the nourishment project are expected as a result of discharges of nourishment sediment on the beach. A study by Reilly and Bellis (1983) was conducted on Bogue Banks and is used as a seminal study on beach projects throughout the Southeast U.S. "The Ecological Impact of Beach Nourishment with Dredged Materials on the Intertidal Zone at Bogue Banks, North Carolina" concluded that beach nourishment virtually destroys existing intertidal macrofauna, but that recovery is rapid once the pumping operation ceases. In most cases, recovery occurs within one or two seasons following the sediment placement. "...a speedy recovery largely depended on recruitment from pelagic larval stocks." Most species fell into this category. The few that did not, and recruited instead from neighboring beaches, were slower to recover.

2.6.4 Impacts to Beach and Terrestrial Resources

After construction the beach sediment will be sampled and analyzed. The primary purpose will be to determine how much of the mud in the nourishment sediment still remains and did not decant off during the construction process.

Since the project is being constructed with offshore sediments, there will be little impact on the upper (dune) portion of the beach. Project construction will result in disturbance and removal of some of the existing vegetation along the seaward side of the existing dune. Dune stabilization with vegetative planting will take place only in the isolated sections of the project where new dunes are built. Most of the project has vegetated dunes. The project is intended to widen the base of the dunes and the beach face, not build up the dune itself. Thus replanting makes sense only for those areas where new dune will be built. The Reilly and Bellis (1983) study that focused on the intertidal zone also encompassed dry-beach sampling. Most species, including all of the larger organisms such as crabs, recruited from pelagic larvae and thus recovered rapidly (one or two seasons). The Environmental Monitoring Plan for Phase 1 will address effects of the nourishment on beach species. The pre-project sampling is scheduled for summer 2001. The standard deviations in previous infauna samplings suggest that there will be sufficient statistical power to detect about a 20 percent change in total infaunal density. Analyses of densities of individual families will be less powerful, but an ordination analysis on the entire community data set will have power similar to that of the test of total infaunal density.

In a 1999 Environmental report on the use of federal offshore sand resources for beach and coastal restoration, U. S. Department of the Interior, Minerals Management Service provided the following assessment of the potential impacts to beach fauna from beach disposal;

As with benthic organisms living in borrow areas, benthic organisms are significantly impacted by beach nourishment activities (Nelson 1985; Van Dolah et. Al. 1992). These impacts, however, are considered shorter in duration than the impacts observed in offshore borrow areas. Because benthic organisms living in the beach habitats are adapted to high energy environments, they are able to quickly recover to orginal levels following beach nourishment events; sometimes in as little as three months (Van Dolah et al. 1994; Levison and Van Dolah, 1996). This is again attributed to the fact that intertidal organisms are living in high energy habitats where disturbances are more common. Because of lower diversity of species compared to other intertidal and shallow subtidal habitats (Hackney et al., 1996), the vast majority of beach habitats are recolonized by the same species that existed before nourishment (Van Dolah et al., 1992, Nelson, 1985; Levision and Van Dolah, 1996; Hackney et al., 1998)

References

Bowen, P.R., and G.A. marsh. 1988. Benthic faunal colonization of an offshore borrow pit in southeastem Florida. Misc. Report No. D-88-5, Dredging Operations Technical Support Program, U. S. Army Corps of Engineers.

CSE Baird/Stroud. 1999 Shoreline assessment and preliminary beach restoration plan: Bogue Banks. Executive Summary Report, 38 PP.

CSE/Stroud. 2001. Final Environmental Impact Statement, Bogue Banks Beach Restoration Plan.

Essential Fish Habitat; A marine fish habitat conservation mandate for federal agencies, NOAA, National Marine Fisheries Service, Feb. 1999, Rev. Oct. 2000.

Hackney, C.T., and M.H. Posey, S.W. Ross, and A.R.Norris. 1996. A review and synthesis of data on surf zone fishes and invertebrates in the south Atlantic Bight and the potential impacts from beach nourishment. Report to U. S. Army Corps of Engineers, Wilmington, NC. 111 pp.

Hanes, D.M. 1994. Turbidity and suspended sediment associated with beach nourishment dredging. In Proc. 24th Intemational Conference, Coastal Engineering '94, ASCE, New York, NY, Vol. 3, pp. 3016-3029.

Hine, A.C., and S. W. Snyder. 1985. Coastal lithosome preservation: evidence from the shoreface and inner continental shelf off Bogue Banks, North Carolina. Marine Geology, Vol. 63, pp. 307-330.

James, W.R. 1975. Techniques in evaluating suitability of borrow material for beach nourishment. Rept. No. TM-60, CERC, U.S. Army Waterways Experiment Station, Vicksburg, Miss.

Navgi, S.M., and E.J. Pullen. 1982. Effects of beach nourishment and borrowing on marine organisms. U.S. Army Corps of Engineers, CERC Misc. Rep. No. 82.-14, 43 pp.

Nelson, W.G. 1985. Beach restoration in the southeastem United States: A review of biology, beach restoration effects, and biological monitoring methods.

Pullen, E.J., and S.M. Navgi. 1983. Biological impacts on beach replenishment and borrowing. CERC Reprint 83-3, U. S. Army Corps of Engineers.

Reilly, F.J., and V.J. Bellis. 1983. The ecological impact of beach nourishment with dredged materials on the intertidal zone at Bogue Banks, North Carolina. USACE, CERC, Ft. Belvoir, VA, Misc. Paper 83-3.

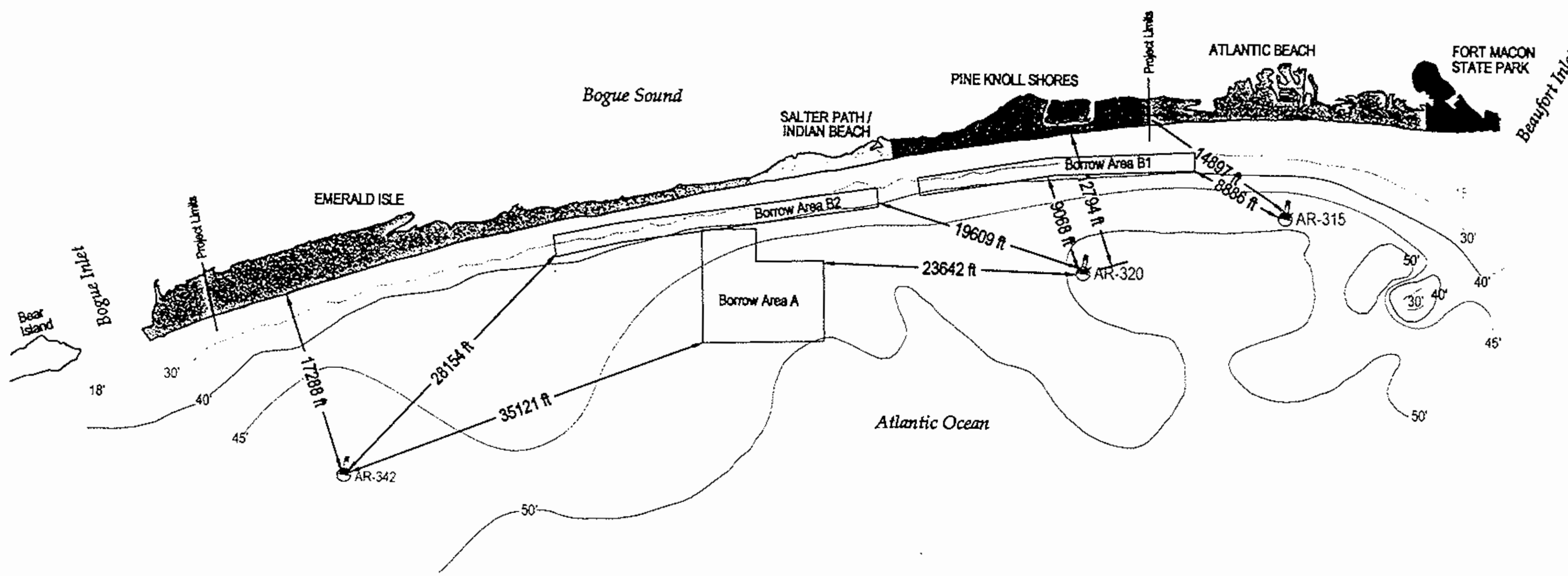
Saloman, C.H., and S.P. Naughton. 1984. Beach restoration with offshore dredged sand: effects on nearshore macrofauna. NOAA tech. Memo. NMFS-SEF-133, U.S. Dept. of Commerce.

USACE. 1976. General Design Memorandum: Morehead City Harbor, North Carolina. Wilmington District, U. S. Army Corps of Engineers, 41pp + app.

USACE. 1993. Environmental Assessment and Finding of No Significant Impact. Disposal of dredged material on the ocean beach of Bogue Banks from combined maintenance dredging and deepening of Morehead City Harbor and pumpout to Brandt Island upland diked disposal site, Carteret County, North Carolina. Wilmington District, U. S. Army Corps of Engineers, 12 pp. + app.

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levision, W.A. Roumillat. 1992. A physical and biological monitoring study of the Hilton Head Island beach nourishment project. Final Report to the Town of Hilton Head Island, South Carolina; S.C. Wildlife & Marine Resources Div., Charleston, 159 pp.

Van Dolah, R.F., R.M. Martore, A.E. Lynch, P.H. Wendt, M.V. Levisen, D. J. Whitaker, and W.D. Anderson. 1994. Environmental evaluation of the Folly Beach project. Final report, U. S. Army Corps of Engineers, Charleston. U. S. Army Corps of Engineers District and the South Carolina Department of Natural Resources, Marine Resources Division.



CSE
Coastal Science & Engineering PLLC

PROJECT NORTH

0 5000 10000

Bogue Banks
Beach Nourishment
North Carolina

Prepared For:
Carteret County
North Carolina

Drawing Title:

Fig 2.1

ARTIFICIAL REEF LOCATIONS

APPENDIX E

APPENDIX E

Geotechnical Data

APPENDIX E. PROPOSED BORROW AREAS

This section summarizes results of field sampling of offshore sediments.

E-1. SURVEY DESIGN

Despite a limited supply of beach-quality sand offshore of Bogue Banks as inferred from the literature (see Section 2), more detailed confirmation was required before ruling out alternative borrow areas. The applicants initiated a reconnaissance-level survey during initial planning of the Bogue Banks restoration project based on the following desirable criteria:

- Viable sand deposits closer to the project areas than Beaufort or Bogue Inlets could potentially yield very large cost savings for the project.
- Sediments that are somewhat coarser (on average) than the native beach and coarser than the material typically available from channel maintenance would improve the durability of the nourishment projects.
- Deposits with lower mud/fine-sand content than previously used in Corps disposal projects would reduce the rate of fill losses and minimize turbidity in nearshore waters.
- If broad, shallow areas (at least 1-2 ft thick) could be confirmed, hopper dredges or alternate equipment could be used for excavations, and the rate of environmental recovery might be more rapid based on experience elsewhere (Jutte et al 1999a,b).

The sediment survey encompassed the following field sampling over three phases between June 1999 and November 2001:

- **Beach sampling and textural analysis** (June 1999) to quantify native material — 20 samples divided among dune (2), berm (6), beach face (6), and low-tide terrace (6) at CSE-Stroud transect 10 (west Emerald Isle), transect 30 (central Emerald Isle), transect 50 (Indian Beach), transect 70 (Pine Knoll Shores east), transect 90 (Atlantic Beach), transect 110 (Coast Guard Station); spacing of transects was approximately 20,000 ft. These were supplemented by 64 additional beach samples (32 analyzed pairs) between transects 48 and 78 in May 2001 following a request for more data from the USFWS (interagency meeting of 11 May 2001–detailed results submitted 24 May 2001 with letter to Garland Pardue, USFWS, Raleigh, NC).
- **Phase I borrow source sampling** (June 1999) — *offshore reconnaissance* — 53 short cores by divers in a regional grid pattern encompassing a 16-mile length of coast

from central Atlantic Beach to central Emerald Isle and extending between ~0.25 and 3 miles offshore. Generally consisted of shore-perpendicular transects of 3-5 boring locations at approximate two-mile intervals in the longshore direction. Additional, more closely spaced cores were collected 0.5-1 mile from the most promising sites. Cores average about 2 ft long. Other potential sources were sampled but rejected for various reasons as detailed in the EIS for the project. Three offshore borrow areas (A, B1, and B2) were tentatively identified for further sampling (CSE Baird-Stroud 1999).

- **Phase II confirmation sampling** (November 1999)
  - *Borrow area A (western half)* — 46 borings (averaging ~2.3 ft) at ~1200-1500 ft spacing; eight vibracores (3-9 ft) at ~3000 ft spacing.
  - *Borrow area B1* — four diver borings (~2.8 ft); three vibracores (7.5-11 ft).
  - *Borrow area B2* — seven diver borings (~2.9 ft); three vibracores (~9-10 ft).
  - Phase II sampling formed the basis of proposed borrow areas A, B1, and B2 as shown on the permit application for the project (P/N ID #200000362).

- **Phase III borrow area refinement sampling** (November 2000-March 2001)
  - *Borrow area A)* — 13 additional borings (averaging ~2 ft)
  - *Borrow area B1* — 32 additional borings (averaging ~3.4 ft)
  - *Borrow area B2* — 25 additional borings (averaging ~3.0 ft)

  Phase III sampling serves as the basis for further refining the borrow areas proposed for the project as detailed herein. (Note: The refined areas are fully within the boundaries specified in the permit application for the project.)

CSE Baird (now Coastal Science & Engineering) performed all Phase I and Phase III sampling and the diver sampling for Phase II. Athena Technologies, Inc. (Columbia, SC) performed the vibracore sampling under subcontract to CSE.

E-2. LABORATORY ANALYSIS

Sediment samples were collected and stored as follows.

Diver cores — two-inch aluminum barrels driven by hammer to refusal, cut, and temporarily capped in situ; then decanted, cut to sediment level, and recapped in the field noting penetration depth and recovery thickness; stored vertically for transport to the lab.

Vibracores — 2½-inch steel barrels driven remotely via large-scale vibrator to the depth of refusal; removed, cut, capped, and measured for penetration depth and recovery thickness.

Grab samples (beach) — hand samples from the upper three inches placed in sample bags.

Samples were logged, split, and analyzed as follows.

1) **Diver and vibracore cores** — split by saw, logged, and one-half sampled as a single or multiple composite; the remaining core half was sealed in plastic in its half barrel and archived.

   Phase I samples — visual estimates of mud percentages; then washed, dried, and dry-sieved using 0.25 phi (ϕ) intervals from -1ϕ to 4ϕ – that is, granule (2 mm) to very fine sand (0.0625 mm); fractions retained >2 mm and <0.0625 mm were noted.

   Phase II and Phase III samples — same handling and grain-size analysis procedures as Phase I samples except nearly all tested for percent mud and percent carbonate via subsampling.

   - *Percent mud* was determined by drying an undisturbed sample (composite from the length of the core), weighing it, rewetting and disagregating the sample, decanting the mud fraction until the water ran clear, redrying the sample, then reweighing it. Percent mud is computed from the difference in dry weight of the unwashed and washed samples.

   - *Percent calcium carbonate* was determined from a 20-gram subsample that had been washed and dried, then treated with repeated quantities of 10 percent dilute HCL for several hours until all reactions stopped. Samples were redried and reweighed for comparison with the untreated sample weight, and the percentage of carbonate material is computed.

2) **Native beach samples** — representative splits were obtained, washed, dried, and dry-sieved at 0.25ϕ intervals. No mud analyses were performed because the grab samples were void of mud. Percent calcium carbonate was determined via the same procedure for Phase II cores and groupings of native beach samples (ie, physical composites of multiple berm, beach face, etc, samples).

Raw data were entered into spreadsheets and analyzed via custom software (CSE's BPAS system) which automates computation of standard statistical parameters [including moment measures and the graphic parameters of Inman (1952) and Folk and Ward (1957)]. Grain-size distributions (GSDs) were graphed as frequency and cumulative frequency distributions using phi (ϕ) and millimeter (mm) axes for cross-reference. To facilitate evaluation and comparison with other engineering sieve sizes, Figure 3.24 (main text) shows the general relationships of grain size (mm), phi value, sediment classification, and ASTM sieve mesh sizes.

Sediment quality and compatibility for beach nourishment were based on the technique of James (1975) (CERC 1984), whereby a population of potential borrow area samples is compared statistically with the native beach size distribution. James (1975) presents methodology for computing the "overfill ratio" (R_A), which represents how similar a particular size distribution of sediments is compared to the native population of sediments. R_A's of nearly 1.0 suggest the sample will perform more or less equal to the native population. Higher R_A's represent the ratio of non-native "borrow" material required to perform as 1.0 unit of native material. Thus, an R_A equal to 2.0 suggests it will take twice as much material to equal 1.0 unit of native sediment.

The concept of overfill ratios is not a perfect predictor of nourishment performance, but it remains perhaps the most useful and proven technique for comparing nourishment sediments (NAS 1995). The primary factors considered are mean grain size and sorting (standard deviation measure of the size distribution). Experience has shown that borrow sources at least as coarse as the native beach (Dean 1991, CERC 1984) or having significant coarse fractions (Kana and Mohan 1998) perform equal to or better than native sediments (as measured by durability of the dry beach). Borrow sediments that are finer than native or that contain high percentages of fine material perform worse (NAS 1995). This response is related to profile adjustment (function of wave energy and wave steepness) as well as the background erosion rate. Obviously, the concept of R_A as a predictor of performance assumes that the scale of the nourishment is relatively large and covers a reasonable length of shoreline. Short projects do not perform as well for another reason–because end losses cause spreading away from the nourishment "bulge" (NAS 1995).

For purposes of the present study, we determined R_A's following standard practice, using the James (1975) nomogram in CERC (1984). Sediment quality and borrow area suitability was based on the R_A's, mean grain size and sorting parameters, percent mud, percent carbonate, percent coarser than 2 mm (ie, granule, or larger), and proximity to the project area. Isopach maps of various sediment size and quality parameters are appended after this section.

E-3. SEDIMENT RESULTS

This section provides a summary of results and refers to data sets contained in the EIS (CSE-Stroud 2001) and various supplements (eg, 24 May 2001 letter and data set to Garland Pardue, USFWS; 19 June 2001 letter to Col. J. DeLony, USACE). These previously submitted data sets include core locations, beach sample locations, and offshore core sediment characteristics (grain-size distribution curves and statistics).

E-3.1 Beach Composites

Native-beach size distributions were established using statistical composites of physical composite results of individual samples. Table 3.3 (main text) contains the individual sample results (primary statistics) from 21 dune/beach/low-tide terrace samples distributed in six transects along Bogue Banks collected in 1999 and 64 (32 pairs) supplementary samples collected in May 2001. Of the three dune samples from 1999, only two were considered representative of natural dunes, which tend to have finer sediment than beach-face samples. At stations CSE-Stroud 30, CSE-Stroud 50, and CSE-Stroud 70, repeated dune scraping has introduced anomalously coarse sands from the berm. Therefore, these stations were not sampled at the dune. At station 110 (Coast Guard station), nourishment via Corps spoil projects has introduced a coarse sediment which similarly does not reflect native dune sands; therefore, it was eliminated from the 1999 composites (top half of Table 3.3). The supplementary samples in 2001 yielded nearly identical composite statistics based on 28 or 32 samples depending on how many dune samples are included in the analysis (bottom of Table 3.3).

Review of the results confirmed coarsest sediments tend to reside on the berm and beach face (medium sand, moderately sorted, coarse-skewed) with finer sediments occurring along undisturbed dunes and low-tide terrace (typically fine sand, well sorted). Composite "12" (from the initial 1999 samples) yielded a mean grain size of 0.362 mm (1999 samples) along the beach face and berm, whereas composite "20" yielded a mean size of 0.302 mm. Considering that the proposed nourishment is designed to widen the recreational beach including part of the underwater profile, we elected to use the composite "20" as a "native" beach (1999 samples). This weights the composite toward the coarse sizes common along the beach face, berm. and low-tide terrace where the majority of the nourishment sand will be placed.

We also elected not to include samples over the outer bar or further offshore (even if these areas are part of the littoral zone), because they tend to be much finer than the beach face and would weight the "result" toward less stable sediment sizes. Similarly, we elected to only include two dune samples in composite "20" because a relatively small percentage of nourishment sediments will be subject to aeolian processes or contribute to dune building after construction. In updating these results with additional samples in 2001, we found virtually the same mean grain size and sorting for the 28 or 32 sample composites (bottom of Table 3.3). Combining the 1999 samples and 2001 samples yielded a composite of 48 beach samples as follows: mean = 0.300 mm, standard deviation = 0.601 mm. These latter values were adopted as the revised **native beach** composite.

The "native" composite selected for a baseline in the 1999 study is considerably coarser than the native sediment distribution used by the USACE (1976) in planning for potential disposal projects along Atlantic Beach. The Corps sampled at 2-ft intervals from the berm to -30 ft mean low water (MLW) along four transects at the eastern end of Bogue Banks. Their statistical composites yielded a mean grain size of 0.17 mm (2.52ϕ) and standard deviation of 0.77ϕ. The Corps results confirm the fining of sediments offshore but tend to weight the result toward less stable material. The native composite we chose is much more conservative for beach nourishment planning because it eliminates from consideration certain fine deposits that characterize the area seaward of the bar. Use of a coarser "native" size distribution lowers the amount of potentially beach-compatible material in our search areas. At the same time, it better distinguishes beach-compatible sediment from marginally acceptable sediment.

E-3.2 Phases I-III Offshore Core Samples

The Phases I-III sediment test results are presented in Table 3.4 (main text) and in Figures 3.25 and 3.26 (overfill ratios only). Detailed isopach maps of mean grain size, percent mud, percent calcium carbonate material, and percent coarser than 2 mm are given in this Appendix.

E-3.3 Proposed Borrow Areas

Offshore borings were used to delineate three potential borrow areas: A, B1, and B2 offshore of Pine Knoll Shores, Indian Beach, and Emerald Isle as described in the permit application (ID 200000362). As a result of additional sampling in January-March 2001, we have further refined the potential borrow areas as shown by shading on Figures 3.25 and 3.26 (main text) based on the following general criteria:

- R_A's should be as low as possible, approaching 1.0.
- Mud percent should be as low as possible and generally less than 5 percent.
- Calcium carbonate percentage should be at least 20 percent to match the native beach.
- Borrow sediments should be coarse-skewed, with a significant portion of granular-sized sediments to improve stability and match the coarse sediments in the lower beach face/step along Bogue Banks.

Based on this review, the preferred borrow sediment is a combination of sediments from portions of borrow areas A, B1, and B2 as shown by shading and as given by specific coordinates in Figures 3.25 and 3.26.

The revised borrow areas total 2,810 acres and are represented by 133 borings. Table 3.5 (main text) summarizes key sediment parameters (averages of individual sample results). The mean grain size in borrow area:

- A ranges from 0.51 mm to 0.54 mm (coarse sand).
- B1 averages 0.28 mm (medium sand).
- B2 averages 0.313 mm (medium sand).

Note that the native beach averages 0.30 mm. Percent mud in each borrow area averages 3.1 to 4.0 (state standard is 10 percent). The percentage of shell material (calcium carbonate) averages 27-45 percent. Approximately 7-20 percent of each deposit considered for use as borrow sediment consists of granular-shelly material with grain diameters of >2 mm.

Figures 3.27 to 3.29 (main text) show three typical cross-sections along borrow areas A, B1, and B2 – illustrating the sediments in the profile. Based on available borings, sediments are confirmed to approximately 10 ft in borrow areas B1 and B2 with more detailed confirmation in the upper 3-4 ft. Borrow area A is confirmed to ~5.5 ft with more detailed confirmation in the upper 2-2.5 ft. Based on these data and the project goal of limiting the depth of excavations to shallow cuts of the order 2-3 ft following best-management practices, **we have set a limit of ~3 ft for excavations in borrow areas B1 and B2 and ~2 ft for excavations in borrow area A**.

Applying the respective cut limits for each borrow area yields a total of ~8.7 million cubic yards. As noted in Table E.1, these estimates assume that at least 15 percent of revised borrow areas B1 and B2 will not be dredged and at least 33 percent of revised borrow areas A1 and A2 will not be dredged. The purpose of leaving some undredged corridors running through each borrow area is twofold:

1) Undredged corridors leave undisturbed areas in close proximity to each cut such that natural recruitment of biota is accelerated after construction (Jutte et al 1999a,b).

2) The anticipated type of dredging equipment (hopper dredges) reportedly works more efficiently if gaps are left between each cut (E. Elefson, Weeks Marine, August 1999, pers. comm.).

The effect of these undredged corridors will be to reduce the total acreage impacted in the offshore area. A further reduction in impacted area will result if a lesser fill quantity is needed for the project than requested in the permit. Following standard practice, we have identified and confirmed approximately 25 percent more borrow area sediment than required (Figs 3.25 to 3.29 and Table E.1). It is also prudent to have extra borrow-area sediment available for emergency nourishments after catastrophic storms. These factors are anticipated to reduce **the total acreage impacted directly by excavations to ~731 acres in borrow area A, 330 acres in borrow area B1, and 530 acres in borrow area B2 (total ~1,591 acres or ~2.5 square miles)**.

TABLE E.1. Summary R_A's and representative statistics for revised borrow areas A, B1, and B2, based on Phases I-III samples. See Figures Section 2 for revised borrow area delineations and coordinates.

Borrow Area	# Samples	Mean Grain Size (mm)	Mean Grain Size (ϕ)	% Mud	R_A's Revised
A1	22	0.509	0.974	3.2	**1.14**
A2	35	0.539	2.105	3.9	**1.15**
B1	36	0.276	1.729	3.1	**1.58**
B2	40	0.313	1.255	4.0	**1.50**
Native Beach	48	0.300	1.736	<1	**1**

Borrow Area	Area Acres	% Calcium Carbonate	% >2mm (granular)	Average Core Length (ft)	Confirmed Borrow Volume (cubic yards)
A1	653	45	17	2.3	*1.4 million
A2	807	45	20	2.2	*1.7 million
B1	520	27	7	3.2	**2.2 million
B2	830	30	8	2.9	**3.4 million
Native Beach		~15-20	~5		* @ 2 ft cut ** @ 3 ft cut

The confirmed borrow volumes represent the potential maximum volume of material that could be obtained from the indicated borrow areas. In keeping with best management practice, more source sediment must be confirmed so that some undisturbed areas can be left around each dredge cut to promote rapid recruitment of species after the project is complete. The above volumes assume 33 percent of the indicated Areas in A1 and A2 will not be dredged for purposes of wildlife recruitment, and 15 percent of the B1 and B2 will not be dredged for purposes of wildlife recruitment. Details of the Phase I excavation plan and anticipated Phase II plan are given in a later section.

E-3.4 Sediment Compatibility

Groups of samples for each potential borrow area were compared with the native beach. Using the method of James (1975), borrow composites were compared with native beach composites to yield an overfill (R_A) factor for each borrow area (see Table 3.4). The results, using beach composites of 48 samples, show that the majority of samples have R_A's under 2.0. R_A's for revised borrow area A were 1.15. Revised borrow areas B1 and B2 had slightly finer sands on average, yielding R_A's of 1.58 and 1.50 (respectively).

Upon further review of the sediment quality data and specific requirements of the project, we determined that the optimal borrow sediment will be a mixture of sands from borrow areas A and B1 or A and B2. Borrow areas B1 and B2 contain more fine sand and are slightly less stable for nourishment than borrow area A (ie, approximately 33 percent of the B1 and B2 deposits will serve as overfill). The finer sands in these areas will migrate to the outer bar after placement and will build up the underwater profile (a desired outcome). Sediments in borrow area A are slightly coarser than the native beach (lower end of the coarse sand range). These sediments will be more stable in the berm and beach face and will serve to improve the longevity of the dry beach.

As shown in Table E.1, approximately 65 percent of the borrow sediment is anticipated to be derived from revised borrow areas B1 and B2. The remaining 35 percent would be excavated from borrow area A. Using these approximate proportions, we have developed composite grain-size distributions for representative combinations of borrow areas A and B1 or A and B2 as detailed in previous correspondence to USACE (letter and attachments dated 19 June 2001 in response to 1 June 2001 comments from USFWS). Table E.2 and Figure 3.30 (main text) provide example results. Using 62 representative cores from borrow areas B1, B2, and A, we computed composite grain-size distributions for mixtures of borrow areas A and B2 and A and B2. This simulates the effect of mixing sediments during placement. The composite size distributions resulting from each mixture yield overfill ratios of 1.25 to 1.3 (Table E.2). Grain-size distribution curves for the composites are given in Figure 3.31(main text). Only 25-30 percent more borrow sand would be required in these cases to match the performance of the native beach. As NAS (1995) and experience suggest, borrow areas with R_A's under 1.5 are generally considered to be good matches with the native beach.

The selected borrow areas have several advantages:

1) They are in close proximity to the project site and will result in lower transportation costs and more rapid construction.
2) They contain a broad range of sediment sizes that fully encompass the natural variation that presently exists on the beach.
3) They have relatively low mud content (<4 percent on average).
4) They contain a sizable portion of granular material which will be more stable on the beach.

5) They are relatively free of large shell clasts. Most of the shell material consists of *Donax* sp., which is thinner walled and more friable than heavy shell such as *Crassostrea* sp.
6) They are situated in water depths of 30-50 ft, beyond the limit of normal sediment exchange with the beach.

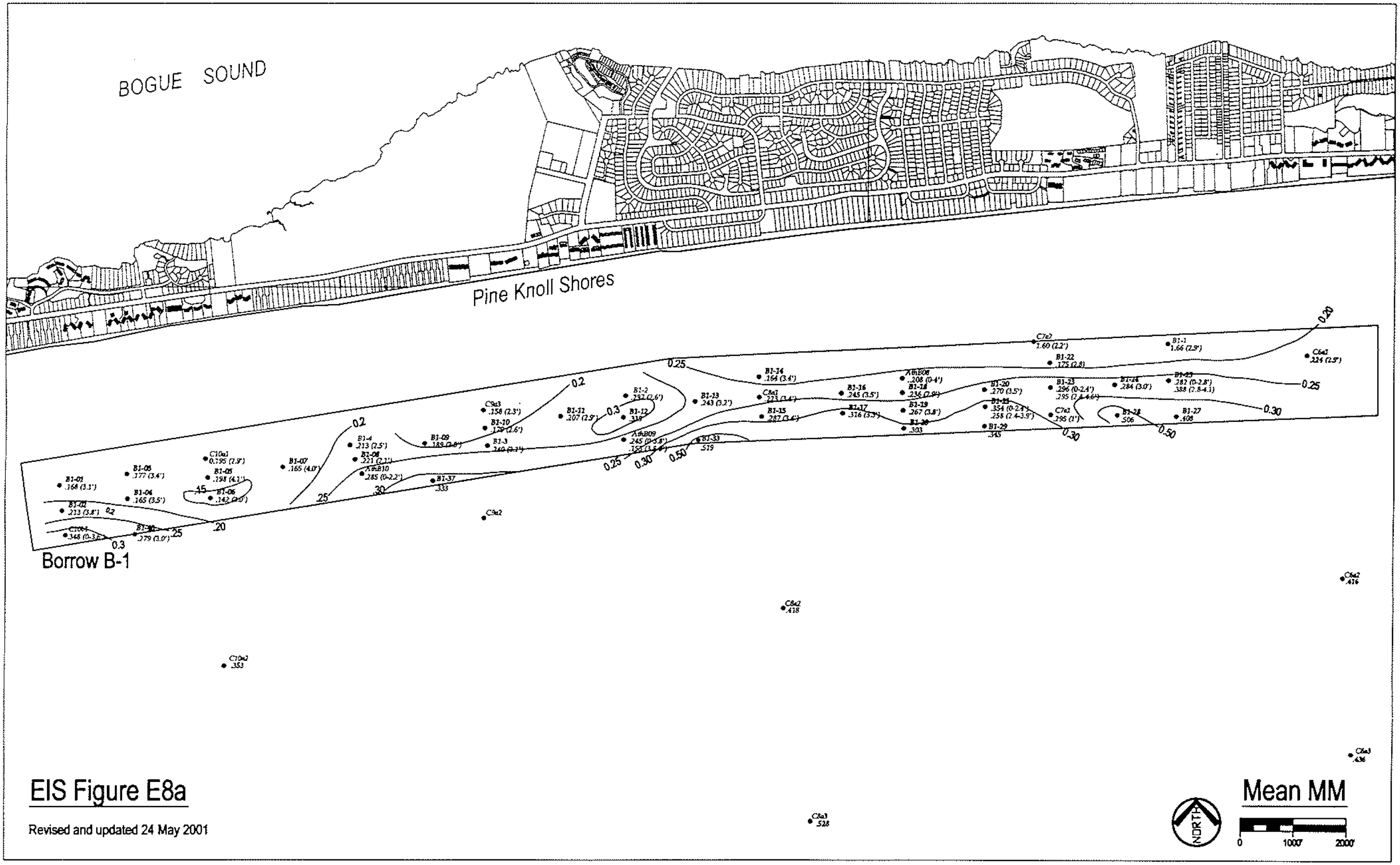
The result of the above-listed refinements of the proposed borrow areas for the proposed project is to yield a beach-compatible sediment. Final plans and specifications for contractors will direct hopper dredges (the anticipated equipment) to alternate between borrow areas A and B1, or A and B2 in proportion to the volumes prescribed for each area. Construction will be monitored closely by the applicants' engineer with frequent sand sampling for quality control.

TABLE E.2. Example composite overfill ratios for borrow areas B1 and A and borrow areas B2 and A, assuming mixture of sediment to yield a more compatible fill. (Example to simulate mixture of ~65 percent B1 and 35 percent of A or 65 percent of B2 and 35 percent of A.) See CSE response letter dated 19 June 2001 to USACE for more details. [*See Table 3.3 for definitions.]

Composite Groups	Number of Samples	Sediment Description*	Mean ϕ (mm)	Standard Deviation	R_A
A–11	11	MS,PS,SCS	1.363	1.416	**1.18**
B1–29	29	MS,PS,SCS	1.789	1.390	**1.34**
B2–22	22	MS,PS,SCS	1.664	1.441	**1.31**
A–B1	40	MS,PS,SCS	1.672	1.410	**1.30**
A–B2	33	MS,PS,SCS	1.564	1.439	**1.25**
Native Beach	48	MS,MWS,C-S	1.736	0.735	N/A

Cores used in composites for borrow areas A, B1, and B2

Borrow Area A	Borrow Area B1	Borrow Area B2
BA-02	C7A1	C11A2
BA-04	C8A1	C12A2
BA-06	C10A1	B2-08 S1
BA-11	C10B1	B2-09
A-11 s-1	B 1-02	B2-10
A-17	B 1-05	B2-13
A-23	B 1-12	B2-15
A-29	B 1-13	B2-17
A-35 s-1	B 1-15	B2-19
A-41	B 1-16	B2-21
A-47	B 1-17	B2-22
	B 1-18	B2-24
	B 1-19	B2-25
	B 1-20	B2-26
	B 1-21 S1	B2-27
	B 1-23 S1	B2-28
	B 1-24	B2-29
	B 1-25 S1	B2-30
	B 1-27	B2-31
	B 1-28	B2-32
	B 1-29	B-2-2
	B 1-30	B-2-4
	B 1-33	
	B 1-37	
	B 1-40	
	B-1-2	
	B-1-3	
	ATH-B-09	
	ATH-B10	

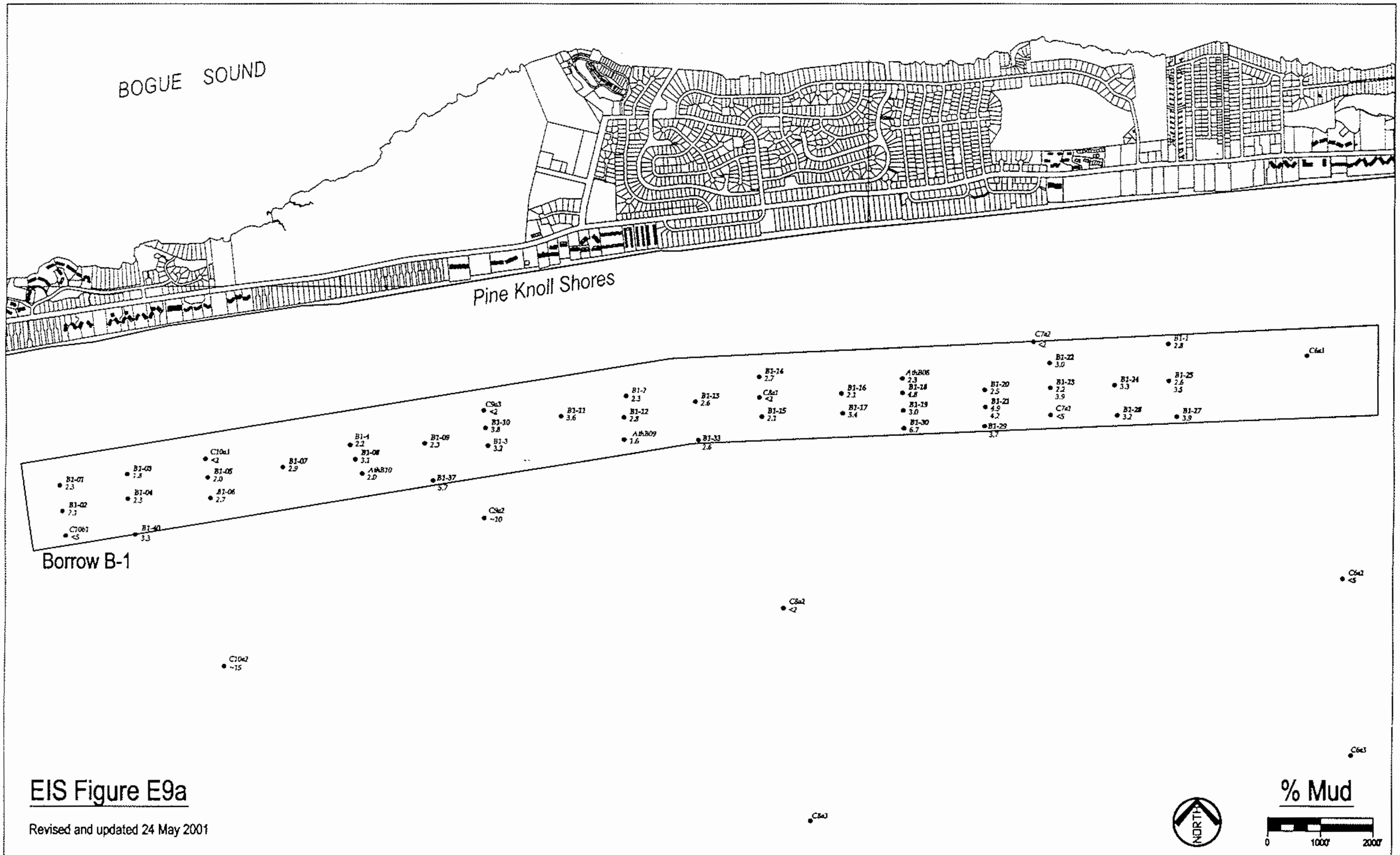


EIS Figure E8a

Revised and updated 24 May 2001

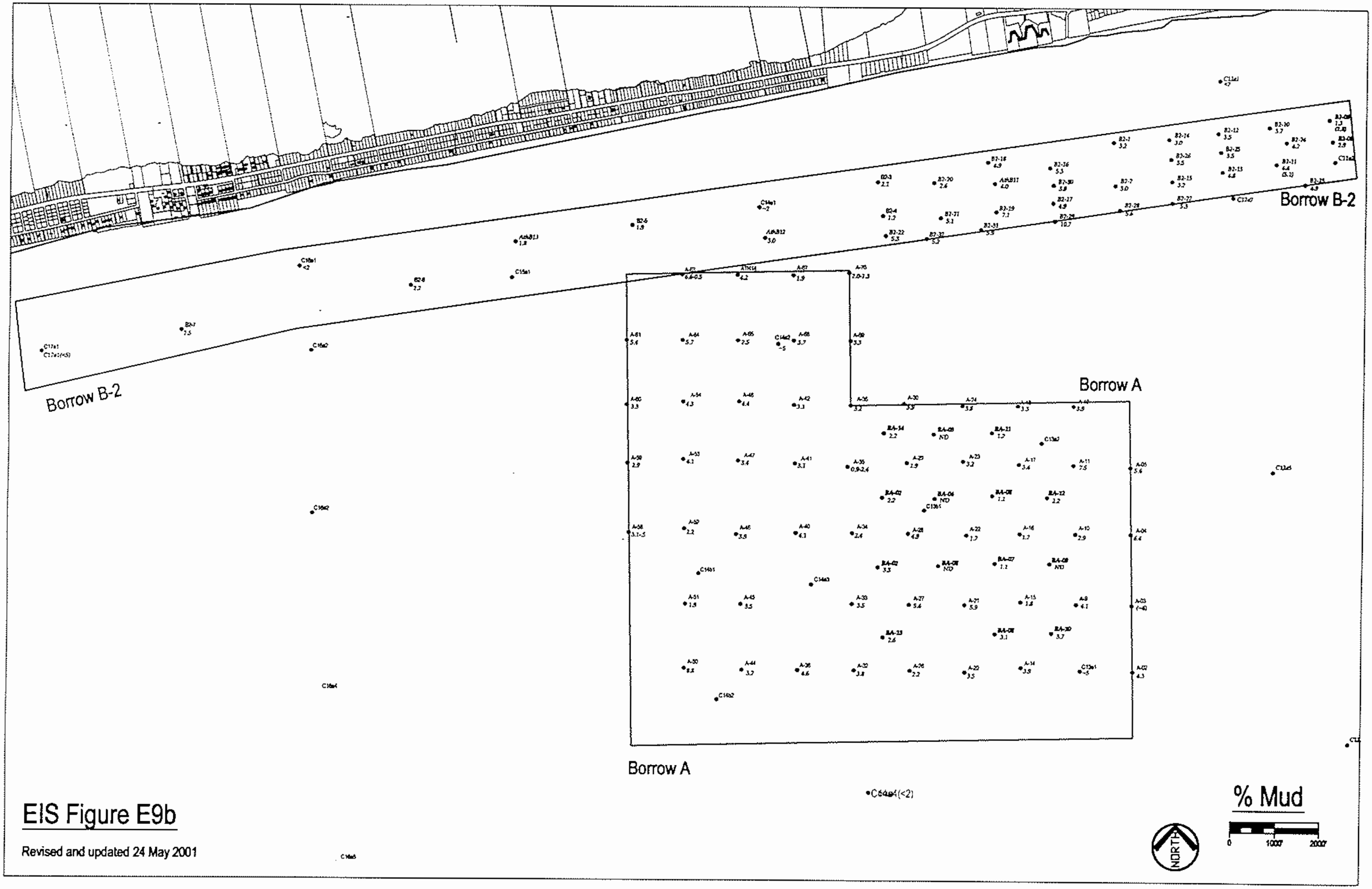
EIS Figure E8b

Revised and updated 24 May 2001



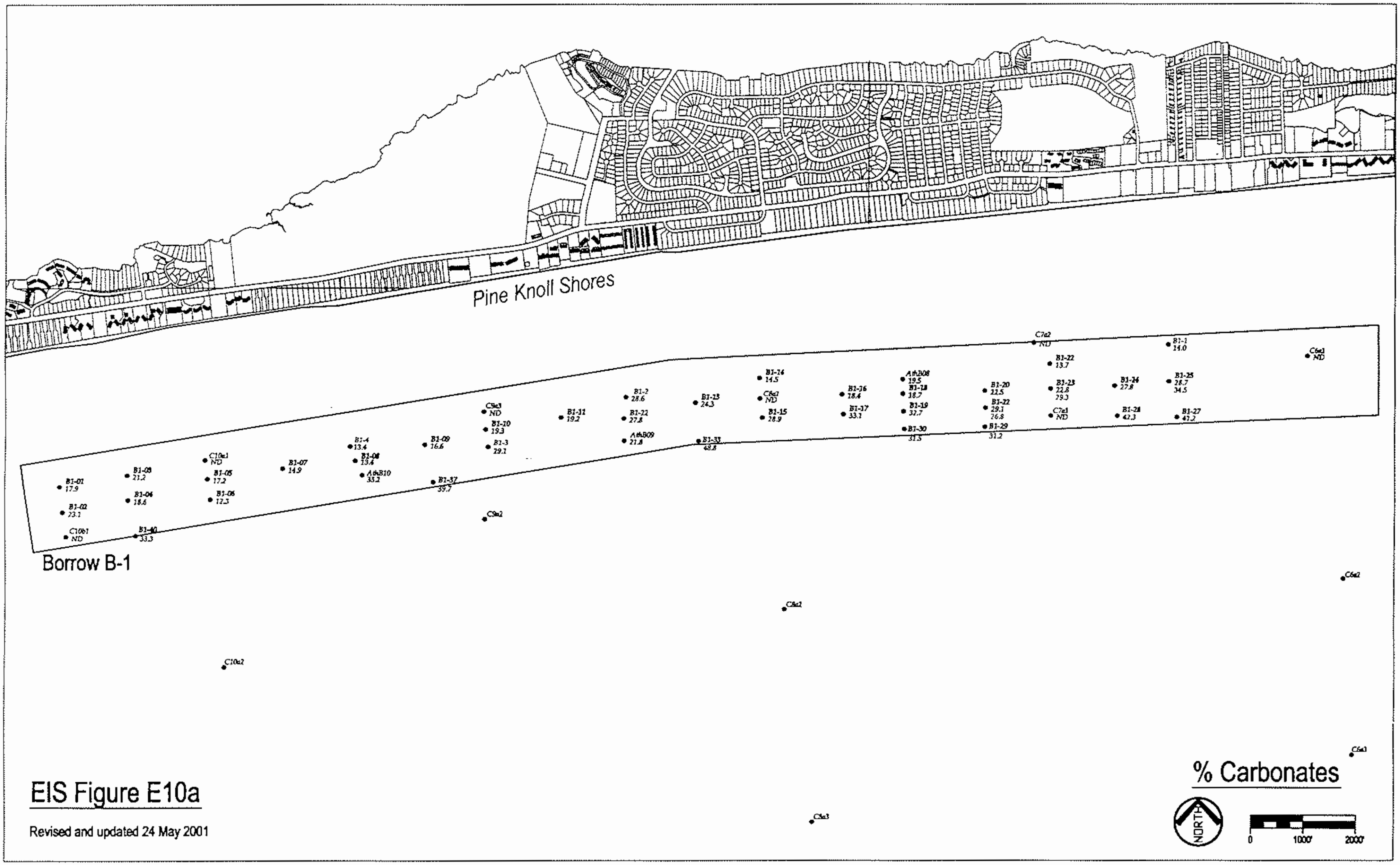
EIS Figure E9a

Revised and updated 24 May 2001



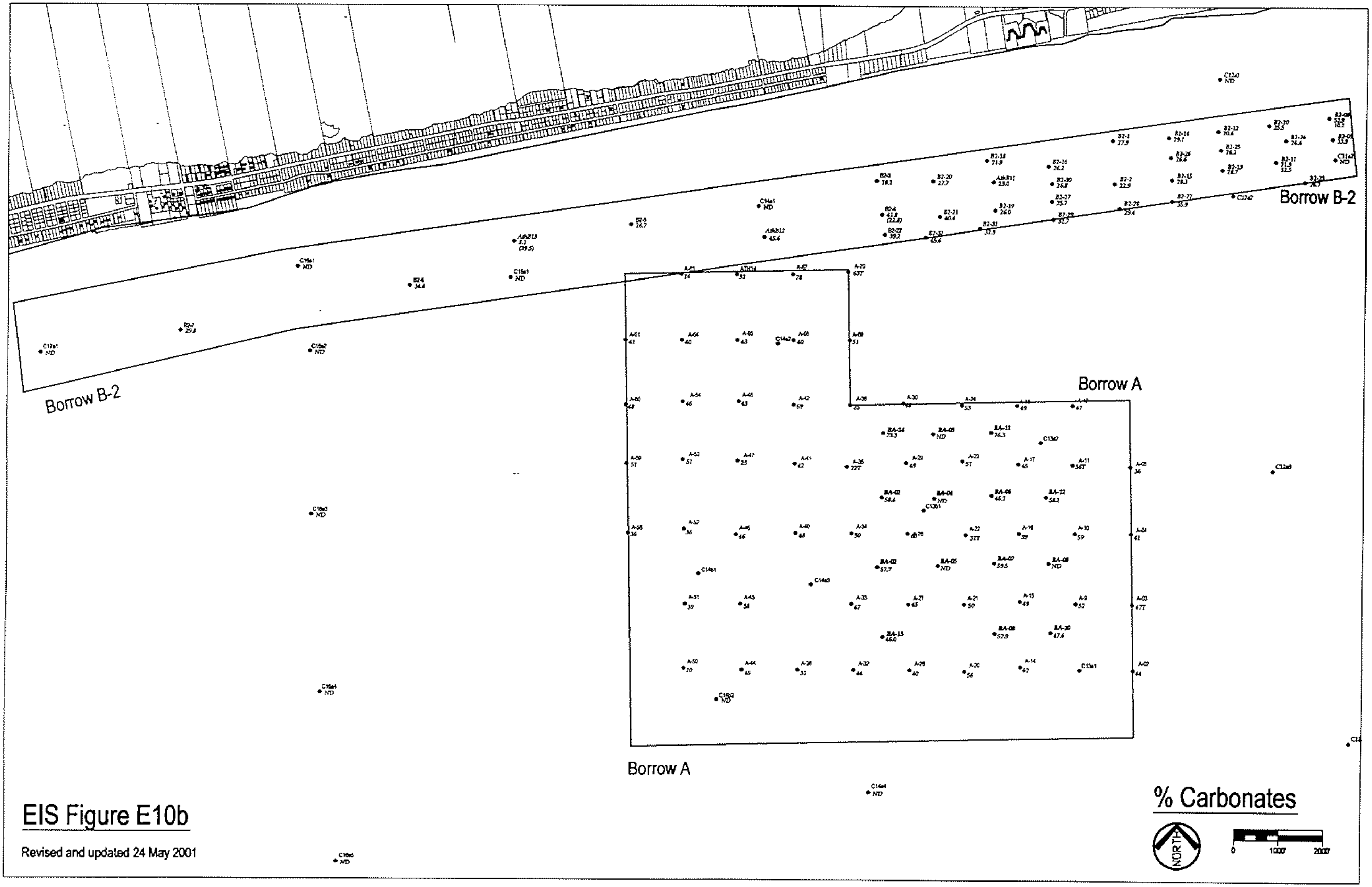
EIS Figure E9b

Revised and updated 24 May 2001



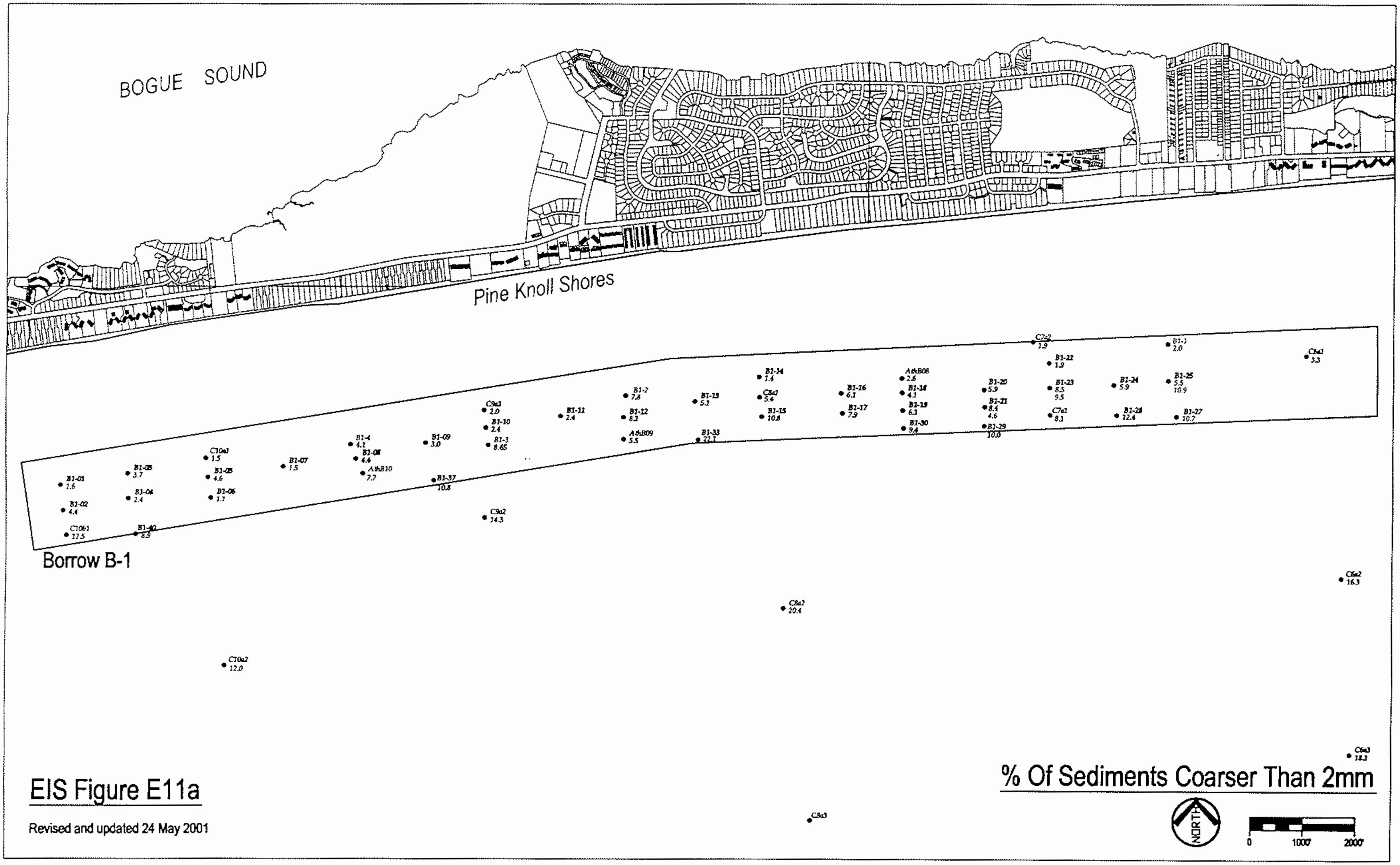
EIS Figure E10a

Revised and updated 24 May 2001



EIS Figure E10b

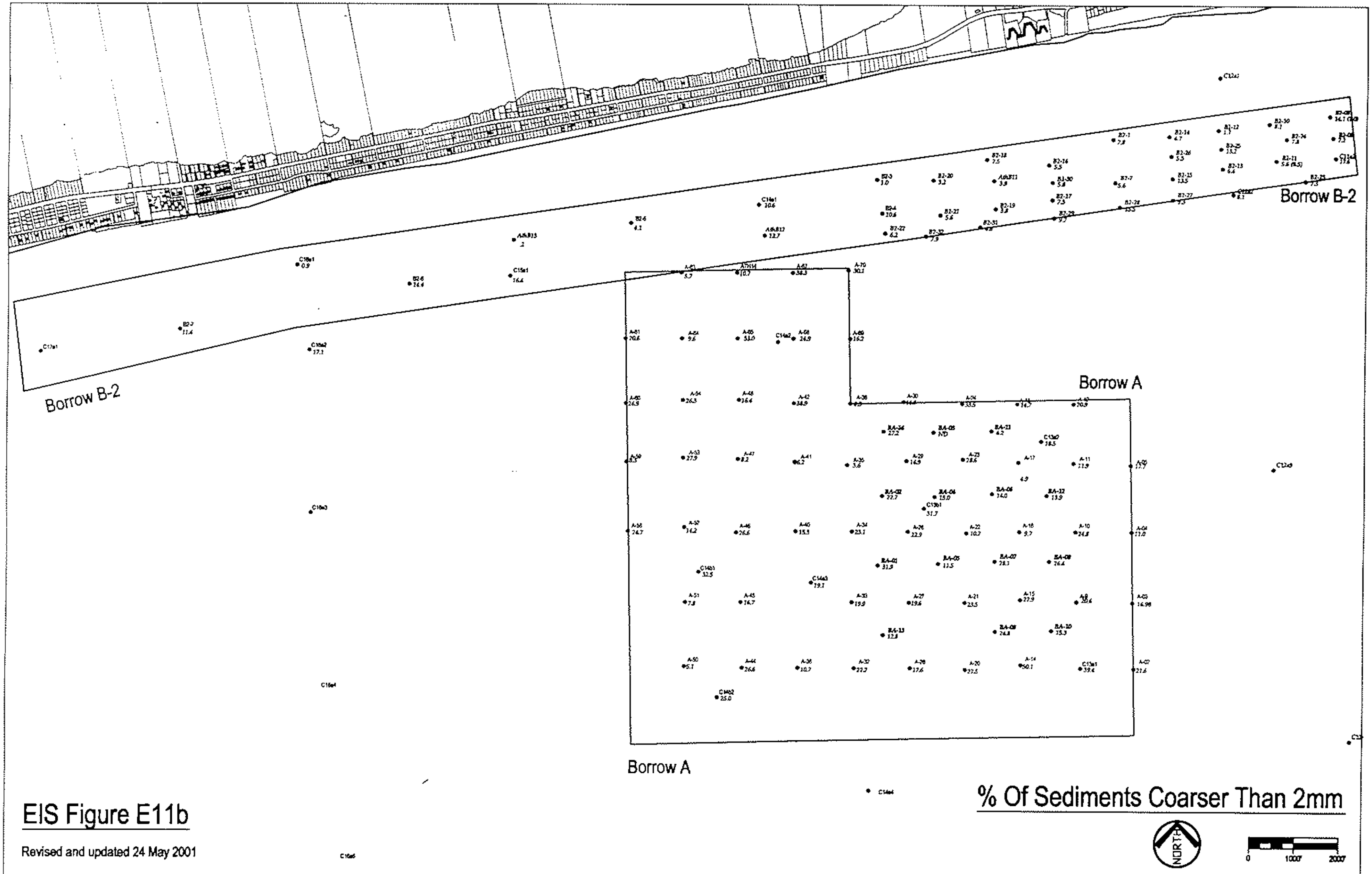
Revised and updated 24 May 2001



% Of Sediments Coarser Than 2mm

EIS Figure E11a

Revised and updated 24 May 2001



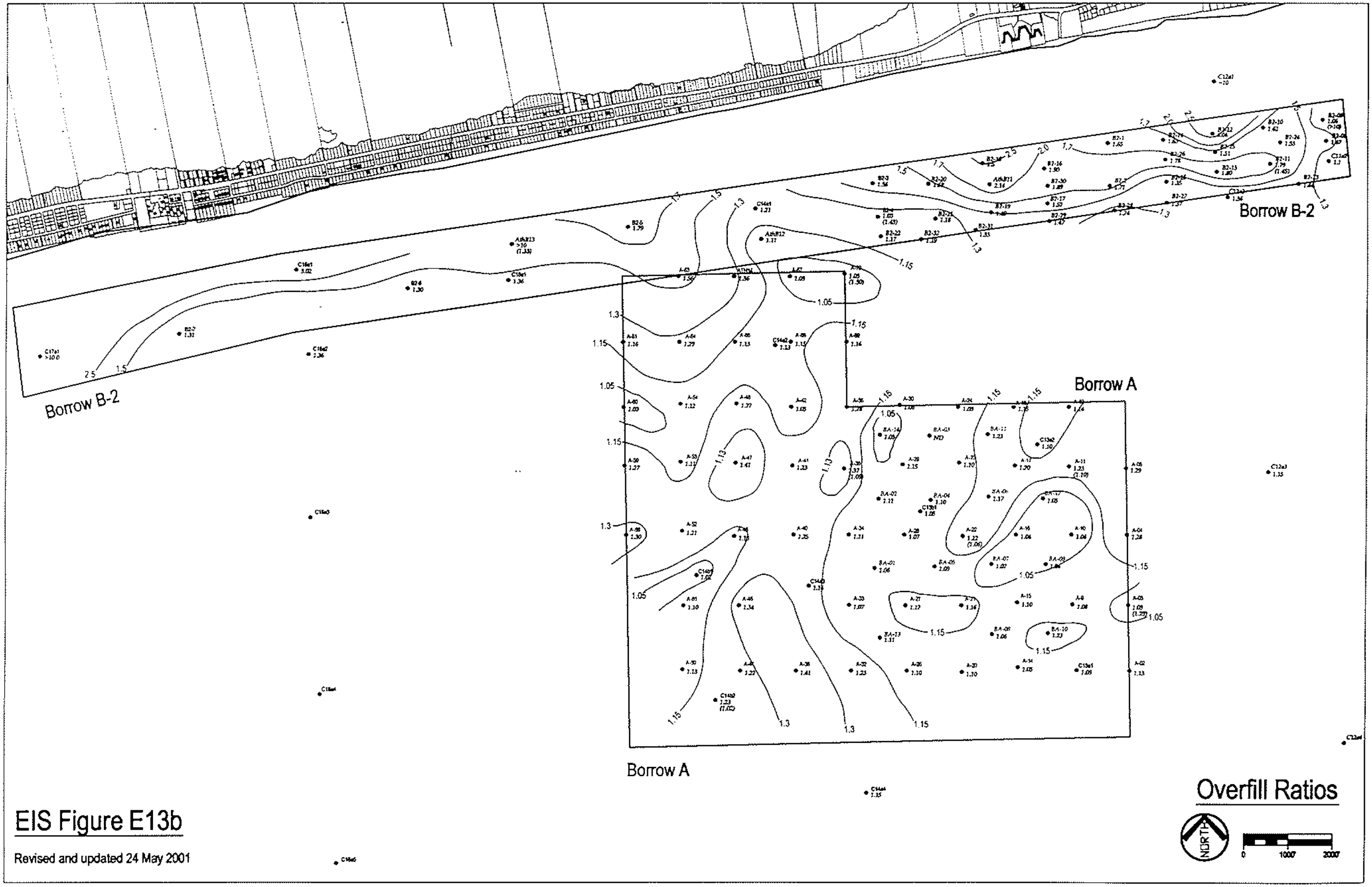
% Of Sediments Coarser Than 2mm

EIS Figure E11b

Revised and updated 24 May 2001

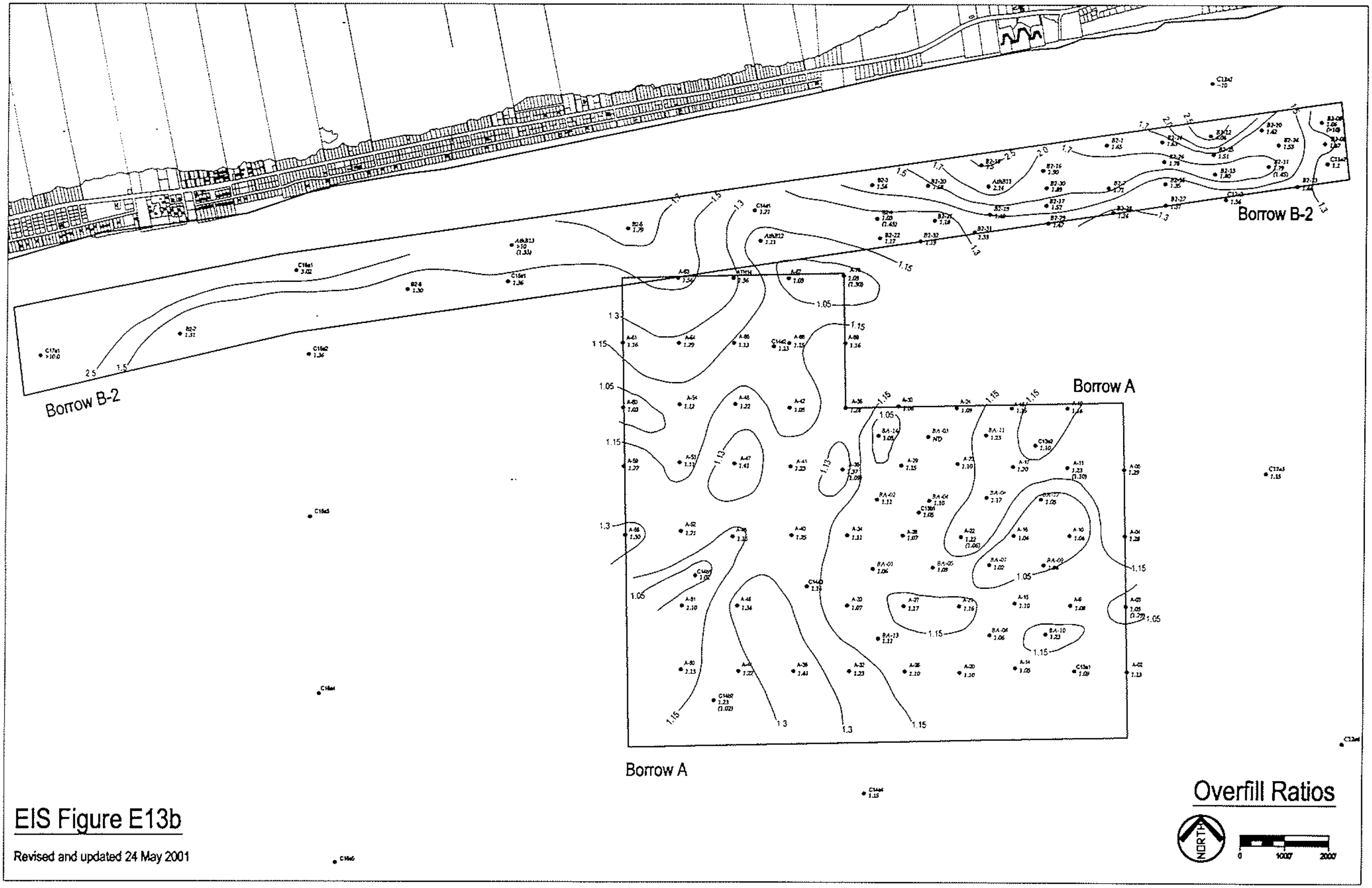
EIS Figure E13a

Revised and updated 24 May 2001



EIS Figure E13b

Revised and updated 24 May 2001



Overfill Ratios

EIS Figure E13b

Revised and updated 24 May 2001

ANNEX E-1

Bogue Banks — Offshore Sediment Characteristics — Nov 2000 - March 2001 Surveys

Locality *(Borrow Area)*	~Water Depth (Ft)	ID	Recovery Lgth (Ft)	Interval (Ft)	Grain Size Distributions Mean (mm)	*Std Dev. (mm)*	*Skewness*	*%Coarser Than 2 mm*	*% Mud*	*% CaCO3*	Sediment Description*
A	52	BA-01	0.9	0.9	0.799	0.371	0.279	31.9	3.3	57.7	CS,ps,sc-s
Supplementary	51	BA-02	2.9	2.9	0.556	0.345	-0.016	22.7	2.2	58.4	CS,ps,c-s
Nov-00	50	BA-04	1.8	1.8	0.459	0.385	-0.205	15.0	ND	ND	MS,ps,sc-s
Samples	51	BA-05	2.2	2.2	0.460	0.402	-0.164	11.5	ND	ND	MS,ps,c-s
	56	BA-06	2.0	2.0	0.427	0.360	-0.103	14.0	1.1	46.1	MS,ps,c-s
	51	BA-07	2.1	2.1	0.840	0.442	0.163	28.1	1.1	59.5	CS,ps,sym
	52	BA-08	1.7	1.7	0.709	0.377	0.208	24.8	3.1	52.9	CS,ps,f-s
	50	BA-09	2.2	2.2	0.714	0.365	0.216	26.4	ND	ND	CS,ps,f-s
	51	BA-10	1.7	1.7	0.409	0.345	-0.216	15.3	3.7	47.6	MS,ps,sc-s
	51	BA-11	2.1	2.1	0.291	0.450	-0.495	4.2	1.2	26.3	MS,ps,sc-s
	54	BA-12	1.6	1.6	0.575	0.415	0.041	13.9	2.2	58.2	CS,ps,sym
	48	BA-13	1.8	1.8	0.482	0.399	-0.157	12.8	2.6	46.0	CS,ps,c-s
	50	BA-14	1.9	1.9	0.824	0.408	0.262	27.2	2.2	73.3	CS,ps,f-s
B1	33	B1-01	3.1	3.1	0.168	0.518	-1.085	1.6	2.3	18.1	FS,ms,sc-s
Supplementary	40	B1-02	3.8	3.8	0.213	0.406	-0.619	4.4	2.1	23.4	FS,ps,sc-s
Nov-00	35	B1-03	3.4	3.4	0.177	0.461	-1.029	3.7	1.8	21.4	FS,ms,sc-s
Samples	41	B1-04	3.5	3.5	0.165	0.480	-1.000	2.4	2.3	18.8	FS,ms,sc-s
	39	B1-05	4.1	4.1	0.198	0.412	-0.750	4.6	2.0	17.3	FS,ps,sc-s
	45	B1-06	3	3	0.142	0.563	-1.288	1.1	2.7	12.5	FS,mws,c-s
	40	B1-07	4	4	0.165	0.531	-1.070	1.5	2.9	15.1	FS,ms,sc-s
	40	B1-08	2.1	2.1	0.221	0.489	-0.910	4.4	3.1	13.6	FS,ms,sc-s
	39	B1-09	3.8	3.8	0.189	0.474	-0.869	3.0	2.3	16.8	FS,ms,c-s
	39	B1-10	2.6	2.6	0.179	0.505	-1.030	2.4	3.8	19.7	FS,ms,sc-s
	38	B1-11	2.9	2.9	0.207	0.464	-0.716	2.4	3.6	19.6	FS,ps,sc-s
	38	B1-12	3.2	3.2	0.319	0.401	-0.442	8.2	2.8	28.2	MS,ps,sc-s
	37	B1-13	3.2	3.2	0.243	0.418	-0.620	5.1	2.6	24.7	FS,ps,sc-s
	34	B1-14	3.4	3.4	0.164	0.563	-1.131	1.4	2.7	14.7	FS,mws,c-s
	39	B1-15	3.4	3.4	0.287	0.351	-0.428	10.8	2.1	29.2	MS,ps,sc-s
	38	B1-16	3.5	3.5	0.245	0.412	-0.612	6.1	2.1	18.6	FS,ps,sc-s
	41	B1-17	3.3	3.3	0.316	0.390	-0.357	7.9	3.4	33.7	MS,ps,sc-s
	37	B1-18	2.9	2.9	0.236	0.463	-0.710	4.1	4.8	19.2	FS,ps,sc-s
	39	B1-19	3.8	3.8	0.267	0.400	-0.480	6.1	3.0	33.2	MS,ps,sc-s
	39	B1-20	3.5	3.5	0.270	0.412	-0.495	5.9	2.5	22.8	MS,ps,sc-s
	41	B1-21a	3.9	0-2.4	0.354	0.396	-0.258	8.4	4.9	29.9	MS,ps,c-s
		B1-21b		2.4-3.9	0.258	0.417	-0.477	4.6	4.2	27.4	MS,ps,sc-s
	35	B1-22	2.8	2.8	0.175	0.534	-1.058	1.9	3.0	13.9	FS,ms,c-s
	39	B1-23a	4.6	0-2.4	0.296	0.388	-0.439	8.5	2.2	23.1	MS,ps,sc-s
		B1-23b		2.4-4.6	0.295	0.373	-0.434	9.5	3.9	29.9	MS,ps,sc-s
	39	B1-24	3	3	0.284	0.437	-0.552	5.9	3.3	28.3	MS,ps,sc-s
	38	B1-25a	4.1	0-2.8	0.282	0.415	-0.462	5.5	2.6	29.1	MS,ps,sc-s

Annex E1 - Table E1-F. Supplement To Final EIS - Offshore Samples

	B1-25b		2.8-4.1	0.388	0.369	-0.202	10.9	3.5	35.1	FS,ps,sc-s
B1	B1-27	3.2	3.2	0.408	0.374	-0.183	10.7	3.9	41.2	MS,ps,c-s
Supplementary	B1-28	2.8	2.8	0.506	0.409	-0.046	12.4	3.2	42.3	CS,ps,sym
Mar-01	B1-29	3.1	3.1	0.345	0.375	-0.295	10.0	3.7	31.2	MS,ps,sc-s
Samples	B1-30	3.05	3.05	0.303	0.368	-0.386	9.4	6.7	31.5	MS,ps,sc-s
	B1-33	3.75	0-2.05	0.519	0.322	0.024	22.1	2.6	48.8	CS,ps,sym
	B1-37	2.9	0-2.0	0.330	0.342	-0.261	10.8	5.7	39.7	MS,ps,sc-s
	B1-40	3.2	3.2	0.279	0.365	-0.444	8.9	3.3	33.3	MS,ps,sc-s
B2	B2-08a	4.1	0-1.75	0.549	0.397	0.034	14.1	1.3	52.9	CS,ps,sym
Supplementary	B2-08b	-	1.75-4.05	0.141	0.596	-1.428	1.0	2.8	10.1	FS,mws,c-s
Jan-01	B2-09	3.0	3.0	0.259	0.373	-0.472	7.2	2.9	33.9	MS,ps,sc-s
Samples	B2-10	2.7	2.7	0.239	0.366	-0.543	8.1	3.7	25.5	FS,ps,sc-s
	B2-11a	4.9	0-3.0	0.209	0.406	-0.703	5.6	4.4	21.9	FS,ps,sc-s
	B2-11b	-	3.0-4.85	0.278	0.359	-0.408	9.5	5.2	32.5	MS,ps,sc-s
	B2-12	3.0	3.0	0.161	0.526	-1.116	1.7	3.5	20.6	FS,ms,sc-s
	B2-13	2.3	2.3	0.208	0.409	-0.737	6.4	4.8	28.7	FS,ps,sc-s
	B2-14	3.2	3.2	0.229	0.406	-0.561	4.7	3.0	29.1	FS,ps,sc-s
	B2-15	3.2	3.2	0.332	0.332	-0.276	13.5	3.2	28.3	MS,ps,sc-s
	B2-16	3.0	3.0	0.200	0.401	-0.718	5.5	5.3	26.2	FS,ps,sc-s
	B2-17	3.0	3.0	0.255	0.378	-0.473	7.3	4.9	25.7	MS,ps,sc-s
	B2-18	3.2	3.2	0.180	0.480	-0.885	2.5	4.9	21.9	FS,ms,sc-s
	B2-19	3.2	3.2	0.252	0.439	-0.478	3.8	7.1	26.0	FS,ps,sc-s
	B2-20	2.3	2.3	0.220	0.433	-0.528	3.2	2.6	27.7	FS,ps,sc-s
	B2-21	2.3	2.3	0.381	0.422	-0.151	5.7	5.1	40.4	MS,ps,c-s
	B2-22	2.3	2.3	0.410	0.413	-0.033	6.2	5.3	39.2	MS,ps,sym
B2										
Supplementary	B2-23	2.7	2.7	0.271	0.396	-0.520	7.3	4.9	26.7	MS,ps,sc-s
Mar-01	B2-24	3.3	3.3	0.251	0.375	-0.519	7.8	4.2	26.4	MS,ps,sc-s
Samples	B2-25	2.6	2.6	0.265	0.333	-0.467	13.2	3.5	26.2	MS,ps,sc-s
	B2-26	2.7	2.7	0.209	0.402	-0.641	5.3	3.5	26.6	FS,ps,sc-s
	B2-27	2.8	2.8	0.308	0.371	-0.357	9.3	5.3	35.9	MS,ps,sc-s
	B2-28	3.2	3.2	0.415	0.356	-0.190	15.5	5.6	29.4	MS,ps,sc-s
	B2-29	3.0	3.0	0.296	0.365	-0.387	9.7	10.7	31.7	MS,ps,sc-s
	B2-30	2.7	2.7	0.199	0.412	-0.747	5.8	3.8	26.8	FS,ps,sc-s
	B2-31	3.1	3.1	0.295	0.436	-0.402	4.6	5.9	32.9	MS,ps,sc-s
	B2-32	3.1	3.1	0.400	0.399	-0.113	7.9	5.2	45.6	MS,ps,c-s

**CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution

Table E3. Beach Sediment Characteristics and Composites - Revised May 2001

Bogue Banks | **Beach Sediment Characteristics** | **Updated 22 May 2001**

Profile # - Locality	Sample	ID	Grain Size Distributions Mean (mm)	Std Dev. (mm)	Skewness	Sediment Description*	%CaCo3	Notes
June 1999 Samples								
10 - Emerald Isle	Berm	BB10B	**0.365**	0.630	-0.299	MS,mws,sym		
10	MBF	BB10C	**0.290**	0.622	-0.496	MS,mws,sc-s		
10	LTT	BB10D	**0.380**	0.525	-0.482	MS,ms,sc-s		
30 - Emerald Isle	Dune	BB30A	**0.246**	0.740	-0.034	FS,ws,sym		
30	Berm	BB30B	**0.384**	0.619	-0.149	MS,mws,sym		
30	MBF	BB30C	**0.312**	0.714	-0.495	MS,ws,sym		
30	LTT	BB30D	**0.270**	0.709	-0.646	MS,ws,sym		
50 - Indian Beach	Berm	BB50B	**0.418**	0.544	-0.439	MS,ms,sc-s		
50	MBF	BB50C	**0.302**	0.760	-0.455	MS,ws,sym		
50	LTT	BB50D	**0.215**	0.693	-0.683	FS,ws,c-s		
70 - Pine Knoll Shores	Berm	BB70B	**0.338**	0.566	-0.733	MS,ms,sc-s		
70	UBF	BB70C	**0.475**	0.517	-0.288	MS,ms,c-s		
70	LTT	BB70D	**0.288**	0.669	-0.744	MS,mws,c-s		
90 - Atlantic Beach	Dune	BB90A	**0.234**	0.750	0.074	FS,ws,sym		Nourished Section
90	Berm	BB90B	**0.228**	0.708	-0.830	FS,ws,c-s		Nourished Section
90	UBF	BB90C	**0.244**	0.630	-0.614	FS,mws,c-s		Nourished Section
90	LTT	BB90D	**0.243**	0.636	-0.569	FS,mws,c-s		Nourished Section
110 - Coast Guard Station	Dune1***	BB110A	**0.801**	0.432	-0.090	CS,ps,sym		Spoil Area
110	Berm	BB110B	**0.541**	0.514	-0.169	CS,ms,c-s		Spoil Area
110	MBF	BB110B	**0.457**	0.472	-0.347	MS,ps,c-s		Spoil Area
110	LTT	BB110B	**0.200**	0.599	-1.247	FS,mws,c-s		Spoil Area
Composites -1999	Dune***	(2)	**0.240**	0.745	0.390	FS,ws,sym	ND	
Composites	Berm	(6)	**0.368**	0.552	-0.460	MS,ms,c-s	16.1	Based on Physical
Composites	Beach Face	(6)	**0.357**	0.574	-0.634	MS,ms,c-s	11.8	Composites
Composites	LTT	(6)	**0.265**	0.602	-0.717	MS,mws,c-s	17.0	
Comp - 1999 - Omit 1 Dune	All***	(20)	**0.302**	0.585	-0.648	MS,mws,c-s	ND	
****Note: BB110A Omitted from Composites*								
Supplementary Samples	May-01							
Sta 48-50	Dune	B4850a	**0.262**	0.742	-0.213	MS,ws,c-s	3.2	Sta 48 Scraped Dune
Sta 48-50	Berm	B4850b	**0.266**	0.758	-0.078	MS,ws,sym	3.2	
Sta 48-50	Beach Face	B4850c	**0.278**	0.770	0.089	MS,ws,f-s	4.4	
Sta 48-50	LTT	B4850d	**0.460**	0.557	-0.397	MS,ms,c-s	15.2	
Sta 52-54	Dune	B5254a	**0.250**	0.732	-0.426	FS,ws,c-s	2.2	Sta 52 Scraped Dune
Sta 52-54	Berm	B5254b	**0.224**	0.766	0.276	FS,ws,sym	2.2	
Sta 52-54	Beach Face	B5254c	**0.314**	0.675	-0.425	MS,mws,sym	6.1	
Sta 52-54	LTT	B5254d	**0.329**	0.619	-0.563	MS,mws,c-s	7.2	
Sta 56-58	Dune**	B5658a	**0.321**	0.636	-0.719	MS,mws,sym	9.3	Sta 56 & 58 Scraped
Sta 56-58	Berm	B5658b	**0.227**	0.717	0.280	FS,ws,f-s	2.6	
Sta 56-58	Beach Face	B5658c	**0.348**	0.756	0.230	MS,ws,f-s	11.9	
Sta 56-58	LTT	B5658d	**0.374**	0.575	-0.495	MS,ms,c-s	17.1	
Sta 60-62	Dune**	B6062a	**0.500**	0.559	-0.410	MS,ms,sc-s	27.9	Sta 60 & 62 Scraped
Sta 60-62	Berm	B6062b	**0.274**	0.770	-0.066	MS,ws,sym	4.1	
Sta 60-62	Beach Face	B6062c	**0.347**	0.610	-0.563	MS,mws,c-s	11.0	

Table E3. Beach Sediment Characteristics and Composites - Revised May 2001

Sta 60-62	LTT	B6062d	**0.346**	0.585	-0.610	MS,mws,c-s	13.7	
Sta 64-66	Dune**	B6466a	**0.310**	0.735	-0.216	MS,ws,sym	12.9	Sta 64 Scraped Dune
Sta 64-66	Berm	B6466b	**0.231**	0.727	0.243	FS,ws,sym	4.4	
Sta 64-66	Beach Face	B6466c	**0.293**	0.779	0.166	MS,ws,f-s	5.4	
Sta 64-66	LTT	B6466d	**0.382**	0.527	-0.545	MS,ms,sc-s	43.0	
Sta 68-70	Dune	B6870a	**0.245**	0.711	0.112	FS,ws,sym	2.8	Sta 68 Scraped Dune
Sta 68-70	Berm	B6870b	**0.222**	0.774	0.129	FS,ws,sym	2.2	
Sta 68-70	Beach Face	B6870c	**0.422**	0.541	-0.521	MS,ms,sc-s	31.5	
Sta 68-70	LTT	B6870d	**0.348**	0.606	-0.622	MS,mws,c-s	13.1	
Sta 72-74	Dune**	B7274a	**0.279**	0.649	-0.896	MS,mws,c-s	6.2	Sta 72 & 74 Scraped
Sta 72-74	Berm	B7274b	**0.258**	0.747	-0.320	MS,ws,c-s	3.2	
Sta 72-74	Beach Face	B7274c	**0.326**	0.537	-0.834	MS,ms,sc-s	8.8	
Sta 72-74	LTT	B7274d	**0.268**	0.617	-0.842	MS,mws,sc-s	8.1	
Sta 76-78	Dune	B7678a	**0.233**	0.726	-0.418	FS,ws,c-s	2.9	
Sta 76-78	Berm	B7678b	**0.236**	0.787	-0.112	FS,vws,c-s	2.1	
Sta 76-78	Beach Face	B7678c	**0.492**	0.522	-0.375	MS,ms,sc-s	40.3	
Sta 76-78	LTT	B7678d	**0.293**	0.597	-0.596	MS,mws,c-s	11.7	
							Ranges %CaCO3	
Composites -2001	Dune	(8)	**0.291**	0.636	-0.694	MS,mws,c-s	2.2 - 27.9	
Composites	Dune**	(4)	**0.247**	0.725	-0.204	FS,ws,c-s	2.2 - 2.8	
Composites	Berm	(8)	**0.242**	0.746	0.060	FS,ws,sym	2.1 - 4.1	
Composites	Beach Face	(8)	**0.347**	0.603	-0.734	MS,mws,c-s	4.4 - 40.3	
Composites	LTT	(8)	**0.346**	0.571	-0.560	MS,ms,c-s	7.2 - 43.0	
Comp - 2001 - All	Comp 32	(32)	**0.303**	0.614	-0.704	MS,mws,c-s	2.1 - 43.0	
Comp - 2001 - Omit 4 Dune	Comp 28**	(28)	**0.298**	0.617	-0.714	MS,mws,c-s	2.1 - 43.0	

***Note: B5658a, B6062a, B6466a, & B7274a Omitted from Composite*

**CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution
MBF-mid beachface; UBF-upper beach face; LTT-Low Tide Terrace

Note: Scraped Dunes At Stations 30, 50, & 70 Not Representative
Spoil At Station 110 Dune Contains non-natural coarse material

Summary

1) As Reported In SEPA Final EIS dated 4 April 2001

Native Composite (20 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)
Mean=1.725 phi (Mn) ***Std dev=0.773 phi (SDn)*** ***Skewness=-0.648***
Mean=0.302 mm ***Std dev=.585 mm*** ***Skewness=-0.648***

Native Composite (12 Samples @ Berm, Beach Face)
Mean=1.466 phi (Mn) *Std dev=0.* *Skewness=-0.542*
Mean=0.362 mm *Std dev=.5* *Skewness=-0.542*

2) Based On May 2001 Supplementary Beach Sampling For Beach Transects 48 - 78

Native Composite (28 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)
Mean=1.747 phi (Mn) ***Std dev=0.696 phi (SDn)*** ***Skewness=-0.714***
Mean=0.298 mm ***Std dev=.617 mm*** ***Skewness=-0.714***

3) Average of June 1999 and May 2001 Results

Native Composite (48 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)
Mean=1.736 phi (Mn) ***Std dev=0.735 phi (SDn)*** ***Skewness=-0.681***
Mean=0.300 mm ***Std dev=.601 mm*** ***Skewness=-0.681***

Table E5. Potential Borrow Area Sediment Quality and Compatibility Factors (RA). Revised May 2001

Bogue Banks **Sediment Compatibility** Prepared January 2000 **Revised May 2001**

Revised 5/01 Note: **Individual Samples vs Overall Beach Composites (incl Dune & LTT samples)**
Native Composite (48 Samples @ Dune Face, Berm, Beach Face, Low tide terrace)
Mean=1.736 phi (Mn) *Std dev=0.735 phi (SDn)* *Skewness=-0.681* MS,mws,c-s
Mean=0.300 mm *Std dev=.601 mm* *Skewness=-0.681*

Beach Samples Jun-99 Transect - Locality	Sample ID	**Type**	**Recovery** Length(ft)	**Interval** (feet)	**Sediment Description****	**% Mud** to indicated samp interval	**Moment Measures** Mean phi	Std Dev phi	Skewness	
10 - Emerald Isle	BB10B	Berm	n/a	n/a	MS,mws,sym	0	1.455	0.667	-0.299	
10	BB10C	MBF	n/a	n/a	MS,mws,sc-s	0	1.785	0.684	-0.496	
10	BB10D	LTT	n/a	n/a	MS,ms,sc-s	0	1.395	0.930	-0.452	
30 - Emerald Isle	BB30A	Dune	n/a	n/a	FS,ws,sym	0	2.023	0.435	-0.034	
30	BB30B	Berm	n/a	n/a	MS,mws,sym	0	1.379	0.693	-0.149	
30	BB30C	MBF	n/a	n/a	MS,ws,sym	0	1.680	0.486	-0.495	
30	BB30D	LTT	n/a	n/a	MS,ws,sym	0	1.887	0.497	-0.646	
50 - Indian Beach	BB50B	Berm	n/a	n/a	MS,ms,sc-s	0	1.258	0.878	-0.439	
50	BB50C	MBF	n/a	n/a	MS,ws,sym	0	1.727	0.395	-0.455	
50	BB50D	LTT	n/a	n/a	FS,ws,c-s	0	2.128	0.529	-0.683	
70 - Pine Knoll Shores	BB70B	Berm	n/a	n/a	MS,ms,sc-s	0	1.564	0.821	-0.496	
70	BB70C	UBF	n/a	n/a	MS,ms,c-s	0	1.073	0.953	-0.288	
70	BB70D	LTT	n/a	n/a	MS,mws,c-s	0	1.794	0.581	-0.744	
90 - Atlantic Beach	BB90A	Dune	n/a	n/a	FS,ws,sym	0	2.094	0.415	0.074	Nourished Section
90	BB90B	Berm	n/a	n/a	FS,ws,c-s	0	2.131	0.499	-0.830	Nourished Section
90	BB90C	UBF	n/a	n/a	FS,mws,c-s	0	2.036	0.666	-0.614	Nourished Section
90	BB90D	LTT	n/a	n/a	FS,mws,c-s	0	2.041	0.654	-0.569	Nourished Section
110 - Coast Guard Station	BB110A	Dune	n/a	n/a	CS,ps,sym	0	0.321	1.212	0.090	Spoil Area
110	BB110B	Berm	n/a	n/a	CS,ms,c-s	0	0.855	0.961	-0.169	Spoil Area
110	BB110B	MBF	n/a	n/a	MS,ps,c-s	0	1.130	1.083	-0.347	Spoil Area
110	BB110B	LTT	n/a	n/a	FS,mws,c-s	0	2.320	0.739	-1.247	Spoil Area
Supplementary Beach Samples	May-01									
IB Sta 48-50	B4850a	Dune	n/a	n/a	MS,ws,c-s	0	1.934	0.431	-0.213	
Sta 48-50	B4850b	Berm	n/a	n/a	MS,ws,sym	0	1.910	0.400	-0.078	
Sta 48-50	B4850c	Beach Face	n/a	n/a	MS,ws,f-s	0	1.848	0.377	0.089	
Sta 48-50	B4850d	LTT	n/a	n/a	MS,ms,c-s	0	1.119	0.844	-0.397	
IB Sta 52-54	B5254a	Dune	n/a	n/a	FS,ws,c-s	0	2.002	0.450	-0.426	
Sta 52-54	B5254b	Berm	n/a	n/a	FS,ws,sym	0	2.156	0.384	0.276	
Sta 52-54	B5254c	Beach Face	n/a	n/a	MS,mws,sym	0	1.671	0.566	-0.425	
Sta 52-54	B5254d	LTT	n/a	n/a	MS,mws,c-s	0	1.604	0.691	-0.563	
IB Sta 56-58	B5658a	Dune	n/a	n/a	MS,mws,sym	0	1.639	0.654	-0.719	
Sta 56-58	B5658b	Berm	n/a	n/a	FS,ws,f-s	0	2.138	0.480	0.280	
Sta 56-58	B5658c	Beach Face	n/a	n/a	MS,ws,f-s	0	1.523	0.404	0.230	
Sta 56-58	B5658d	LTT	n/a	n/a	MS,ms,c-s	0	1.419	0.798	-0.495	
PKS Sta 60-62	B6062a	Dune	n/a	n/a	MS,ms,sc-s	0	1.001	0.838	-0.410	
Sta 60-62	B6062b	Berm	n/a	n/a	MS,ws,sym	0	1.867	0.378	-0.066	
Sta 60-62	B6062c	Beach Face	n/a	n/a	MS,mws,c-s	0	1.528	0.714	-0.563	

Table E5 (con't)

Table E5. Potential Borrow Area Sediment Quality and Compatibility Factors (RA). Revised May 2001

Sta 60-62	B6062d	LTT	n/a	n/a	MS,mws,c-s	0	1.532	0.774	-0.610
PKS Sta 64-66	B6466a	Dune	n/a	n/a	MS,ws,sym	0	1.691	0.445	-0.216
Sta 64-66	B6466b	Berm	n/a	n/a	FS,ws,sym	0	2.112	0.460	0.243
Sta 64-66	B6466c	Beach Face	n/a	n/a	MS,ws,f-s	0	1.771	0.361	0.166
Sta 64-66	B6466d	LTT	n/a	n/a	MS,ms,sc-s	0	1.389	0.923	-0.545
PKS Sta 68-70	B6870a	Dune	n/a	n/a	FS,ws,sym	0	2.029	0.493	0.112
Sta 68-70	B6870b	Berm	n/a	n/a	FS,ws,sym	0	2.173	0.369	0.129
Sta 68-70	B6870c	Beach Face	n/a	n/a	MS,ms,sc-s	:0	1.243	0.885	-0.521
Sta 68-70	B6870d	LTT	n/a	n/a	MS,mws,c-s	0	1.522	0.720	-0.622
PKS Sta 72-74	B7274a	Dune	n/a	n/a	MS,mws,c-s	0	1.844	0.623	-0.896
Sta 72-74	B7274b	Berm	n/a	n/a	MS,ws,c-s	0	1.952	0.421	-0.320
Sta 72-74	B7274c	Beach Face	n/a	n/a	MS,ms,sc-s	0	1.615	0.898	-0.834
Sta 72-74	B7274d	LTT	n/a	n/a	MS,mws,sc-s	0	1.898	0.696	-0.842
AB Sta 76-78	B7678a	Dune	n/a	n/a	FS,ws,c-s	0	2.099	0.461	-0.418
Sta 76-78	B7678b	Berm	n/a	n/a	FS,vws,c-s	0	2.081	0.345	-0.112
Sta 76-78	B7678c	Beach Face	n/a	n/a	MS,ms,sc-s	0	1.024	0.937	-0.375
Sta 76-78	B7678d	LTT	n/a	n/a	MS,mws,c-s	0	1.772	0.745	-0.596

Revised Overfill Ratios Based On Additional Beach Sampling - May 2001

Borrow Area	Sample ID	Type	Recovery Length(ft)	Interval (feet)	Sediment Description**	% Mud to indicated samp interval	Moment Measures M-phi-b	Moment Measures Sigma-b	X (Mb-Mn)/SDn	Y (SDb/SDn)	Revised RA May-01	SEPA EIS Overfill RA (SPM '84)
A	10A-4	Core	2.5	0-2.5	MS,ps,sc-s	~5	1.717	1.125	-0.03	1.53	**1.21**	1.20
Preliminary	11A-1	Core	3.0	0-3.0	CS,ps,sym	<5	0.761	1.662	-1.33	2.26	**1.11**	1.10
	* 12A-3	Core	2.5	0-2.5	CS,ps,sym	<2	0.871	1.707	-1.18	2.32	**1.14**	1.14
Jun-99	13A-2	Core	2.7	0-2.7	CS,ps,sym	~2	0.819	1.501	-1.25	2.04	**1.08**	1.08
Samples	13A-1	Core	2.7	0-2.7	CS,ps,sf-s	~5	0.337	1.554	-1.90	2.11	**1.04**	1.04
	13B-1	Core	1.9	0-1.9	CS,ps,f-s	~2	0.394	1.396	-1.83	1.90	**1.03**	1.02
	14A-2	Core	2.0	0-2.0	CS,ps,sym	~5	0.819	1.501	-1.25	2.04	**1.08**	1.08
	14A-3	Core	2.3	0-2.3	CS,ps,c-s	<5	0.979	1.518	-1.03	2.07	**1.12**	1.11
	14A-4	Core	1.6	0-1.6	CS,ps,c-s	<2	0.945	1.627	-1.08	2.21	**1.14**	1.13
	14B-1	Core	1.9	0-1.9	CS,ps,sf-s	<2	0.244	1.338	-2.03	1.82	**<1.02**	<1.02
	14B-2a	Core	2.4	0-1.8	MS,ps,sc-s	<5	1.161	1.645	-0.78	2.24	**1.19**	1.18
	14B-2b	Core		1.8-2.4	VCS,vws,c-s	<5	-0.927	0.166	-3.62	0.23	**<<1.02**	<<1.02
										Avg	*1.114*	*1.108*
A	A-02	Core	2.8	2.8	CS,ps,sym	4.3	0.824	1.497	-1.24	2.04	**1.09**	1.09
Supplementary	A-03s1	Core	2.7	0-.1.0	CS,ps,c-s	<1	0.852	1.235	-1.20	1.68	**1.03**	1.03
Nov-99	A-03s2	Core		1.0-2.7	CS,ps,f-s	21.5	0.814	1.465	-1.25	1.99	**1.08**	1.08
Samples	A-04	Core	3.6	3.6	MS,ps,sc-s	6.4	1.506	1.416	-0.31	1.93	**1.22**	1.21
	A-05	Core	2.7	2.7	MS,ps,sc-s	5.6	1.392	1.554	-0.47	2.11	**1.23**	1.22
	A-09	Core	2.8	2.8	CS,ps,sym	4.1	0.641	1.390	-1.49	1.89	**1.04**	1.04
	A-10	Core	2.3	2.3	CS,ps,f-s	2.9	0.297	1.224	-1.96	1.67	**<1.02**	<1.02
	A-11s-1	Core	7.1	0-3.3	MS,ps,sc-s	7.5	1.312	1.407	-0.58	1.91	**1.16**	1.15
	A-11s-2	Core		3.3-7.1	CS,ps,sym	3.0	0.660	1.543	-1.46	2.10	**1.07**	1.07
	A-12	Core	2.6	2.6	CS,ps,c-s	3.9	0.911	1.506	-1.12	2.05	**1.10**	1.10
	A-14	Core	1.7	1.7	CS,ps,sf-s	3.9	-0.172	1.233	-2.60	1.68	**<1.02**	<1.02
	A-15	Core	1.2	1.2	CS,ps,sym	1.8	0.813	1.480	-1.26	2.01	**1.08**	1.08
	A-16	Core	1.8	1.8	CS,ps,c-s	1.7	0.892	1.128	-1.15	1.53	**1.02**	1.02

Tat (con't)

Table [illegible]. Potential Borrow Area Sediment Quality and Compatibility Factors (RA). Revised May 2001

	A-17	Core	2.0	2.0	MS,ps,sc-s	3.4	1.584	1.201	-0.21	1.63	**1.17**	1.16
	A-18	Core	2.4	2.4	MS,ps,c-s	3.3	1.103	1.439	-0.86	1.96	**1.12**	1.12
*										*Avg*	*1.108*	*1.105*
	A-20	Core	8.8	0-4.8	CS,ps,f-s	3.5	0.608	1.504	-1.53	2.05	**1.06**	1.05
	A-21	Core	1.6	1.6	CS,ps,c-s	5.9	0.871	1.527	-1.18	2.08	**1.10**	1.09
*	A-22s-1	Core	5.8	0-3.0	MS,ps,sc-s	1.7	1.488	1.337	-0.34	1.82	**1.20**	1.18
	A-22s-2	Core		3.0-4.8	CS,ps,sf-s	2.9	0.291	1.489	-1.97	2.03	**1.03**	1.03
	A-23	Core	1.5	1.5	CS,ps,sym	3.2	0.705	1.539	-1.40	2.09	**1.07**	1.07
	A-24	Core	1.4	1.4	CS,ps,sf-s	3.8	0.454	1.551	-1.74	2.11	**1.05**	1.04
	A-26	Core	2.0	2.0	CS,ps,c-s	2.2	0.961	1.380	-1.05	1.88	**1.08**	1.08
	A-27	Core	1.6	1.6	CS,ps,c-s	5.4	1.022	1.497	-0.97	2.04	**1.12**	1.11
	A-28	Core	1.8	1.8	CS,ps,f-s	4.9	0.457	1.308	-1.74	1.78	**1.02**	1.02
	A-29	Core	1.8	1.8	MS,ps,sc-s	2.0	1.212	1.410	-0.71	1.92	**1.13**	1.13
	A-30	Core	1.6	1.6	CS,ps,sf-s	3.9	0.103	1.441	-2.22	1.96	**1.02**	1.02
	A-32	Core	2.0	2.0	MS,ps,sc-s	3.8	1.194	1.615	-0.74	2.20	**1.19**	1.18
	A-33	Core	3.2	3.2	CS,ps,sym	3.4	0.655	1.330	-1.47	1.81	**1.04**	1.04
	A-34	Core	2.5	2.5	CS,ps,c-s	2.4	0.887	1.501	-1.16	2.04	**1.09**	1.09
	A-35s-1	Core	5.6	0-2.4	FS,ms,sc-s	0.9	1.964	0.999	0.31	1.36	**1.36**	1.35
	A-35s-2	Core		2.4-5.6	CS,ps,f-s	3.6	0.512	1.508	-1.67	2.05	**1.05**	1.04
	A-36	Core	2.4	2.4	MS,ps,sc-s	3.2	1.701	1.244	-0.05	1.69	**1.25**	1.30
	A-38	Core	1.6	1.6	MS,ps,sc-s	4.6	1.813	1.377	0.10	1.87	**1.36**	1.34
										Avg	*1.123*	*1.120*
	A-40	Core	1.8	1.8	MS,ps,sc-s	4.1	1.361	1.519	-0.51	2.07	**1.21**	1.20
	A-41	Core	2.1	2.1	MS,ps,sc-s	3.0	1.349	1.484	-0.53	2.02	**1.20**	1.19
	A-42	Core	1.9	1.9	CS,ps,sf-s	3.3	0.086	1.329	-2.24	1.81	**<1.02**	<1.02
	A-44	Core	2.2	2.2	MS,ps,sc-s	3.2	1.070	1.682	-0.91	2.29	**1.19**	1.17
	A-45	Core	1.5	1.5	MS,ps,sc-s	3.5	1.515	1.569	-0.30	2.13	**1.31**	1.27
	A-46	Core	5.7	5.7	CS,ps,sym	3.9	0.819	1.603	-1.25	2.18	**1.11**	1.10
	A-47	Core	1.5	1.5	MS,ps,sc-s	3.4	1.889	1.283	0.21	1.75	**1.38**	1.35
*	A-48	Core	2.6	2.6	MS,ps,sc-s	4.4	1.228	1.547	-0.69	2.10	**1.18**	1.17
*	A-50	Core	4.4	0-3.0	FS,ms,sc-s	8.8	2.413	1.160	0.92	1.58	**1.04**	1.03
	A-51	Core	1.8	0-1.3	CS,ps,c-s	1.9	0.746	1.499	-1.35	2.04	**1.08**	1.07
	A-52	Core	2.1	2.1	MS,ps,sc-s	2.2	1.355	1.461	-0.52	1.99	**1.19**	1.18
	A-53	Core	2.7	2.7	CS,ps,f-s	4.1	0.614	1.545	-1.53	2.10	**1.07**	1.06
*	A-54	Core	2.8	2.8	CS,ps,f-s	4.3	0.662	1.560	-1.46	2.12	**1.08**	1.07
	A-58	Core	4.1	0.0-.5;2-4.1	CS,ps,sym	~23	0.701	1.491	-1.41	2.03	**1.07**	1.06
	A-59	Core	2.0	2.0	MS,ps,sc-s	3.0	1.437	1.552	-0.41	2.11	**1.24**	1.23
										Avg	*1.168*	*1.154*
*	A-60	Core	1.8	1.8	CS,ps,sym	3.3	0.330	1.201	-1.91	1.63	**<<1.02**	<<1.02
*	A-61	Core	3.0	0-2.5	CS,ps,c-s	5.4	0.937	1.515	-1.09	2.06	**1.11**	1.10
	A-63	Core	3.5	0-.5	FS,ps,sc-s	6.6	2.020	1.269	0.39	1.73	**1.49**	1.47
	A-64	Core	1.8	1.8	MS,ps,sc-s	5.7	1.462	1.393	-0.37	1.90	**1.23**	1.20
	A-65	Core	1.9	1.9	CS,ps,f-s	2.5	0.706	1.649	-1.40	2.24	**1.10**	1.09
	A-66	Core	3.3	3.3	MS,ps,sc-s	4.2	1.707	1.509	-0.04	2.05	**1.34**	1.33
	A-67	Core	1.7	1.7	CS,ps,sf-s	1.9	0.078	1.315	-2.26	1.79	**<<1.02**	<<1.02
	A-68	Core	2.1	2.1	CS,ps,sym	3.7	0.845	1.581	-1.21	2.15	**1.11**	1.10
	A-69	Core	2.0	2.0	MS,ps,sc-s	3.3	1.182	1.428	-0.75	1.94	**1.13**	1.13
	A-70T	Core	2.8	0-1.25	VCS,ps,f-s	2.0	0.000	1.056	-2.36	1.44	**<<1.02**	<<1.02
	A-70B	Core		2.05-2.8	CS,ps,f-s	~30	0.481	1.367	-1.71	1.86	**1.03**	1.02
										Avg	*1.193*	*1.180*

Table E5. Potential Borrow Area Sediment Quality and Compatibility Factors (RA). Revised May 2001

A	BA-01	Core	0.9	0.9	CS,ps,sc-s	3.3	0.323	1.432	-1.92	1.95	**1.03**	1.02
Supplementary	BA-02	Core	2.9	2.9	CS,ps,c-s	2.2	0.847	1.535	-1.21	2.09	**1.09**	1.08
Nov-00	BA-04	Core	1.8	1.8	MS,ps,sc-s	ND	1.124	1.377	-0.83	1.87	**1.10**	1.10
Samples	BA-05	Core	2.2	2.2	MS,ps,c-s	ND	1.121	1.316	-0.84	1.79	**1.09**	1.08
	BA-06	Core	2.0	2.0	MS,ps,c-s	1.1	1.228	1.473	-0.69	2.00	**1.16**	1.15
	BA-07	Core	2.1	2.1	CS,ps,sym	1.1	0.252	1.179	-2.02	1.60	**<<1.02**	<<1.02
	BA-08	Core	1.7	1.7	CS,ps,f-s	3.1	0.496	1.406	-1.69	1.91	**1.03**	1.03
	BA-09	Core	2.2	2.2	CS,ps,f-s	ND	0.487	1.456	-1.70	1.98	**1.04**	1.04
	BA-10	Core	1.7	1.7	MS,ps,sc-s	3.7	1.291	1.535	-0.61	2.09	**1.19**	1.18
	BA-11	Core	2.1	2.1	MS,ps,sc-s	1.2	1.781	1.153	0.06	1.57	**1.22**	1.19
	BA-12	Core	1.6	1.6	CS,ps,sym	2.2	0.799	1.269	-1.27	1.73	**1.03**	1.03
	BA-13	Core	1.8	1.8	CS,ps,c-s	2.6	1.053	1.327	-0.93	1.81	**1.08**	1.08
	BA-14	Core	1.9	1.9	CS,ps,f-s	2.2	0.279	1.292	-1.98	1.76	**<1.02**	<1.02
										Avg	*1.096*	*1.089*
B1	6A-1	Core	2.9	0-2.9	FS,ps,sc-s	<2	2.157	1.077	0.57	1.47	**1.60**	1.62
Preliminary	7A-2	Core	2.8	0-2.8	FS,mws,c-s	<2	2.648	0.829	1.24	1.13	**6.00**	7.00
Jun-99	7A-1	Core	1.0	0-1.0	MS,ps,sc-s	<5	1.761	1.442	0.03	1.96	**1.35**	1.34
Samples	8A-1	Core	3.4	0-3.4	FS,ps,sc-s	<2	2.165	1.209	0.58	1.64	**1.61**	1.60
	9A-3	Core	2.3	0-2.3	FS,mws,c-s	<2	2.660	.830	1.26	1.13	**6.00**	6.50
*	10A-1	Core	2.9	0-2.9	FS,ms,sc-s	<2	2.355	1.018	0.84	1.39	**2.10**	2.20
	10B-1	Core	4.7	0-3.6	MS,ps,sc-s	<5	1.522	1.537	-0.29	2.09	**1.27**	1.26
										Avg	*2.847*	*3.074*
B1	B-1-1	Core	2.9	2.9	FS,mws,c-s	2.8	2.594	0.894	1.17	1.22	**4.00**	4.50
Supplementary	B-1-2	Core	2.6	2.6	MS,ps,sc-s	2.3	1.753	1.326	0.02	1.80	**1.31**	1.30
Nov-99	B-1-3	Core	3.1	3.1	FS,ps,sc-s	3.2	2.058	1.349	0.44	1.84	**1.54**	1.50
*	B-1-4	Core	2.5	2.5	FS,ps,sc-s	2.2	2.233	1.144	0.68	1.56	**1.73**	1.75
	ATHB08	Core	11.2	0-4.0	FS,ps,sc-s	2.2	2.262	1.066	0.72	1.45	**1.85**	1.80
	ATH-9s1	Core	9.0	0-3.8	FS,ps,sc-s	1.6	2.03	1.284	0.40	1.75	**1.49**	1.48
	ATH-9s2	Core	2.9	3.8-9	FS,mws,c-s	0.9	2.711	0.734	1.33	1.00	**>10.0**	>10
	ATHB10	Core	7.5	0-2.2	MS,ps,sc-s	2.0	1.813	1.402	0.10	1.91	**1.36**	1.34
B1										*Avg*	*1.897*	*1.953*
Supplementary	B1-01	Core	3.1	3.1	FS,ms,sc-s	2.3	2.574	0.949	1.14	1.29	**3.00**	3.50
Nov-00	B1-02	Core	3.8	3.8	FS,ps,sc-s	2.1	2.231	1.301	0.67	1.77	**1.72**	1.70
Samples	B1-03	Core	3.4	3.4	FS,ms,sc-s	1.8	2.498	1.116	1.04	1.52	**2.35**	2.40
	B1-04	Core	3.5	3.5	FS,ms,sc-s	2.3	2.596	1.058	1.17	1.44	**2.90**	3.40
	B1-05	Core	4.1	4.1	FS,ps,sc-s	2.0	2.334	1.280	0.81	1.74	**1.85**	1.83
	B1-06	Core	3	3	FS,mws,c-s	2.7	2.821	0.829	1.48	1.13	**9.60**	9.90
	B1-07	Core	4	4	FS,ms,sc-s	2.9	2.601	0.914	1.18	1.24	**3.30**	4.50
	B1-08	Core	2.1	2.1	FS,ms,sc-s	3.1	2.178	1.031	0.60	1.40	**1.69**	1.71
	B1-09	Core	3.8	3.8	FS,ms,c-s	2.3	2.406	1.077	0.91	1.47	**2.18**	2.20
	B1-10	Core	2.6	2.6	FS,ms,sc-s	3.8	2.486	0.985	1.02	1.34	**2.70**	2.85
	B1-11	Core	2.9	2.9	FS,ps,sc-s	3.6	2.275	1.109	0.73	1.51	**1.82**	1.80
	B1-12	Core	3.2	3.2	MS,ps,sc-s	2.8	1.648	1.320	-0.12	1.80	**1.25**	1.24
	B1-13	Core	3.2	3.2	FS,ps,sc-s	2.6	2.039	1.258	0.41	1.71	**1.50**	1.48
	B1-14	Core	3.4	3.4	FS,mws,c-s	2.7	2.604	0.829	1.18	1.13	**5.00**	6.50
	B1-15	Core	3.4	3.4	MS,ps,sc-s	2.1	1.801	1.512	0.09	2.06	**1.40**	1.38
	B1-16	Core	3.5	3.5	FS,ps,sc-s	2.1	2.028	1.279	0.40	1.74	**1.43**	1.46
	B1-17	Core	3.3	3.3	MS,ps,sc-s	3.4	1.663	1.357	-0.10	1.85	**1.27**	1.26
	B1-18	Core	2.9	2.9	FS,ps,sc-s	4.8	2.084	1.112	0.47	1.51	**1.51**	1.50
	B1-19	Core	3.8	3.8	MS,ps,sc-s	3.0	1.904	1.322	0.23	1.80	**1.40**	1.40

Ta ; (con't)

Table E5. Potential Borrow Area Sediment Quality and Compatibility Factors (RA). Revised May 2001

		B1-20	Core	3.5	3.5	MS,ps,sc-s	2.5	1.899	1.281	0.22	1.74	**1.38**	1.39
		B1-21a	Core	3.9	0-2.4	MS,ps,c-s	4.9	1.497	1.338	-0.33	1.82	**1.20**	1.19
		B1-21b	Core		2.4-3.9	MS,ps,sc-s	4.2	1.953	1.263	0.30	1.72	**1.41**	1.39
		B1-22	Core	2.8	2.8	FS,ms,c-s	3.0	2.517	0.905	1.06	1.23	**3.30**	3.50
		B1-23a	Core	4.6	0-2.4	MS,ps,sc-s	2.2	1.756	1.366	0.03	1.86	**1.33**	1.31
		B1-23b	Core		2.4-4.6	MS,ps,sc-s	3.9	1.760	1.422	0.03	1.93	**1.35**	1.32
		B1-24	Core	3	3	MS,ps,sc-s	3.3	1.816	1.194	0.11	1.62	**1.30**	1.28
		B1-25a	Core	4.1	0-2.8	MS,ps,sc-s	2.6	1.825	1.268	0.12	1.73	**1.33**	1.31
		B1-25b	Core		2.8-4.1	FS,ps,sc-s	3.5	1.366	1.438	-0.50	1.96	**1.19**	1.18
											Avg	*2.204*	*2.353*
B1		B1-27	Core	3.2	3.2	MS,ps,c-s	3.9	1.294	1.417	-0.60	1.93	**1.16**	1.15
Supplementary		B1-28	Core	2.8	2.8	CS,ps,sym	3.2	0.982	1.291	-1.03	1.76	**1.06**	1.05
Mar-01		B1-29	Core	3.1	3.1	MS,ps,sc-s	3.7	1.534	1.414	-0.27	1.92	**1.24**	1.22
Samples		B1-30	Core	3.05	3.05	MS,ps,sc-s	6.7	1.724	1.443	-0.02	1.96	**1.33**	1.32
		B1-33	Core	3.75	0-2.05	CS,ps,sym	2.6	0.945	1.637	-1.08	2.23	**1.14**	1.13
		B1-37	Core	2.9	0-2.0	MS,ps,sc-s	5.7	1.599	1.546	-0.19	2.10	**1.31**	1.30
		B1-40	Core	3.2	3.2	MS,ps,sc-s	3.3	1.841	1.453	0.14	1.98	**1.40**	1.38
B2											*Avg*	*1.234*	*1.221*
Preliminary		11A-2	Core	1.6	0-1.6	CS,ps,c-s	~10	0.498	1.098	-1.68	1.49	**<<1.02**	<<1.02
Jun-99		12A-1	Core	3.1	0-3.1	FS,mws,c-s	<2	2.523	.662	1.07	0.90	**10.00**	10.00
Samples		12A-2	Core	1.8	0-1.8	MS-ps,sc-s	~10	1.577	1.438	-0.22	1.96	**1.26**	1.25
		14A-1	Core	2.4	0-2.4	MS,ps,c-s	~2	1.367	1.438	-0.50	1.96	**1.19**	1.18
		15A-1	Core	2.0	0-2.0	MS,ps,sc-s	~10	1.422	1.626	-0.43	2.21	**1.26**	1.25
		16A-1	Core	1.9	0-1.9	FS,mws,sc-s	<2	2.378	.833	0.87	1.13	**3.00**	3.70
		17A-1	Core	1.0	0-1.0	FS,ws,sym	<5	2.807	.523	1.46	0.71	**>>10**	>>10
B2											*Avg*	*3.342*	*3.476*
Supplementary		B-2-1	Core	3.7	3.7	FS,ps,sc-s	8.7	2.099	1.347	0.49	1.83	**1.56**	1.15
Nov-99		B-2-2	Core	4.0	4.0	FS,ps,sc-s	3.0	2.216	1.312	0.65	1.79	**1.68**	1.11
Samples		B-2-3	Core	1.9	0-1.9	FS,ps,sc-s	2.1	2.101	1.068	0.50	1.45	**1.54**	1.05
		B-2-4s1	Core	2.2	0-0.9	CS,ps,c-s	1.2	.661	.992	-1.46	1.35	**<<1.02**	<<1.02
		B-2-4s2	Core		.9-2.2	MS,ps,sc-s	3.4	1.866	1.416	0.18	1.93	**1.40**	1.38
		B-2-5	Core	1.8	1.8	FS,ps,sc-s	1.9	2.264	1.214	0.72	1.65	**1.77**	1.75
		B-2-6	Core	3.1	3.1	MS,ps,sc-s	2.2	1.532	1.552	-0.28	2.11	**1.28**	1.27
	*	B-2-7	Core	2.3	2.3	MS,ps,sc-s	2.5	1.598	1.470	-0.19	2.00	**1.28**	1.27
	*	ATHB11	Core	10.0	0-6.8	FS,ps,sc-s	4.1	2.423	1.168	0.93	1.59	**2.10**	2.05
	*	ATHB12	Core	10.2	0-1.7	CS,ps,c-s	3.0	1.047	1.322	-0.94	1.80	**1.08**	1.07
	*	ATH13s1	Core	9.6	0-2.0	FS,ws,sym	1.8	2.727	.539	1.35	0.73	**>10**	>10
		ATH13s2	Core		2.0-5.6	MS,ps,sc-s	2.5	1.618	1.504	-0.16	2.05	**1.31**	1.28
B2											*Avg*	*1.500*	*1.338*
Supplementary		B2-08a	Core	4.1	0-1.75	CS,ps,sym	1.3	.865	1.330	-1.19	1.81	**1.05**	1.05
Jan-01		B2-08b	Core	-	1.75-4.05	FS,mws,c-s	2.8	2.822	.746	1.48	1.01	**>10**	>10.0
Samples		B2-09	Core	3.0	3.0	MS,ps,sc-s	2.9	1.947	1.423	0.29	1.94	**1.44**	1.43
		B2-10	Core	2.7	2.7	FS,ps,sc-s	3.7	2.062	1.450	0.44	1.97	**1.58**	1.55
		B2-11a	Core	4.9	0-3.0	FS,ps,sc-s	4.4	2.258	1.301	0.71	1.77	**1.75**	1.75
		B2-11b	Core	-	3.0-4.85	MS,ps,sc-s	5.2	1.846	1.478	0.15	2.01	**1.40**	1.40
		B2-12	Core	3.0	3.0	FS,ms,sc-s	3.5	2.633	.928	1.22	1.26	**4.00**	4.50
		B2-13	Core	2.3	2.3	FS,ps,sc-s	4.8	2.265	1.289	0.72	1.75	**1.75**	1.75
		B2-14	Core	3.2	3.2	FS,ps,sc-s	3.0	2.124	1.299	0.53	1.77	**1.60**	1.57
		B2-15	Core	3.2	3.2	MS,ps,sc-s	3.2	1.590	1.592	-0.20	2.17	**1.32**	1.32
		B2-16	Core	3.0	3.0	FS,ps,sc-s	5.3	2.325	1.319	0.80	1.79	**1.85**	1.80

Table E5 (con't)

Table E5. Potential Borrow Area Sediment Quality and Compatibility Factors (RA). Revised May 2001

	B2-17	Core	3.0	3.0	MS,ps,sc-s	4.9	1.970	1.405	0.32	1.91	**1.47**	1.45
	B2-18	Core	3.2	3.2	FS,ms,sc-s	4.9	2.475	1.058	1.01	1.44	**2.45**	2.45
	B2-19	Core	3.2	3.2	FS,ps,sc-s	7.1	1.986	1.189	0.34	1.62	**1.42**	1.41
	B2-20	Core	2.3	2.3	FS,ps,sc-s	2.6	2.183	1.209	0.61	1.64	**1.65**	1.63
	B2-21	Core	2.3	2.3	MS,ps,c-s	5.1	1.391	1.246	-0.47	1.70	**1.13**	1.07
	B2-22	Core	2.3	2.3	MS,ps,sym	5.3	1.285	1.276	-0.61	1.74	**1.12**	1.11
B2										*Avg*	*1.686*	*1.703*
Supplementary	B2-23	Core	2.7	2.7	MS,ps,sc-s	4.9	1.881	1.337	0.20	1.82	**1.39**	1.37
Mar-01	B2-24	Core	3.3	3.3	MS,ps,sc-s	4.2	1.997	1.414	0.36	1.92	**1.49**	1.46
Samples	B2-25	Core	2.6	2.6	MS,ps,sc-s	3.5	1.918	1.586	0.25	2.16	**1.48**	1.45
	B2-26	Core	2.7	2.7	FS,ps,sc-s	3.5	2.260	1.314	0.71	1.79	**1.75**	1.72
	B2-27	Core	2.8	2.8	MS,ps,sc-s	5.3	1.698	1.431	-0.05	1.95	**1.32**	1.31
	B2-28	Core	3.2	3.2	MS,ps,sc-s	5.6	1.268	1.492	-0.64	2.03	**1.18**	1.16
	B2-29	Core	3.0	3.0	MS,ps,sc-s	10.7	1.756	1.455	0.03	1.98	**1.36**	1.30
	B2-30	Core	2.7	2.7	FS,ps,sc-s	3.8	2.327	1.280	0.80	1.74	**1.85**	1.80
	B2-31	Core	3.1	3.1	MS,ps,sc-s	5.9	1.762	1.199	0.04	1.63	**1.27**	1.25
	B2-32	Core	3.1	3.1	MS,ps,c-s	5.2	1.322	1.325	-0.56	1.80	**1.14**	1.13
										Avg	*1.423*	*1.395*

Note: Following RAs based on Final EIS
Native Beach (Mz=1.725 phi; Std Dev.=.773 phi)

Borrow Area	**Sample ID**	**Type**	**Interval (feet)**	**Sediment Description***		**Moment Measures M-phi-b**	**Sigma-b**	**X (Mb-Mn)/SDn**	**Y (SDb/SDn)**		**RA (SPM '84)**
C	BI-2	Grab	upper 0-5 ft	CS,ms,c-s	0	.269	.837	-1.88	1.08	N/A	<<1.02
Preliminary	BI-3A	Grab	upper 0-5 ft	FS,mws,c-s	0	2.001	.521	0.36	0.67	N/A	4.10
Jun-99	BI-3B	Grab	upper 0-5 ft	FS,ms,sym	0	1.276	.953	-0.58	1.23	N/A	1.02
Samples	BI-3C	Grab	upper 0-5 ft	FS,ws,c-s	0	2.217	.571	0.64	0.74	N/A	6.70
	BI-4A	Grab	upper 0-5 ft	FS,vws,sym	0	2.484	.274	0.98	0.35	N/A	>>10
	BI-4B	Grab	upper 0-5 ft	FS,vws,sym	0	2.358	.367	0.82	0.47	N/A	>>10
C	C-01	Grab/Hole	upper 0-5 ft	MS,mws,sc-s	0	1.857	.747	0.17	0.97	N/A	1.25
Supplementary	C-02	Grab/Hole	upper 0-5 ft	FS,mws,sc-s	0	1.946	.629	0.29	0.81	N/A	2.00
Nov-99	C-03	Grab/Hole	upper 0-5 ft	CS,ps,c-s	0	.356	1.025	-1.77	1.33	N/A	<<1.02
Samples	C-04	Grab/Hole	upper 0-5 ft	CS,ps,c-s	0	.568	.994	-1.50	1.29	N/A	<1.02
	C-05	Grab/Hole	upper 0-5 ft	MS,mws,sc-s	0	1.769	.803	0.06	1.04	N/A	1.10
	C-06	Grab/Hole	upper 0-5 ft	FS,vws,sym	0	2.417	.297	0.90	0.38	N/A	>>10
Bogue Sound	BS1	Grab	upper 2 ft	FS,vws,sym	ND	2.346	.356	0.80	0.46	N/A	>>10.0
	BS2	Grab	upper 2 ft	FS,vws,c-s	ND	2.049	.440	0.42	0.57	N/A	>10.0
	BS3	Grab	upper 2 ft	FS,ws,c-s	ND	2.078	.510	0.46	0.66	N/A	5.50
Corps Disposal	BD1	Grab	upper 2 ft	MS,cs,c-s	ND	1.204	1.117	-0.67	1.45	N/A	1.04
	BD2	Grab	upper 2 ft	FS,ws,sym	ND	2.607	.451	1.14	0.58	N/A	>>10.0
	BD3	Grab	upper 2 ft	FS,ws,sym	ND	2.672	.413	1.23	0.53	N/A	>>10.0
	BD4	Grab	upper 2 ft	FS,ws,sym	ND	2.597	.500	1.13	0.65	N/A	>10.0

***CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution
** These samples have a limiting acceptable depth for excavation based on recovered cores*
(ie. Underlying material is considered less suitable for nourishment).

Tab. ɔ (con't)

Bogue Banks, North Carolina 1999 Core Locations

Date	Station Grid Node	Latitude DDMMSS.sss	Longitude DDMMSS.sss	NORTH Nad 83 (Y ft.)	EAST Nad 83 (X ft.)	Equivalent Station
8-Nov-99	A-02	343844.996	765314.962	332797.1391	2635325.2657	
8-Nov-99	A-03	343900.042	765314.962	334317.8248	2635292.9003	
8-Nov-99	A-04	343914.981	765314.962	335827.6936	2635260.7644	
8-Nov-99	A-05	343930.026	765314.962	337348.2776	2635228.4022	
	A-08	See below for coordinates @ C13a1				C13a1
8-Nov-99	A-09	343900.256	765329.967	334312.8051	2634039.1831	ATH-01
4-Nov-99	A-10	343915.008	765329.935	335803.8320	2634010.1870	
8-Nov-99	A-11	343929.785	765330.290	337296.7028	2633948.8123	ATH-02
8-Nov-99	A-12	343944.963	765330.064	338831.1286	2633935.1017	
9-Nov-99	A-14	343845.931	765345.134	332838.1070	2632803.0873	
9-Nov-99	A-15	343900.817	765344.940	334342.9659	2632787.3950	
4-Nov-99	A-16	343915.008	765344.940	335777.2408	2632756.9915	
4-Nov-99	A-17	343929.999	765344.940	337292.3688	2632724.8688	
8-Nov-99	A-18	343944.963	765345.036	338804.5965	2632684.7900	
8-Nov-99	A-19	343844.622	765400.171	332679.2093	2631549.8917	ATH-04
4-Nov-99	A-21	343859.989	765359.944	334232.7395	2631535.9941	
8-Nov-99	A-22	343914.606	765359.233	335711.3255	2631564.1175	ATH-03
9-Nov-99	A-23	343930.774	765359.944	337344.1568	2631470.1640	
9-Nov-99	A-24	343944.963	765359.944	338778.2316	2631439.8196	
8-Nov-99	A-26	343844.996	765414.949	332690.9186	2630314.7277	
4-Nov-99	A-27	343859.989	765414.949	334206.2500	2630282.7329	
8-Nov-99	A-28	343914.981	765414.949	335721.4829	2630250.7349	
9-Nov-99	A-29	343930.319	765415.111	337271.3976	2630204.4751	
9-Nov-99	A-30	343945.470	765415.661	338801.7323	2630126.2106	
4-Nov-99	A-32	343844.996	765429.922	332664.5341	2629064.0748	
8-Nov-99	A-33	343900.095	765430.213	334190.0722	2629007.6115	ATH-05
4-Nov-99	A-34	343915.008	765429.922	335697.8314	2629000.1509	
8-Nov-99	A-35	343929.197	765430.924	337130.1444	2628886.2500	ATH-06
9-Nov-99	A-36	343944.963	765429.890	338725.4232	2628939.0223	
5-Nov-99	A-38	343844.996	765444.959	332638.0938	2627808.0741	
	A-39	See below for coordinates @ C14a3				C14a3
4-Nov-99	A-40	343915.008	765444.927	335671.4501	2627746.9521	
4-Nov-99	A-41	343929.999	765444.927	337186.5814	2627715.0853	
5-Nov-99	A-42	343944.989	765444.959	338701.5584	2627680.5512	
	A-43	See below for coordinates @ C14b2				C14b2
8-Nov-99	A-44	343844.996	765459.899	332611.8734	2626560.1772	
4-Nov-99	A-45	343859.989	765459.931	334127.1555	2626525.6955	
8-Nov-99	A-46	343914.633	765500.869	335605.5741	2626416.2894	ATH-07
9-Nov-99	A-47	343930.747	765500.190	337235.4003	2626438.8156	
9-Nov-99	A-48	343945.871	765459.705	338764.8294	2626447.2343	
9-Nov-99	A-50	343845.397	765515.518	332625.0492	2625254.7113	
4-Nov-99	A-51	343859.989	765514.936	334100.8760	2625272.4311	
9-Nov-99	A-52	343916.076	765514.936	335726.7848	2625238.3727	
9-Nov-99	A-53	343931.067	765515.033	337241.7520	2625198.5302	
9-Nov-99	A-54	343945.818	765514.839	338732.9692	2625183.5039	
8-Nov-99	A-59	343930.026	765530.071	337110.2559	2623944.8392	

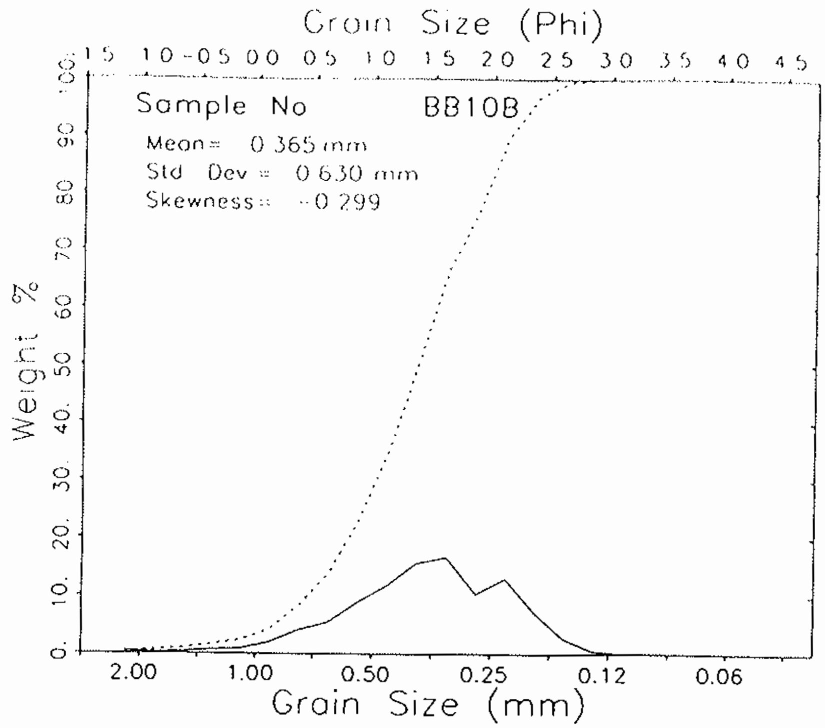
Date	Station Grid Node	Latitude DDMMSS.sss	Longitude DDMMSS.sss	NORTH Nad 83 (Y ft.)	EAST Nad 83 (X ft.)	Equivalent Station
8-Nov-99	A-60	343944.963	765530.071	338619.9344	2623913.2808	
8-Nov-99	A-61	344000.006	765530.071	340140.3281	2623881.4961	
8-Nov-99	A-63	344015.048	765514.969	341687.0079	2625110.7612	
8-Nov-99	A-64	344000.006	765514.969	340166.7192	2625142.6083	
5-Nov-99	A-65	344000.006	765459.964	340192.9921	2626395.6201	
5-Nov-99	A-66	344014.995	765459.931	341707.9823	2626366.5781	ATH-14
5-Nov-99	A-67	344014.995	765444.959	341734.2520	2627616.7684	
9-Nov-99	A-68	344000.006	765444.991	340219.2651	2627645.9580	
9-Nov-99	A-69	344000.006	765429.890	340245.8104	2628906.9816	
9-Nov-99	A-70	344015.689	765430.180	341830.3740	2628849.3635	
5-Nov-99	ATHB08	344112.459	764807.783	348257.9134	2660652.7231	
5-Nov-99	ATHB09	344110.295	764910.680	347923.3924	2655406.6470	
7-Nov-99	ATHB10	344056.671	765010.765	346436.6732	2650420.4823	
5-Nov-99	ATHB11	344033.723	765350.631	343722.8281	2632113.1562	
5-Nov-99	ATHB12	344022.529	765452.364	342482.7100	2626982.4377	
7-Nov-99	ATHB13	344022.609	765559.531	342373.4843	2621373.8255	
5-Nov-99	B1-1	344117.855	764707.116	348915.8497	2665705.2461	
5-Nov-99	B1-2	344102.041	764911.295	347088.0545	2655373.6253	
5-Nov-99	B1-3	344101.427	764942.113	346969.5932	2652802.0833	
5-Nov-99	B1-4	344102.121	765013.416	346982.6706	2650187.1490	
5-Nov-99	B2-1	344042.379	765318.519	344654.6030	2634775.7743	
5-Nov-99	B2-2	344032.788	765318.164	343685.8793	2634826.0367	
5-Nov-99	B2-3			343745.8136	2629483.9501	
5-Nov-99	B2-4	344027.018	765420.835	342991.8406	2629605.5282	
5-Nov-99	B2-5	344025.895	765528.227	342760.1444	2623980.7677	
18-Nov-99	B2-6			341383.5630	2619032.8773	
18-Nov-99	B2-7	344004.307	765729.527	340368.1627	2613897.1818	
19-Nov-99	C-01	343851.570	770649.461	332091.1450	2567278.4613	
19-Nov-99	C-02	343846.546	770702.299	331562.9921	2566215.7480	
19-Nov-99	C-03	343842.590	770613.307	331241.0466	2570315.7021	
19-Nov-99	C-06	343833.022	770558.238	330298.0512	2571592.9495	
5-Jun-99	C04A-1	344133.561	764427.075	350804.2979	2679029.5636	
5-Jun-99	C04A-2	344106.476	764425.458	348070.0066	2679226.8635	
5-Jun-99	C04A-3	344041.017	764417.632	345511.8602	2679938.8451	
5-Jun-99	C04A-4	344014.380	764415.466	342823.8944	2680181.0499	
5-Jun-99	C04A-5	343949.799	764417.277	340336.1549	2680086.4469	
5-Jun-99	C06A-1	344115.211	764635.587	348707.4770	2668343.3301	
5-Jun-99	C06A-2	344033.082	764628.408	344463.0807	2669038.1168	
5-Jun-99	C06A-3	343959.872	764627.179	341108.9633	2669216.0007	
11-Jun-99	C07A-1	344105.033	764734.280	347589.4587	2663466.3615	
11-Jun-99	C07A-2	344118.924	764737.838	348966.7749	2663138.1135	
6-Jun-99	C08A-1	344109.547	764840.283	347903.6483	2657945.9908	
6-Jun-99	C08A-2	344029.716	764835.626	343886.6142	2658423.6056	
6-Jun-99	C08A-3	343949.532	764830.290	339835.1640	2658958.8156	

Offshore Core Locations

Date	Station Grid Node	Latitude DDMMSS.sss	Longitude DDMMSS.sss	NORTH Nad 83 (Y ft.)	EAST Nad 83 (X ft.)	Equivalent Station
8-Jun-99	C09A-1	343923.211	764933.446	337058.9764	2653743.0938	
11-Jun-99	C09A-2	344047.936	764943.245	345604.0223	2652737.4016	
11-Jun-99	C09A-3	344108.238	764942.954	347656.4304	2652716.8110	
6-Jun-99	C10A-1	344100.225	765046.466	346731.0433	2647432.0538	
6-Jun-99	C10A-2	344021.193	765043.005	342792.4245	2647806.6437	
6-Jun-99	C10A-3	343941.569	765042.715	338788.2316	2647917.7986	
6-Jun-99	C10A-4	343903.008	765042.520	334891.2992	2648018.6975	
11-Jun-99	C10B-1	344046.360	765118.480	345271.8537	2644789.5505	
8-Jun-99	C11A-1	343902.474	765128.667	334753.9009	2644165.6102	
11-Jun-99	C11A-2	344044.436	765151.077	345018.7073	2642072.1424	
11-Jun-99	C11B-1	344037.410	765218.791	344258.8976	2639773.4482	
6-Jun-99	C12A-1	344055.843	765249.609	346066.8406	2637160.5184	
6-Jun-99	C12A-2	344029.743	765246.440	343434.5965	2637481.4534	
6-Jun-99	C12A-3	343928.475	765236.609	337259.8622	2638434.7703	
7-Jun-99	C12A-4	343827.864	765217.109	331168.8714	2640194.6752	
8-Jun-99	C13A-1	343845.156	765329.158	332788.0971	2634139.1765	
8-Jun-99	C13A-2	343935.824	765338.925	337891.7487	2633214.7178	
7-Jun-99	C13B-1	343921.234	765410.681	336360.9974	2630593.8419	
6-Jun-99	C14A-1	344029.449	765453.852	343179.5013	2626843.4974	
6-Jun-99	C14A-2	343959.097	765449.131	340120.1214	2627302.1719	
6-Jun-99	C14A-3	343905.227	765441.175	334689.4816	2628081.1155	
7-Jun-99	C14A-4	343818.670	765426.429	330009.9311	2629411.9357	
8-Jun-99	C14B-1	343908.113	765511.379	334928.1923	2625552.3130	
8-Jun-99	C14B-2	343840.185	765506.723	332113.6680	2626000.3806	
11-Jun-99	C15A-1	344014.754	765600.695	341577.5558	2621293.1594	
7-Jun-99	C16A-1	344018.067	765657.771	341813.5564	2616520.2559	
7-Jun-99	C16A-2	343959.311	765654.829	339922.9593	2616805.0951	
7-Jun-99	C16A-3	343922.864	765655.055	336238.8583	2616862.3556	
7-Jun-99	C16A-4	343843.366	765653.309	332249.7999	2617090.7054	
7-Jun-99	C16A-5	343805.359	765649.655	328414.7310	2617475.3675	
11-Jun-99	C17A-1	344000.113	765807.234	339879.6654	2610757.1030	
7-Jun-99	C18A-1	343931.709	765859.783	336919.3570	2606427.2113	
7-Jun-99	C18A-2	343849.512	765856.711	332659.6785	2606770.4626	
7-Jun-99	C18A-3	343811.961	765853.445	328869.9081	2607120.4462	
11-Jun-99	C19A-1	343936.759	770009.536	337311.9751	2600591.4797	
7-Jun-99	C20A-1	343919.497	770108.747	335468.1759	2595681.3287	
7-Jun-99	C20A-2	343853.094	770101.762	332811.2270	2596318.0217	
7-Jun-99	C20A-3	343814.580	770055.359	328929.2388	2596930.6791	
7-Jun-99	C20A-4	343736.383	770045.917	325084.3865	2597796.7356	
11-Jun-99	C21A-1	343905.708	770208.185	333975.8333	2590744.6752	

ANNEX E-2
Part 1

Phase I — June 1999
Sediment Sample Results



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB10B	060699					
Bogue Banks Beach Samples BB10B Berm						
		-1.125	.410	.412	-1.000	.412
		-.875	.200	.201	-.750	.613
		-.625	.310	.312	-.500	.925
		-.375	.620	.624	-.250	1.549
		-.125	.770	.774	.000	2.323
		.125	1.930	1.941	.250	4.264
		.375	4.020	4.043	.500	8.307
		.625	5.390	5.421	.750	13.728
		.875	8.840	8.891	1.000	22.619
		1.125	11.660	11.727	1.250	34.346
		1.375	15.440	15.529	1.500	49.874
		1.625	16.480	16.574	1.750	66.449
		1.875	10.250	10.309	2.000	76.758
		2.125	12.900	12.974	2.250	89.731
		2.375	7.050	7.090	2.500	96.822
		2.625	2.550	2.565	2.750	99.387
		2.875	.500	.503	3.000	99.889
		3.125	.070	.070	3.250	99.960
		3.375	.020	.020	3.500	99.980
		3.625	.010	.010	3.750	99.990
		3.875	.010	.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.430

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

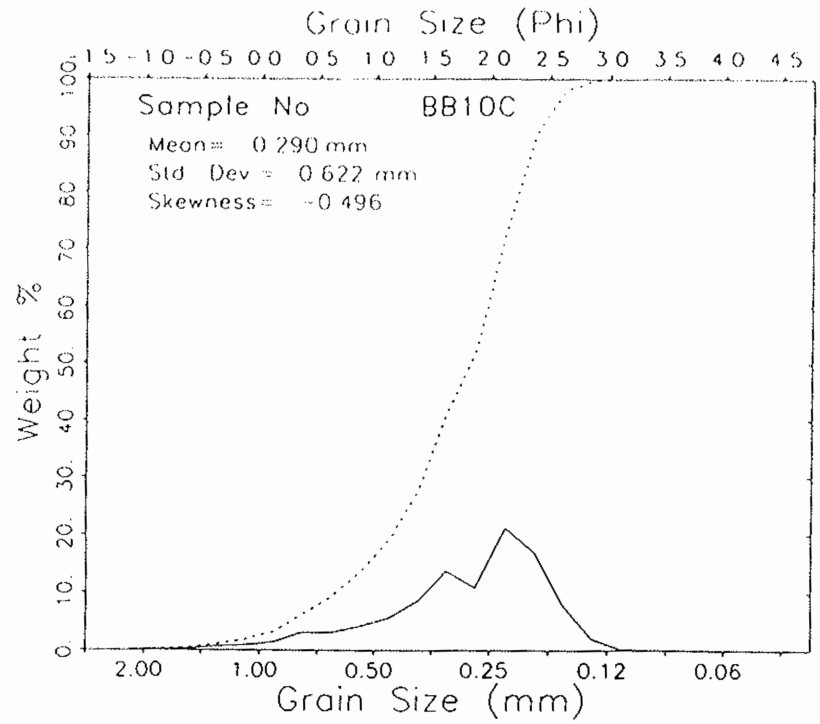
MOMENT MEASURES:

MEAN = 1.455 STANDARD DEVIATION = .667 SKEWNESS = -.299 KURTOSIS = .711
DISPERSION = .421 STANDARD DEVIATION = .638 DEVIATION FROM NORMAL DISTR. = -4.29%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.470	.295	.814	1.051	1.502	1.957	2.140	2.436	2.712

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.477	1.485	MEDIUM SAND
STANDARD DEVIATION	.663	.656	MODERATELY WELL SORTED
SKEWNESS(1)	-.038	-.003	NEAR SYMMETRICAL
SKEWNESS(2)	-.206		
KURTOSIS	.614	.968	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB10C	060699						
Bogue Banks Beach Samples BB10C MBF							
		-1.125	.070		.068	-1.000	.068
		-.875	.130		.125	-.750	.193
		-.625	.230		.222	-.500	.415
		-.375	.640		.617	-.250	1.032
		-.125	.800		.771	.000	1.803
		.125	1.430		1.379	.250	3.182
		.375	3.200		3.086	.500	6.268
		.625	3.210		3.095	.750	9.364
		.875	4.290		4.137	1.000	13.500
		1.125	5.760		5.554	1.250	19.055
		1.375	8.660		8.351	1.500	27.406
		1.625	14.210		13.703	1.750	41.109
		1.875	11.200		10.800	2.000	51.909
		2.125	22.000		21.215	2.250	73.124
		2.375	17.590		16.962	2.500	90.087
		2.625	8.080		7.792	2.750	97.878
		2.875	1.970		1.900	3.000	99.778
		3.125	.180		.174	3.250	99.952
		3.375	.040		.039	3.500	99.990
		3.625	.000		.000	3.750	99.990
		3.875	.010		.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.700

PERCENT FINER THAN 4.00 PHI = .00   PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

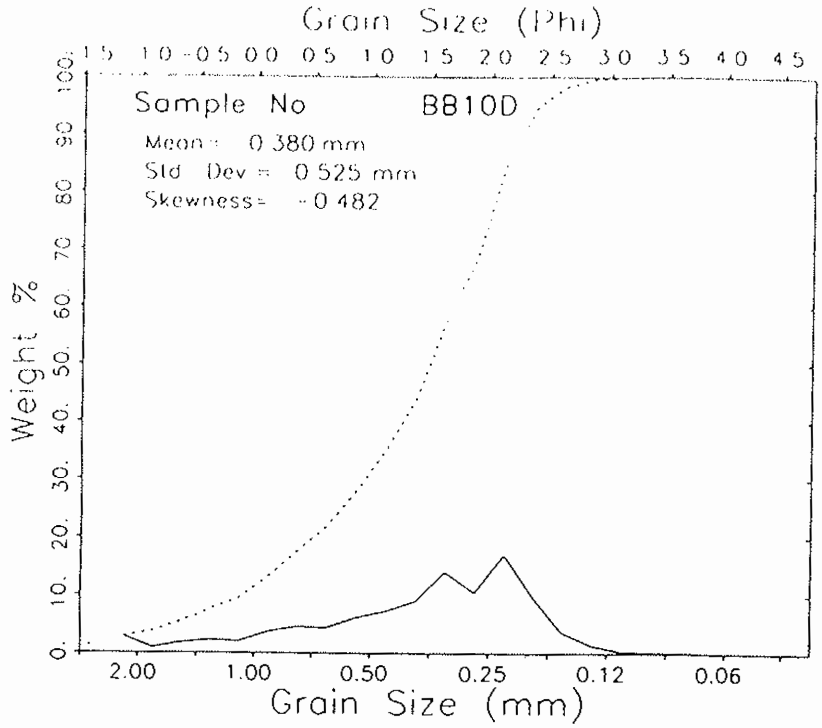
MEAN = 1.785   STANDARD DEVIATION = .684   SKEWNESS = -.496   KURTOSIS = .862

DISPERSION = .397   STANDARD DEVIATION = .604   DEVIATION FROM NORMAL DISTR. = -11.69%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.263	.397	1.113	1.428	1.956	2.278	2.410	2.658	2.898

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.761	1.826	MEDIUM SAND
STANDARD DEVIATION	.649	.667	MODERATELY WELL SORTED
SKEWNESS(1)	-.300	-.339	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.660		
KURTOSIS	.742	1.090	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB10D	060699					
Bogue Banks Beach Samples BB10D LTT						
		-1.125	3.210	2.797	-1.000	2.797
		-.875	1.000	.871	-.750	3.668
		-.625	1.940	1.690	-.500	5.359
		-.375	2.500	2.178	-.250	7.537
		-.125	2.270	1.978	.000	9.515
		.125	4.160	3.625	.250	13.139
		.375	5.120	4.461	.500	17.600
		.625	4.910	4.278	.750	21.879
		.875	6.910	6.021	1.000	27.899
		1.125	8.160	7.110	1.250	35.009
		1.375	10.130	8.826	1.500	43.835
		1.625	16.030	13.967	1.750	57.803
		1.875	11.970	10.430	2.000	68.232
		2.125	19.510	16.999	2.250	85.231
		2.375	10.990	9.576	2.500	94.807
		2.625	4.040	3.520	2.750	98.327
		2.875	1.480	1.290	3.000	99.617
		3.125	.300	.261	3.250	99.878
		3.375	.110	.096	3.500	99.974
		3.625	.030	.026	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 114.770

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

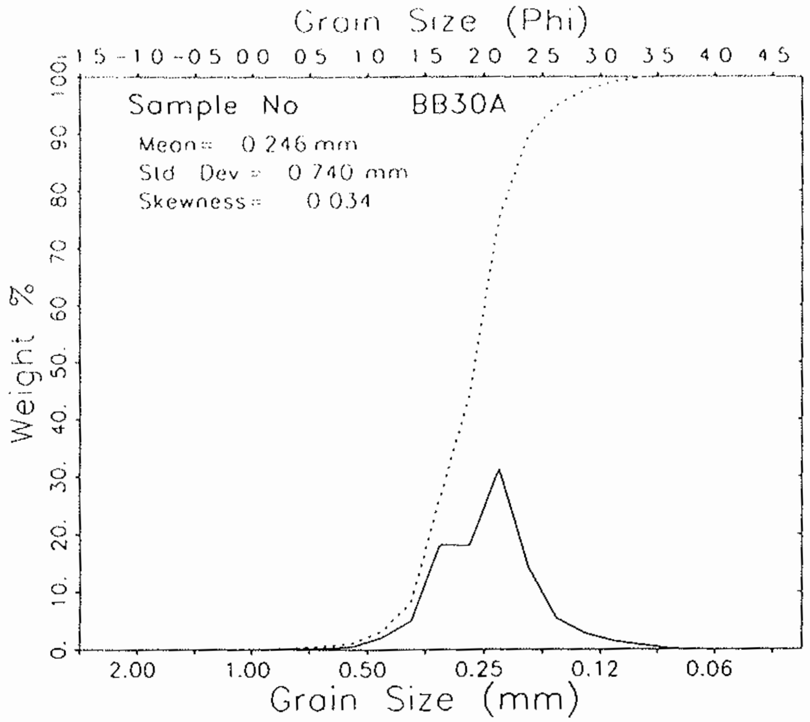
MOMENT MEASURES:

MEAN = 1.395 STANDARD DEVIATION = .930 SKEWNESS = -.452 KURTOSIS = .272
DISPERSION = .515 STANDARD DEVIATION = .791 DEVIATION FROM NORMAL DISTR. = -14.93%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.161	-.553	.410	.800	1.610	2.100	2.232	2.514	2.880

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.321	1.418	MEDIUM SAND
STANDARD DEVIATION	.911	.920	MODERATELY SORTED
SKEWNESS(1)	-.318	-.364	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.692		
KURTOSIS	.684	1.030	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB30A	060699						
Bogue Banks Beach Samples BB30A Dune							
		-1.125	.000		.000	-1.000	.000
		-.875	.010		.010	-.750	.010
		-.625	.040		.040	-.500	.050
		-.375	.030		.030	-.250	.079
		-.125	.010		.010	.000	.089
		.125	.090		.089	.250	.179
		.375	.190		.189	.500	.368
		.625	.230		.229	.750	.596
		.875	.500		.497	1.000	1.093
		1.125	2.100		2.086	1.250	3.179
		1.375	4.930		4.898	1.500	8.077
		1.625	18.220		18.102	1.750	26.180
		1.875	18.080		17.963	2.000	44.143
		2.125	31.490		31.287	2.250	75.430
		2.375	14.380		14.287	2.500	89.717
		2.625	5.320		5.286	2.750	95.002
		2.875	2.740		2.722	3.000	97.725
		3.125	1.420		1.411	3.250	99.136
		3.375	.710		.705	3.500	99.841
		3.625	.150		.149	3.750	99.990
		3.875	.010		.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.650

PERCENT FINER THAN 4.00 PHI = .01 PERCENT COARSER THAN -1.00 PHI = .00

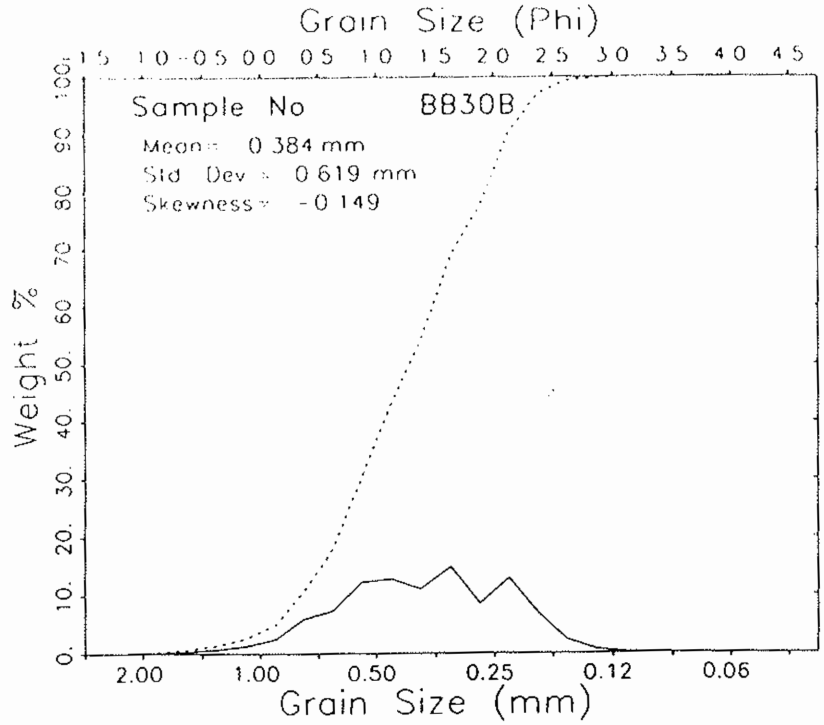
MOMENT MEASURES:

MEAN = 2.023 STANDARD DEVIATION = .435 SKEWNESS = -.034 KURTOSIS = 2.226
DISPERSION = .229 STANDARD DEVIATION = .410 DEVIATION FROM NORMAL DISTR. = -5.83%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.953	1.343	1.609	1.734	2.047	2.247	2.400	2.750	3.226

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.005	2.019	FINE SAND
STANDARD DEVIATION	.395	.411	WELL SORTED
SKEWNESS(1)	-.107	-.054	NEAR SYMMETRICAL
SKEWNESS(2)	-.001		
KURTOSIS	.780	1.124	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB30B	060699						
Bogue Banks Beach Samples BB30B Berm							
		-1.125	.200		.200	-1.000	.200
		-.875	.150		.150	-.750	.350
		-.625	.340		.340	-.500	.689
		-.375	.640		.639	-.250	1.329
		-.125	1.200		1.199	.000	2.528
		.125	2.350		2.348	.250	4.876
		.375	5.860		5.855	.500	10.730
		.625	7.310		7.303	.750	18.034
		.875	12.270		12.259	1.000	30.293
		1.125	12.710		12.699	1.250	42.991
		1.375	11.070		11.060	1.500	54.051
		1.625	14.790		14.777	1.750	68.828
		1.875	8.520		8.512	2.000	77.340
		2.125	12.870		12.858	2.250	90.199
		2.375	6.820		6.814	2.500	97.013
		2.625	2.260		2.258	2.750	99.271
		2.875	.530		.530	3.000	99.800
		3.125	.150		.150	3.250	99.950
		3.375	.050		.050	3.500	100.000
		3.625	.000		.000	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.090

PERCENT FINER THAN 4.00 PHI = .00　　PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

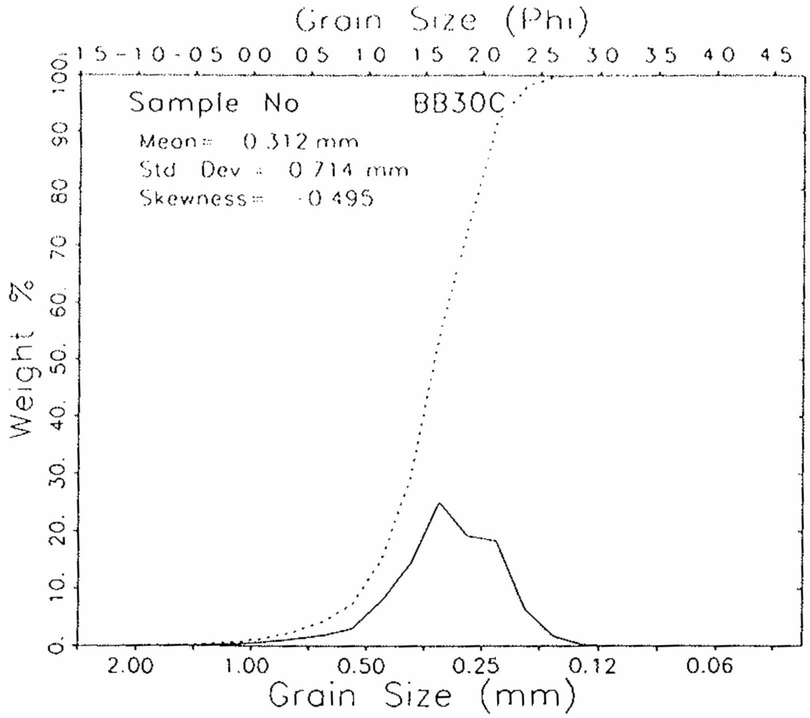
MEAN = 1.379　STANDARD DEVIATION = .693　SKEWNESS = -.149　KURTOSIS = -.139

DISPERSION = .441　STANDARD DEVIATION = .667　DEVIATION FROM NORMAL DISTR. = -3.64%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.379	.255	.680	.892	1.408	1.931	2.129	2.426	2.720

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.405	1.406	MEDIUM SAND
STANDARD DEVIATION	.725	.691	MODERATELY WELL SORTED
SKEWNESS(1)	-.005	-.034	NEAR SYMMETRICAL
SKEWNESS(2)	-.093		
KURTOSIS	.498	.856	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB30C	060699						
Bogue Banks Beach Samples BB30C MBF							
		-1.125	.070		.067	-1.000	.067
		-.875	.060		.058	-.750	.125
		-.625	.100		.096	-.500	.221
		-.375	.200		.192	-.250	.413
		-.125	.300		.288	.000	.700
		.125	.640		.614	.250	1.314
		.375	1.160		1.113	.500	2.427
		.625	1.870		1.794	.750	4.221
		.875	3.140		3.012	1.000	7.233
		1.125	8.150		7.818	1.250	15.052
		1.375	14.700		14.102	1.500	29.154
		1.625	26.100		25.038	1.750	54.192
		1.875	19.970		19.158	2.000	73.350
		2.125	19.120		18.342	2.250	91.692
		2.375	6.680		6.408	2.500	98.101
		2.625	1.730		1.660	2.750	99.760
		2.875	.230		.221	3.000	99.981
		3.125	.010		.010	3.250	99.990
		3.375	.000		.000	3.500	99.990
		3.625	.000		.000	3.750	99.990
		3.875	.010		.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.240

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

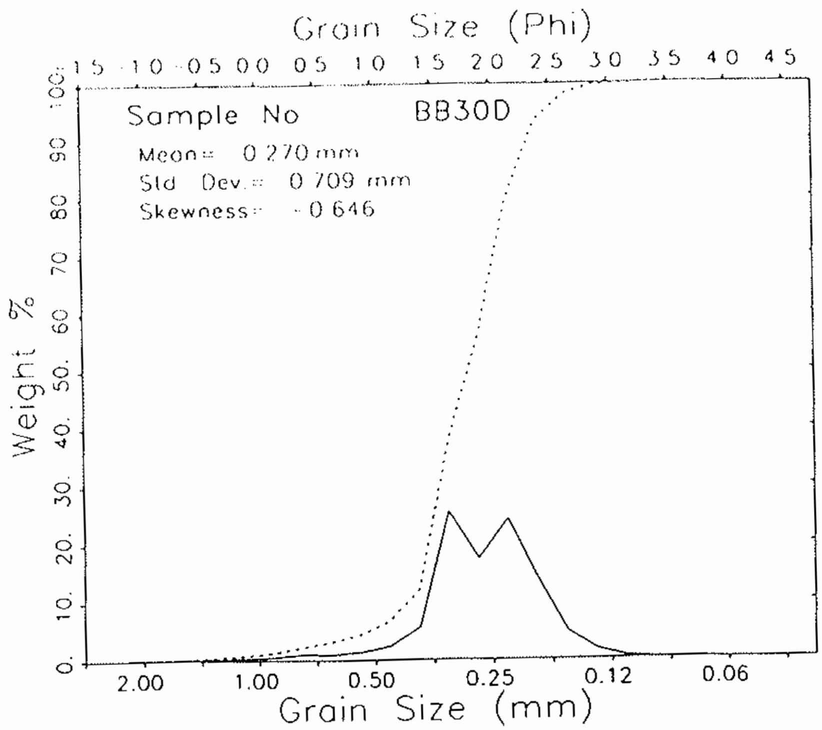
MOMENT MEASURES:

MEAN = 1.680 STANDARD DEVIATION = .486 SKEWNESS = -.495 KURTOSIS = 2.608
DISPERSION = .272 STANDARD DEVIATION = .453 DEVIATION FROM NORMAL DISTR. = -6.80%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.122	.815	1.267	1.426	1.708	2.022	2.145	2.379	2.635

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.706	1.707	MEDIUM SAND
STANDARD DEVIATION	.439	.457	WELL SORTED
SKEWNESS(1)	-.005	-.074	NEAR SYMMETRICAL
SKEWNESS(2)	-.253		
KURTOSIS	.781	1.076	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB30D	060699					
Bogue Banks Beach Samples BB30D LTT						
		-1.125	.100	.099	-1.000	.099
		-.875	.080	.079	-.750	.178
		-.625	.120	.119	-.500	.296
		-.375	.190	.188	-.250	.484
		-.125	.280	.277	.000	.761
		.125	.500	.494	.250	1.255
		.375	.960	.949	.500	2.204
		.625	.860	.850	.750	3.053
		.875	1.340	1.324	1.000	4.377
		1.125	2.360	2.332	1.250	6.709
		1.375	5.600	5.534	1.500	12.243
		1.625	25.900	25.593	1.750	37.836
		1.875	17.630	17.421	2.000	55.257
		2.125	24.560	24.269	2.250	79.526
		2.375	13.980	13.814	2.500	93.340
		2.625	4.790	4.733	2.750	98.073
		2.875	1.570	1.551	3.000	99.625
		3.125	.320	.316	3.250	99.941
		3.375	.060	.059	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.200

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

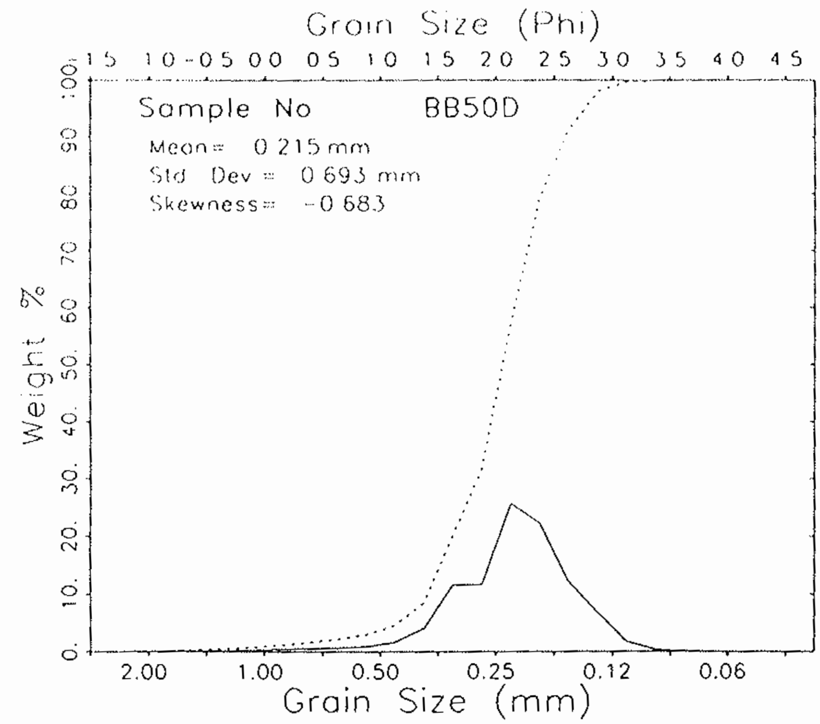
MOMENT MEASURES:

MEAN = 1.887 STANDARD DEVIATION = .497 SKEWNESS = -.646 KURTOSIS = 4.591
DISPERSION = .252 STANDARD DEVIATION = .432 DEVIATION FROM NORMAL DISTR. = -12.98%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.121	1.067	1.537	1.625	1.925	2.203	2.331	2.588	2.899

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.934	1.931	MEDIUM SAND
STANDARD DEVIATION	.397	.429	WELL SORTED
SKEWNESS(1)	.023	-.052	NEAR SYMMETRICAL
SKEWNESS(2)	-.245		
KURTOSIS	.915	1.077	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB50D	D60699						
Bogue Banks Beach Samples BB50D LTT							
		-1.125	.100		.083	-1.000	.083
		-.875	.100		.083	-.750	.166
		-.625	.190		.158	-.500	.323
		-.375	.190		.158	-.250	.481
		-.125	.250		.207	.000	.688
		.125	.430		.357	.250	1.045
		.375	.600		.498	.500	1.543
		.625	.640		.531	.750	2.074
		.875	.970		.805	1.000	2.878
		1.125	1.900		1.576	1.250	4.454
		1.375	4.688		3.882	1.500	8.336
		1.625	13.960		11.579	1.750	19.915
		1.875	13.930		11.554	2.000	31.470
		2.125	30.880		25.614	2.250	57.084
		2.375	26.810		22.238	2.500	79.322
		2.625	14.510		12.036	2.750	91.357
		2.875	8.060		6.685	3.000	98.042
		3.125	1.990		1.651	3.250	99.693
		3.375	.340		.282	3.500	99.975
		3.625	.030		.025	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 120.560

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

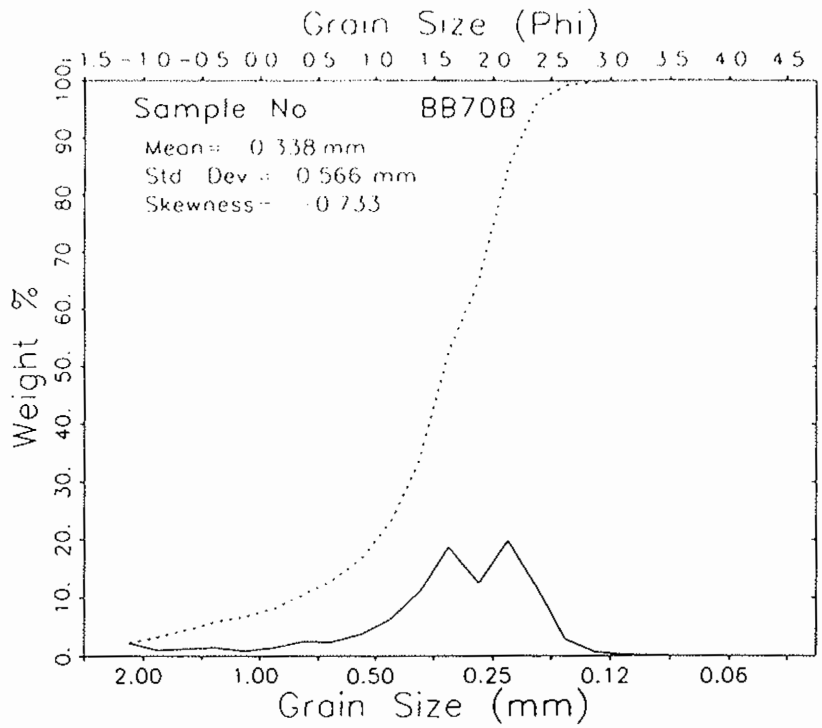
MOMENT MEASURES:

MEAN = 2.128 STANDARD DEVIATION = .529 SKEWNESS = -.683 KURTOSIS = 4.778
DISPERSION = .290 STANDARD DEVIATION = .472 DEVIATION FROM NORMAL DISTR. = -10.75%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.218	1.285	1.665	1.860	2.181	2.451	2.597	2.886	3.145

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.131	2.148	FINE SAND
STANDARD DEVIATION	.466	.476	WELL SORTED
SKEWNESS(1)	-.106	-.113	COARSE-SKEWED
SKEWNESS(2)	-.204		
KURTOSIS	.718	1.110	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB70B	060699					
Bogue Banks Beach Samples BB70B Berm						
		-1.125	2.780	2.235	-1.000	2.235
		-.875	1.250	1.005	-.750	3.241
		-.625	1.520	1.222	-.500	4.463
		-.375	1.730	1.391	-.250	5.854
		-.125	1.050	.844	.000	6.698
		.125	1.750	1.407	.250	8.105
		.375	3.030	2.436	.500	10.542
		.625	2.980	2.396	.750	12.938
		.875	4.640	3.731	1.000	16.669
		1.125	7.720	6.208	1.250	22.877
		1.375	13.510	10.864	1.500	33.741
		1.625	23.290	18.728	1.750	52.469
		1.875	15.440	12.416	2.000	64.884
		2.125	24.590	19.773	2.250	84.657
		2.375	14.500	11.660	2.500	96.317
		2.625	3.510	2.822	2.750	99.140
		2.875	.790	.635	3.000	99.775
		3.125	.230	.185	3.250	99.960
		3.375	.050	.040	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 124.360

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

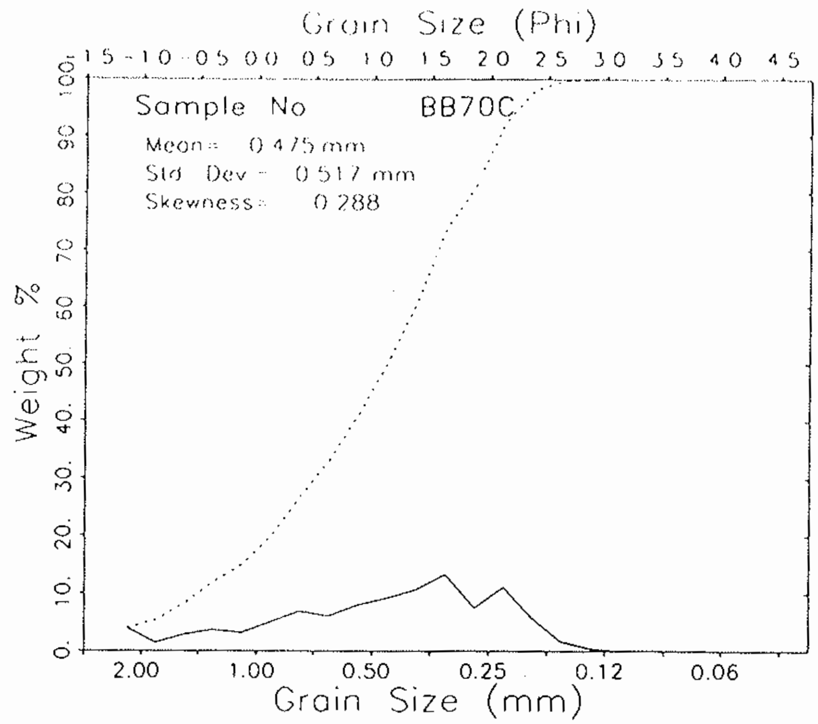
MOMENT MEASURES:

MEAN = 1.564 STANDARD DEVIATION = .821 SKEWNESS = -.733 KURTOSIS = 2.158
DISPERSION = .420 STANDARD DEVIATION = .636 DEVIATION FROM NORMAL DISTR. = -22.59%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.130	-.403	.955	1.299	1.717	2.128	2.242	2.472	2.738

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.598	1.638	MEDIUM SAND
STANDARD DEVIATION	.643	.757	MODERATELY SORTED
SKEWNESS(1)	-.184	-.330	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.062		
KURTOSIS	1.235	1.421	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB70C	060699						
Bogue Banks Beach Samples BB70C UBF							
		-1.125	4.350		3.966	-1.000	3.966
		-.875	1.560		1.422	-.750	5.388
		-.625	3.040		2.771	-.500	8.159
		-.375	4.020		3.665	-.250	11.824
		-.125	3.400		3.100	.000	14.924
		.125	5.570		5.078	.250	20.002
		.375	7.520		6.856	.500	26.858
		.625	6.650		6.063	.750	32.920
		.875	8.770		7.995	1.000	40.915
		1.125	10.040		9.153	1.250	50.068
		1.375	11.540		10.521	1.500	60.589
		1.625	14.500		13.219	1.750	73.808
		1.875	8.180		7.457	2.000	81.265
		2.125	12.110		11.040	2.250	92.306
		2.375	6.260		5.707	2.500	98.013
		2.625	1.780		1.623	2.750	99.635
		2.875	.400		.365	3.000	100.000
		3.125	.000		.000	3.250	100.000
		3.375	.000		.000	3.500	100.000
		3.625	.000		.000	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.690

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

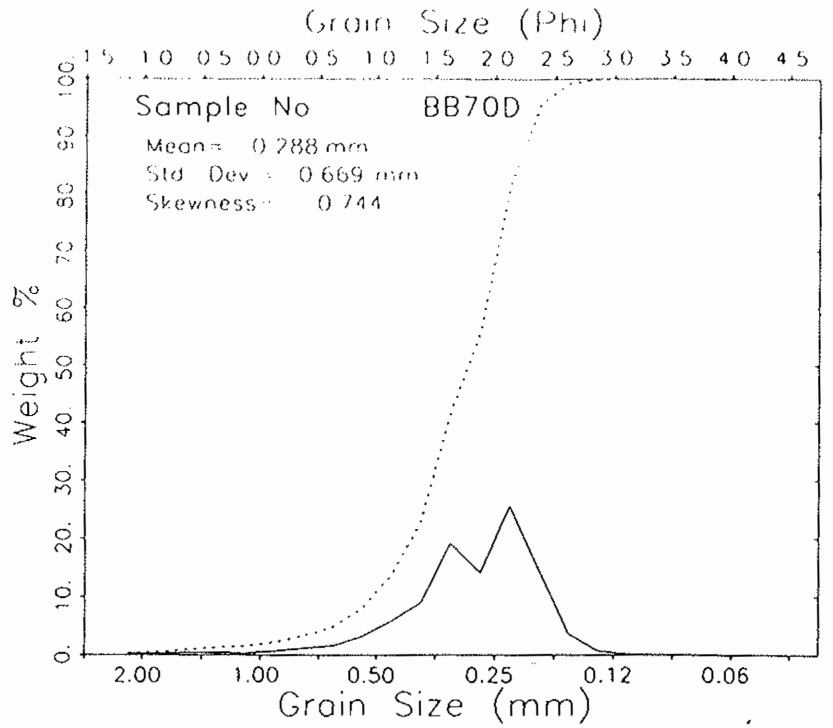
MOMENT MEASURES:

MEAN = 1.073 STANDARD DEVIATION = .953 SKEWNESS = -.288 KURTOSIS = -.432
DISPERSION = .542 STANDARD DEVIATION = .843 DEVIATION FROM NORMAL DISTR. = -11.57%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.187	-.818	.053	.432	1.248	1.790	2.062	2.368	2.652

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.057	1.121	MEDIUM SAND
STANDARD DEVIATION	1.004	.985	MODERATELY SORTED
SKEWNESS(1)	-.190	-.243	COARSE-SKEWED
SKEWNESS(2)	-.471		
KURTOSIS	.506	.962	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB70D	060699					
Bogue Banks Beach Samples BB70D						
		-1.125	.390	.310	-1.000	.310
		-.875	.280	.222	-.750	.532
		-.625	.440	.350	-.500	.882
		-.375	.460	.365	-.250	1.247
		-.125	.390	.310	.000	1.557
		.125	.760	.604	.250	2.161
		.375	1.430	1.136	.500	3.297
		.625	1.920	1.526	.750	4.823
		.875	3.930	3.123	1.000	7.945
		1.125	7.230	5.744	1.250	13.690
		1.375	11.050	8.780	1.500	22.469
		1.625	24.170	19.204	1.750	41.673
		1.875	17.720	14.079	2.000	55.752
		2.125	32.250	25.624	2.250	81.376
		2.375	17.970	14.278	2.500	95.654
		2.625	4.490	3.567	2.750	99.221
		2.875	.770	.612	3.000	99.833
		3.125	.150	.119	3.250	99.952
		3.375	.050	.040	3.500	99.992
		3.625	.010	.008	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 125.860

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

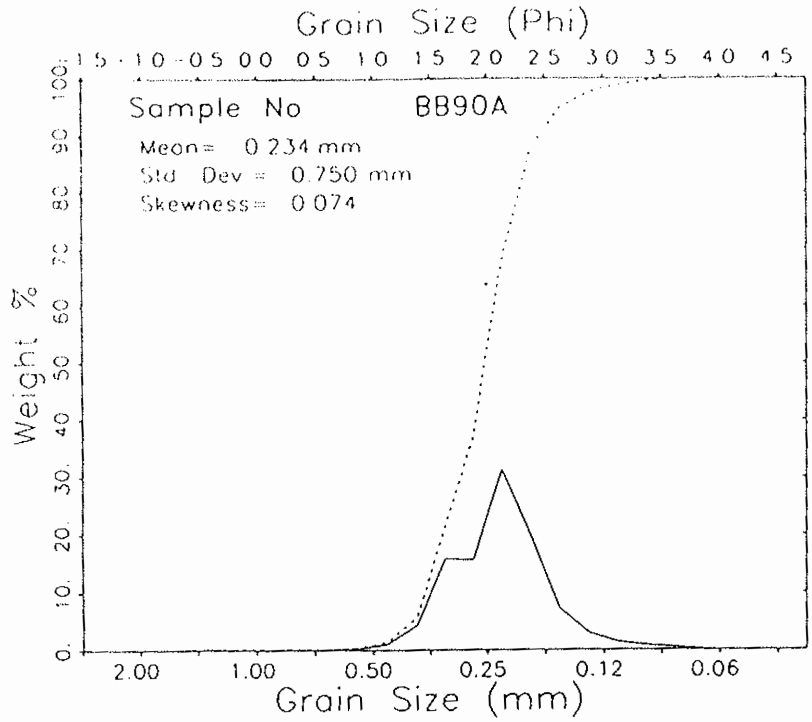
MOMENT MEASURES:

MEAN = 1.794 STANDARD DEVIATION = .581 SKEWNESS = -.744 KURTOSIS = 3.952
DISPERSION = .311 STANDARD DEVIATION = .495 DEVIATION FROM NORMAL DISTR. = -14.69%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.419	.764	1.316	1.533	1.898	2.188	2.296	2.489	2.734

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.806	1.837	MEDIUM SAND
STANDARD DEVIATION	.490	.506	MODERATELY WELL SORTED
SKEWNESS(1)	-.188	-.251	COARSE-SKEWED
SKEWNESS(2)	-.554		
KURTOSIS	.759	1.079	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB90A	060699						
Bogue Banks Beach Samples BB90A Dune							
		-1.125	.000		.000	-1.000	.000
		-.875	.000		.000	-.750	.000
		-.625	.000		.000	-.500	.000
		-.375	.100		.097	-.250	.097
		-.125	.000		.000	.000	.097
		.125	.010		.010	.250	.106
		.375	.020		.019	.500	.126
		.625	.040		.039	.750	.164
		.875	.200		.193	1.000	.358
		1.125	.990		.957	1.250	1.314
		1.375	4.310		4.165	1.500	5.479
		1.625	16.300		15.750	1.750	21.229
		1.875	16.200		15.654	2.000	36.883
		2.125	32.380		31.288	2.250	68.171
		2.375	20.230		19.548	2.500	87.719
		2.625	7.260		7.015	2.750	94.734
		2.875	2.900		2.802	3.000	97.536
		3.125	1.360		1.314	3.250	98.850
		3.375	.770		.744	3.500	99.594
		3.625	.380		.367	3.750	99.961
		3.875	.040		.039	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.490

PERCENT FINER THAN 4.00 PHI = .01 PERCENT COARSER THAN -1.00 PHI = .00

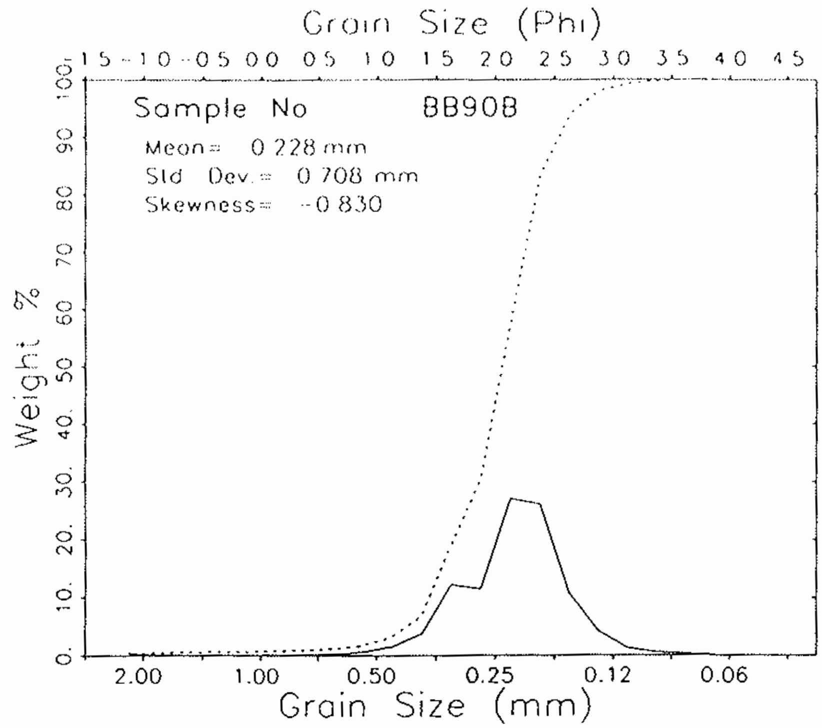
MOMENT MEASURES:

MEAN = 2.094 STANDARD DEVIATION = .415 SKEWNESS = .074 KURTOSIS = 2.041
DISPERSION = .210 STANDARD DEVIATION = .392 DEVIATION FROM NORMAL DISTR. = -5.42%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.160	1.471	1.667	1.810	2.105	2.337	2.452	2.774	3.300

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.060	2.075	FINE SAND
STANDARD DEVIATION	.393	.394	WELL SORTED
SKEWNESS(1)	-.115	-.044	NEAR SYMMETRICAL
SKEWNESS(2)	.045		
KURTOSIS	.658	1.013	MESOKURTIC



R LANGUAGE=PCL3GUI

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB90B	060699					
Bogue Banks Beach Sample BB90B Dune						
		-1.125	.390	.386	-1.000	.386
		-.875	.090	.089	-.750	.475
		-.625	.070	.069	-.500	.544
		-.375	.080	.079	-.250	.624
		-.125	.040	.040	.000	.663
		.125	.110	.109	.250	.772
		.375	.150	.148	.500	.921
		.625	.210	.208	.750	1.128
		.875	.570	.564	1.000	1.693
		1.125	1.450	1.435	1.250	3.128
		1.375	3.670	3.633	1.500	6.760
		1.625	12.270	12.145	1.750	18.905
		1.875	11.520	11.403	2.000	30.308
		2.125	27.240	26.962	2.250	57.270
		2.375	26.290	26.022	2.500	83.292
		2.625	10.700	10.591	2.750	93.883
		2.875	4.150	4.108	3.000	97.991
		3.125	1.200	1.188	3.250	99.178
		3.375	.510	.505	3.500	99.683
		3.625	.280	.277	3.750	99.960
		3.875	.040	.040	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.030

PERCENT FINER THAN 4.00 PHI = .02 PERCENT COARSER THAN -1.00 PHI = .00

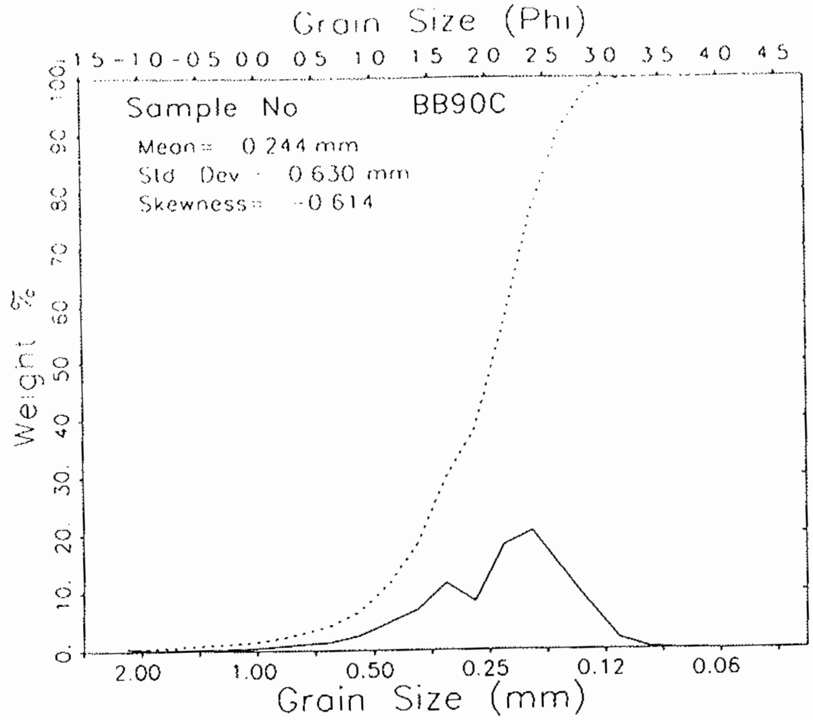
MOMENT MEASURES:

MEAN = 2.131 STANDARD DEVIATION = .499 SKEWNESS = -.830 KURTOSIS = 8.976
DISPERSION = .248 STANDARD DEVIATION = .428 DEVIATION FROM NORMAL DISTR. = -14.14%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.596	1.379	1.690	1.884	2.183	2.420	2.517	2.818	3.212

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.103	2.130	FINE SAND
STANDARD DEVIATION	.413	.425	WELL SORTED
SKEWNESS(1)	-.191	-.154	COARSE-SKEWED
SKEWNESS(2)	-.204		
KURTOSIS	.741	1.099	MESOKURTIC



? LANGUAGE=PCL3GUI

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB90C	060699					
Bigue Banks Beach Sample BB90C UBF						
		-1.125	.390	.365	-1.000	.365
		-.875	.150	.141	-.750	.506
		-.625	.230	.216	-.500	.722
		-.375	.260	.244	-.250	.965
		-.125	.280	.262	.000	1.228
		.125	.620	.581	.250	1.809
		.375	1.050	.984	.500	2.793
		.625	1.400	1.312	.750	4.105
		.875	2.670	2.502	1.000	6.607
		1.125	4.990	4.676	1.250	11.283
		1.375	7.280	6.822	1.500	18.105
		1.625	12.220	11.452	1.750	29.557
		1.875	8.850	8.294	2.000	37.850
		2.125	19.180	17.974	2.250	55.824
		2.375	21.790	20.420	2.500	76.244
		2.625	14.940	14.001	2.750	90.245
		2.875	8.120	7.609	3.000	97.854
		3.125	1.930	1.809	3.250	99.663
		3.375	.310	.291	3.500	99.953
		3.625	.050	.047	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.710

PERCENT FINER THAN 4.00 PHI = .00   PERCENT COARSER THAN -1.00 PHI = .00

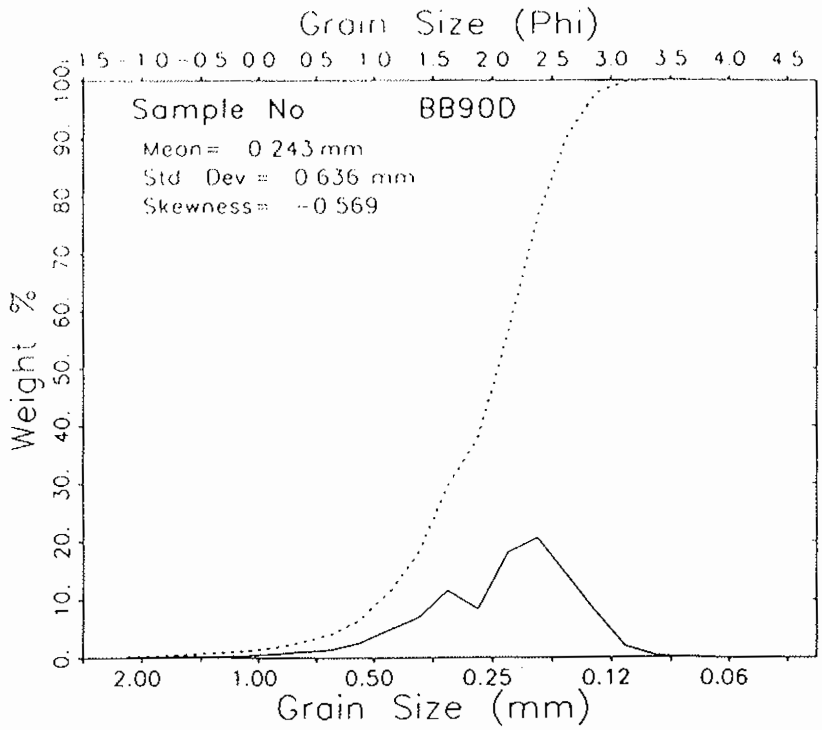
MOMENT MEASURES:

MEAN = 2.036   STANDARD DEVIATION = .666   SKEWNESS = -.614   KURTOSIS = 2.631
DISPERSION = .386   STANDARD DEVIATION = .589   DEVIATION FROM NORMAL DISTR. = -11.52%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.217	.839	1.423	1.651	2.169	2.485	2.638	2.906	3.158

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.031	2.077	FINE SAND
STANDARD DEVIATION	.608	.617	MODERATELY WELL SORTED
SKEWNESS(1)	-.228	-.257	COARSE-SKEWED
SKEWNESS(2)	-.487		
KURTOSIS	.700	1.015	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB90D	060699					
Bogue Banks Beach Samples BB90D LTT						
		-1.125	.220	.206	-1.000	.206
		-.875	.150	.141	-.750	.347
		-.625	.230	.216	-.500	.563
		-.375	.260	.244	-.250	.807
		-.125	.280	.263	.000	1.070
		.125	.620	.582	.250	1.652
		.375	1.050	.986	.500	2.638
		.625	1.400	1.314	.750	3.952
		.875	2.670	2.506	1.000	6.458
		1.125	4.990	4.684	1.250	11.141
		1.375	7.280	6.833	1.500	17.974
		1.625	12.220	11.470	1.750	29.444
		1.875	8.850	8.307	2.000	37.751
		2.125	19.180	18.003	2.250	55.754
		2.375	21.790	20.452	2.500	76.206
		2.625	14.940	14.023	2.750	90.229
		2.875	8.120	7.622	3.000	97.851
		3.125	1.930	1.812	3.250	99.662
		3.375	.310	.291	3.500	99.953
		3.625	.050	.047	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.540

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

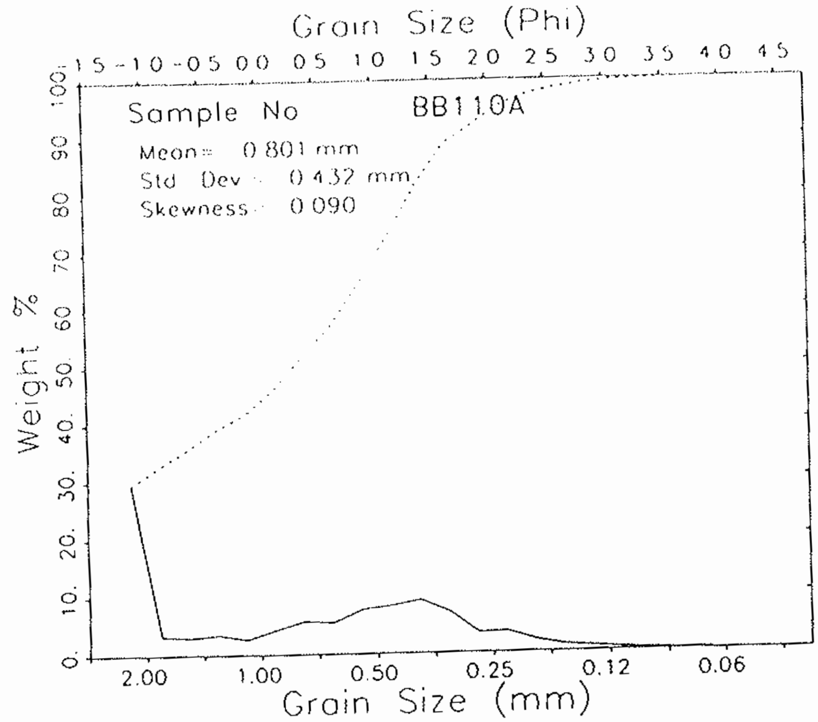
MOMENT MEASURES:

MEAN = 2.041 STANDARD DEVIATION = .654 SKEWNESS = -.569 KURTOSIS = 2.215
DISPERSION = .384 STANDARD DEVIATION = .586 DEVIATION FROM NORMAL DISTR. = -10.47%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.067	.855	1.428	1.653	2.170	2.485	2.639	2.906	3.159

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.033	2.079	FINE SAND
STANDARD DEVIATION	.606	.614	MODERATELY WELL SORTED
SKEWNESS(1)	-.226	-.254	COARSE-SKEWED
SKEWNESS(2)	-.478		
KURTOSIS	.694	1.011	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB110A	060699					
Bogue Banks Beach Samples BB110A Dune						
		-1.125	29.540	29.419	-1.000	29.419
		-.875	3.230	3.217	-.750	32.636
		-.625	3.020	3.008	-.500	35.644
		-.375	3.410	3.396	-.250	39.040
		-.125	2.630	2.619	.000	41.659
		.125	4.230	4.213	.250	45.872
		.375	5.640	5.617	.500	51.489
		.625	5.410	5.388	.750	56.877
		.875	7.620	7.589	1.000	64.466
		1.125	8.150	8.117	1.250	72.582
		1.375	9.070	9.033	1.500	81.615
		1.625	7.030	7.001	1.750	88.617
		1.875	3.360	3.346	2.000	91.963
		2.125	3.500	3.486	2.250	95.449
		2.375	1.980	1.972	2.500	97.421
		2.625	1.040	1.036	2.750	98.456
		2.875	.730	.727	3.000	99.183
		3.125	.360	.359	3.250	99.542
		3.375	.220	.219	3.500	99.761
		3.625	.130	.129	3.750	99.890
		3.875	.110	.110	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.410

PERCENT FINER THAN 4.00 PHI = .19 PERCENT COARSER THAN -1.00 PHI = .00

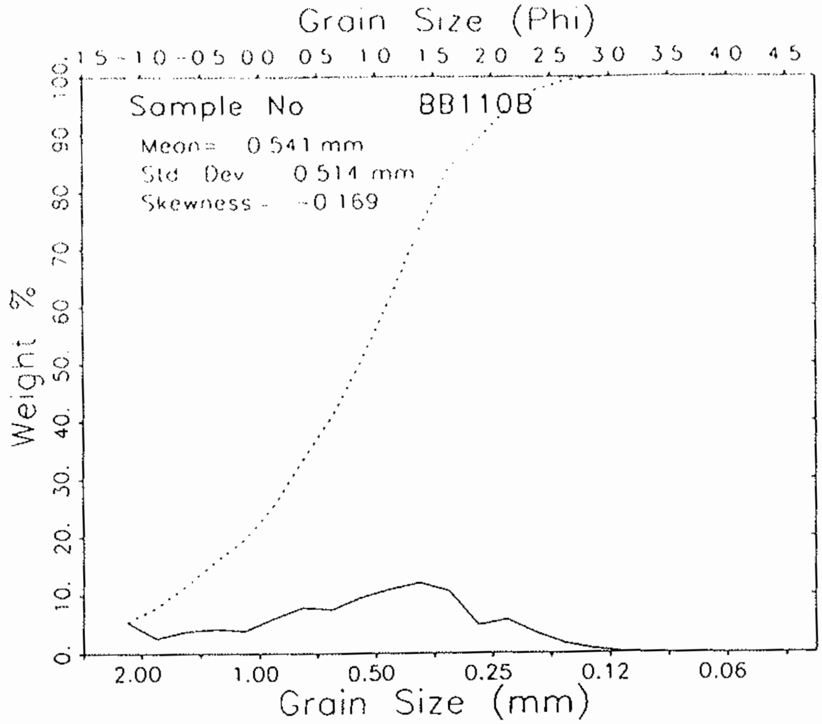
MOMENT MEASURES:

MEAN = .321 STANDARD DEVIATION = 1.212 SKEWNESS = .090 KURTOSIS = -1.145
DISPERSION = .476 STANDARD DEVIATION = .724 DEVIATION FROM NORMAL DISTR. = -40.23%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.208	-1.114	-1.038	.434	1.317	1.585	2.218	2.937

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.236	.302	COARSE SAND
STANDARD DEVIATION	1.350	1.194	POORLY SORTED
SKEWNESS(1)	-.147	-.053	NEAR SYMMETRICAL
SKEWNESS(2)	.053		
KURTOSIS	.269	.596	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB110B	060699					
Bogue Banks Beach Samples BB110B Berm						
		-1.125	5.260	5.284	-1.000	5.284
		-.875	2.550	2.562	-.750	7.845
		-.625	3.720	3.737	-.500	11.582
		-.375	4.130	4.149	-.250	15.731
		-.125	3.800	3.817	.000	19.548
		.125	5.930	5.957	.250	25.505
		.375	7.740	7.775	.500	33.280
		.625	7.470	7.504	.750	40.784
		.875	9.520	9.563	1.000	50.347
		1.125	10.890	10.939	1.250	61.286
		1.375	11.990	12.044	1.500	73.330
		1.625	10.570	10.618	1.750	83.948
		1.875	4.720	4.741	2.000	88.689
		2.125	5.610	5.635	2.250	94.324
		2.375	3.320	3.335	2.500	97.659
		2.625	1.540	1.547	2.750	99.206
		2.875	.610	.613	3.000	99.819
		3.125	.140	.141	3.250	99.960
		3.375	.040	.040	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.550

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

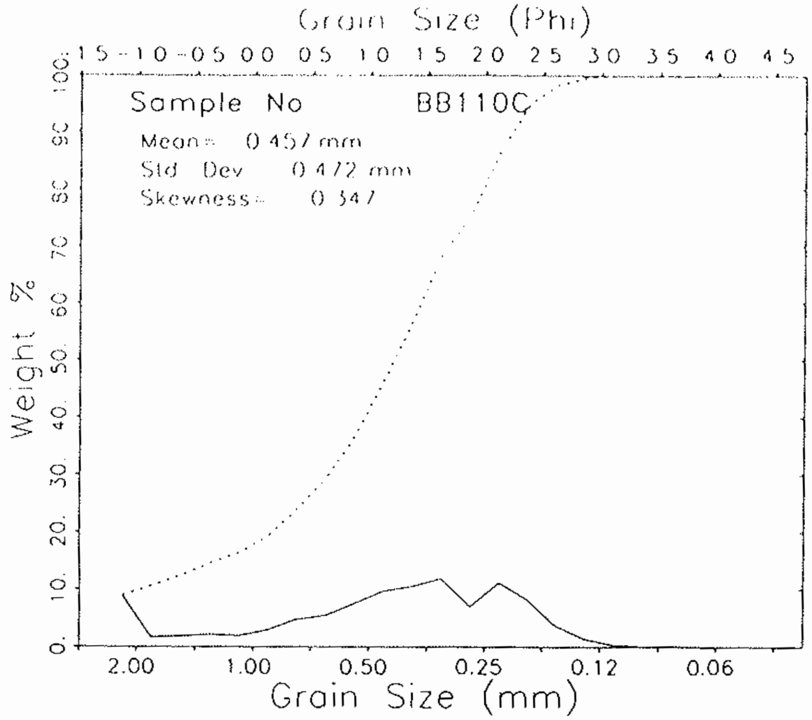
MOMENT MEASURES:

MEAN = .855 STANDARD DEVIATION = .961 SKEWNESS = -.169 KURTOSIS = -.532
DISPERSION = .561 STANDARD DEVIATION = .880 DEVIATION FROM NORMAL DISTR. = -8.39%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.203	-1.013	-.232	.229	.991	1.539	1.753	2.301	2.717

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.760	.837	COARSE SAND
STANDARD DEVIATION	.993	.998	MODERATELY SORTED
SKEWNESS(1)	-.232	-.221	COARSE-SKEWED
SKEWNESS(2)	-.350		
KURTOSIS	.669	1.036	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB110C	060699					
Bogue Banks Beach Sample BB110C MBF						
		-1.125	10.350	8.926	-1.000	8.926
		-.875	1.850	1.596	-.750	10.522
		-.625	2.100	1.811	-.500	12.333
		-.375	2.450	2.113	-.250	14.446
		-.125	2.160	1.863	.000	16.309
		.125	3.370	2.906	.250	19.215
		.375	5.480	4.726	.500	23.941
		.625	6.210	5.356	.750	29.297
		.875	8.670	7.477	1.000	36.774
		1.125	11.140	9.608	1.250	46.382
		1.375	12.070	10.410	1.500	56.792
		1.625	13.710	11.824	1.750	68.616
		1.875	7.990	6.891	2.000	75.507
		2.125	12.780	11.022	2.250	86.529
		2.375	9.480	8.176	2.500	94.705
		2.625	4.150	3.579	2.750	98.284
		2.875	1.550	1.337	3.000	99.621
		3.125	.330	.285	3.250	99.905
		3.375	.090	.078	3.500	99.983
		3.625	.020	.017	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.950

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

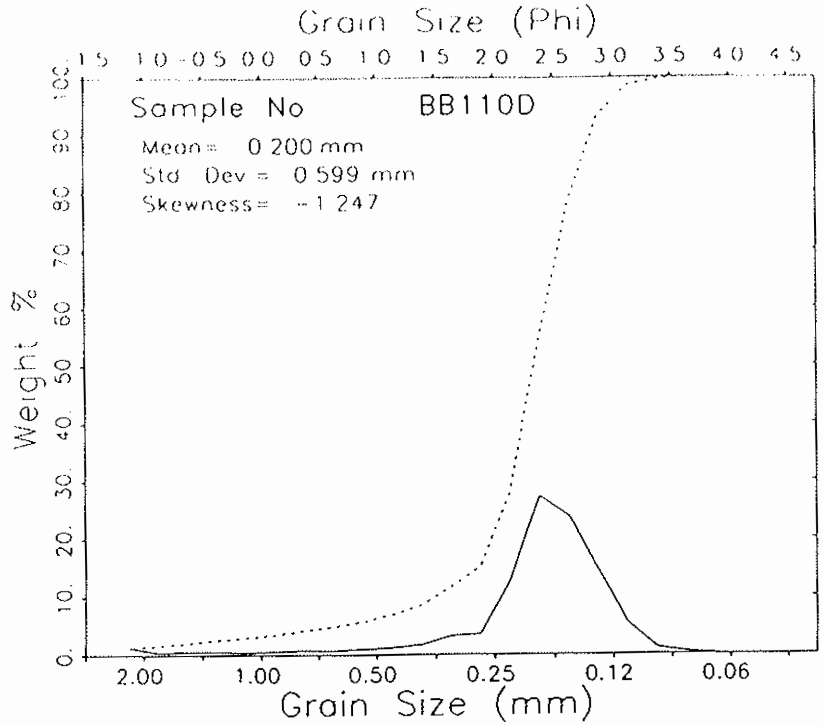
MOMENT MEASURES:

MEAN = 1.130 STANDARD DEVIATION = 1.083 SKEWNESS = -.347 KURTOSIS = -.345
DISPERSION = .550 STANDARD DEVIATION = .859 DEVIATION FROM NORMAL DISTR. = -20.64%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.222	-1.110	-.041	.549	1.337	1.982	2.193	2.521	2.884

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.076	1.163	MEDIUM SAND
STANDARD DEVIATION	1.117	1.109	POORLY SORTED
SKEWNESS(1)	-.234	-.291	COARSE-SKEWED
SKEWNESS(2)	-.565		
KURTOSIS	.625	1.039	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BB110D	060699					
Bogue Banks Beach Samples B110D LTT						
		-1.125	1.220	1.212	-1.000	1.212
		-.875	.350	.348	-.750	1.560
		-.625	.440	.437	-.500	1.997
		-.375	.480	.477	-.250	2.474
		-.125	.430	.427	.000	2.902
		.125	.540	.537	.250	3.438
		.375	.730	.725	.500	4.164
		.625	.600	.596	.750	4.760
		.875	.880	.874	1.000	5.635
		1.125	1.170	1.163	1.250	6.797
		1.375	1.640	1.630	1.500	8.427
		1.625	3.150	3.130	1.750	11.557
		1.875	3.480	3.458	2.000	15.015
		2.125	12.630	12.551	2.250	27.566
		2.375	27.360	27.189	2.500	54.755
		2.625	23.900	23.750	2.750	78.505
		2.875	14.680	14.588	3.000	93.094
		3.125	5.460	5.426	3.250	98.519
		3.375	1.060	1.053	3.500	99.573
		3.625	.350	.348	3.750	99.921
		3.875	.080	.079	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.630

PERCENT FINER THAN 4.00 PHI = .02 PERCENT COARSER THAN -1.00 PHI = .00

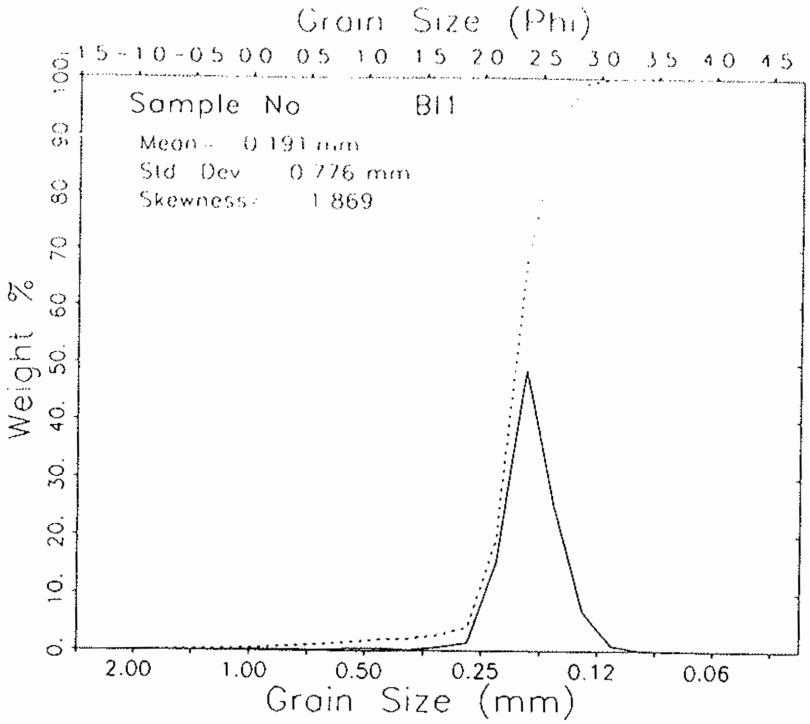
MOMENT MEASURES:

MEAN = 2.320 STANDARD DEVIATION = .739 SKEWNESS = -1.247 KURTOSIS = 7.816
DISPERSION = .307 STANDARD DEVIATION = .491 DEVIATION FROM NORMAL DISTR. = -33.62%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.044	.819	2.020	2.199	2.456	2.713	2.844	3.080	3.364

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.432	2.440	FINE SAND
STANDARD DEVIATION	.412	.550	MODERATELY WELL SORTED
SKEWNESS(1)	-.059	-.251	COARSE-SKEWED
SKEWNESS(2)	-1.220		
KURTOSIS	1.752	1.809	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B11	060699					
Bogue Banks Bogue Inlet B11 Grab						
		-1.125	.060	.060	-1.000	.060
		-.875	.060	.060	-.750	.120
		-.625	.090	.090	-.500	.210
		-.375	.090	.090	-.250	.300
		-.125	.120	.120	.000	.421
		.125	.200	.200	.250	.621
		.375	.250	.250	.500	.871
		.625	.260	.260	.750	1.132
		.875	.360	.361	1.000	1.492
		1.125	.420	.421	1.250	1.913
		1.375	.160	.160	1.500	2.073
		1.625	.580	.581	1.750	2.654
		1.875	1.290	1.292	2.000	3.946
		2.125	15.250	15.273	2.250	19.219
		2.375	48.750	48.823	2.500	68.042
		2.625	24.420	24.457	2.750	92.499
		2.875	6.610	6.620	3.000	99.119
		3.125	.790	.791	3.250	99.910
		3.375	.090	.090	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.850

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

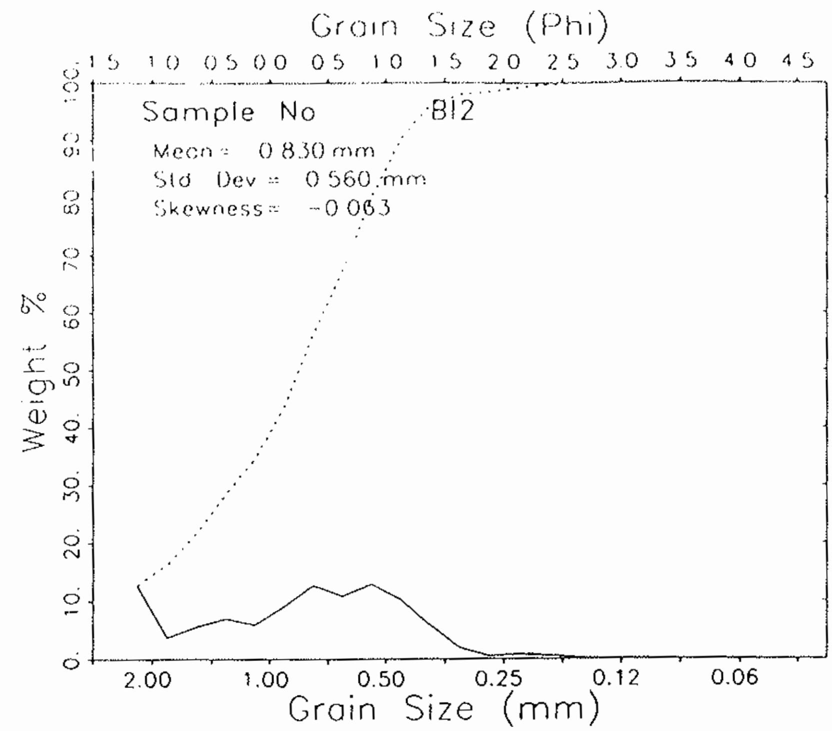
MEAN = 2.388 STANDARD DEVIATION = .366 SKEWNESS = -1.869 KURTOSIS = 24.790

DISPERSION = .014 STANDARD DEVIATION = .250 DEVIATION FROM NORMAL DISTR. = -31.67%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.624	2.017	2.197	2.280	2.408	2.571	2.663	2.844	2.996

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.430	2.423	FINE SAND
STANDARD DEVIATION	.233	.242	VERY WELL SORTED
SKEWNESS(1)	.097	.077	NEAR SYMMETRICAL
SKEWNESS(2)	.100		
KURTOSIS	.776	1.163	LEPTOKURTIC



SAMPLE NO. DATE

BI2 060699

Bogue Banks Bogue Inlet BI2 Grab

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	12.610	12.649	-1.000	12.649
-.875	3.600	3.611	-.750	16.260
-.625	5.530	5.547	-.500	21.808
-.375	6.840	6.861	-.250	28.669
-.125	5.900	5.918	.000	34.587
.125	9.050	9.078	.250	43.665
.375	12.630	12.669	.500	56.335
.625	10.760	10.793	.750	67.128
.875	12.810	12.850	1.000	79.978
1.125	10.220	10.252	1.250	90.230
1.375	5.790	5.808	1.500	96.038
1.625	1.880	1.886	1.750	97.924
1.875	.490	.492	2.000	98.415
2.125	.720	.722	2.250	99.137
2.375	.570	.572	2.500	99.709
2.625	.220	.221	2.750	99.930
2.875	.070	.070	3.000	100.000
3.125	.000	.000	3.250	100.000
3.375	.000	.000	3.500	100.000
3.625	.000	.000	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.690

PERCENT FINER THAN 4.00 PHI = .00   PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

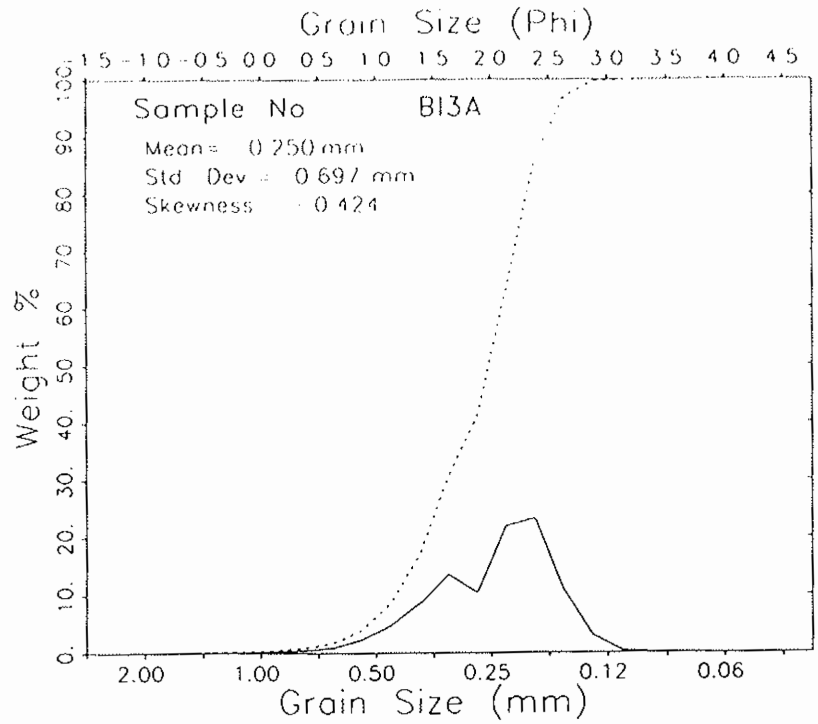
MEAN = .269   STANDARD DEVIATION = .837   SKEWNESS = -.063   KURTOSIS = -.665

DISPERSION = .466   STANDARD DEVIATION = .708   DEVIATION FROM NORMAL DISTR. = -15.36%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.230	-1.151	-.768	-.384	.375	.903	1.098	1.455	2.202

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.165	.235	COARSE SAND
STANDARD DEVIATION	.933	.861	MODERATELY SORTED
SKEWNESS(1)	-.225	-.198	COARSE-SKEWED
SKEWNESS(2)	-.239		
KURTOSIS	.397	.830	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B13A	070699					
Bogue Inlet - Station 3A						
		-1.125	.020	.020	-1.000	.020
		-.875	.060	.059	-.750	.079
		-.625	.040	.039	-.500	.118
		-.375	.040	.039	-.250	.158
		-.125	.100	.099	.000	.257
		.125	.190	.188	.250	.444
		.375	.410	.405	.500	.849
		.625	.800	.790	.750	1.638
		.875	2.260	2.231	1.000	3.869
		1.125	4.740	4.678	1.250	8.547
		1.375	8.560	8.448	1.500	16.996
		1.625	13.730	13.551	1.750	30.547
		1.875	10.520	10.383	2.000	40.930
		2.125	22.140	21.852	2.250	62.781
		2.375	23.530	23.223	2.500	86.005
		2.625	10.870	10.728	2.750	96.733
		2.875	2.920	2.882	3.000	99.615
		3.125	.320	.316	3.250	99.931
		3.375	.070	.069	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.320

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

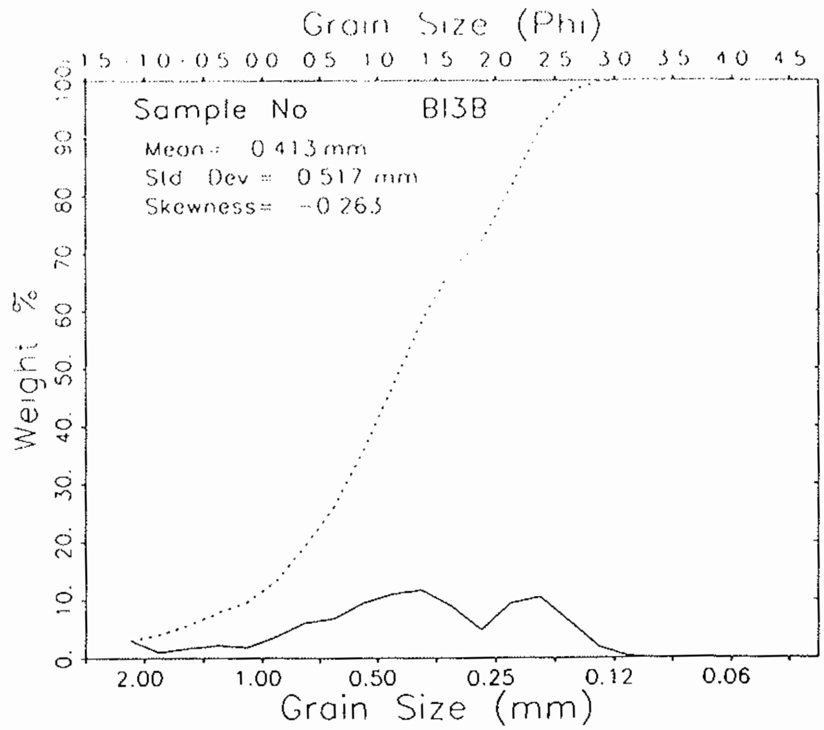
MOMENT MEASURES:

MEAN = 2.001 STANDARD DEVIATION = .521 SKEWNESS = -.424 KURTOSIS = 1.274
DISPERSION = .297 STANDARD DEVIATION = .480 DEVIATION FROM NORMAL DISTR. = -7.94%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.548	1.060	1.471	1.648	2.104	2.382	2.478	2.710	2.947

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.974	2.018	FINE SAND
STANDARD DEVIATION	.504	.502	MODERATELY WELL SORTED
SKEWNESS(1)	-.257	-.261	COARSE-SKEWED
SKEWNESS(2)	-.434		
KURTOSIS	.636	.921	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B13B	060699						
Bogue Banks Bogue Inlet B13B Middle							
		-1.125	3.710	3.059	-1.000	3.059	
		-.875	1.170	.965	-.750	4.023	
		-.625	1.950	1.608	-.500	5.631	
		-.375	2.600	2.144	-.250	7.775	
		-.125	2.220	1.830	.000	9.605	
		.125	4.560	3.760	.250	13.365	
		.375	7.380	6.085	.500	19.449	
		.625	8.220	6.777	.750	26.226	
		.875	11.450	9.440	1.000	35.667	
		1.125	13.280	10.949	1.250	46.616	
		1.375	14.090	11.617	1.500	58.232	
		1.625	10.810	8.913	1.750	67.145	
		1.875	5.790	4.774	2.000	71.919	
		2.125	11.390	9.391	2.250	81.309	
		2.375	12.740	10.504	2.500	91.813	
		2.625	7.540	6.217	2.750	98.030	
		2.875	2.160	1.781	3.000	99.810	
		3.125	.230	.190	3.250	100.000	
		3.375	.000	.000	3.500	100.000	
		3.625	.000	.000	3.750	100.000	
		3.875	.000	.000	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 121.290

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

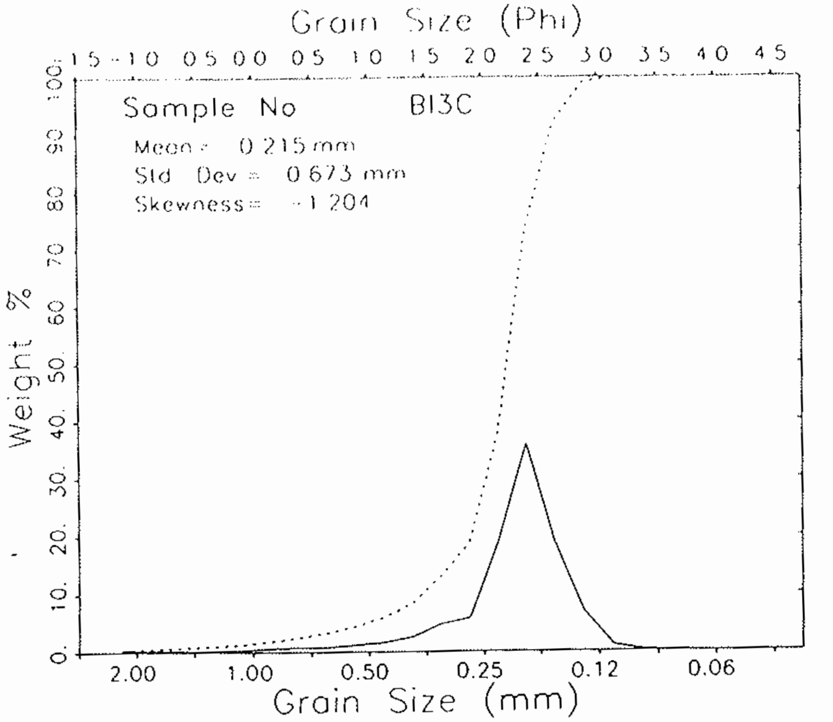
MOMENT MEASURES:

MEAN = 1.276 STANDARD DEVIATION = .953 SKEWNESS = -.263 KURTOSIS = -.164
DISPERSION = .545 STANDARD DEVIATION = .848 DEVIATION FROM NORMAL DISTR. = -10.99%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.160	-.598	.358	.705	1.323	2.082	2.314	2.628	2.886

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.336	1.332	MEDIUM SAND
STANDARD DEVIATION	.978	.978	MODERATELY SORTED
SKEWNESS(1)	.014	-.009	NEAR SYMMETRICAL
SKEWNESS(2)	-.315		
KURTOSIS	.650	.960	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
BI3C	060699					
Bogue Banks Bogue Inlet BI3C Lowe						
		-1.125	.330	.321	-1.000	.321
		-.875	.200	.195	-.750	.516
		-.625	.210	.204	-.500	.720
		-.375	.220	.214	-.250	.934
		-.125	.260	.253	.000	1.187
		.125	.530	.516	.250	1.702
		.375	.730	.710	.500	2.412
		.625	.780	.759	.750	3.171
		.875	1.170	1.138	1.000	4.309
		1.125	1.630	1.585	1.250	5.894
		1.375	2.510	2.441	1.500	8.336
		1.625	4.840	4.708	1.750	13.043
		1.875	5.850	5.690	2.000	18.734
		2.125	19.340	18.811	2.250	37.545
		2.375	36.940	35.930	2.500	73.475
		2.625	19.160	18.636	2.750	92.112
		2.875	6.990	6.799	3.000	98.911
		3.125	.960	.934	3.250	99.844
		3.375	.130	.126	3.500	99.971
		3.625	.030	.029	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.810

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

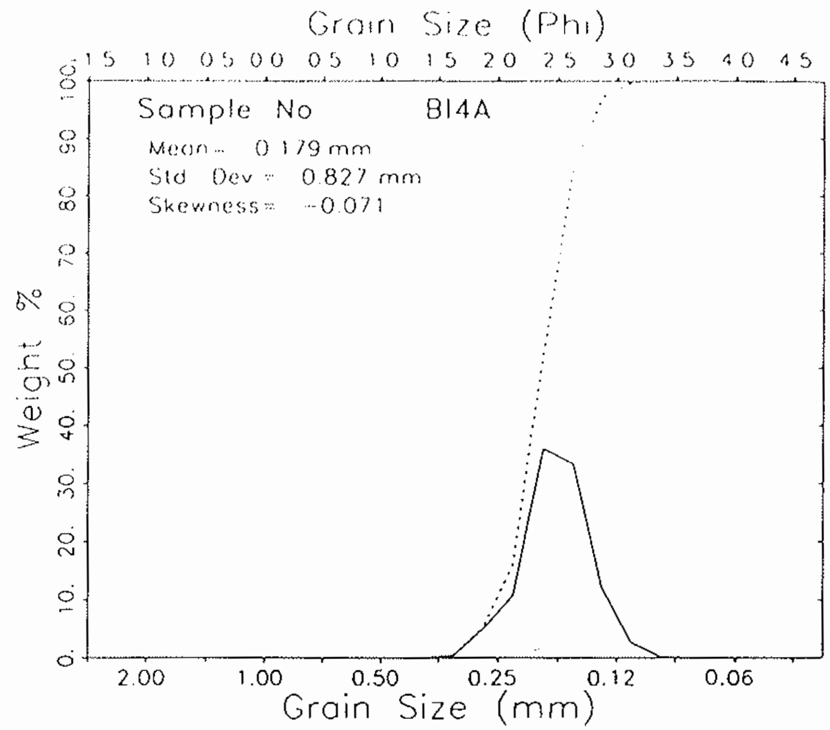
MOMENT MEASURES:

MEAN = 2.217 STANDARD DEVIATION = .571 SKEWNESS = -1.204 KURTOSIS = 8.483
DISPERSION = .231 STANDARD DEVIATION = .412 DEVIATION FROM NORMAL DISTR. = -27.91%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.185	1.109	1.880	2.083	2.337	2.520	2.641	2.856	3.024

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.261	2.206	FINE SAND
STANDARD DEVIATION	.381	.455	WELL SORTED
SKEWNESS(1)	-.200	-.303	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.930		
KURTOSIS	1.295	1.638	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BI4A	060699					
Bogue Banks Bogue Inlet B14A						
		-1.125	.000	.000	-1.000	.000
		-.875	.000	.000	-.750	.000
		-.625	.000	.000	-.500	.000
		-.375	.000	.000	-.250	.000
		-.125	.000	.000	.000	.000
		.125	.000	.000	.250	.000
		.375	.000	.000	.500	.000
		.625	.000	.000	.750	.000
		.875	.000	.000	1.000	.000
		1.125	.000	.000	1.250	.000
		1.375	.000	.000	1.500	.000
		1.625	.340	.341	1.750	.341
		1.875	4.850	4.865	2.000	5.206
		2.125	10.810	10.844	2.250	16.050
		2.375	35.910	36.022	2.500	52.071
		2.625	33.210	33.313	2.750	85.385
		2.875	11.880	11.917	3.000	97.302
		3.125	2.550	2.558	3.250	99.860
		3.375	.140	.140	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.690

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

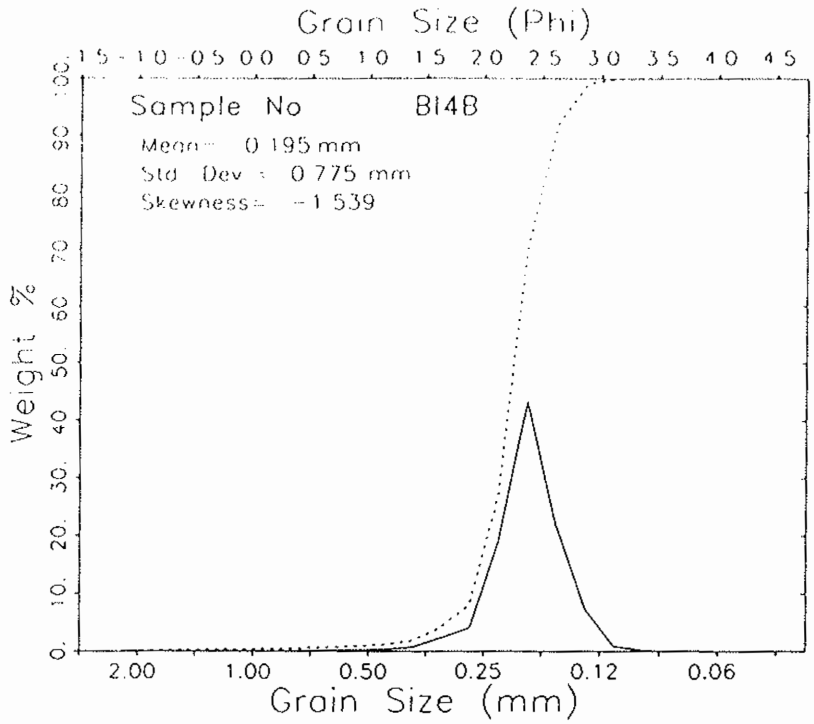
MOMENT MEASURES:

MEAN = 2.484 STANDARD DEVIATION = .274 SKEWNESS = -.071 KURTOSIS = .270
DISPERSION = .048 STANDARD DEVIATION = .271 DEVIATION FROM NORMAL DISTR. = -1.40%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.784	1.989	2.249	2.312	2.486	2.672	2.740	2.952	3.166

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.494	2.491	FINE SAND
STANDARD DEVIATION	.245	.268	VERY WELL SORTED
SKEWNESS(1)	.035	.002	NEAR SYMMETRICAL
SKEWNESS(2)	-.061		
KURTOSIS	.961	1.096	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B148	060699					
Bogue Banks Bogue Inlet B148 Lower						
		-1.125	.140	.124	-1.000	.124
		-.875	.070	.062	-.750	.187
		-.625	.090	.080	-.500	.266
		-.375	.070	.062	-.250	.329
		-.125	.060	.053	.000	.382
		.125	.090	.080	.250	.462
		.375	.120	.107	.500	.568
		.625	.110	.098	.750	.666
		.875	.210	.187	1.000	.853
		1.125	.360	.320	1.250	1.172
		1.375	.710	.631	1.500	1.803
		1.625	2.490	2.212	1.750	4.015
		1.875	4.480	3.979	2.000	7.994
		2.125	21.300	18.920	2.250	26.914
		2.375	48.890	43.427	2.500	70.341
		2.625	24.300	21.585	2.750	91.926
		2.875	8.020	7.124	3.000	99.050
		3.125	.940	.835	3.250	99.885
		3.375	.130	.115	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 112.580

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

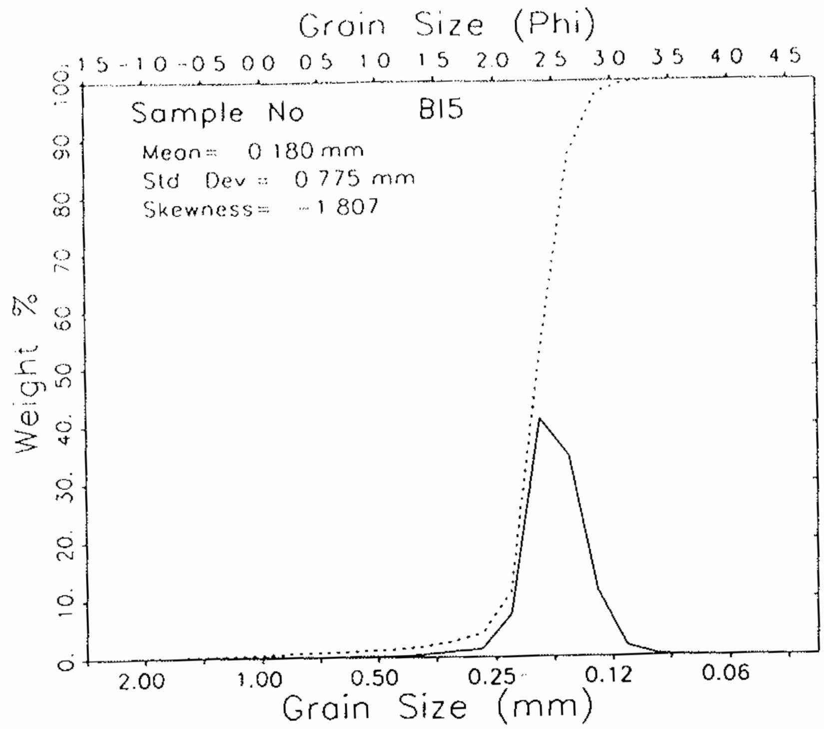
MOMENT MEASURES:

MEAN = 2.358 STANDARD DEVIATION = .367 SKEWNESS = -1.539 KURTOSIS = 22.052
DISPERSION = .078 STANDARD DEVIATION = .290 DEVIATION FROM NORMAL DISTR. = -21.17%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.115	1.812	2.106	2.225	2.383	2.554	2.658	2.850	2.998

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.382	2.382	FINE SAND
STANDARD DEVIATION	.276	.297	VERY WELL SORTED
SKEWNESS(1)	-.003	-.048	NEAR SYMMETRICAL
SKEWNESS(2)	-.174		
KURTOSIS	.893	1.302	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B15	D60699					
Bogue Banks Bogue Inlet B15 Grab						
		-1.125	.060	.059	-1.000	.059
		-.875	.050	.049	-.750	.108
		-.625	.080	.079	-.500	.187
		-.375	.130	.128	-.250	.315
		-.125	.110	.108	.000	.423
		.125	.190	.187	.250	.611
		.375	.170	.167	.500	.778
		.625	.150	.148	.750	.926
		.875	.190	.187	1.000	1.113
		1.125	.220	.217	1.250	1.329
		1.375	.410	.404	1.500	1.733
		1.625	.880	.867	1.750	2.600
		1.875	1.330	1.310	2.000	3.909
		2.125	7.450	7.336	2.250	11.246
		2.375	41.680	41.044	2.500	52.290
		2.625	35.090	34.554	2.750	86.844
		2.875	11.250	11.078	3.000	97.922
		3.125	1.730	1.704	3.250	99.626
		3.375	.310	.305	3.500	99.931
		3.625	.070	.069	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.550

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

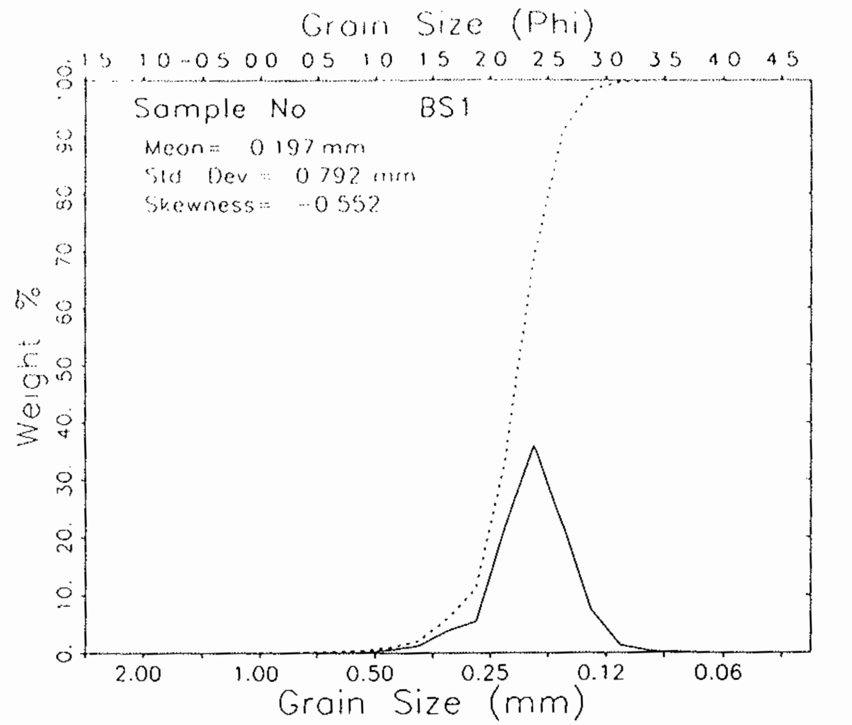
MOMENT MEASURES:

MEAN = 2.470 STANDARD DEVIATION = .367 SKEWNESS = -1.807 KURTOSIS = 25.170
DISPERSION = .035 STANDARD DEVIATION = .262 DEVIATION FROM NORMAL DISTR. = -28.60%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.849	2.037	2.279	2.334	2.486	2.664	2.729	2.934	3.158

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.504	2.498	FINE SAND
STANDARD DEVIATION	.225	.249	VERY WELL SORTED
SKEWNESS(1)	.081	.040	NEAR SYMMETRICAL
SKEWNESS(2)	-.002		
KURTOSIS	.991	1.112	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bs1	060699					
Bogue Banks Bogue Sound BS1 Surface						
		-1.125	.000	.000	-1.000	.000
		-.875	.000	.000	-.750	.000
		-.625	.040	.039	-.500	.039
		-.375	.020	.019	-.250	.058
		-.125	.030	.029	.000	.087
		.125	.040	.039	.250	.126
		.375	.060	.058	.500	.185
		.625	.080	.078	.750	.262
		.875	.180	.175	1.000	.437
		1.125	.450	.437	1.250	.875
		1.375	1.170	1.137	1.500	2.012
		1.625	3.860	3.753	1.750	5.765
		1.875	5.560	5.405	2.000	11.171
		2.125	22.380	21.758	2.250	32.928
		2.375	37.000	35.971	2.500	68.899
		2.625	22.790	22.156	2.750	91.056
		2.875	7.540	7.330	3.000	98.386
		3.125	1.220	1.186	3.250	99.572
		3.375	.310	.301	3.500	99.874
		3.625	.130	.126	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.860

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

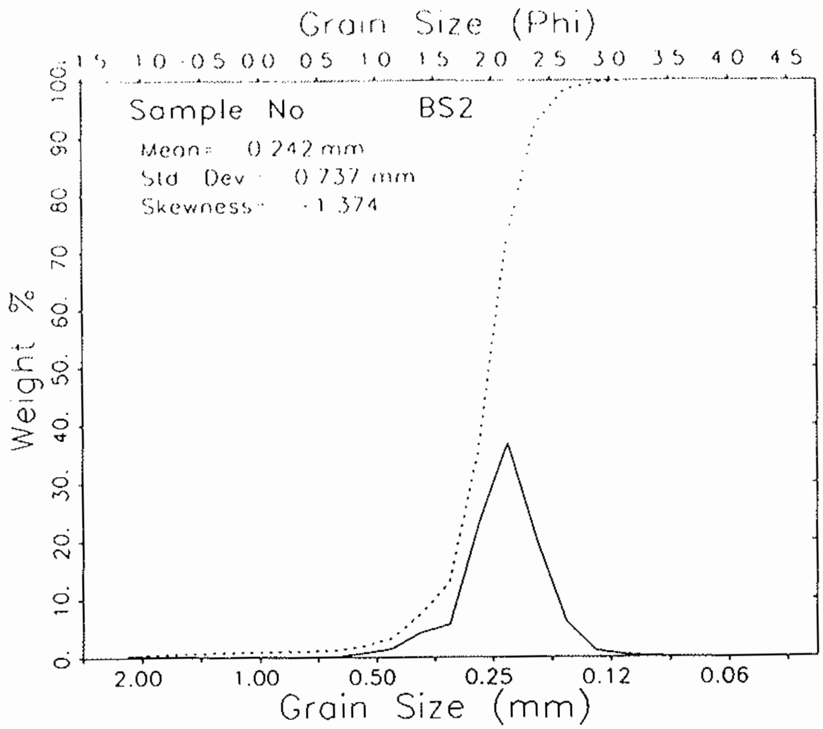
MEAN = 2.346 STANDARD DEVIATION = .356 SKEWNESS = -.552 KURTOSIS = 5.481

DISPERSION = .132 STANDARD DEVIATION = .328 DEVIATION FROM NORMAL DISTR. = -7.91%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.277	1.699	2.055	2.159	2.369	2.569	2.670	2.885	3.129

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.363	2.365	FINE SAND
STANDARD DEVIATION	.307	.333	VERY WELL SORTED
SKEWNESS(1)	-.019	-.074	NEAR SYMMETRICAL
SKEWNESS(2)	-.250		
KURTOSIS	.928	1.185	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BS2	060699					
Bogue Banks Bogue Sound BS2 (-2.5')						
		-1.125	.340	.343	-1.000	.343
		-.875	.180	.182	-.750	.525
		-.625	.210	.212	-.500	.736
		-.375	.030	.030	-.250	.767
		-.125	.110	.111	.000	.878
		.125	.120	.121	.250	.999
		.375	.060	.061	.500	1.059
		.625	.090	.091	.750	1.150
		.875	.660	.666	1.000	1.816
		1.125	1.370	1.382	1.250	3.198
		1.375	4.080	4.116	1.500	7.314
		1.625	5.480	5.528	1.750	12.842
		1.875	22.660	22.859	2.000	35.701
		2.125	36.530	36.851	2.250	72.551
		2.375	19.730	19.903	2.500	92.454
		2.625	5.960	6.012	2.750	98.467
		2.875	1.050	1.059	3.000	99.526
		3.125	.360	.363	3.250	99.889
		3.375	.110	.111	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.130

PERCENT FINER THAN 4.00 PHI = .00   PERCENT COARSER THAN -1.00 PHI = .00

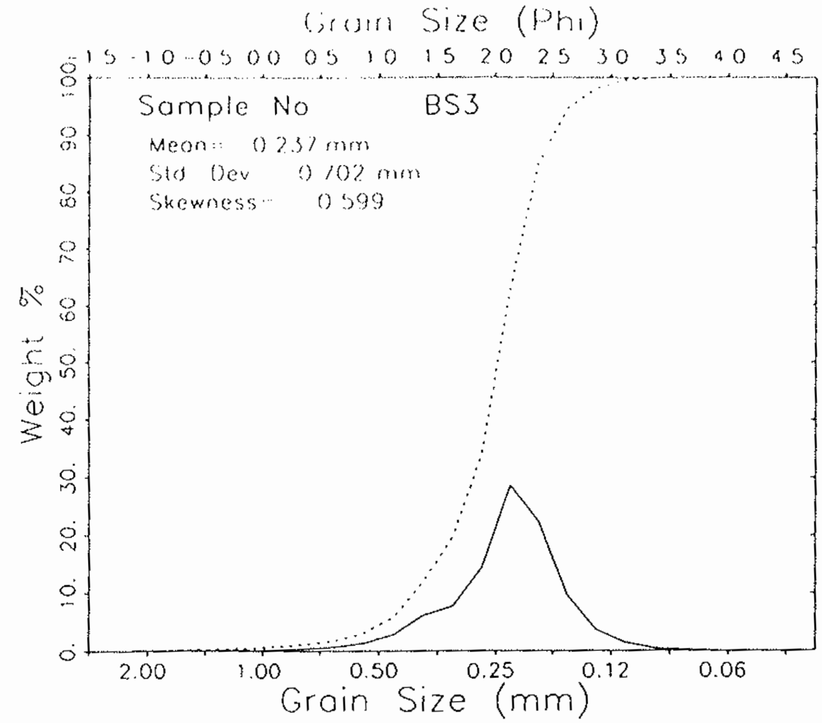
MOMENT MEASURES:

MEAN = 2.049   STANDARD DEVIATION = .440   SKEWNESS = -1.374   KURTOSIS = 15.852
DISPERSION = .149   STANDARD DEVIATION = .341   DEVIATION FROM NORMAL DISTR. = -22.53%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.255	1.359	1.785	1.883	2.097	2.281	2.394	2.606	2.876

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.089	2.092	FINE SAND
STANDARD DEVIATION	.305	.341	VERY WELL SORTED
SKEWNESS(1)	-.026	-.105	COARSE-SKEWED
SKEWNESS(2)	-.375		
KURTOSIS	1.046	1.284	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BS3	060699					
Bogue Banks Bogue Sound BS3 Surface						
		-1.125	.110	.100	-1.000	.100
		-.875	.030	.027	-.750	.127
		-.625	.110	.100	-.500	.227
		-.375	.180	.164	-.250	.391
		-.125	.110	.100	.000	.491
		.125	.260	.236	.250	.727
		.375	.450	.409	.500	1.136
		.625	.670	.609	.750	1.746
		.875	1.440	1.309	1.000	3.055
		1.125	3.070	2.791	1.250	5.846
		1.375	6.630	6.028	1.500	11.874
		1.625	8.440	7.673	1.750	19.547
		1.875	15.820	14.383	2.000	33.930
		2.125	31.550	28.684	2.250	62.615
		2.375	24.570	22.338	2.500	84.953
		2.625	10.550	9.592	2.750	94.545
		2.875	3.920	3.564	3.000	98.109
		3.125	1.510	1.373	3.250	99.482
		3.375	.460	.418	3.500	99.900
		3.625	.110	.100	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.990

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

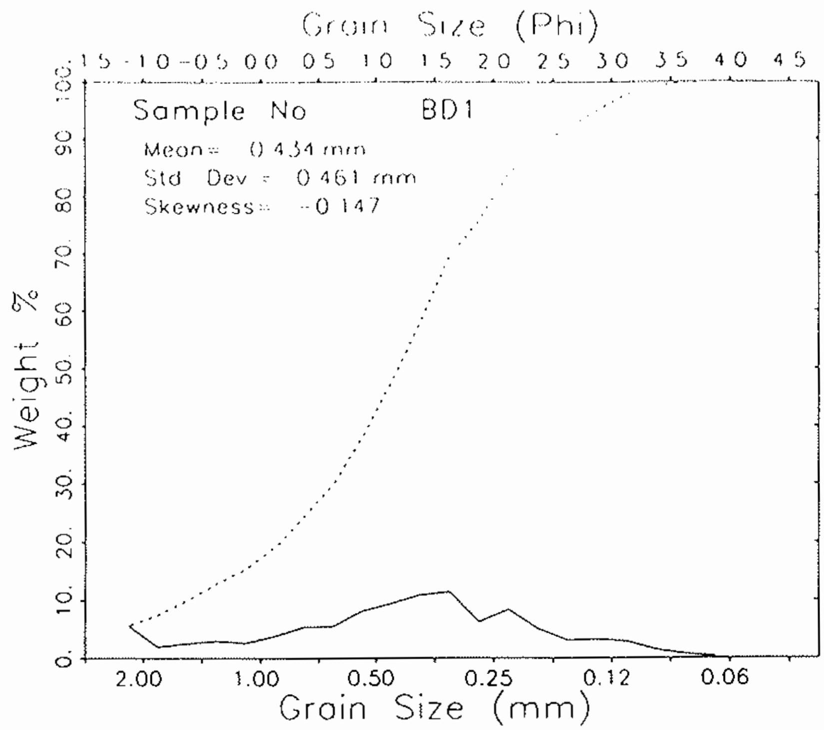
MOMENT MEASURES:

MEAN = 2.078 STANDARD DEVIATION = .510 SKEWNESS = -.599 KURTOSIS = 4.166
DISPERSION = .279 STANDARD DEVIATION = .460 DEVIATION FROM NORMAL DISTR. = -9.85%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.417	1.174	1.634	1.845	2.140	2.389	2.489	2.782	3.162

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.062	2.088	FINE SAND
STANDARD DEVIATION	.427	.457	WELL SORTED
SKEWNESS(1)	-.183	-.192	COARSE-SKEWED
SKEWNESS(2)	-.379		
KURTOSIS	.881	1.212	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BD1	060699					
Bogue Banks USACE Disposal at Plum						
		-1.125	5.520	5.547	-1.000	5.547
		-.875	1.860	1.869	-.750	7.416
		-.625	2.470	2.482	-.500	9.898
		-.375	2.870	2.884	-.250	12.781
		-.125	2.530	2.542	.000	15.324
		.125	3.740	3.758	.250	19.082
		.375	5.310	5.336	.500	24.417
		.625	5.360	5.386	.750	29.803
		.875	8.020	8.059	1.000	37.862
		1.125	9.270	9.315	1.250	47.176
		1.375	10.730	10.782	1.500	57.958
		1.625	11.370	11.425	1.750	69.383
		1.875	6.160	6.190	2.000	75.573
		2.125	8.300	8.340	2.250	83.913
		2.375	4.920	4.944	2.500	88.857
		2.625	2.940	2.954	2.750	91.811
		2.875	3.130	3.145	3.000	94.956
		3.125	2.810	2.824	3.250	97.779
		3.375	1.410	1.417	3.500	99.196
		3.625	.600	.603	3.750	99.799
		3.875	.200	.201	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.520

PERCENT FINER THAN 4.00 PHI = .34 PERCENT COARSER THAN -1.00 PHI = .00

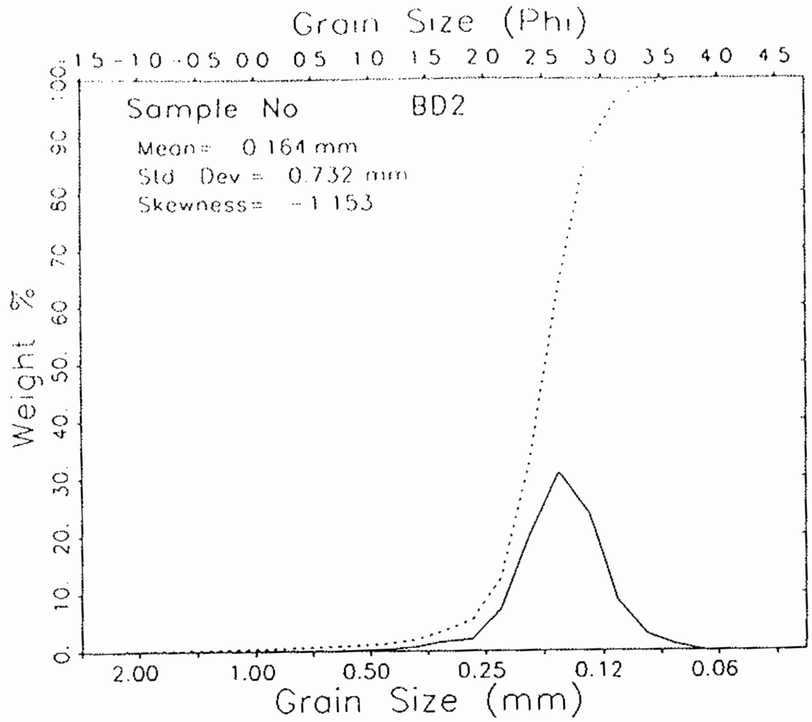
MOMENT MEASURES:

MEAN = 1.204 STANDARD DEVIATION = 1.117 SKEWNESS = -.147 KURTOSIS = -.336
DISPERSION = .621 STANDARD DEVIATION = 1.011 DEVIATION FROM NORMAL DISTR. = -9.45%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.205	-1.025	.045	.527	1.315	1.977	2.254	3.004	3.465

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.150	1.205	MEDIUM SAND
STANDARD DEVIATION	1.105	1.163	POORLY SORTED
SKEWNESS(1)	-.150	-.156	COARSE-SKEWED
SKEWNESS(2)	-.295		
KURTOSIS	.823	1.139	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BD2	060699					
Bogue Banks USACE disposal BD2 100M Plum						
		-1.125	.120	.111	-1.000	.111
		-.875	.080	.074	-.750	.186
		-.625	.080	.074	-.500	.260
		-.375	.080	.074	-.250	.334
		-.125	.080	.074	.000	.408
		.125	.110	.102	.250	.511
		.375	.130	.121	.500	.631
		.625	.140	.130	.750	.761
		.875	.200	.186	1.000	.947
		1.125	.320	.297	1.250	1.244
		1.375	.640	.594	1.500	1.838
		1.625	1.630	1.513	1.750	3.351
		1.875	2.090	1.940	2.000	5.291
		2.125	7.800	7.240	2.250	12.531
		2.375	21.650	20.097	2.500	32.628
		2.625	33.290	30.901	2.750	63.529
		2.875	25.850	23.995	3.000	87.524
		3.125	9.310	8.642	3.250	96.166
		3.375	3.050	2.831	3.500	98.997
		3.625	1.080	1.003	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.730

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

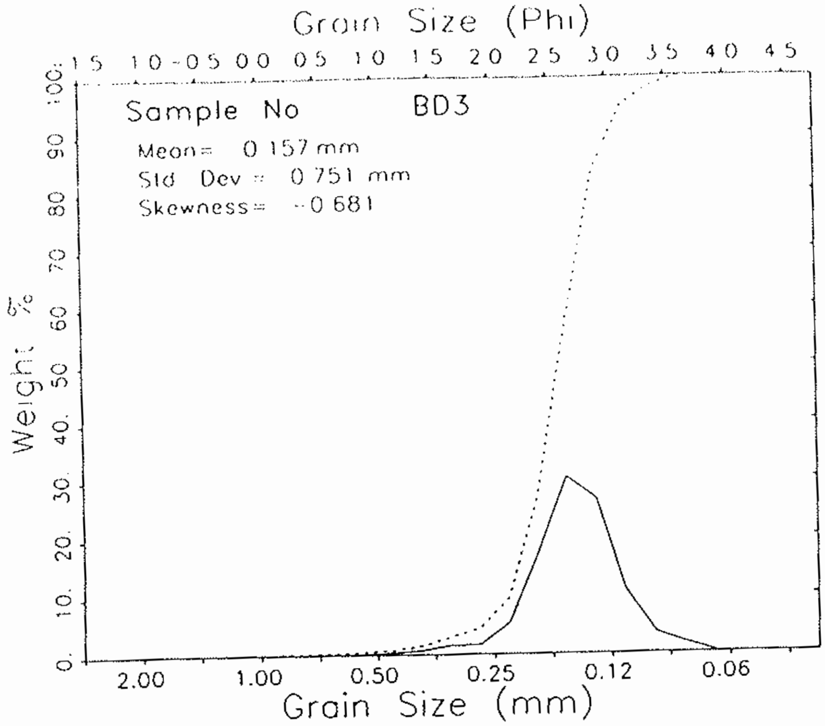
MOMENT MEASURES:

MEAN = 2.607 STANDARD DEVIATION = .451 SKEWNESS = -1.153 KURTOSIS = 13.763
DISPERSION = .192 STANDARD DEVIATION = .377 DEVIATION FROM NORMAL DISTR. = -16.45%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.045	1.962	2.293	2.405	2.641	2.870	2.963	3.216	3.501

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.628	2.632	FINE SAND
STANDARD DEVIATION	.335	.357	WELL SORTED
SKEWNESS(1)	-.037	-.059	NEAR SYMMETRICAL
SKEWNESS(2)	-.153		
KURTOSIS	.871	1.106	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BD3	060699					
Bogue Banks USACE Disposal BD3 500M Plum						
		-1.125	.020	.019	-1.000	.019
		-.875	.020	.019	-.750	.037
		-.625	.030	.028	-.500	.065
		-.375	.030	.028	-.250	.093
		-.125	.030	.028	.000	.121
		.125	.060	.056	.250	.177
		.375	.070	.065	.500	.243
		.625	.080	.075	.750	.317
		.875	.170	.159	1.000	.476
		1.125	.300	.280	1.250	.756
		1.375	.700	.654	1.500	1.410
		1.625	1.570	1.466	1.750	2.876
		1.875	1.620	1.513	2.000	4.389
		2.125	5.650	5.276	2.250	9.665
		2.375	18.490	17.266	2.500	26.931
		2.625	32.400	30.255	2.750	57.186
		2.875	28.580	26.688	3.000	83.873
		3.125	11.610	10.841	3.250	94.715
		3.375	3.690	3.446	3.500	98.160
		3.625	1.840	1.718	3.750	99.879
		3.875	.130	.121	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.090

PERCENT FINER THAN 4.00 PHI = .41   PERCENT COARSER THAN -1.00 PHI = .00

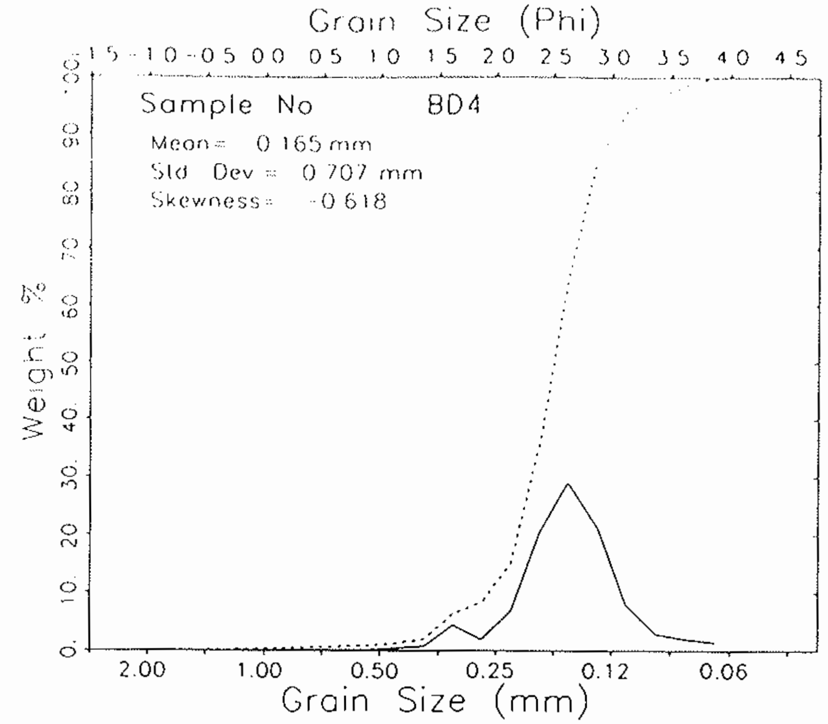
MOMENT MEASURES:

MEAN = 2.672   STANDARD DEVIATION = .413   SKEWNESS = -.681   KURTOSIS = 7.561
DISPERSION = .187   STANDARD DEVIATION = .372   DEVIATION FROM NORMAL DISTR. = -9.97%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.343	2.029	2.342	2.472	2.691	2.917	3.003	3.271	3.622

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	2.672	2.678	FINE SAND
STANDARD DEVIATION	.331	.353	WELL SORTED
SKEWNESS(1)	-.055	-.061	NEAR SYMMETRICAL
SKEWNESS(2)	-.123		
KURTOSIS	.878	1.144	LEPTOKURTIC



SAMPLE NO. DATE

BD4 060699

Bogue Banks USACE Disposal BD4 2' below

MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.050	.049	-1.000	.049
-.875	.040	.039	-.750	.087
-.625	.070	.068	-.500	.155
-.375	.060	.058	-.250	.213
-.125	.100	.097	.000	.310
.125	.130	.126	.250	.437
.375	.170	.165	.500	.602
.625	.150	.146	.750	.747
.875	.130	.126	1.000	.873
1.125	.370	.359	1.250	1.232
1.375	.710	.689	1.500	1.921
1.625	4.560	4.424	1.750	6.346
1.875	1.950	1.892	2.000	8.238
2.125	7.010	6.802	2.250	15.039
2.375	21.130	20.502	2.500	35.541
2.625	29.883	28.995	2.750	64.536
2.875	22.020	21.366	3.000	85.902
3.125	8.160	7.917	3.250	93.819
3.375	2.950	2.862	3.500	96.682
3.625	1.990	1.931	3.750	98.612
3.875	1.430	1.388	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.063

PERCENT FINER THAN 4.00 PHI = 1.00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

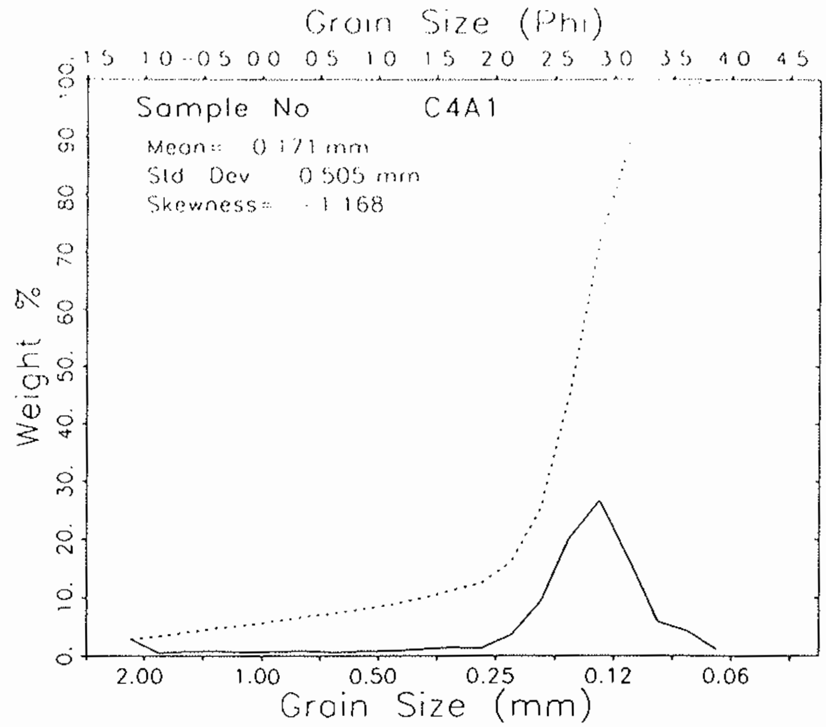
MEAN = 2.597 STANDARD DEVIATION = .500 SKEWNESS = -.618 KURTOSIS = 6.563

DISPERSION = .250 STANDARD DEVIATION = .430 DEVIATION FROM NORMAL DISTR. = -14.00%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.088	1.674	2.262	2.371	2.625	2.872	2.978	3.353	3.820

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	2.620	2.621	FINE SAND
STANDARD DEVIATION	.358	.433	WELL SORTED
SKEWNESS(1)	-.014	-.073	NEAR SYMMETRICAL
SKEWNESS(2)	-.310		
KURTOSIS	1.345	1.374	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
c4a1	060699						
Bogue Banks C4A1 0-2.2							
		-1.125	3.080		2.861	-1.000	2.861
		-.875	.470		.437	-.750	3.298
		-.625	.730		.678	-.500	3.976
		-.375	.780		.725	-.250	4.700
		-.125	.560		.520	.000	5.221
		.125	.760		.706	.250	5.927
		.375	.820		.762	.500	6.688
		.625	.630		.585	.750	7.274
		.875	.810		.752	1.000	8.026
		1.125	.870		.808	1.250	8.834
		1.375	1.100		1.022	1.500	9.856
		1.625	1.480		1.375	1.750	11.231
		1.875	1.270		1.180	2.000	12.411
		2.125	3.770		3.502	2.250	15.913
		2.375	10.150		9.429	2.500	25.341
		2.625	21.970		20.409	2.750	45.750
		2.875	28.660		26.623	3.000	72.373
		3.125	17.890		16.619	3.250	88.992
		3.375	6.260		5.815	3.500	94.807
		3.625	4.500		4.180	3.750	98.987
		3.875	1.090		1.013	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.650

PERCENT FINER THAN 4.00 PHI = .55 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.544 STANDARD DEVIATION = .986 SKEWNESS = -1.168 KURTOSIS = 5.469

DISPERSION = .361 STANDARD DEVIATION = .556 DEVIATION FROM NORMAL DISTR. = -43.63%

PERCENTILES:

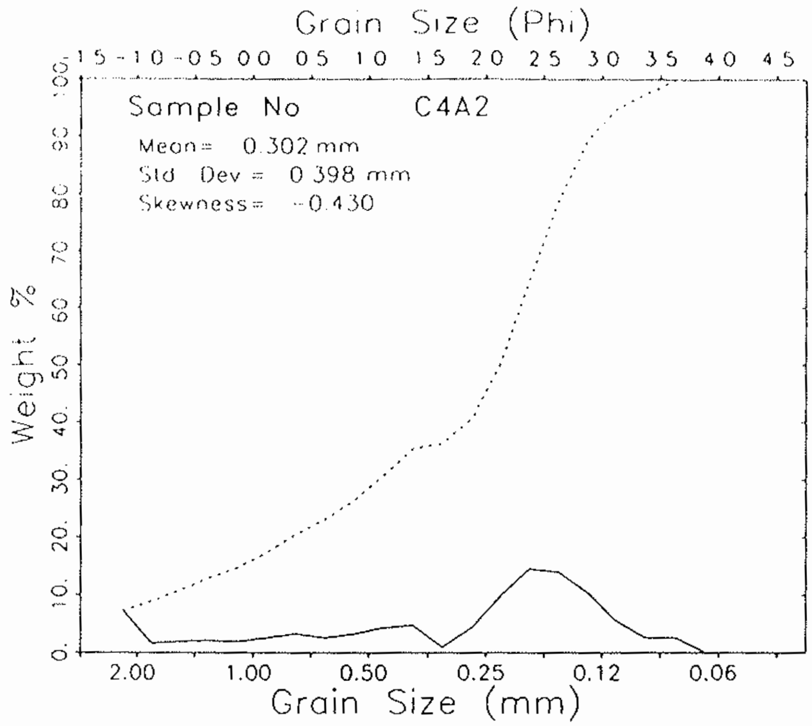
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.163	-.106	2.252	2.491	2.790	3.040	3.175	3.512	3.753

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.714	2.739	FINE SAND
STANDARD DEVIATION	.461	.779	MODERATELY SORTED
SKEWNESS(1)	-.165	-.383	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-2.357		
KURTOSIS	2.921	2.703	VERY LEPTOKURTIC

.779

MODERATELY SORTED

SKEWNESS(1) -.165



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C4A2	060699					
Bogue Banks C4A2 0-2.7						
		-1.125	7.340	7.280	-1.000	7.280
		-.875	1.630	1.617	-.750	8.897
		-.625	1.900	1.885	-.500	10.782
		-.375	2.110	2.093	-.250	12.874
		-.125	1.870	1.855	.000	14.729
		.125	2.610	2.589	.250	17.318
		.375	3.280	3.253	.500	20.571
		.625	2.590	2.569	.750	23.140
		.875	3.230	3.204	1.000	26.344
		1.125	4.310	4.275	1.250	30.619
		1.375	4.740	4.701	1.500	35.320
		1.625	.910	.903	1.750	36.223
		1.875	4.320	4.285	2.000	40.508
		2.125	9.930	9.849	2.250	50.357
		2.375	14.580	14.461	2.500	64.818
		2.625	14.080	13.965	2.750	78.784
		2.875	10.590	10.504	3.000	89.288
		3.125	5.530	5.485	3.250	94.773
		3.375	2.590	2.569	3.500	97.342
		3.625	2.580	2.559	3.750	99.901
		3.875	.100	.099	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.820

PERCENT FINER THAN 4.00 PHI = 5.11 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.725 STANDARD DEVIATION = 1.329 SKEWNESS = -.430 KURTOSIS = -.389

DISPERSION = .582 STANDARD DEVIATION = .925 DEVIATION FROM NORMAL DISTR. = -30.41%

PERCENTILES:

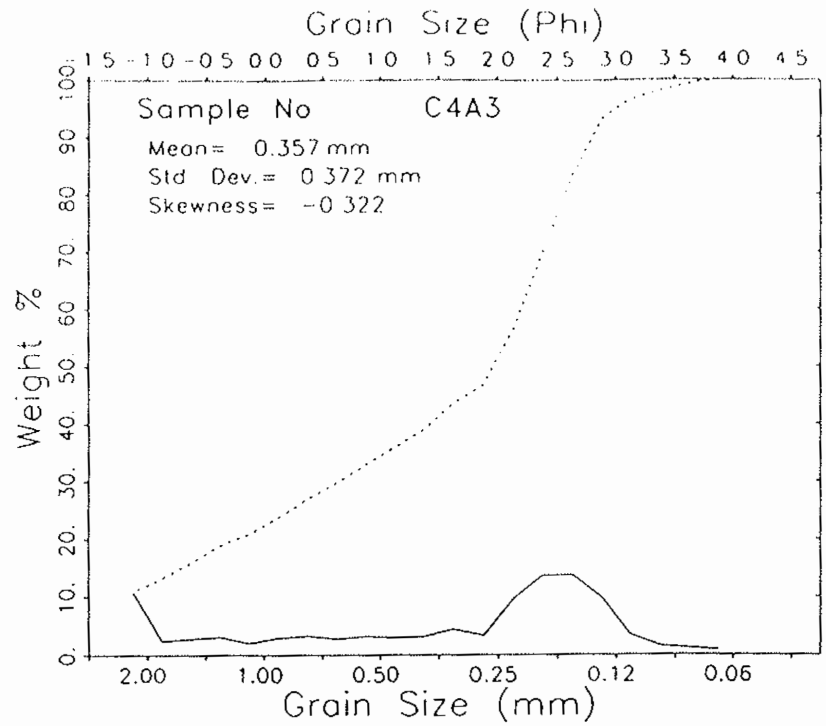
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.216	-1.078	.123	.895	2.241	2.682	2.874	3.272	3.662

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.498	1.746	MEDIUM SAND
STANDARD DEVIATION	1.376	1.347	POORLY SORTED
SKEWNESS(1)	-.540	-.533	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.832		
KURTOSIS	.581	.998	MESOKURTIC

1.347

POORLY SORTED

SKEWNESS(1) -.540



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C4A3	060699					
Bogue Banks C4A3 Comp						
		-1.125	11.800	10.823	-1.000	10.823
		-.875	2.580	2.366	-.750	13.189
		-.625	2.980	2.733	-.500	15.922
		-.375	3.310	3.036	-.250	18.958
		-.125	2.120	1.944	.000	20.903
		.125	3.140	2.880	.250	23.782
		.375	3.520	3.228	.500	27.011
		.625	3.000	2.752	.750	29.762
		.875	3.430	3.146	1.000	32.908
		1.125	3.280	3.008	1.250	35.917
		1.375	3.390	3.109	1.500	39.026
		1.625	4.800	4.402	1.750	43.428
		1.875	3.610	3.311	2.000	46.739
		2.125	10.300	9.447	2.250	56.186
		2.375	14.790	13.565	2.500	69.751
		2.625	14.840	13.611	2.750	83.362
		2.875	10.660	9.777	3.000	93.140
		3.125	3.720	3.412	3.250	96.551
		3.375	1.630	1.495	3.500	98.046
		3.625	1.270	1.165	3.750	99.211
		3.875	.860	.789	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.030

PERCENT FINER THAN 4.00 PHI = 3.04 PERCENT COARSER THAN -1.00 PHI = .00

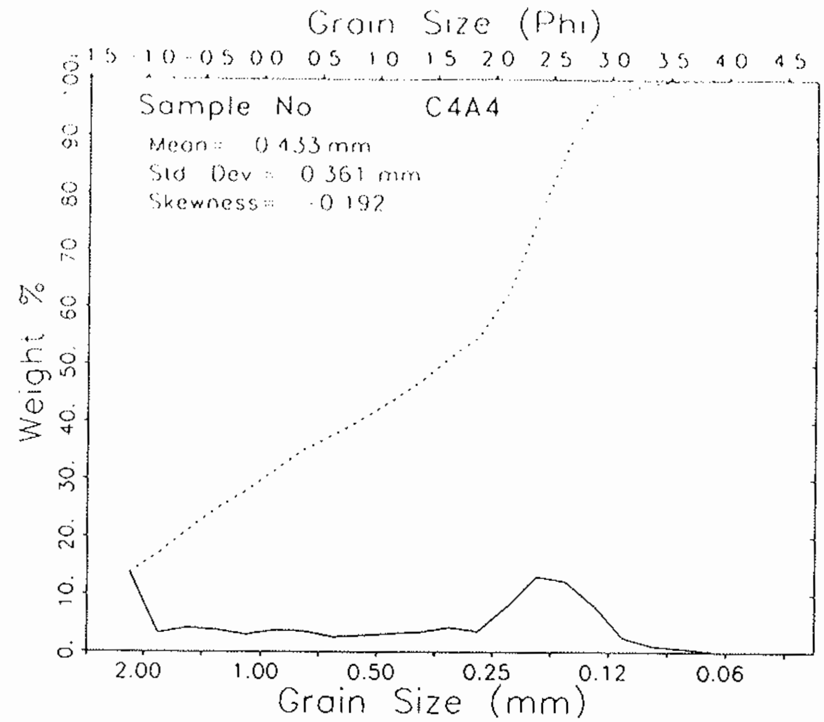
MOMENT MEASURES:

MEAN = 1.488 STANDARD DEVIATION = 1.427 SKEWNESS = -.322 KURTOSIS = -.922
DISPERSION = .595 STANDARD DEVIATION = .951 DEVIATION FROM NORMAL DISTR. = -33.33%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.135	-.494	.344	2.086	2.596	2.766	3.136	3.705

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.136	1.453	MEDIUM SAND
STANDARD DEVIATION	1.630	1.462	POORLY SORTED
SKEWNESS(1)	-.503	-.546	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.666		
KURTOSIS	.310	.777	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C4A4	060699						
Bogue Banks C4A4 0-2.5							
		-1.125	14.340		13.758	-1.000	13.758
		-.875	3.380		3.243	-.750	17.001
		-.625	4.270		4.097	-.500	21.098
		-.375	4.000		3.838	-.250	24.935
		-.125	3.120		2.993	.000	27.929
		.125	3.880		3.723	.250	31.651
		.375	3.680		3.531	.500	35.182
		.625	2.670		2.562	.750	37.743
		.875	2.940		2.821	1.000	40.564
		1.125	3.260		3.128	1.250	43.692
		1.375	3.530		3.387	1.500	47.079
		1.625	4.400		4.221	1.750	51.300
		1.875	3.670		3.521	2.000	54.821
		2.125	8.310		7.973	2.250	62.794
		2.375	13.580		13.029	2.500	75.823
		2.625	12.720		12.204	2.750	88.026
		2.875	8.360		8.021	3.000	96.047
		3.125	2.450		2.351	3.250	98.398
		3.375	.980		.940	3.500	99.338
		3.625	.590		.566	3.750	99.904
		3.875	.100		.096	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.230

PERCENT FINER THAN 4.00 PHI = 1.07 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.207 STANDARD DEVIATION = 1.471 SKEWNESS = -.192 KURTOSIS = -1.347

DISPERSION = .592 STANDARD DEVIATION = .945 DEVIATION FROM NORMAL DISTR. = -35.74%

PERCENTILES:

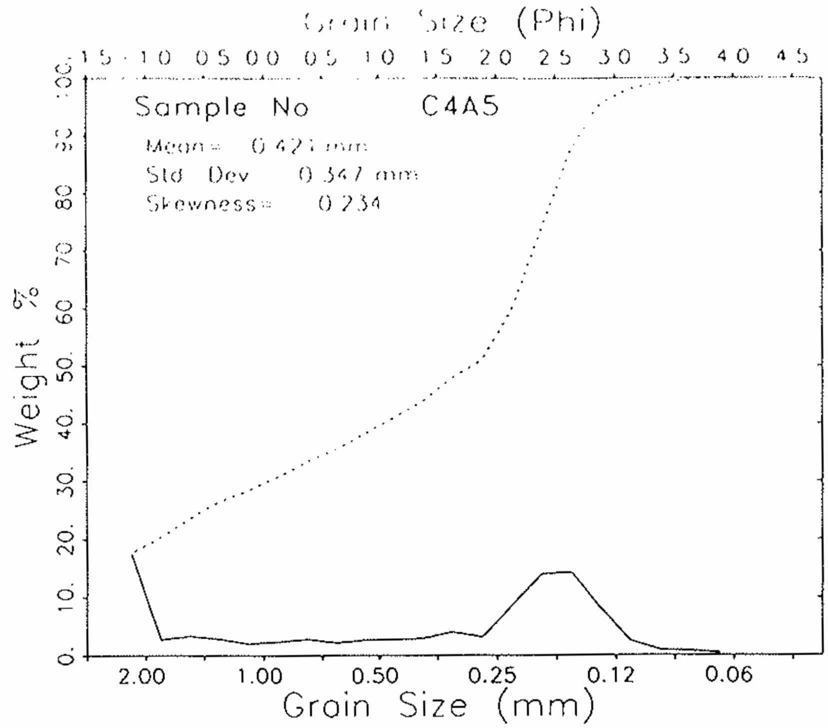
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.232	-1.159	-.827	-.245	1.673	2.484	2.668	2.967	3.410

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	.920	1.171	MEDIUM SAND
STANDARD DEVIATION	1.747	1.499	POORLY SORTED
SKEWNESS(1)	-.431	-.402	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.440		
KURTOSIS	.101	.620	VERY PLATYKURTIC

1.499

POORLY SORTED

SKEWNESS(1) -.431



SAMPLE NO. DATE

C4A5 060699

Bogue Banks C4A5 0-2.8

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	19.140	17.564	-1.000	17.564
-.875	2.970	2.726	-.750	20.290
-.625	3.600	3.304	-.500	23.594
-.375	3.090	2.836	-.250	26.429
-.125	2.170	1.991	.000	28.421
.125	2.490	2.285	.250	30.706
.375	3.010	2.762	.500	33.468
.625	2.310	2.120	.750	35.588
.875	2.900	2.661	1.000	38.249
1.125	2.930	2.689	1.250	40.938
1.375	3.130	2.872	1.500	43.810
1.625	4.350	3.992	1.750	47.802
1.875	3.460	3.175	2.000	50.977
2.125	9.420	8.645	2.250	59.622
2.375	15.140	13.894	2.500	73.516
2.625	15.390	14.123	2.750	87.639
2.875	8.720	8.002	3.000	95.641
3.125	2.660	2.441	3.250	98.082
3.375	.950	.872	3.500	98.954
3.625	.750	.688	3.750	99.642
3.875	.390	.358	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.970

PERCENT FINER THAN 4.00 PHI = .94 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.248 STANDARD DEVIATION = 1.527 SKEWNESS = -.234 KURTOSIS = -1.332

DISPERSION = .548 STANDARD DEVIATION = .854 DEVIATION FROM NORMAL DISTR. = -44.10%

PERCENTILES:

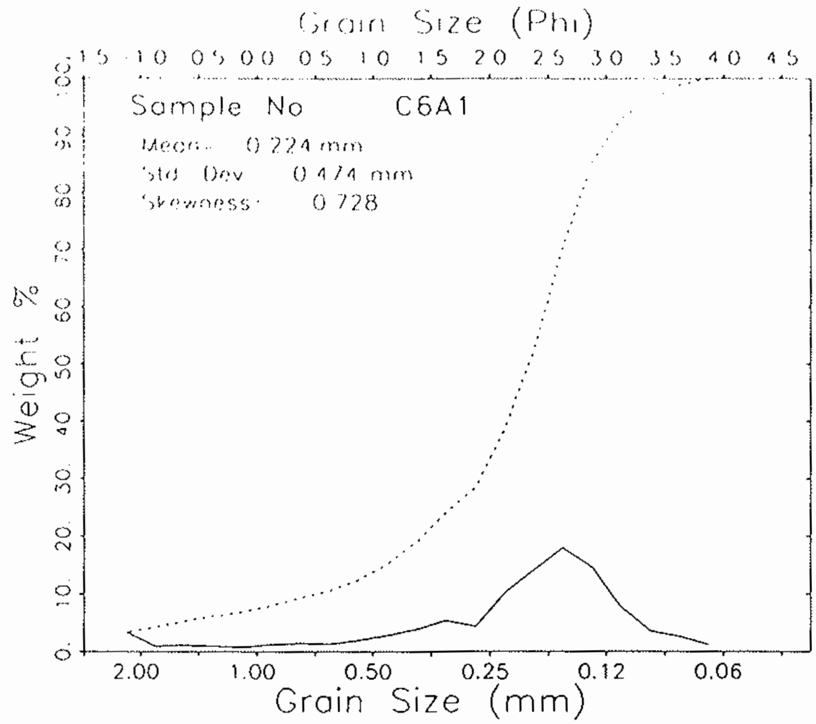
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.179	-1.022	-.376	1.923	2.526	2.686	2.980	3.517

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.832	1.195	MEDIUM SAND
STANDARD DEVIATION	1.854	1.557	POORLY SORTED
SKEWNESS(1)	-.589	-.540	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.552		
KURTOSIS	.122	.587	VERY PLATYKURTIC

1.557

POORLY SORTED

SKEWNESS(1) -.589



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C6A1	060699					
Bogue Banks C6A1 0-2.9						
		-1.125	3.210	3.280	-1.000	3.280
		-.875	.830	.848	-.750	4.128
		-.625	1.020	1.042	-.500	5.170
		-.375	.880	.899	-.250	6.069
		-.125	.700	.715	.000	6.784
		.125	1.090	1.114	.250	7.897
		.375	1.390	1.420	.500	9.318
		.625	1.180	1.206	.750	10.523
		.875	1.870	1.911	1.000	12.434
		1.125	2.650	2.707	1.250	15.141
		1.375	3.640	3.719	1.500	18.860
		1.625	5.160	5.272	1.750	24.132
		1.875	4.200	4.291	2.000	28.423
		2.125	9.900	10.114	2.250	38.537
		2.375	13.810	14.109	2.500	52.646
		2.625	17.530	17.910	2.750	70.556
		2.875	14.360	14.671	3.000	85.227
		3.125	7.490	7.652	3.250	92.879
		3.375	3.370	3.443	3.500	96.322
		3.625	2.460	2.513	3.750	98.835
		3.875	1.140	1.165	4.000	100.000

TOTAL WEIGHT (GRAMS) = 97.880

PERCENT FINER THAN 4.00 PHI = 2.20 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

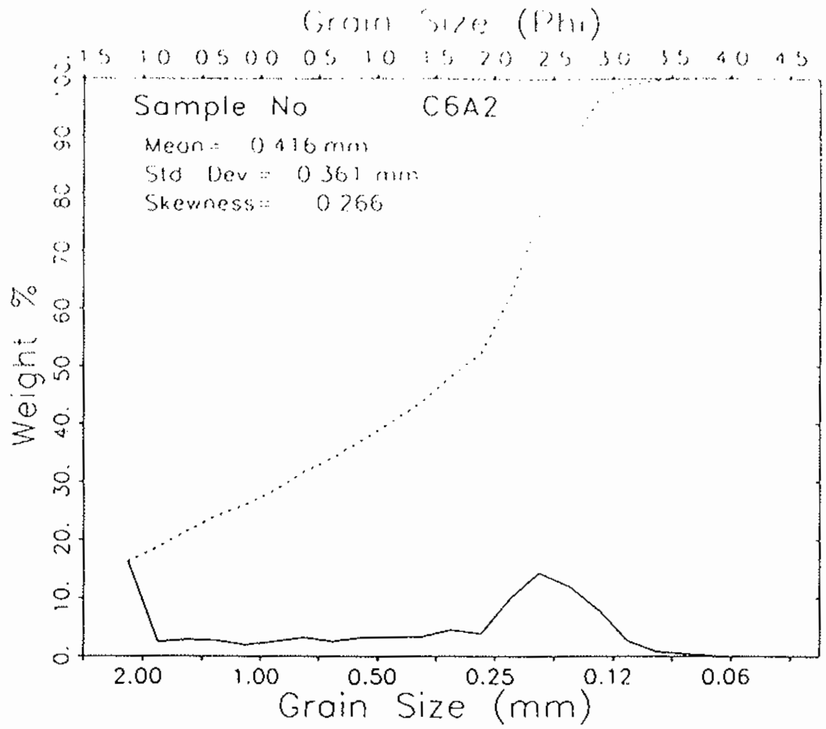
MEAN = 2.157 STANDARD DEVIATION = 1.077 SKEWNESS = -.728 KURTOSIS = 1.916

DISPERSION = .519 STANDARD DEVIATION = .800 DEVIATION FROM NORMAL OISTR. = -25.72%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.174	-.541	1.308	1.801	2.453	2.826	2.979	3.404	3.785

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.143	2.247	FINE SAND
STANDARD DEVIATION	.836	1.016	POORLY SORTED
SKEWNESS(1)	-.371	-.444	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.222		
KURTOSIS	1.360	1.577	VERY LEPTOKURTIC
1.016			POORLY SORTED
SKEWNESS(1)	-.371		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
C6A2	060699					
Bogue Bank C6A2 0-1.2						
		-1.125	17.870	16.275	-1.000	16.275
		-.875	2.620	2.386	-.750	18.661
		-.625	3.090	2.814	-.500	21.475
		-.375	2.870	2.614	-.250	24.089
		-.125	2.110	1.922	.000	26.011
		.125	2.740	2.495	.250	28.506
		.375	3.450	3.142	.500	31.648
		.625	2.710	2.468	.750	34.117
		.875	3.400	3.097	1.000	37.213
		1.125	3.500	3.188	1.250	40.401
		1.375	3.650	3.324	1.500	43.725
		1.625	4.920	4.481	1.750	48.206
		1.875	4.200	3.825	2.000	52.031
		2.125	10.900	9.927	2.250	61.958
		2.375	15.690	14.290	2.500	76.248
		2.625	13.280	12.095	2.750	88.342
		2.875	8.790	8.005	3.000	96.348
		3.125	2.800	2.550	3.250	98.898
		3.375	.770	.701	3.500	99.599
		3.625	.390	.355	3.750	99.954
		3.875	.050	.046	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.800

PERCENT FINER THAN 4.00 PHI = .51 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.266 STANDARD DEVIATION = 1.471 SKEWNESS = -.266 KURTOSIS = -1.225
DISPERSION = .553 STANDARD DEVIATION = .865 DEVIATION FROM NORMAL DISTR. = -41.20%

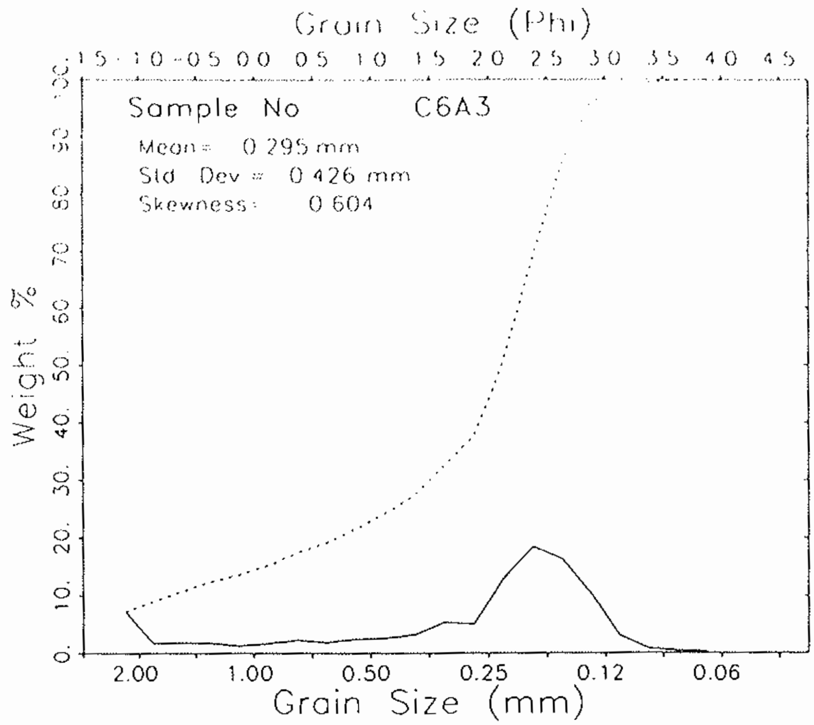
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.173	-1.004	-.132	1.867	2.478	2.660	2.958	3.286

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.828	1.174	MEDIUM SAND
STANDARD DEVIATION	1.832	1.542	POORLY SORTED
SKEWNESS(1)	-.567	-.520	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.532		
KURTOSIS	.127	.649	VERY PLATYKURTIC

1.542 POORLY SORTED

SKEWNESS(1) -.567



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C6A3	060699					
Bogue Banks C6A3 Part 1						
		-1.125	8.220	7.229	-1.000	7.229
		-.875	1.970	1.732	-.750	8.961
		-.625	1.930	1.697	-.500	10.659
		-.375	1.910	1.680	-.250	12.338
		-.125	1.350	1.187	.000	13.526
		.125	1.890	1.662	.250	15.188
		.375	2.510	2.207	.500	17.395
		.625	2.030	1.785	.750	19.180
		.875	2.680	2.357	1.000	21.537
		1.125	2.940	2.586	1.250	24.123
		1.375	3.600	3.166	1.500	27.289
		1.625	6.010	5.285	1.750	32.574
		1.875	5.700	5.013	2.000	37.587
		2.125	14.780	12.998	2.250	50.585
		2.375	20.930	18.406	2.500	68.991
		2.625	18.550	16.313	2.750	85.305
		2.875	11.820	10.395	3.000	95.700
		3.125	3.370	2.964	3.250	98.663
		3.375	.840	.739	3.500	99.402
		3.625	.460	.405	3.750	99.807
		3.875	.220	.193	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.710

PERCENT FINER THAN 4.00 PHI = .50 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.760 STANDARD DEVIATION = 1.232 SKEWNESS = -.604 KURTOSIS = .326
DISPERSION = .508 STANDARD DEVIATION = .779 DEVIATION FROM NORMAL DISTR. = -36.79%

PERCENTILES:

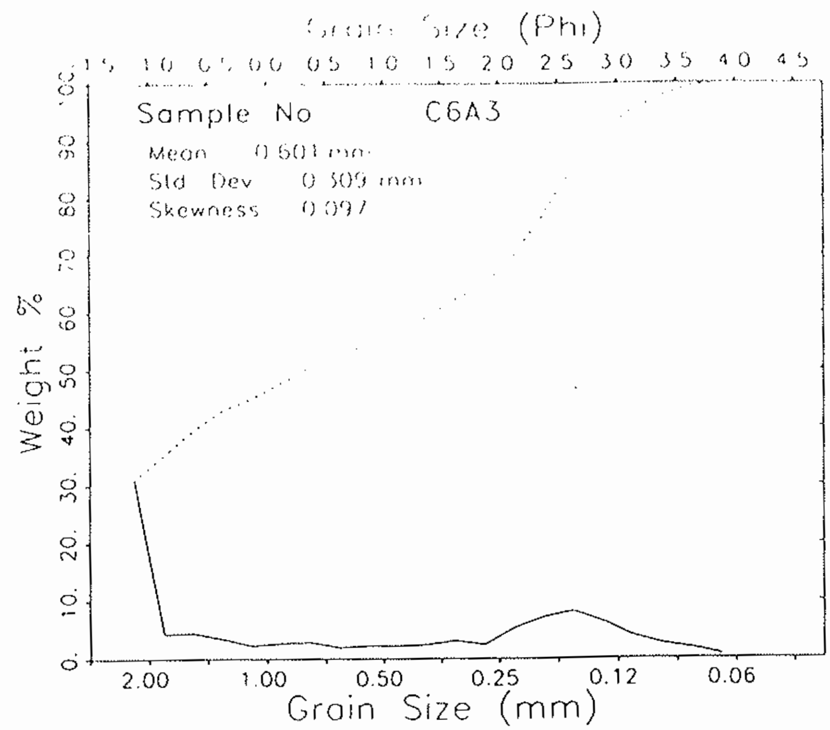
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.215	-1.077	.342	1.319	2.239	2.592	2.730	2.983	3.364

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.536	1.770	MEDIUM SAND
STANDARD DEVIATION	1.194	1.212	POORLY SORTED
SKEWNESS(1)	-.509	-.611	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.077		
KURTOSIS	.700	1.307	LEPTOKURTIC

1.212

POORLY SORTED

SKEWNESS(1) -.509



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C6A3	060699					
Bogue Banks C6A3 Part 2						
		-1.125	31.640	30.829	-1.000	30.829
		-.875	4.350	4.239	-.750	35.068
		-.625	4.510	4.394	-.500	39.462
		-.375	3.510	3.420	-.250	42.882
		-.125	2.260	2.202	.000	45.084
		.125	2.720	2.650	.250	47.735
		.375	2.890	2.816	.500	50.551
		.625	1.910	1.861	.750	52.412
		.875	2.280	2.222	1.000	54.633
		1.125	2.180	2.124	1.250	56.757
		1.375	2.410	2.348	1.500	59.106
		1.625	3.160	3.079	1.750	62.185
		1.875	2.470	2.407	2.000	64.591
		2.125	5.330	5.193	2.250	69.785
		2.375	7.280	7.093	2.500	76.878
		2.625	8.300	8.087	2.750	84.965
		2.875	6.470	6.304	3.000	91.270
		3.125	4.020	3.917	3.250	95.187
		3.375	2.540	2.475	3.500	97.661
		3.625	1.780	1.734	3.750	99.396
		3.875	.620	.604	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.630

PERCENT FINER THAN 4.00 PHI = .74 PERCENT COARSER THAN -1.00 PHI = .00

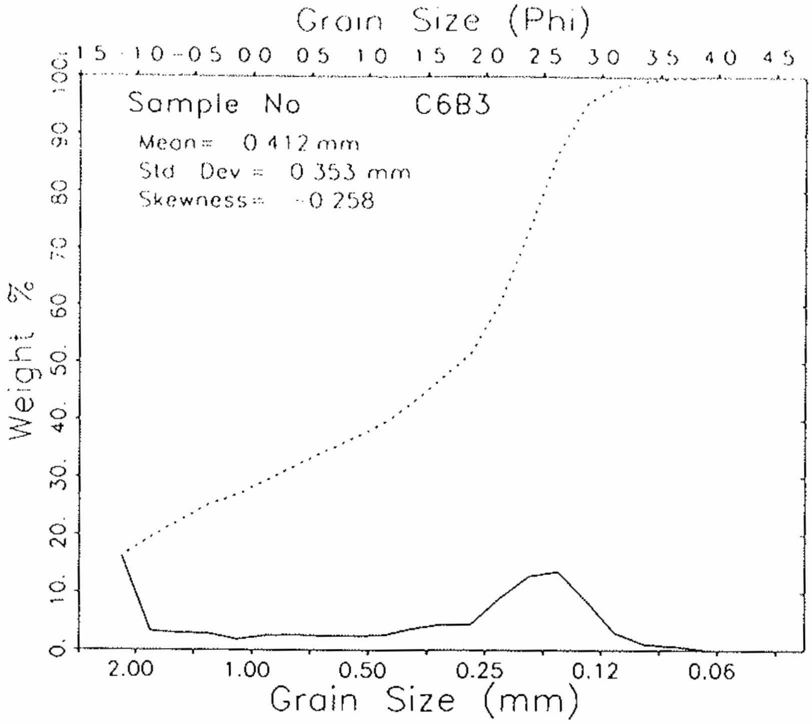
MOMENT MEASURES:

MEAN = .734 STANDARD DEVIATION = 1.694 SKEWNESS = .097 KURTOSIS = -1.590
DISPERSION = .525 STANDARD DEVIATION = .810 DEVIATION FROM NORMAL DISTR. = -52.18%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.209	-1.120	-1.047	.451	2.434	2.720	3.238	3.693

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	.800	.684	COARSE SAND
STANDARD DEVIATION	1.920	1.634	POORLY SORTED
SKEWNESS(1)	.182	.217	FINE-SKEWED
SKEWNESS(2)	.293		
KURTOSIS	.158	.524	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C6B3	060699					
Bogue Banks C6B3 Part 2 (0-1.3)						
		-1.125	17.050	16.257	-1.000	16.257
		-.875	3.350	3.194	-.750	19.451
		-.625	3.000	2.860	-.500	22.311
		-.375	2.960	2.822	-.250	25.133
		-.125	1.880	1.793	.000	26.926
		.125	2.610	2.489	.250	29.415
		.375	2.700	2.574	.500	31.989
		.625	2.540	2.422	.750	34.411
		.875	2.520	2.403	1.000	36.813
		1.125	2.620	2.498	1.250	39.312
		1.375	3.780	3.604	1.500	42.916
		1.625	4.580	4.367	1.750	47.283
		1.875	4.570	4.357	2.000	51.640
		2.125	9.430	8.991	2.250	60.631
		2.375	13.380	12.757	2.500	73.389
		2.625	14.240	13.577	2.750	86.966
		2.875	8.860	8.448	3.000	95.414
		3.125	2.990	2.851	3.250	98.265
		3.375	1.040	.992	3.500	99.256
		3.625	.670	.639	3.750	99.895
		3.875	.110	.105	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.880

PERCENT FINER THAN 4.00 PHI = 1.26 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

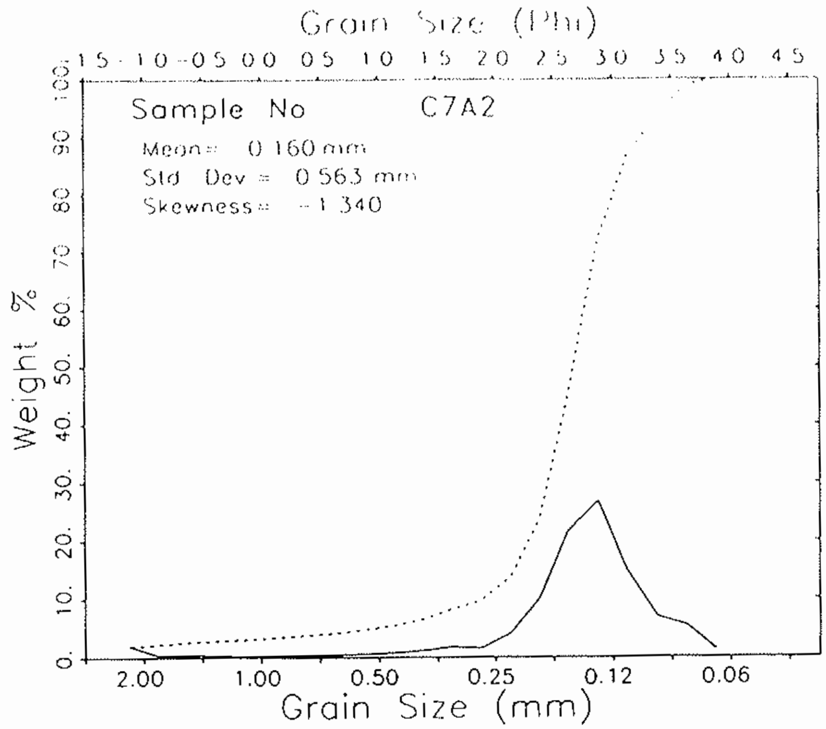
MEAN = 1.281 STANDARD DEVIATION = 1.502 SKEWNESS = -.258 KURTOSIS = -1.261

DISPERSION = .560 STANDARD DEVIATION = .879 DEVIATION FROM NORMAL DISTR. = -41.46%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.173	-1.004	-.262	1.906	2.530	2.695	2.988	3.435

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.846	1.199	MEDIUM SAND
STANDARD DEVIATION	1.850	1.555	POORLY SORTED
SKEWNESS(1)	-.573	-.527	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.540		
KURTOSIS	.125	.611	VERY PLATYKURTIC
1.555			POORLY SORTED
SKEWNESS(1)	-.573		



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C7A2	060699					
Bogue Banks C7A2 0-2.7						
		-1.125	1.840	1.865	-1.000	1.865
		-.875	.260	.264	-.750	2.129
		-.625	.380	.385	-.500	2.514
		-.375	.270	.274	-.250	2.788
		-.125	.220	.223	.000	3.011
		.125	.330	.335	.250	3.345
		.375	.390	.395	.500	3.740
		.625	.380	.385	.750	4.126
		.875	.530	.537	1.000	4.663
		1.125	.710	.720	1.250	5.383
		1.375	1.010	1.024	1.500	6.406
		1.625	1.700	1.723	1.750	8.130
		1.875	1.460	1.480	2.000	9.610
		2.125	3.920	3.974	2.250	13.583
		2.375	9.870	10.005	2.500	23.588
		2.625	21.380	21.673	2.750	45.261
		2.875	26.390	26.751	3.000	72.012
		3.125	14.360	14.557	3.250	86.569
		3.375	6.730	6.822	3.500	93.391
		3.625	5.280	5.352	3.750	98.743
		3.875	1.240	1.257	4.000	100.000

TOTAL WEIGHT (GRAMS) = 98.650

PERCENT FINER THAN 4.00 PHI = 1.30 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.648 STANDARD DEVIATION = .829 SKEWNESS = -1.314 KURTOSIS = 8.726
DISPERSION = .338 STANDARD DEVIATION = .527 DEVIATION FROM NORMAL DISTR. = -36.47%

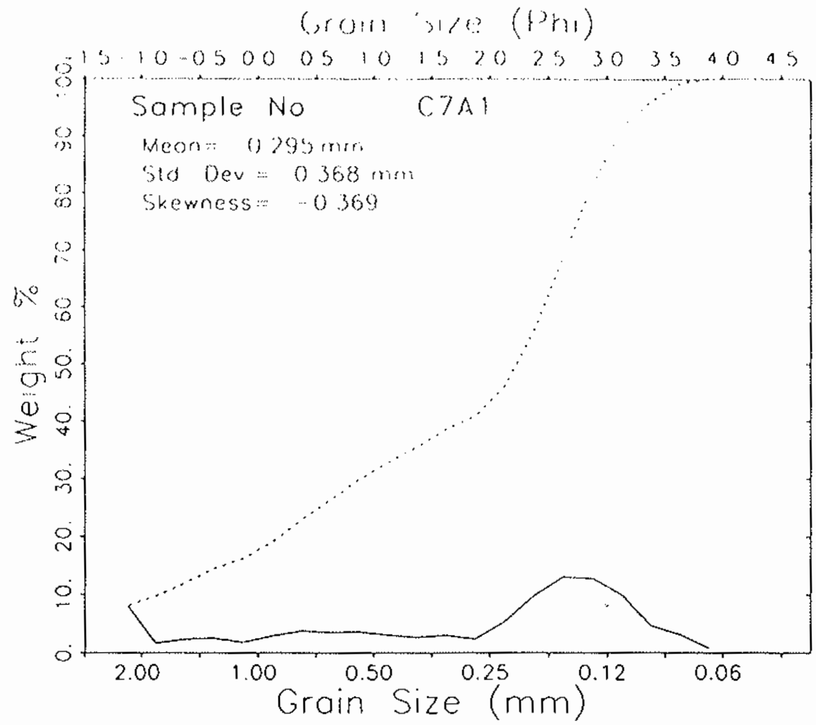
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.116	1.117	2.310	2.516	2.794	3.051	3.206	3.575	3.801

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.758	2.770	FINE SAND
STANDARD DEVIATION	.448	.596	MODERATELY WELL SORTED
SKEWNESS(1)	-.081	-.223	COARSE-SKEWED
SKEWNESS(2)	-1.001		
KURTOSIS	1.745	1.883	VERY LEPTOKURTIC

.596 MODERATELY WELL SORTED

SKEWNESS(1) -.081



SAMPLE NO. DATE

C7A1 060699
Bogue Banks C7A1 0-1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	8.130	8.046	-1.000	8.046
-.875	1.690	1.672	-.750	9.718
-.625	2.310	2.286	-.500	12.004
-.375	2.500	2.474	-.250	14.478
-.125	1.780	1.762	.000	16.239
.125	2.950	2.919	.250	19.159
.375	3.750	3.711	.500	22.870
.625	3.480	3.444	.750	26.314
.875	3.590	3.553	1.000	29.866
1.125	3.080	3.048	1.250	32.914
1.375	2.660	2.632	1.500	35.547
1.625	3.040	3.008	1.750	38.555
1.875	2.300	2.276	2.000	40.831
2.125	5.380	5.324	2.250	46.155
2.375	9.820	9.718	2.500	55.873
2.625	13.140	13.003	2.750	68.877
2.875	12.820	12.687	3.000	81.564
3.125	9.980	9.876	3.250	91.440
3.375	4.660	4.612	3.500	96.051
3.625	3.190	3.157	3.750	99.208
3.875	.800	.792	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.050

PERCENT FINER THAN 4.00 PHI = 1.47 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.761 STANDARD DEVIATION = 1.442 SKEWNESS = -.369 KURTOSIS = -.737
DISPERSION = .615 STANDARD DEVIATION = .996 DEVIATION FROM NORMAL DISTR. = -30.88%

PERCENTILES:

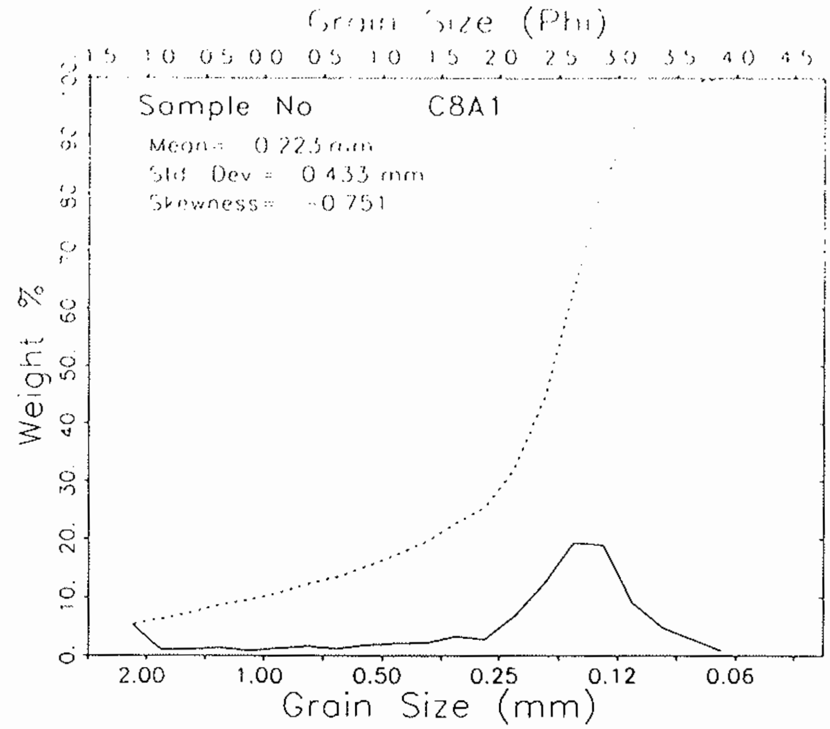
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.219	-1.095	-.034	.655	2.349	2.871	3.062	3.443	3.734

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.514	1.792	MEDIUM SAND
STANDARD DEVIATION	1.548	1.461	POORLY SORTED
SKEWNESS(1)	-.540	-.529	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.759		
KURTOSIS	.466	.839	PLATYKURTIC

1.461

POORLY SORTED

SKEWNESS(1) -.540



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C8A1	060699						
Bogue Banks C8A1 0-3.4							
		-1.125	5.410		5.346	-1.000	5.346
		-.875	.950		.939	-.750	6.285
		-.625	1.080		1.067	-.500	7.352
		-.375	1.340		1.324	-.250	8.676
		-.125	.830		.820	.000	9.496
		.125	1.260		1.245	.250	10.741
		.375	1.600		1.581	.500	12.322
		.625	1.180		1.166	.750	13.488
		.875	1.850		1.828	1.000	15.316
		1.125	2.050		2.026	1.250	17.342
		1.375	2.160		2.134	1.500	19.476
		1.625	3.220		3.182	1.750	22.658
		1.875	2.740		2.708	2.000	25.366
		2.125	6.770		6.690	2.250	32.055
		2.375	12.530		12.381	2.500	44.437
		2.625	19.510		19.279	2.750	63.715
		2.875	19.150		18.923	3.000	82.638
		3.125	9.050		8.943	3.250	91.581
		3.375	4.890		4.832	3.500	96.413
		3.625	2.850		2.816	3.750	99.229
		3.875	.780		.771	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.200

PERCENT FINER THAN 4.00 PHI = 2.75 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.165 STANDARD DEVIATION = 1.209 SKEWNESS = -.751 KURTOSIS = 1.423
DISPERSION = .497 STANDARD DEVIATION = .761 DEVIATION FROM NORMAL DISTR. = -37.09%

PERCENTILES:

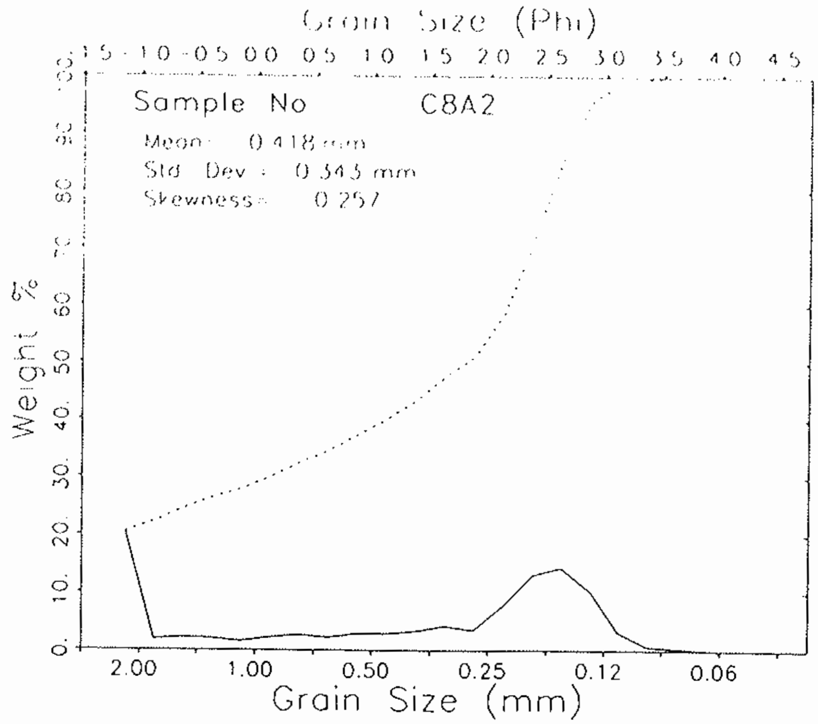
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.203	-1.016	1.084	1.966	2.572	2.899	3.038	3.427	3.730

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.061	2.232	FINE SAND
STANDARD DEVIATION	.977	1.162	POORLY SORTED
SKEWNESS(1)	-.523	-.569	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.399		
KURTOSIS	1.274	1.952	VERY LEPTOKURTIC

1.162

POORLY SORTED

SKEWNESS(1) -.523



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C8A2	060699					
Bogue Bank C8A2 0-1.6						
		-1.125	22.380	20.390	-1.000	20.390
		-.875	2.000	1.822	-.750	22.212
		-.625	2.350	2.141	-.500	24.353
		-.375	2.150	1.959	-.250	26.312
		-.125	1.610	1.467	.000	27.779
		.125	2.340	2.132	.250	29.911
		.375	2.770	2.524	.500	32.434
		.625	2.310	2.105	.750	34.539
		.875	3.040	2.770	1.000	37.309
		1.125	3.110	2.833	1.250	40.142
		1.375	3.520	3.207	1.500	43.349
		1.625	4.580	4.173	1.750	47.522
		1.875	3.700	3.371	2.000	50.893
		2.125	8.340	7.598	2.250	58.491
		2.375	14.240	12.974	2.500	71.465
		2.625	15.580	14.195	2.750	85.660
		2.875	11.200	10.204	3.000	95.864
		3.125	3.390	3.089	3.250	98.952
		3.375	.700	.638	3.500	99.590
		3.625	.360	.328	3.750	99.918
		3.875	.090	.082	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.760

PERCENT FINER THAN 4.00 PHI = .39 PERCENT COARSER THAN -1.00 PHI = .00

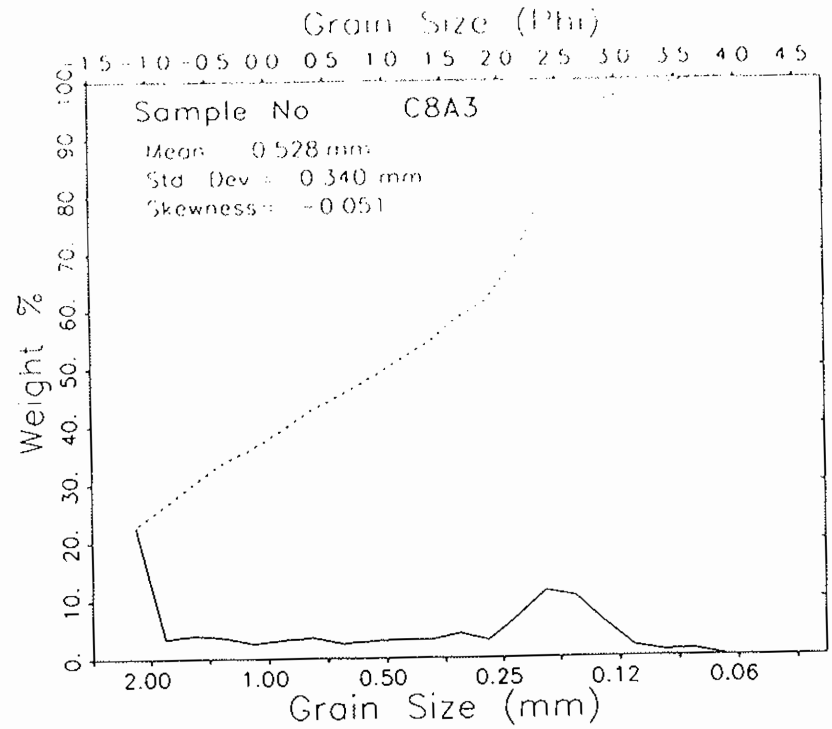
MOMENT MEASURES:

MEAN = 1.257 STANDARD DEVIATION = 1.545 SKEWNESS = -.257 KURTOSIS = -1.324
DISPERSION = .513 STANDARD DEVIATION = .788 DEVIATION FROM NORMAL DISTR. = -48.99%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.189	-1.054	-.417	1.934	2.562	2.721	2.979	3.269

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.833	1.200	MEDIUM SAND
STANDARD DEVIATION	1.887	1.575	POORLY SORTED
SKEWNESS(1)	-.583	-.541	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.550		
KURTOSIS	.104	.573	VERY PLATYKURTIC
1.575			POORLY SORTED
SKEWNESS(1)	-.583		



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C8A3	060699					
Bogue Bank C8A3 0-1.5						
		-1.125	25.170	22.749	-1.000	22.749
		-.875	3.770	3.407	-.750	26.157
		-.625	4.410	3.986	-.500	30.143
		-.375	3.890	3.516	-.250	33.659
		-.125	2.780	2.513	.000	36.171
		.125	3.470	3.136	.250	39.308
		.375	3.900	3.525	.500	42.833
		.625	2.750	2.486	.750	45.318
		.875	3.210	2.901	1.000	48.219
		1.125	3.440	3.109	1.250	51.329
		1.375	3.390	3.064	1.500	54.393
		1.625	4.540	4.103	1.750	58.496
		1.875	3.320	3.001	2.000	61.497
		2.125	7.720	6.978	2.250	68.474
		2.375	12.590	11.379	2.500	79.854
		2.625	11.560	10.448	2.750	90.302
		2.875	6.500	5.875	3.000	96.177
		3.125	1.960	1.772	3.250	97.948
		3.375	.990	.895	3.500	98.843
		3.625	1.120	1.012	3.750	99.855
		3.875	.160	.145	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.640

PERCENT FINER THAN 4.00 PHI = 2.07 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .921 STANDARD DEVIATION = 1.558 SKEWNESS = -.051 KURTOSIS = -1.552
DISPERSION = .557 STANDARD DEVIATION = .872 DEVIATION FROM NORMAL DISTR. = -44.06%

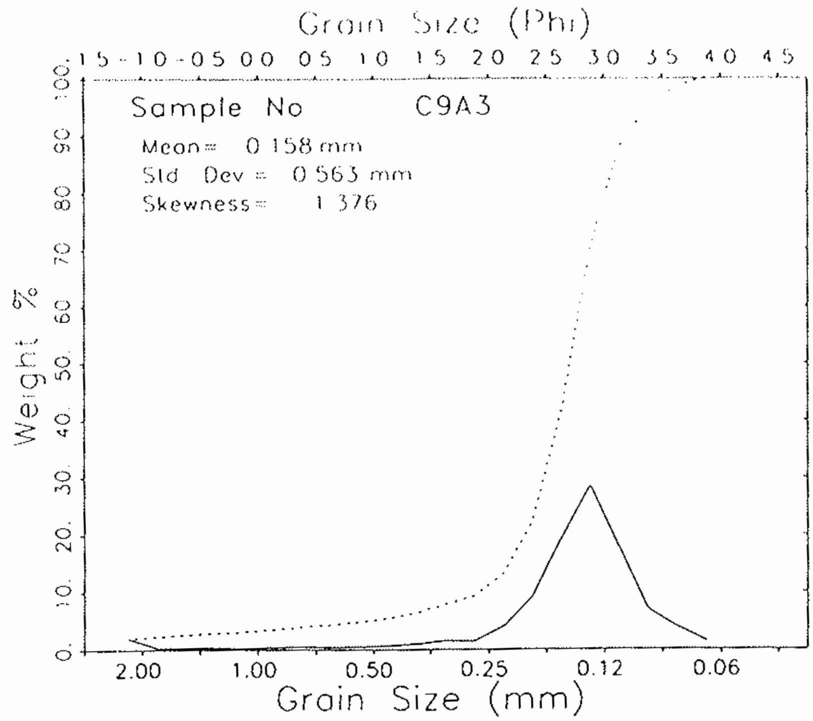
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.195	-1.074	-.835	1.143	2.393	2.599	2.950	3.539

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.763	.889	COARSE SAND
STANDARD DEVIATION	1.837	1.546	POORLY SORTED
SKEWNESS(1)	-.207	-.168	COARSE-SKEWED
SKEWNESS(2)	-.145		
KURTOSIS	.128	.526	VERY PLATYKURTIC

1.546 POORLY SORTED

SKEWNESS(1) -.207



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
c9a-3	070699						
Bogue Banks - Core C9A-3							
		-1.125	2.190		1.996	-1.000	1.996
		-.875	.290		.264	-.750	2.261
		-.625	.310		.283	-.500	2.543
		-.375	.310		.283	-.250	2.826
		-.125	.240		.219	.000	3.044
		.125	.420		.383	.250	3.427
		.375	.530		.483	.500	3.910
		.625	.410		.374	.750	4.284
		.875	.550		.501	1.000	4.785
		1.125	.690		.629	1.250	5.414
		1.375	.950		.866	1.500	6.280
		1.625	1.630		1.486	1.750	7.766
		1.875	1.560		1.422	2.000	9.188
		2.125	4.320		3.938	2.250	13.126
		2.375	10.090		9.197	2.500	22.322
		2.625	21.050		19.187	2.750	41.509
		2.875	31.290		28.521	3.000	70.030
		3.125	19.560		17.829	3.250	87.859
		3.375	7.690		7.009	3.500	94.868
		3.625	4.200		3.828	3.750	98.697
		3.875	1.430		1.303	4.000	100.000

TOTAL WEIGHT (GRAMS) • 109.710

PERCENT FINER THAN 4.00 PHI • 1.12 PERCENT COARSER THAN -1.00 PHI • .00

MOMENT MEASURES:

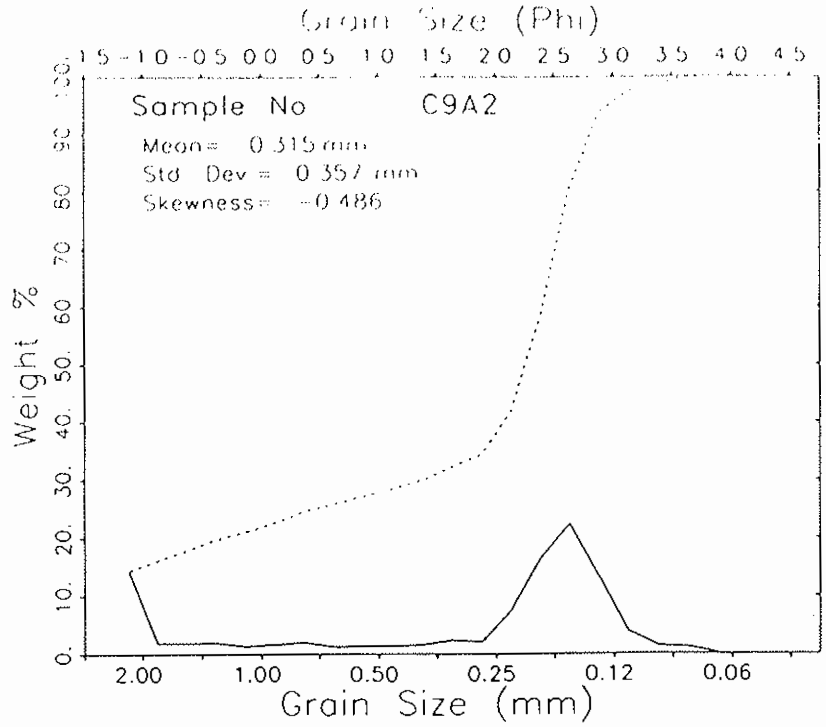
MEAN • 2.660 STANDARD DEVIATION • .830 SKEWNESS • -1.376 KURTOSIS • 9.189

DISPERSION • .322 STANDARD DEVIATION • .508 DEVIATION FROM NORMAL DISTR. • -38.83%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.125	1.085	2.328	2.535	2.824	3.070	3.196	3.509	3.808

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.762	2.783	FINE SAND
STANDARD DEVIATION	.434	.584	MODERATELY WELL SORTED
SKEWNESS(1)	-.144	-.290	COARSE-SKEWED
SKEWNESS(2)	-1.216		
KURTOSIS	1.793	1.857	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C9A2	060699						
Bogue Bank C9A2 0-2.2							
		-1.125	14.120	14.266	-1.000	14.266	
		-.875	1.780	1.798	-.750	16.064	
		-.625	1.790	1.808	-.500	17.872	
		-.375	1.870	1.889	-.250	19.762	
		-.125	1.290	1.303	.000	21.065	
		.125	1.580	1.596	.250	22.661	
		.375	1.910	1.930	.500	24.591	
		.625	1.210	1.222	.750	25.813	
		.875	1.310	1.323	1.000	27.137	
		1.125	1.270	1.283	1.250	28.420	
		1.375	1.500	1.515	1.500	29.935	
		1.625	2.310	2.334	1.750	32.269	
		1.875	2.030	2.051	2.000	34.320	
		2.125	7.360	7.436	2.250	41.756	
		2.375	16.240	16.407	2.500	58.163	
		2.625	22.070	22.297	2.750	80.461	
		2.875	13.030	13.164	3.000	93.625	
		3.125	3.750	3.789	3.250	97.414	
		3.375	1.260	1.273	3.500	98.687	
		3.625	1.160	1.172	3.750	99.859	
		3.875	.140	.141	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 98.980

PERCENT FINER THAN 4.00 PHI = 1.38 PERCENT COARSER THAN -1.00 PHI = .00

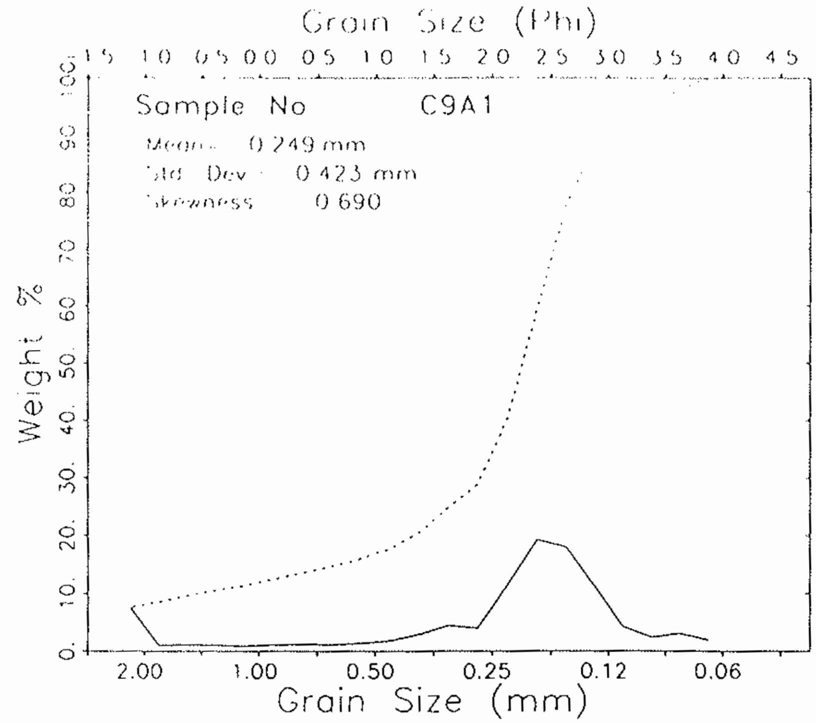
MOMENT MEASURES:

MEAN = 1.665 STANDARD DEVIATION = 1.485 SKEWNESS = -.486 KURTOSIS = -.633
DISPERSION = .452 STANDARD DEVIATION = .685 DEVIATION FROM NORMAL DISTR. = -53.89%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.232	-1.162	-.759	.584	2.376	2.689	2.817	3.091	3.567

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.029	1.478	MEDIUM SAND
STANDARD DEVIATION	1.788	1.538	POORLY SORTED
SKEWNESS(1)	-.753	-.708	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.789		
KURTOSIS	.189	.828	PLATYKURTIC
1.538			POORLY SORTED
SKEWNESS(1)	-.753		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT / CLASS LIMITS (PHI)	CUM PERCENT
C9A1	060699					
Bogue Bank C9A1 0-1.4						
		-1.125	7.890	7.534	-1.000	7.534
		-.875	1.010	.964	-.750	8.499
		-.625	1.130	1.079	-.500	9.578
		-.375	1.040	.993	-.250	10.571
		-.125	.820	.783	.000	11.354
		.125	1.110	1.060	.250	12.414
		.375	1.210	1.155	.500	13.570
		.625	1.120	1.070	.750	14.639
		.875	1.380	1.318	1.000	15.957
		1.125	1.840	1.757	1.250	17.714
		1.375	2.900	2.769	1.500	20.483
		1.625	4.580	4.374	1.750	24.857
		1.875	4.110	3.925	2.000	28.782
		2.125	11.970	11.430	2.250	40.212
		2.375	20.130	19.223	2.500	59.435
		2.625	18.800	17.953	2.750	77.387
		2.875	11.820	11.287	3.000	88.675
		3.125	4.350	4.154	3.250	92.828
		3.375	2.440	2.330	3.500	95.159
		3.625	3.090	2.951	3.750	98.109
		3.875	1.980	1.891	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.720

PERCENT FINER THAN 4.00 PHI = 3.75 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.006 STANDARD DEVIATION = 1.242 SKEWNESS = -.690 KURTOSIS = 1.142

DISPERSION = .497 STANDARD DEVIATION = .759 DEVIATION FROM NORMAL DISTR. = -38.87%

PERCENTILES:

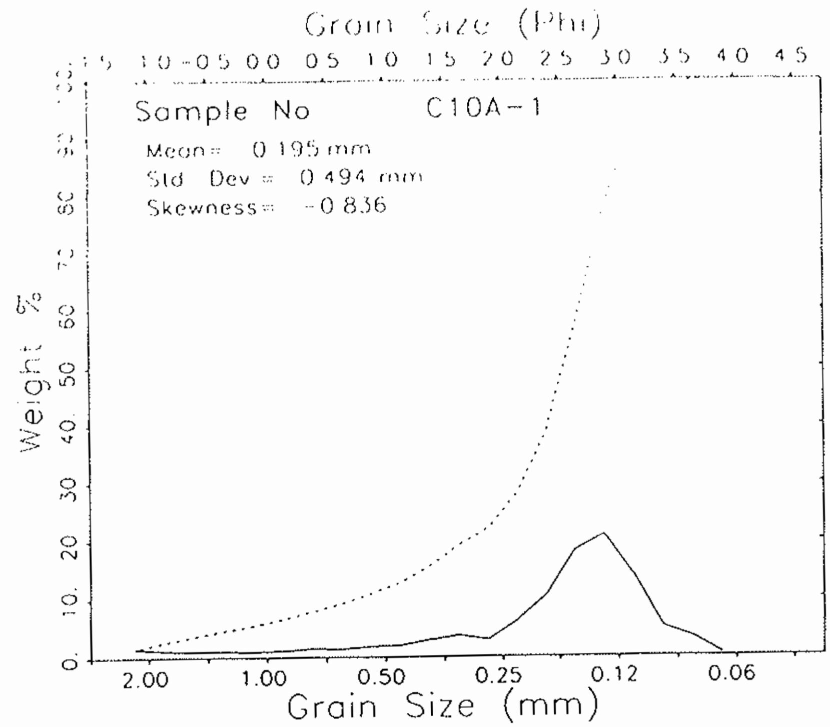
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.217	-1.084	1.006	1.759	2.377	2.717	2.896	3.483	3.868

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.951	2.093	FINE SAND
STANDARD DEVIATION	.945	1.165	POORLY SORTED
SKEWNESS(1)	-.451	-.403	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.246		
KURTOSIS	1.416	1.955	VERY LEPTOKURTIC

1.165

POORLY SORTED

SKEWNESS(1) -.451



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10A-1	070699						
Bogue Banks - Core C10A-1							
		-1.125	1.480		1.470	-1.000	1.470
		-.875	1.110		1.103	-.750	2.573
		-.625	.950		.944	-.500	3.517
		-.375	.950		.944	-.250	4.461
		-.125	.870		.864	.000	5.325
		.125	1.100		1.093	.250	6.418
		.375	1.370		1.361	.500	7.779
		.625	1.340		1.331	.750	9.110
		.875	1.690		1.679	1.000	10.789
		1.125	1.920		1.907	1.250	12.696
		1.375	2.850		2.831	1.500	15.528
		1.625	3.610		3.586	1.750	19.114
		1.875	2.810		2.792	2.000	21.905
		2.125	6.130		6.090	2.250	27.995
		2.375	10.430		10.362	2.500	38.357
		2.625	18.230		18.110	2.750	56.467
		2.875	20.970		20.833	3.000	77.300
		3.125	14.170		14.077	3.250	91.377
		3.375	5.020		4.987	3.500	96.364
		3.625	3.240		3.219	3.750	99.583
		3.875	.420		.417	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.660

PERCENT FINER THAN 4.00 PHI = 1.57 PERCENT COARSER THAN -1.00 PHI = .00

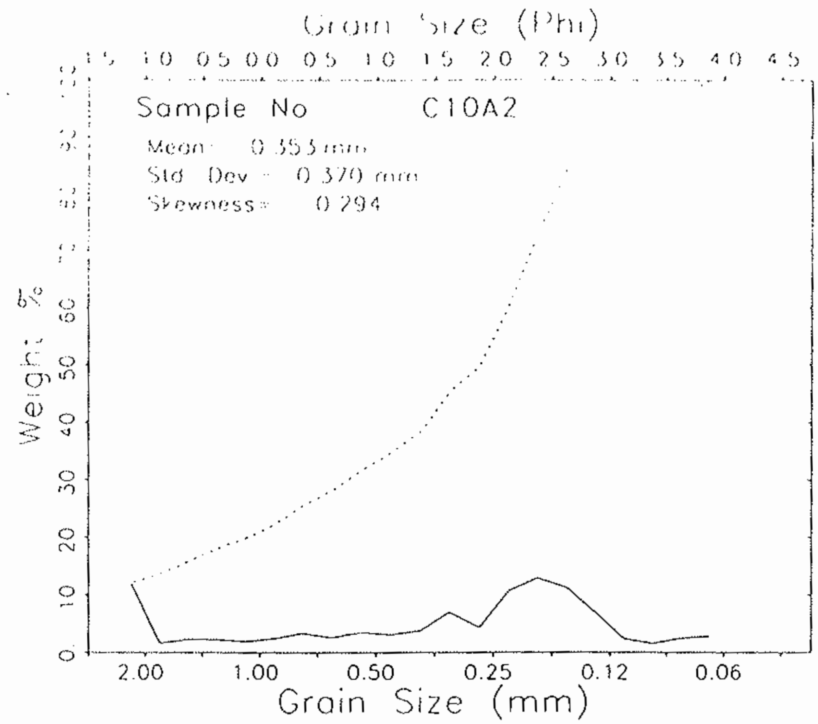
MOMENT MEASURES:

MEAN = 2.355 STANDARD DEVIATION = 1.018 SKEWNESS = -.836 KURTOSIS = 2.531
DISPERSION = .471 STANDARD DEVIATION = .716 DEVIATION FROM NORMAL DISTR. = -29.66%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.080	-.094	1.533	2.127	2.661	2.972	3.119	3.432	3.705

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.326	2.438	FINE SAND
STANDARD DEVIATION	.793	.931	MODERATELY SORTED
SKEWNESS(1)	-.422	-.492	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.251		
KURTOSIS	1.223	1.709	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10A2	060699					
Bogue Banks C10A2 1-2.5						
		-1.125	11.510	11.956	-1.000	11.956
		-.875	1.510	1.569	-.750	13.524
		-.625	2.110	2.192	-.500	15.716
		-.375	2.150	2.233	-.250	17.950
		-.125	1.780	1.849	.000	19.798
		.125	2.300	2.389	.250	22.188
		.375	3.190	3.314	.500	25.501
		.625	2.460	2.555	.750	28.057
		.875	3.380	3.511	1.000	31.567
		1.125	2.940	3.054	1.250	34.621
		1.375	3.560	3.698	1.500	38.319
		1.625	6.730	6.991	1.750	45.310
		1.875	4.150	4.311	2.000	49.621
		2.125	10.280	10.678	2.250	60.299
		2.375	12.300	12.777	2.500	73.076
		2.625	10.820	11.239	2.750	84.315
		2.875	6.610	6.866	3.000	91.181
		3.125	2.210	2.296	3.250	93.477
		3.375	1.390	1.444	3.500	94.921
		3.625	2.280	2.368	3.750	97.289
		3.875	2.610	2.711	4.000	100.000

TOTAL WEIGHT (GRAMS) = 96.270

PERCENT FINER THAN 4.00 PHI = 6.04 PERCENT COARSER THAN -1.00 PHI = .00

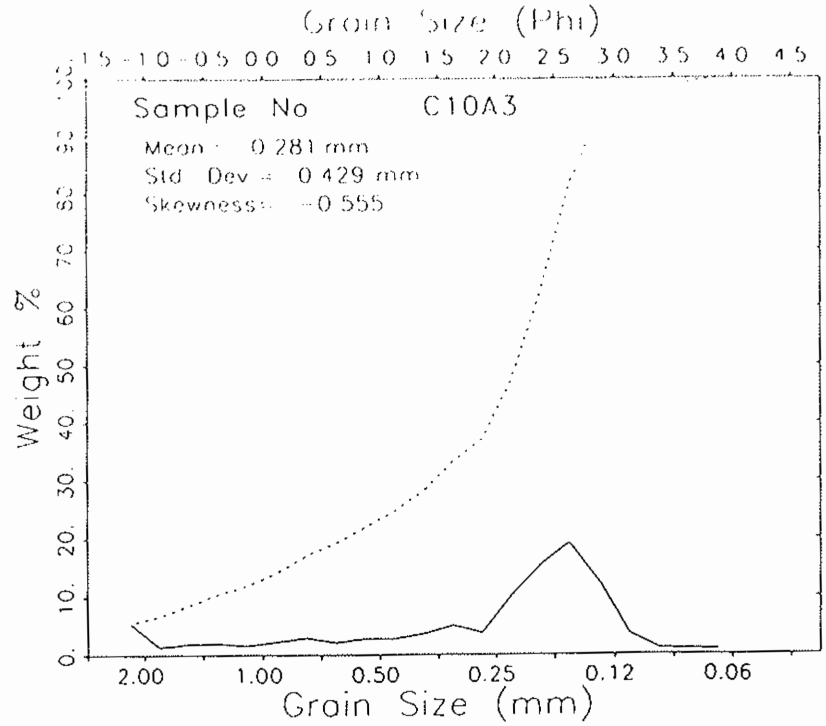
MOMENT MEASURES:

MEAN = 1.503 STANDARD DEVIATION = 1.433 SKEWNESS = -.294 KURTOSIS = -.769
DISPERSION = .610 STANDARD DEVIATION = .985 DEVIATION FROM NORMAL DISTR. = -31.24%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.229	-1.145	-.468	.462	2.009	2.543	2.743	3.508	3.908

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.137	1.428	MEDIUM SAND
STANDARD DEVIATION	1.606	1.508	POORLY SORTED
SKEWNESS(1)	-.543	-.449	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.515		
KURTOSIS	.449	.917	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10A3	060699						
Bogue Banks C10A3 1-2.5							
		-1.125	5.670	5.356	-1.000	5.356	
		-.875	1.400	1.322	-.750	6.678	
		-.625	1.950	1.842	-.500	8.520	
		-.375	2.030	1.917	-.250	10.437	
		-.125	1.640	1.549	.000	11.986	
		.125	2.370	2.239	.250	14.225	
		.375	3.090	2.919	.500	17.144	
		.625	2.200	2.078	.750	19.222	
		.875	2.870	2.711	1.000	21.933	
		1.125	2.890	2.730	1.250	24.662	
		1.375	3.770	3.561	1.500	28.223	
		1.625	5.220	4.931	1.750	33.154	
		1.875	3.970	3.750	2.000	36.904	
		2.125	10.680	10.088	2.250	46.992	
		2.375	16.230	15.330	2.500	62.322	
		2.625	20.160	19.042	2.750	81.364	
		2.875	13.120	12.393	3.000	93.756	
		3.125	3.720	3.514	3.250	97.270	
		3.375	1.060	1.001	3.500	98.271	
		3.625	.970	.916	3.750	99.188	
		3.875	.860	.812	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 105.870

PERCENT FINER THAN 4.00 PHI = 1.76 PERCENT COARSER THAN -1.00 PHI = .00

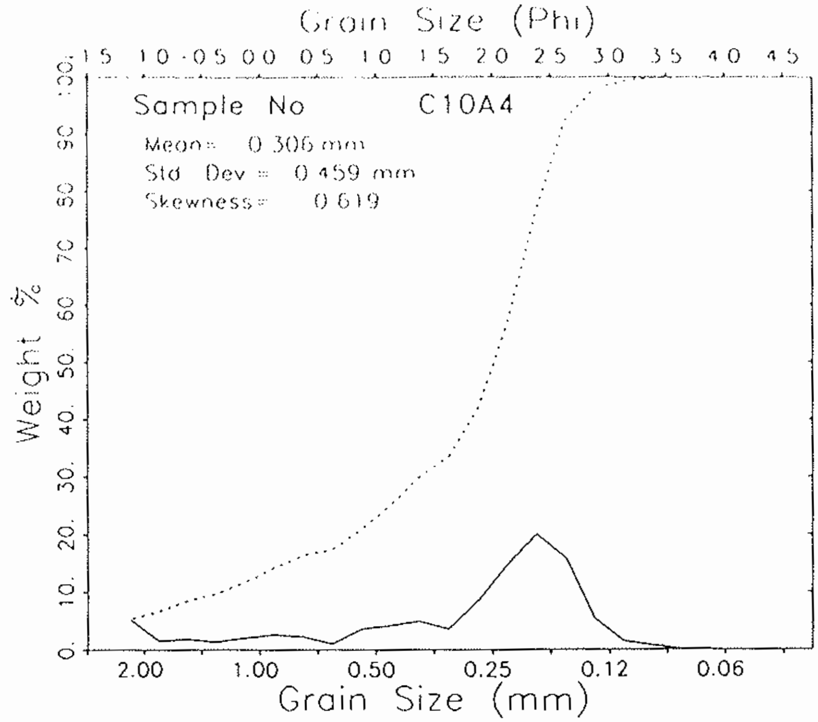
MOMENT MEASURES:

MEAN = 1.831 STANDARD DEVIATION = 1.220 SKEWNESS = -.555 KURTOSIS = .236
DISPERSION = .537 STANDARD DEVIATION = .833 DEVIATION FROM NORMAL DISTR. = -31.75%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.203	-1.017	.402	1.274	2.299	2.666	2.803	3.088	3.699

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.603	1.835	MEDIUM SAND
STANDARD DEVIATION	1.201	1.222	POORLY SORTED
SKEWNESS(1)	-.580	-.598	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.052		
KURTOSIS	.710	1.208	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10A4	060699						
Bogue Bank C10A4 0-2.5							
		-1.125	5.430		5.218	-1.000	5.218
		-.875	1.490		1.432	-.750	6.649
		-.625	1.850		1.778	-.500	8.427
		-.375	1.330		1.278	-.250	9.705
		-.125	2.030		1.951	.000	11.656
		.125	2.620		2.518	.250	14.173
		.375	2.270		2.181	.500	16.354
		.625	.970		.932	.750	17.286
		.875	3.730		3.584	1.000	20.871
		1.125	4.310		4.141	1.250	25.012
		1.375	5.110		4.910	1.500	29.922
		1.625	3.700		3.555	1.750	33.477
		1.875	8.780		8.437	2.000	41.914
		2.125	15.340		14.740	2.250	56.654
		2.375	20.780		19.967	2.500	76.621
		2.625	16.540		15.893	2.750	92.515
		2.875	5.500		5.285	3.000	97.800
		3.125	1.480		1.422	3.250	99.222
		3.375	.620		.596	3.500	99.817
		3.625	.080		.077	3.750	99.894
		3.875	.110		.106	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.070

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.717 STANDARD DEVIATION = 1.125 SKEWNESS = -.619 KURTOSIS = .565

DISPERSION = .493 STANDARD DEVIATION = .752 DEVIATION FROM NORMAL DISTR. = -33.11%

PERCENTILES:

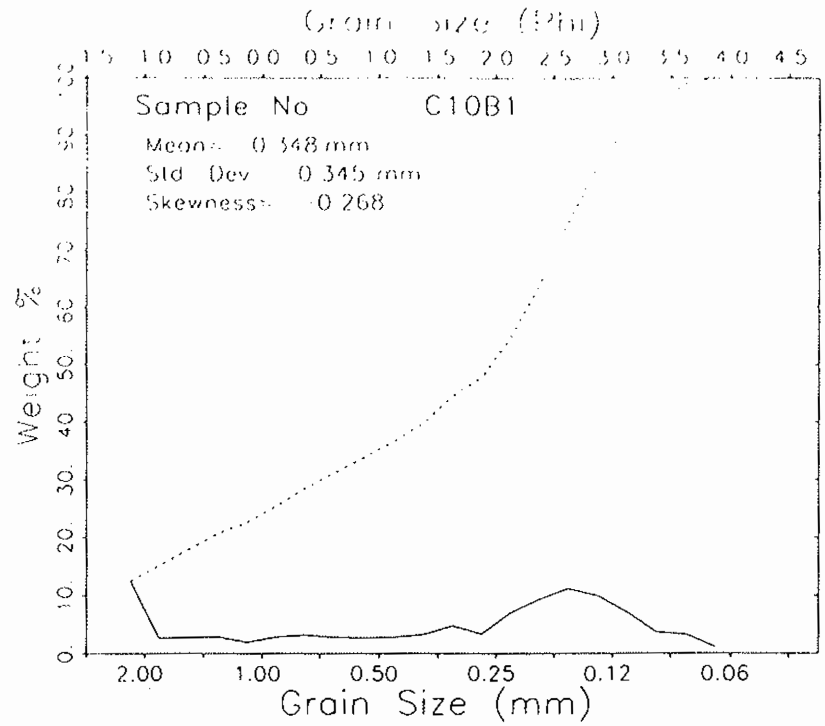
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.202	-1.010	.459	1.249	2.137	2.400	2.616	2.868	3.211

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.530	1.738	MEDIUM SAND
STANDARD DEVIATION	1.078	1.127	POORLY SORTED
SKEWNESS(1)	-.556	-.590	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.121		
KURTOSIS	.798	1.292	LEPTOKURTIC

1.127

POORLY SORTED

SKEWNESS(1) -.556



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C10B1	060699						
Bogue Bank C10B2 0-3.6							
		-1.125	13.070		12.473	-1.000	12.473
		-.875	2.780		2.653	-.750	15.125
		-.625	2.870		2.739	-.500	17.864
		-.375	2.940		2.806	-.250	20.670
		-.125	1.990		1.899	.000	22.569
		.125	2.940		2.806	.250	25.375
		.375	3.250		3.101	.500	28.476
		.625	2.820		2.691	.750	31.167
		.875	2.790		2.662	1.000	33.830
		1.125	2.830		2.701	1.250	36.530
		1.375	3.340		3.187	1.500	39.718
		1.625	4.940		4.714	1.750	44.432
		1.875	3.430		3.273	2.000	47.705
		2.125	7.270		6.938	2.250	54.643
		2.375	9.760		9.314	2.500	63.956
		2.625	11.690		11.156	2.750	75.112
		2.875	10.360		9.886	3.000	84.999
		3.125	7.400		7.062	3.250	92.060
		3.375	3.810		3.636	3.500	95.696
		3.625	3.400		3.245	3.750	98.941
		3.875	1.110		1.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.790

PERCENT FINER THAN 4.00 PHI = 1.60 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

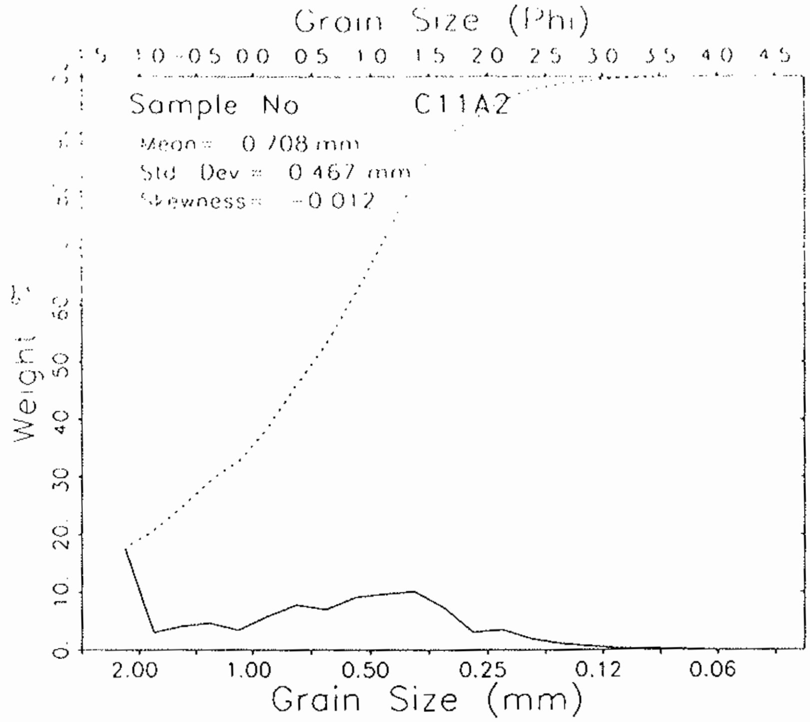
MEAN = 1.522 STANDARD DEVIATION = 1.537 SKEWNESS = -.268 KURTOSIS = -1.085

DISPERSION = .632 STANDARD DEVIATION = 1.037 DEVIATION FROM NORMAL DISTR. = -32.50%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.230	-1.150	-.670	.217	2.083	2.747	2.975	3.452	3.764

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.152	1.462	MEDIUM SAND
STANDARD DEVIATION	1.822	1.608	POORLY SORTED
SKEWNESS(1)	-.511	-.458	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.511		
KURTOSIS	.263	.745	PLATYKURTIC
1.608			POORLY SORTED
SKEWNESS(1)	-.511		



SAMPLE NO. DATE

C11A2 060699

Bogue Bank C11A2 0-1.1 , 1.4-1.6'

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	17.840	17.630	-1.000	17.630
-.875	3.040	3.004	-.750	20.634
-.625	4.090	4.042	-.500	24.676
-.375	4.630	4.576	-.250	29.252
-.125	3.460	3.419	.000	32.671
.125	5.780	5.712	.250	38.383
.375	7.810	7.718	.500	46.101
.625	7.090	7.007	.750	53.108
.875	9.180	9.072	1.000	62.180
1.125	9.760	9.645	1.250	71.825
1.375	10.190	10.070	1.500	81.895
1.625	7.430	7.343	1.750	89.238
1.875	3.110	3.073	2.000	92.312
2.125	3.470	3.429	2.250	95.741
2.375	1.910	1.888	2.500	97.628
2.625	1.090	1.077	2.750	98.705
2.875	.610	.603	3.000	99.308
3.125	.340	.336	3.250	99.644
3.375	.200	.198	3.500	99.842
3.625	.120	.119	3.750	99.960
3.875	.040	.040	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.190

PERCENT FINER THAN 4.00 PHI = .10 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .498 STANDARD DEVIATION = 1.098 SKEWNESS = -.012 KURTOSIS = -.882

DISPERSION = .541 STANDARD DEVIATION = .840 DEVIATION FROM NORMAL DISTR. = -23.50%

PERCENTILES:

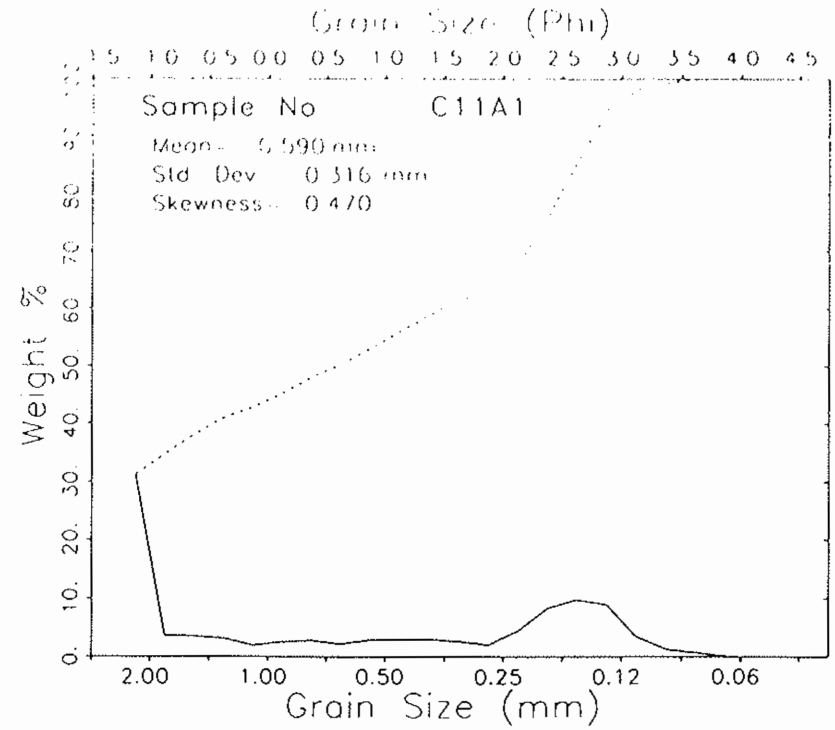
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.179	-1.023	-.482	.639	1.329	1.572	2.196	2.872

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.274	.396	COARSE SAND
STANDARD DEVIATION	1.297	1.160	POORLY SORTED
SKEWNESS(1)	-.281	-.179	COARSE-SKEWED
SKEWNESS(2)	-.101		
KURTOSIS	.301	.764	PLATYKURTIC

.297 1.160

POORLY SORTED

SKEWNESS(1) -.281



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C11A1	060699						
Bogue Bank C11A1 0-3.0							
		-1.125	34.160	31.111		-1.000	31.111
		-.875	3.880	3.534		-.750	34.645
		-.625	3.680	3.352		-.500	37.996
		-.375	3.320	3.024		-.250	41.020
		-.125	2.110	1.922		.000	42.942
		.125	2.680	2.441		.250	45.383
		.375	3.020	2.750		.500	48.133
		.625	2.360	2.149		.750	50.282
		.875	3.070	2.796		1.000	53.078
		1.125	3.170	2.887		1.250	55.965
		1.375	3.130	2.851		1.500	58.816
		1.625	2.810	2.559		1.750	61.375
		1.875	2.150	1.958		2.000	63.333
		2.125	4.830	4.399		2.250	67.732
		2.375	9.100	8.288		2.500	76.020
		2.625	10.640	9.690		2.750	85.710
		2.875	9.800	8.925		3.000	94.636
		3.125	3.740	3.406		3.250	98.042
		3.375	1.350	1.230		3.500	99.271
		3.625	.730	.665		3.750	99.936
		3.875	.070	.064		4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.800

PERCENT FINER THAN 4.00 PHI = .73 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .761 STANDARD DEVIATION = 1.662 SKEWNESS = .047 KURTOSIS = -1.656
DISPERSION = .491 STANDARD DEVIATION = .749 DEVIATION FROM NORMAL DISTR. = -54.91%

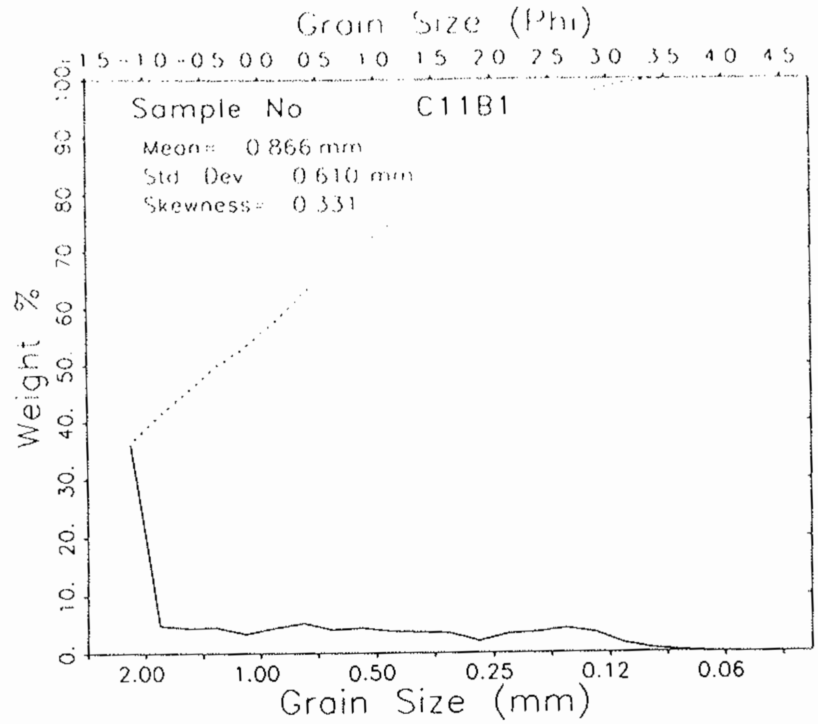
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.210	-1.121	-1.049	.717	2.469	2.706	3.027	3.445

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.792	.767	COARSE SAND
STANDARD DEVIATION	1.914	1.599	POORLY SORTED
SKEWNESS(1)	.039	.065	NEAR SYMMETRICAL
SKEWNESS(2)	.100		
KURTOSIS	.107	.493	VERY PLATYKURTIC

1.599 POORLY SORTED

SKEWNESS(1) .039



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C11B-1	070699					
Bogue Bank - C11B-1						
		-1.125	36.650	36.316	-1.000	36.316
		-.875	4.780	4.736	-.750	41.052
		-.625	4.360	4.320	-.500	45.373
		-.375	4.400	4.360	-.250	49.732
		-.125	3.340	3.310	.000	53.042
		.125	4.360	4.320	.250	57.362
		.375	5.150	5.103	.500	62.465
		.625	3.980	3.944	.750	66.409
		.875	4.320	4.281	1.000	70.690
		1.125	3.750	3.716	1.250	74.405
		1.375	3.620	3.587	1.500	77.992
		1.625	3.390	3.359	1.750	81.352
		1.875	2.010	1.992	2.000	83.343
		2.125	3.270	3.240	2.250	86.583
		2.375	3.530	3.498	2.500	90.081
		2.625	4.200	4.162	2.750	94.243
		2.875	3.450	3.419	3.000	97.662
		3.125	1.460	1.447	3.250	99.108
		3.375	.570	.565	3.500	99.673
		3.625	.250	.248	3.750	99.921
		3.875	.080	.079	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.920

PERCENT FINER THAN 4.00 PHI = .12 PERCENT COARSER THAN -1.00 PHI = .00

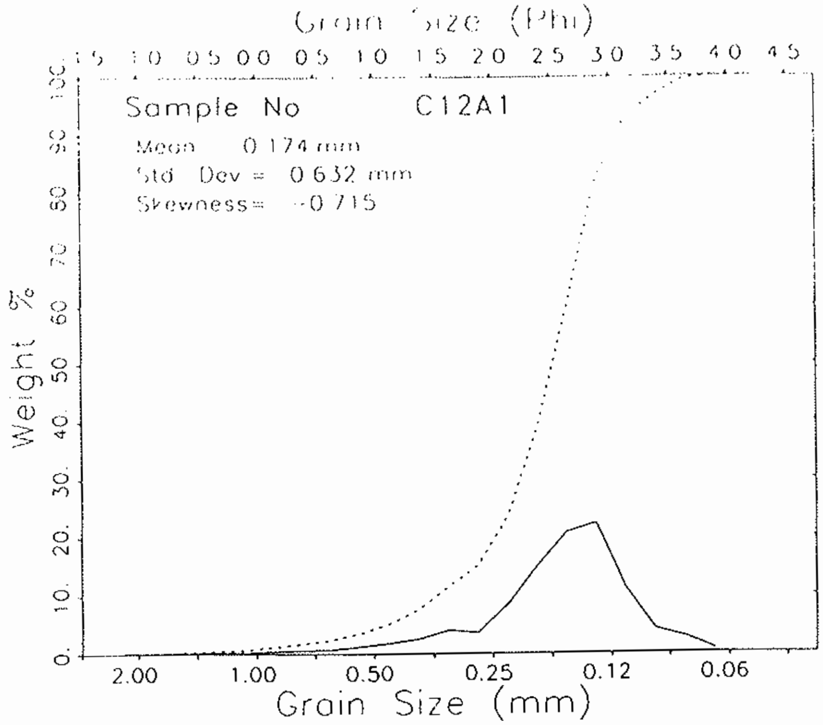
MOMENT MEASURES:

MEAN = .208 STANDARD DEVIATION = 1.403 SKEWNESS = .331 KURTOSIS = -.914
DISPERSION = .470 STANDARD DEVIATION = .714 DEVIATION FROM NORMAL DISTR. = -49.12%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.243	-1.216	-1.140	-1.078	-.230	1.291	2.051	2.805	3.231

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.455	.227	COARSE SAND
STANDARD DEVIATION	1.595	1.407	POORLY SORTED
SKEWNESS(1)	.430	.470	STRONGLY FINE-SKEWED
SKEWNESS(2)	.642		
KURTOSIS	.260	.696	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT / WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C12A1	060699					
Bogue Bank C12A1 Parts 1&2						
		-1.125	.120	.113	-1.000	.113
		-.875	.050	.047	-.750	.160
		-.625	.120	.113	-.500	.273
		-.375	.210	.198	-.250	.471
		-.125	.190	.179	.000	.650
		.125	.440	.414	.250	1.064
		.375	.620	.584	.500	1.648
		.625	.690	.650	.750	2.297
		.875	1.180	1.111	1.000	3.408
		1.125	1.790	1.685	1.250	5.093
		1.375	2.610	2.457	1.500	7.550
		1.625	4.180	3.935	1.750	11.486
		1.875	3.800	3.577	2.000	15.063
		2.125	8.970	8.445	2.250	23.508
		2.375	16.010	15.072	2.500	38.580
		2.625	22.060	20.768	2.750	59.349
		2.875	23.570	22.190	3.000	81.538
		3.125	11.680	10.996	3.250	92.534
		3.375	4.330	4.076	3.500	96.611
		3.625	2.930	2.758	3.750	99.369
		3.875	.670	.631	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.220

PERCENT FINER THAN 4.00 PHI = .27 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.523 STANDARD DEVIATION = .662 SKEWNESS = -.715 KURTOSIS = 3.625
DISPERSION = .372 STANDARD DEVIATION = .570 DEVIATION FROM NORMAL DISTR. = -13.88%

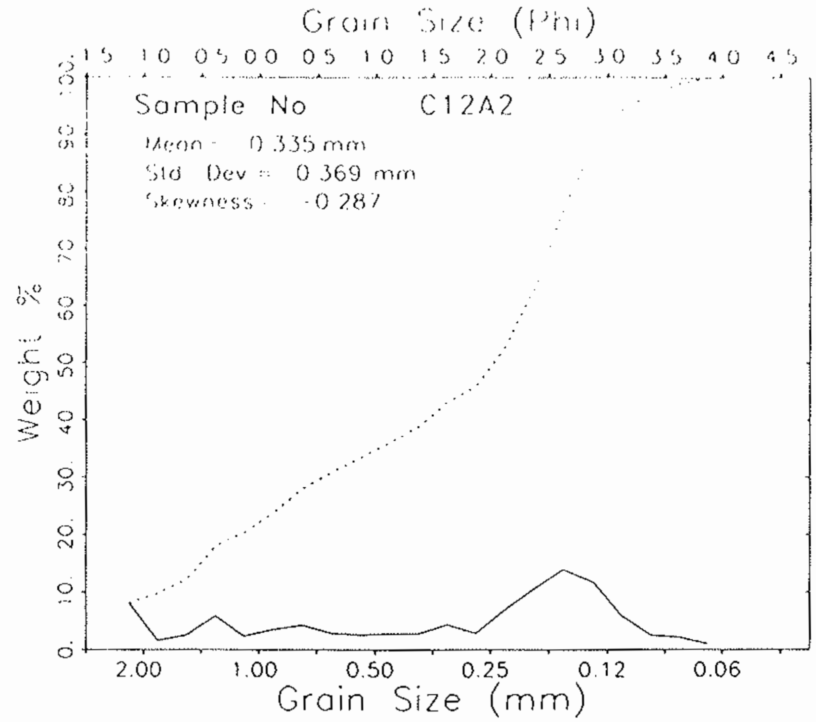
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.211	1.236	2.028	2.275	2.637	2.926	3.056	3.401	3.717

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	2.542	2.574	FINE SAND
STANDARD DEVIATION	.514	.585	MODERATELY WELL SORTED
SKEWNESS(1)	-.186	-.240	COARSE-SKEWED
SKEWNESS(2)	-.620		
KURTOSIS	1.106	1.362	LEPTOKURTIC

.585 MODERATELY WELL SORTED

SKEWNESS(1) -.186



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C12A@	060699					
Bogue Banks C12A2 COMP						
		-1.125	8.980	8.087	-1.000	8.087
		-.875	1.720	1.549	-.750	9.636
		-.625	2.730	2.459	-.500	12.095
		-.375	6.490	5.845	-.250	17.939
		-.125	2.580	2.323	.000	20.263
		.125	3.850	3.467	.250	23.730
		.375	4.680	4.215	.500	27.945
		.625	3.130	2.819	.750	30.764
		.875	2.840	2.558	1.000	33.321
		1.125	2.980	2.684	1.250	36.005
		1.375	3.010	2.711	1.500	38.716
		1.625	4.810	4.332	1.750	43.048
		1.875	3.140	2.828	2.000	45.875
		2.125	7.640	6.880	2.250	52.756
		2.375	11.640	10.483	2.500	63.238
		2.625	15.300	13.779	2.750	77.017
		2.875	12.900	11.617	3.000	88.635
		3.125	6.430	5.791	3.250	94.425
		3.375	2.750	2.477	3.500	96.902
		3.625	2.330	2.098	3.750	99.000
		3.875	1.110	1.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.040

PERCENT FINER THAN 4.00 PHI = 2.60 PERCENT COARSER THAN -1.00 PHI = .00

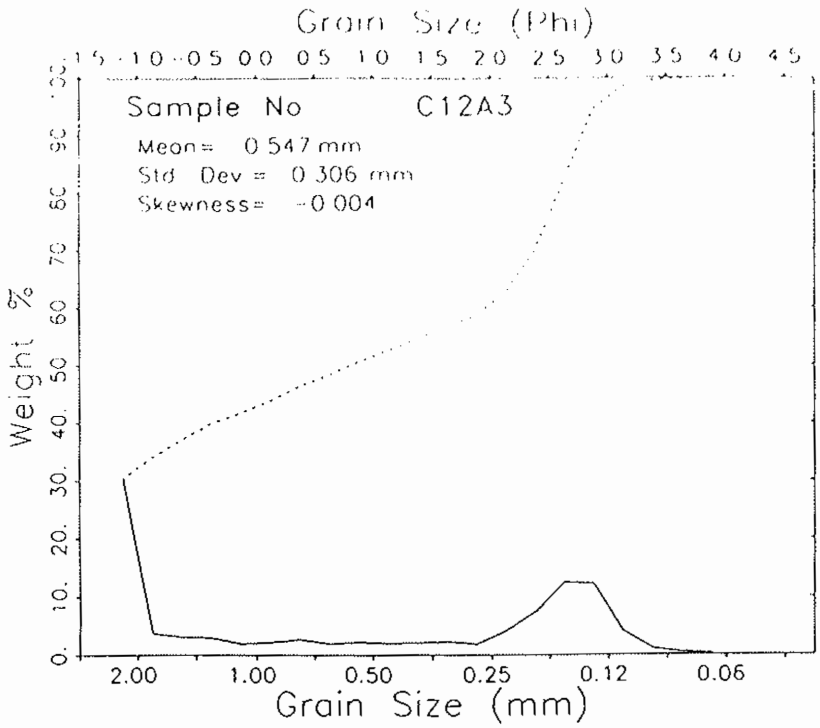
MOMENT MEASURES:

MEAN = 1.577 STANDARD DEVIATION = 1.438 SKEWNESS = -.287 KURTOSIS = -1.002
DISPERSION = .621 STANDARD DEVIATION = 1.011 DEVIATION FROM NORMAL DISTR. = -29.71%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.219	-1.095	-.333	.325	2.150	2.713	2.900	3.300	3.750

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.284	1.572	MEDIUM SAND
STANDARD DEVIATION	1.617	1.475	POORLY SORTED
SKEWNESS(1)	-.536	-.505	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.646		
KURTOSIS	.362	.756	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C12A3	060699					
Bogue Bank C12A3 0-2.4						
		-1.125	31.800	30.355	-1.000	30.355
		-.875	3.780	3.608	-.750	33.963
		-.625	3.170	3.026	-.500	36.989
		-.375	2.990	2.854	-.250	39.843
		-.125	2.000	1.909	.000	41.753
		.125	2.230	2.129	.250	43.881
		.375	2.720	2.596	.500	46.478
		.625	2.000	1.909	.750	48.387
		.875	2.250	2.148	1.000	50.535
		1.125	2.090	1.995	1.250	52.530
		1.375	2.120	2.024	1.500	54.553
		1.625	2.320	2.215	1.750	56.768
		1.875	1.930	1.842	2.000	58.610
		2.125	4.210	4.019	2.250	62.629
		2.375	7.670	7.321	2.500	69.950
		2.625	12.970	12.381	2.750	82.331
		2.875	12.730	12.152	3.000	94.483
		3.125	4.140	3.952	3.250	98.435
		3.375	1.010	.964	3.500	99.399
		3.625	.410	.391	3.750	99.790
		3.875	.220	.210	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.760

PERCENT FINER THAN 4.00 PHI = .37 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .871 STANDARD DEVIATION = 1.707 SKEWNESS = -.004 KURTOSIS = -1.725
DISPERSION = .465 STANDARD DEVIATION = .706 DEVIATION FROM NORMAL DISTR. = -58.66%

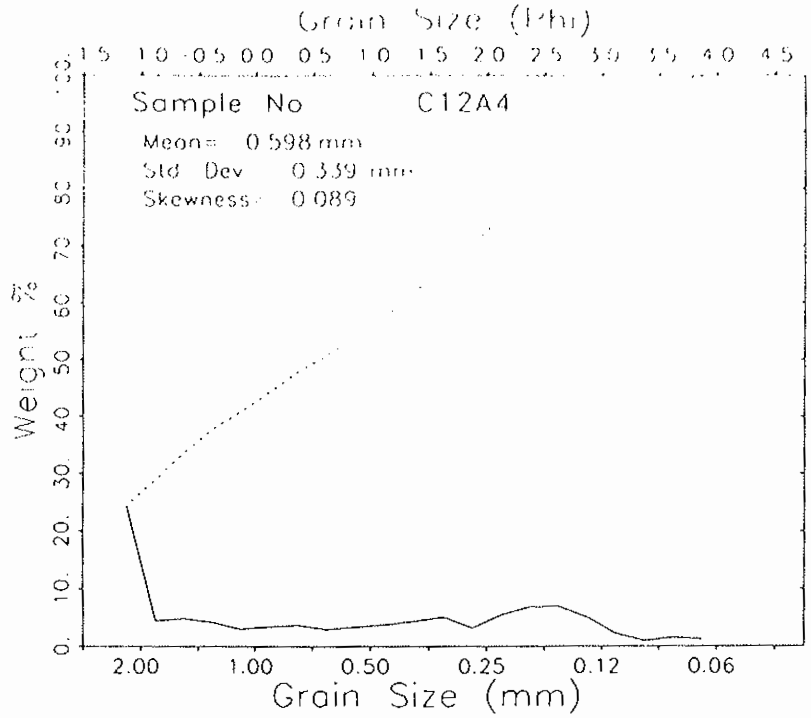
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.209	-1.118	-1.044	.938	2.602	2.784	3.033	3.397

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.833	.868	COARSE SAND
STANDARD DEVIATION	1.951	1.618	POORLY SORTED
SKEWNESS(1)	-.054	-.033	NEAR SYMMETRICAL
SKEWNESS(2)	-.013		
KURTOSIS	.087	.477	VERY PLATYKURTIC

1.618 POORLY SORTED

SKEWNESS(1) -.054



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C12A4	060699					
Bogue Bank C12A4 0-3.7						
		-1.125	45.210	24.450	-1.000	24.450
		-.875	8.170	4.418	-.750	28.868
		-.625	8.880	4.802	-.500	33.670
		-.375	7.680	4.153	-.250	37.824
		-.125	5.510	2.980	.000	40.804
		.125	6.300	3.407	.250	44.211
		.375	6.740	3.645	.500	47.856
		.625	5.270	2.850	.750	50.706
		.875	6.070	3.283	1.000	53.988
		1.125	6.890	3.726	1.250	57.715
		1.375	7.890	4.267	1.500	61.982
		1.625	9.400	5.084	1.750	67.065
		1.875	5.760	3.115	2.000	70.180
		2.125	10.030	5.424	2.250	75.604
		2.375	12.580	6.803	2.500	82.408
		2.625	12.710	6.874	2.750	89.281
		2.875	9.140	4.943	3.000	94.224
		3.125	3.910	2.115	3.250	96.339
		3.375	1.700	.919	3.500	97.258
		3.625	2.790	1.509	3.750	98.767
		3.875	2.280	1.233	4.000	100.000

TOTAL WEIGHT (GRAMS) = 184.910

PERCENT FINER THAN 4.00 PHI = 3.67 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .742 STANDARD DEVIATION = 1.561 SKEWNESS = .009 KURTOSIS = -1.393
DISPERSION = .591 STANDARD DEVIATION = .943 DEVIATION FROM NORMAL DISTR. = -39.58%

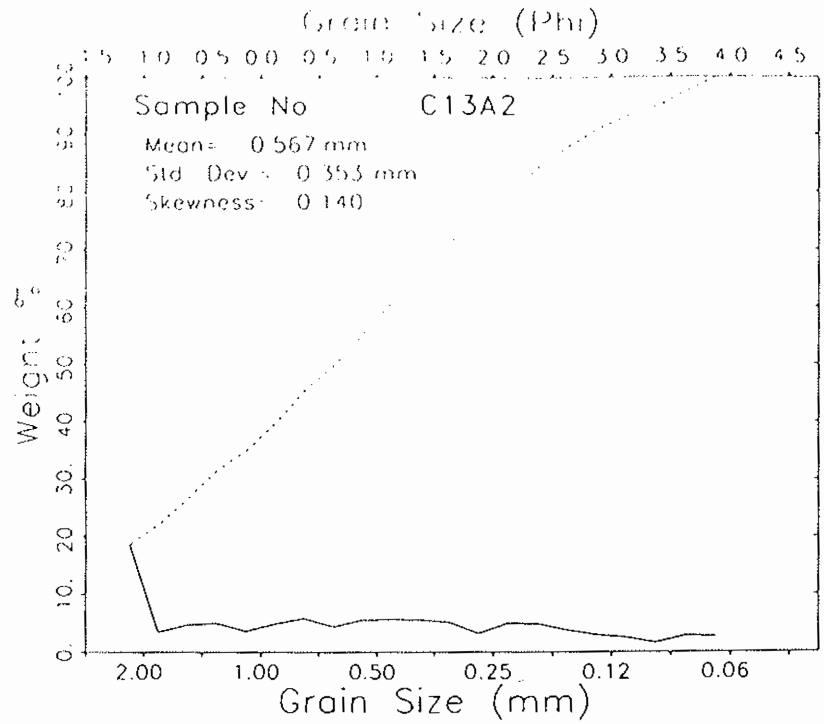
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.199	-1.086	-.969	.688	2.222	2.558	3.092	3.797

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.736	.720	COARSE SAND
STANDARD DEVIATION	1.822	1.561	POORLY SORTED
SKEWNESS(1)	.026	.073	NEAR SYMMETRICAL
SKEWNESS(2)	.142		
KURTOSIS	.177	.551	VERY PLATYKURTIC

1.561 POORLY SORTED

SKEWNESS(1) .026



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C13A2	060699					
Bogue Bank C13A2 0-1.9						
		-1.125	17.710	18.469	-1.000	18.469
		-.875	3.260	3.400	-.750	21.869
		-.625	4.420	4.609	-.500	26.478
		-.375	4.660	4.860	-.250	31.338
		-.125	3.410	3.556	.000	34.894
		.125	4.640	4.839	.250	39.733
		.375	5.450	5.684	.500	45.417
		.625	4.100	4.276	.750	49.692
		.875	5.260	5.485	1.000	55.178
		1.125	5.320	5.548	1.250	60.726
		1.375	5.210	5.433	1.500	66.159
		1.625	4.840	5.047	1.750	71.207
		1.875	3.030	3.160	2.000	74.366
		2.125	4.660	4.860	2.250	79.226
		2.375	4.640	4.839	2.500	84.065
		2.625	3.560	3.713	2.750	87.778
		2.875	2.770	2.889	3.000	90.666
		3.125	2.330	2.430	3.250	93.096
		3.375	1.500	1.564	3.500	94.661
		3.625	2.600	2.711	3.750	97.372
		3.875	2.520	2.628	4.000	100.000

TOTAL WEIGHT (GRAMS) = 95.890

PERCENT FINER THAN 4.00 PHI = 8.24 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .819 STANDARD DEVIATION = 1.501 SKEWNESS = .140 KURTOSIS = -1.031
DISPERSION = .650 STANDARD DEVIATION = 1.081 DEVIATION FROM NORMAL DISTR. = -27.95%

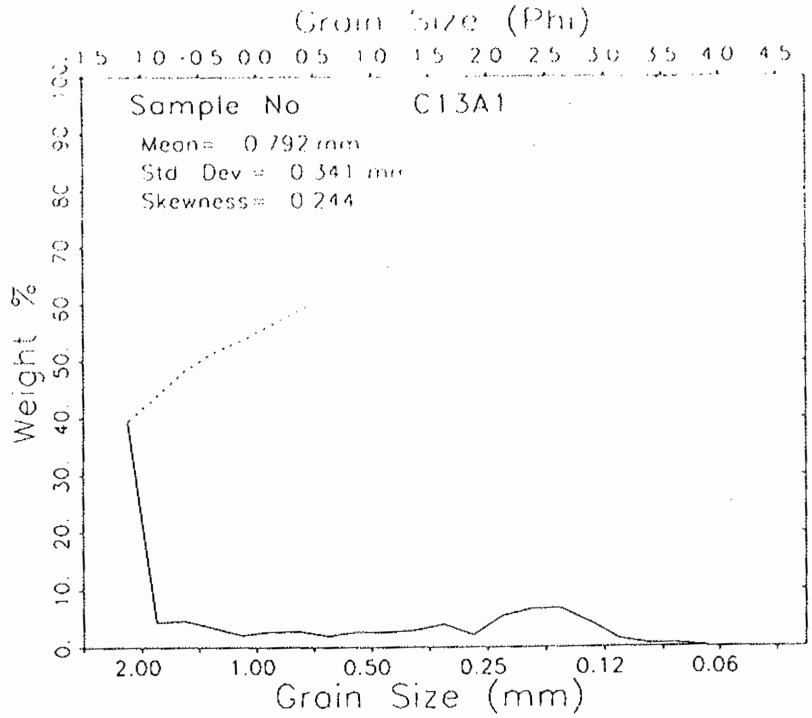
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.182	-1.033	-.580	.764	2.033	2.497	3.531	3.905

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.732	.742	COARSE SAND
STANDARD DEVIATION	1.765	1.597	POORLY SORTED
SKEWNESS(1)	-.018	.078	NEAR SYMMETRICAL
SKEWNESS(2)	.233		
KURTOSIS	.335	.739	PLATYKURTIC

1.597 POORLY SORTED

SKEWNESS(1) -.018



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C13A1 060699						
Bogue Bank C13A1 0-2.7						
	-1.125	41.450	39.397	-1.000	39.397	
	-.875	4.550	4.325	-.750	43.722	
	-.625	4.770	4.534	-.500	48.256	
	-.375	3.490	3.317	-.250	51.573	
	-.125	2.140	2.034	.000	53.607	
	.125	2.810	2.671	.250	56.278	
	.375	2.880	2.737	.500	59.015	
	.625	1.990	1.891	.750	60.907	
	.875	2.730	2.595	1.000	63.502	
	1.125	2.720	2.585	1.250	66.087	
	1.375	3.060	2.908	1.500	68.995	
	1.625	4.050	3.849	1.750	72.845	
	1.875	2.140	2.034	2.000	74.879	
	2.125	5.550	5.275	2.250	80.154	
	2.375	6.940	6.596	2.500	86.750	
	2.625	6.990	6.644	2.750	93.394	
	2.875	4.420	4.201	3.000	97.595	
	3.125	1.380	1.312	3.250	98.907	
	3.375	.510	.485	3.500	99.392	
	3.625	.510	.485	3.750	99.876	
	3.875	.130	.124	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 105.210

PERCENT FINER THAN 4.00 PHI = 1.16 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .337 STANDARD DEVIATION = 1.554 SKEWNESS = .244 KURTOSIS = -1.385

DISPERSION = .426 STANDARD DEVIATION = .645 DEVIATION FROM NORMAL DISTR. = -58.48%

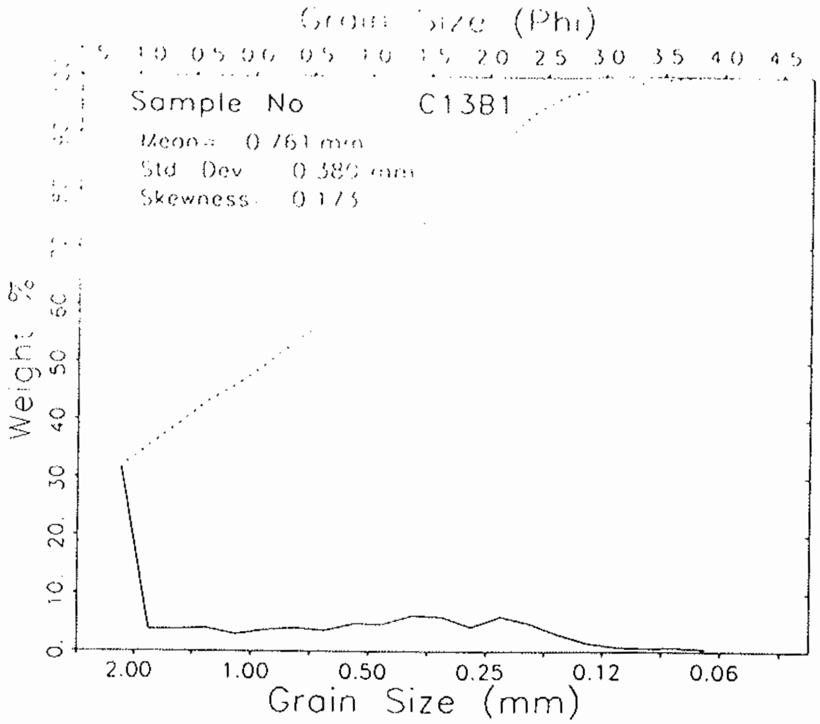
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.244	-1.218	-1.148	-1.091	-.369	2.006	2.396	2.846	3.298

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.624	.293	COARSE SAND
STANDARD DEVIATION	1.772	1.502	POORLY SORTED
SKEWNESS(1)	.560	.571	STRONGLY FINE-SKEWED
SKEWNESS(2)	.667		
KURTOSIS	.147	.538	VERY PLATYKURTIC

1.502 POORLY SORTED

SKEWNESS(1) .560



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C13B1	060699						
Bouge Bank C13B1 0-2.2							
		-1.125	32.400	31.730		-1.000	31.730
		-.875	3.840	3.761		-.750	35.491
		-.625	3.780	3.702		-.500	39.193
		-.375	4.030	3.947		-.250	43.140
		-.125	2.950	2.889		.000	46.029
		.125	3.740	3.663		.250	49.692
		.375	4.070	3.986		.500	53.677
		.625	3.670	3.594		.750	57.272
		.875	4.790	4.691		1.000	61.963
		1.125	4.700	4.603		1.250	66.565
		1.375	6.290	6.160		1.500	72.725
		1.625	6.050	5.925		1.750	78.650
		1.875	4.200	4.113		2.000	82.764
		2.125	6.060	5.935		2.250	88.698
		2.375	4.900	4.799		2.500	93.497
		2.625	2.930	2.869		2.750	96.367
		2.875	1.440	1.410		3.000	97.777
		3.125	.700	.686		3.250	98.462
		3.375	.530	.519		3.500	98.981
		3.625	.640	.627		3.750	99.608
		3.875	.400	.392		4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.110

PERCENT FINER THAN 4.00 PHI = .81 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .394 STANDARD DEVIATION = 1.396 SKEWNESS = .173 KURTOSIS = -1.203
DISPERSION = .507 STANDARD DEVIATION = .778 DEVIATION FROM NORMAL DISTR. = -44.23%

PERCENTILES:

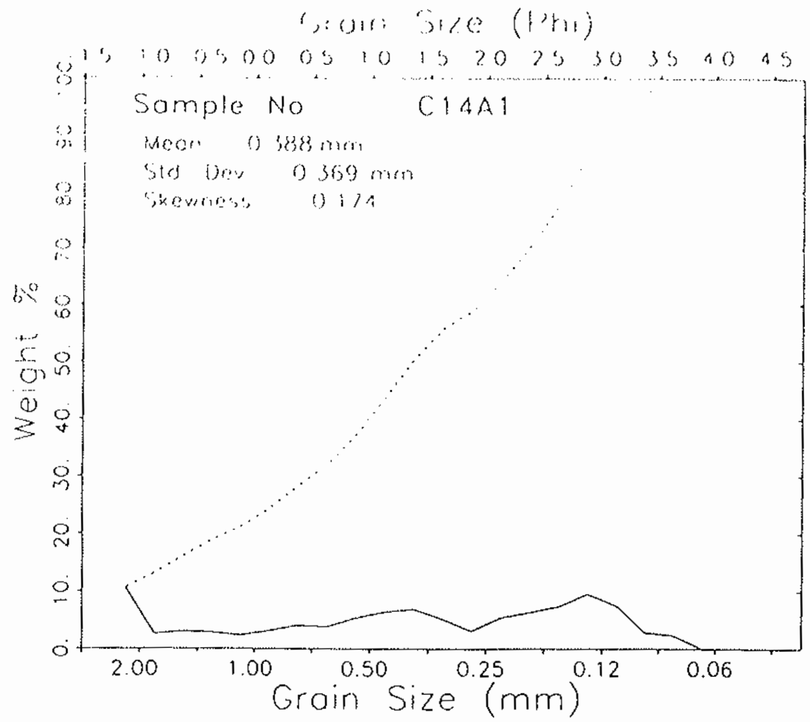
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.211	-1.124	-1.053	.269	1.596	2.052	2.631	3.507

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.464	.399	COARSE SAND
STANDARD DEVIATION	1.508	1.376	POORLY SORTED
SKEWNESS(1)	.123	.176	FINE-SKEWED
SKEWNESS(2)	.278		
KURTOSIS	.210	.594	VERY PLATYKURTIC

1.376

POORLY SORTED

SKEWNESS(1) .123



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14A1	060699					
Bogue Banks C14A1 0-2.4						
		-1.125	11.190	10.606	-1.000	10.606
		-.875	2.650	2.512	-.750	13.117
		-.625	3.110	2.948	-.500	16.065
		-.375	2.990	2.834	-.250	18.899
		-.125	2.430	2.303	.000	21.202
		.125	3.210	3.042	.250	24.244
		.375	4.190	3.971	.500	28.215
		.625	4.000	3.791	.750	32.006
		.875	5.620	5.327	1.000	37.333
		1.125	6.770	6.416	1.250	43.749
		1.375	7.260	6.881	1.500	50.630
		1.625	5.440	5.156	1.750	55.786
		1.875	3.240	3.071	2.000	58.857
		2.125	5.690	5.393	2.250	64.250
		2.375	6.660	6.312	2.500	70.562
		2.625	7.720	7.317	2.750	77.879
		2.875	9.970	9.449	3.000	87.328
		3.125	7.910	7.497	3.250	94.825
		3.375	2.950	2.796	3.500	97.621
		3.625	2.420	2.294	3.750	99.915
		3.875	.090	.085	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.510

PERCENT FINER THAN 4.00 PHI = .58 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.367 STANDARD DEVIATION = 1.438 SKEWNESS = -.174 KURTOSIS = -1.069

DISPERSION = .653 STANDARD DEVIATION = 1.089 DEVIATION FROM NORMAL DISTR. = -24.28%

PERCENTILES:

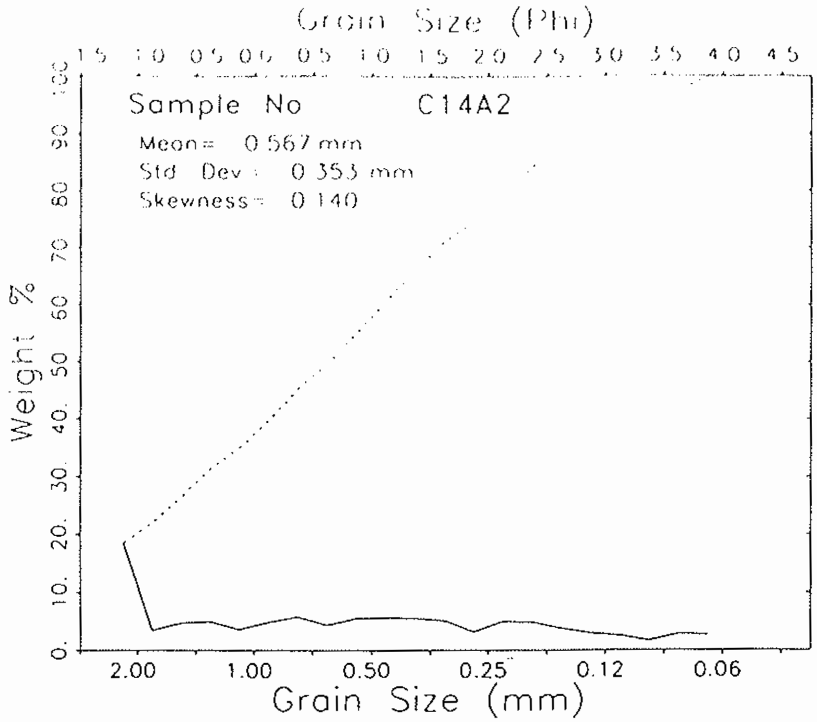
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.226	-1.132	-.505	.298	1.477	2.652	2.912	3.266	3.650

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.203	1.295	MEDIUM SAND
STANDARD DEVIATION	1.709	1.521	POORLY SORTED
SKEWNESS(1)	-.160	-.173	COARSE-SKEWED
SKEWNESS(2)	-.240		
KURTOSIS	.287	.766	PLATYKURTIC

1.709 1.521

POORLY SORTED

SKEWNESS(1) -.160



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14A2	060699					
Bogue Bank C14A2 0-1.9						
		-1.125	17.710	18.469	-1.000	18.469
		-.875	3.260	3.400	-.750	21.869
		-.625	4.420	4.609	-.500	26.478
		-.375	4.660	4.860	-.250	31.338
		-.125	3.410	3.556	.000	34.894
		.125	4.640	4.839	.250	39.733
		.375	5.450	5.684	.500	45.417
		.625	4.100	4.276	.750	49.692
		.875	5.260	5.485	1.000	55.178
		1.125	5.320	5.548	1.250	60.726
		1.375	5.210	5.433	1.500	66.159
		1.625	4.840	5.047	1.750	71.207
		1.875	3.030	3.160	2.000	74.366
		2.125	4.660	4.860	2.250	79.226
		2.375	4.640	4.839	2.500	84.065
		2.625	3.560	3.713	2.750	87.778
		2.875	2.770	2.889	3.000	90.666
		3.125	2.330	2.430	3.250	93.096
		3.375	1.500	1.564	3.500	94.661
		3.625	2.600	2.711	3.750	97.372
		3.875	2.520	2.628	4.000	100.000

TOTAL WEIGHT (GRAMS) = 95.890

PERCENT FINER THAN 4.00 PHI = 8.24 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .819 STANDARD DEVIATION = 1.501 SKEWNESS = .140 KURTOSIS = -1.031
DISPERSION = .650 STANDARD DEVIATION = 1.081 DEVIATION FROM NORMAL DISTR. = -27.95%

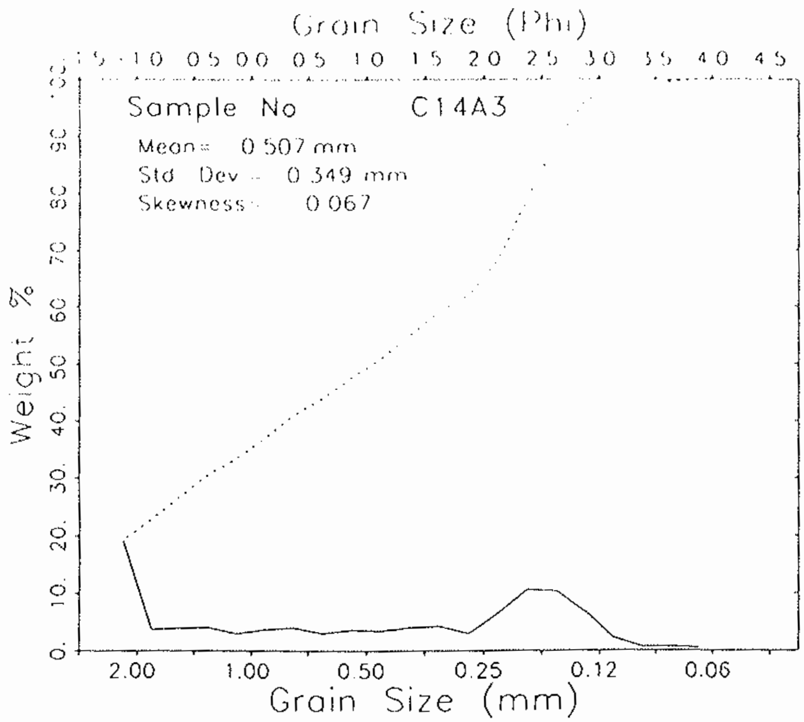
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.182	-1.033	-.580	.764	2.033	2.497	3.531	3.905

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.732	.742	COARSE SAND
STANDARD DEVIATION	1.765	1.597	POORLY SORTED
SKEWNESS(1)	-.018	.078	NEAR SYMMETRICAL
SKEWNESS(2)	.233		
KURTOSIS	.335	.739	PLATYKURTIC

1.597 POORLY SORTED

SKEWNESS(1) -.018



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14A3	060699					
Bogue Bank C14A3 Part 3, 0-2.5						
		-1.125	20.460	19.111	-1.000	19.111
		-.875	3.910	3.652	-.750	22.763
		-.625	4.130	3.858	-.500	26.621
		-.375	4.220	3.942	-.250	30.562
		-.125	3.060	2.858	.000	33.421
		.125	3.880	3.624	.250	37.045
		.375	4.230	3.951	.500	40.996
		.625	3.140	2.933	.750	43.929
		.875	3.840	3.587	1.000	47.515
		1.125	3.630	3.391	1.250	50.906
		1.375	4.250	3.970	1.500	54.876
		1.625	4.530	4.231	1.750	59.107
		1.875	3.070	2.868	2.000	61.975
		2.125	6.960	6.501	2.250	68.476
		2.375	11.330	10.583	2.500	79.058
		2.625	11.020	10.293	2.750	89.352
		2.875	7.200	6.725	3.000	96.077
		3.125	2.290	2.139	3.250	98.216
		3.375	.710	.663	3.500	98.879
		3.625	.700	.654	3.750	99.533
		3.875	.500	.467	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.060

PERCENT FINER THAN 4.00 PHI = .94 PERCENT COARSER THAN -1.00 PHI = .00

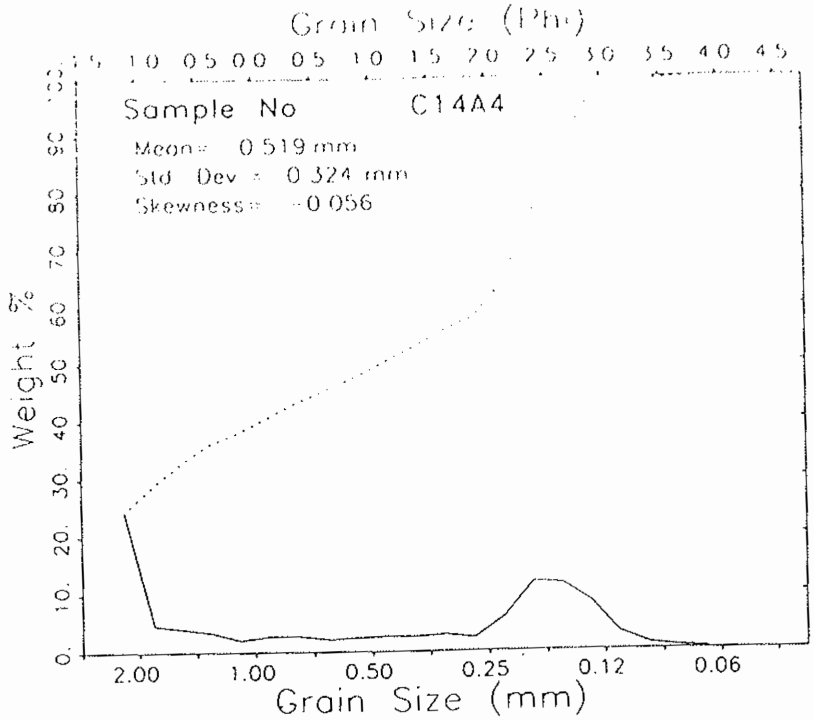
MOMENT MEASURES:

MEAN = .979 STANDARD DEVIATION = 1.518 SKEWNESS = -.067 KURTOSIS = -1.471
DISPERSION = .590 STANDARD DEVIATION = .942 DEVIATION FROM NORMAL DISTR. = -37.95%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.237	-1.185	-1.041	-.605	1.183	2.404	2.620	2.960	3.546

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.790	.921	COARSE SAND
STANDARD DEVIATION	1.830	1.543	POORLY SORTED
SKEWNESS(1)	-.215	-.179	COARSE-SKEWED
SKEWNESS(2)	-.161		
KURTOSIS	.132	.564	VERY PLATYKURTIC
1.543			POORLY SORTED
SKEWNESS(1)	-.215		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14A4	060699						
Bogue Bank C14A4 0-1.4							
		-1.125	26.410		24.187	-1.000	24.187
		-.875	4.990		4.570	-.750	28.757
		-.625	4.320		3.956	-.500	32.714
		-.375	3.650		3.343	-.250	36.056
		-.125	2.180		1.997	.000	38.053
		.125	2.910		2.665	.250	40.718
		.375	2.880		2.638	.500	43.356
		.625	2.220		2.033	.750	45.389
		.875	2.540		2.326	1.000	47.715
		1.125	2.770		2.537	1.250	50.252
		1.375	2.720		2.491	1.500	52.743
		1.625	3.080		2.821	1.750	55.564
		1.875	2.460		2.253	2.000	57.817
		2.125	6.290		5.761	2.250	63.577
		2.375	12.880		11.796	2.500	75.373
		2.625	12.650		11.585	2.750	86.959
		2.875	9.150		8.380	3.000	95.338
		3.125	3.270		2.995	3.250	98.333
		3.375	1.070		.980	3.500	99.313
		3.625	.550		.504	3.750	99.817
		3.875	.200		.183	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.190

PERCENT FINER THAN 4.00 PHI = .26 PERCENT COARSER THAN -1.00 PHI = .00

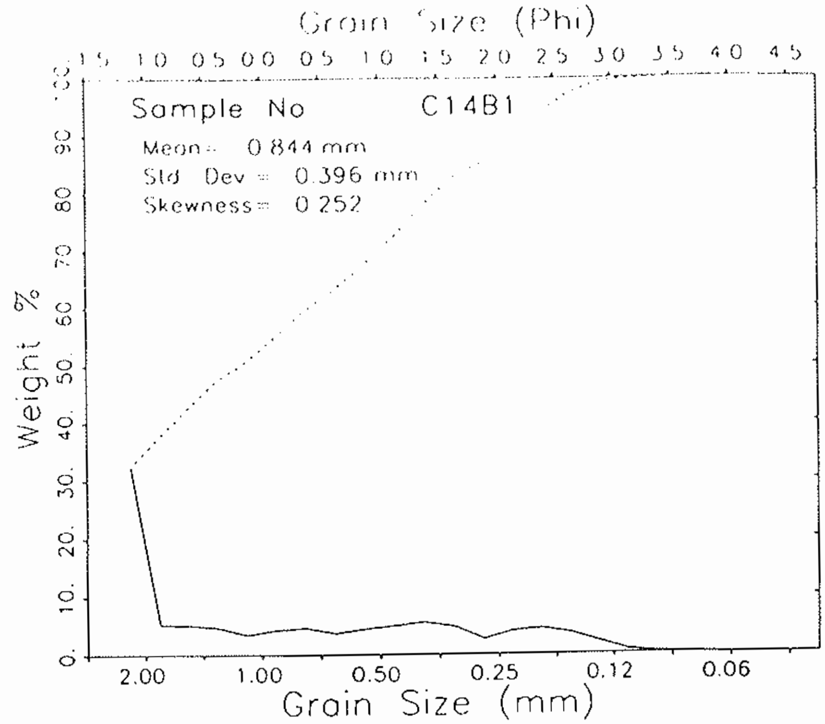
MOMENT MEASURES:

MEAN = .945 STANDARD DEVIATION = 1.627 SKEWNESS = -.056 KURTOSIS = -1.650
DISPERSION = .526 STANDARD DEVIATION = .812 DEVIATION FROM NORMAL DISTR. = -50.08%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.198	-1.085	-.956	1.225	2.492	2.686	2.990	3.420

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.801	.942	COARSE SAND
STANDARD DEVIATION	1.805	1.577	POORLY SORTED
SKEWNESS(1)	-.225	-.191	COARSE-SKEWED
SKEWNESS(2)	-.175		
KURTOSIS	.111	.490	VERY PLATYKURTIC
1.577			POORLY SORTED
SKEWNESS(1)	-.225		



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14B1	060699					
Bogue Bank C14B1 0-1.9						
		-1.125	34.820	32.512	-1.000	32.512
		-.875	5.510	5.145	-.750	37.656
		-.625	5.370	5.014	-.500	42.670
		-.375	5.010	4.678	-.250	47.348
		-.125	3.620	3.380	.000	50.728
		.125	4.550	4.248	.250	54.977
		.375	4.880	4.556	.500	59.533
		.625	3.870	3.613	.750	63.147
		.875	4.720	4.407	1.000	67.554
		1.125	5.210	4.865	1.250	72.418
		1.375	5.830	5.444	1.500	77.862
		1.625	5.060	4.725	1.750	82.586
		1.875	2.760	2.577	2.000	85.163
		2.125	4.250	3.968	2.250	89.132
		2.375	4.740	4.426	2.500	93.557
		2.625	3.780	3.529	2.750	97.087
		2.875	2.190	2.045	3.000	99.132
		3.125	.570	.532	3.250	99.664
		3.375	.160	.149	3.500	99.813
		3.625	.110	.103	3.750	99.916
		3.875	.090	.084	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.100

PERCENT FINER THAN 4.00 PHI = .14 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

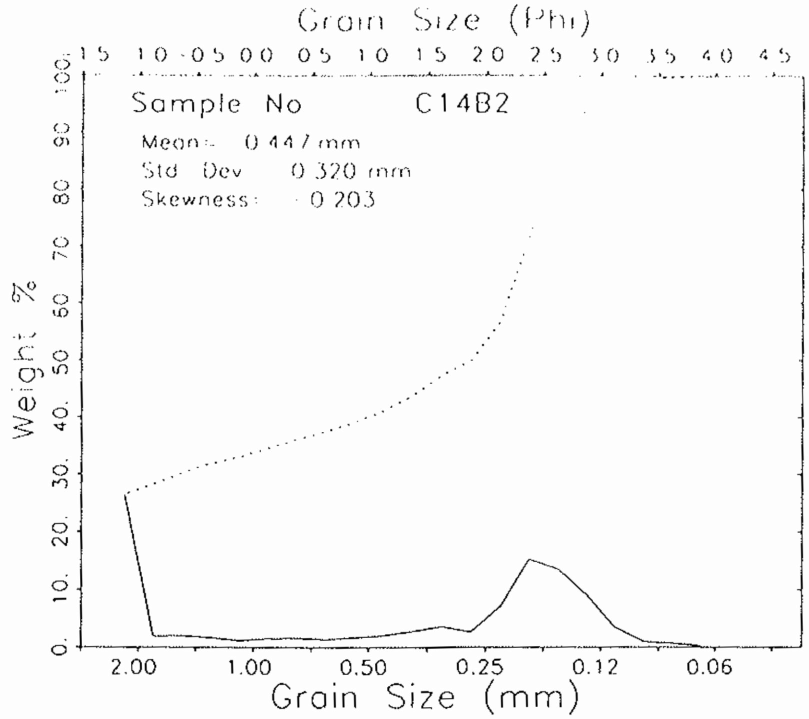
MEAN = .244 STANDARD DEVIATION = 1.338 SKEWNESS = .252 KURTOSIS = -1.109

DISPERSION = .491 STANDARD DEVIATION = .749 DEVIATION FROM NORMAL DISTR. = -43.99%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.212	-1.127	-1.058	-.054	1.369	1.887	2.602	2.984

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.380	.235	COARSE SAND
STANDARD DEVIATION	1.507	1.331	POORLY SORTED
SKEWNESS(1)	.208	.340	STRONGLY FINE-SKEWED
SKEWNESS(2)	.497		
KURTOSIS	.265	.644	VERY PLATYKURTIC
1.331			POORLY SORTED
SKEWNESS(1)	.208		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C14B2	060699						
Bogue Bank C14B2 Part 1, 0-1.8							
		-1.125	28.430		26.370	-1.000	26.370
		-.875	2.020		1.874	-.750	28.244
		-.625	2.130		1.976	-.500	30.220
		-.375	1.800		1.670	-.250	31.889
		-.125	1.220		1.132	.000	33.021
		.125	1.610		1.493	.250	34.514
		.375	1.710		1.586	.500	36.101
		.625	1.390		1.289	.750	37.390
		.875	1.790		1.660	1.000	39.050
		1.125	2.140		1.985	1.250	41.035
		1.375	2.890		2.681	1.500	43.716
		1.625	3.840		3.562	1.750	47.278
		1.875	2.860		2.653	2.000	49.930
		2.125	7.520		6.975	2.250	56.906
		2.375	16.430		15.240	2.500	72.145
		2.625	14.660		13.598	2.750	85.743
		2.875	9.860		9.146	3.000	94.889
		3.125	3.690		3.423	3.250	98.312
		3.375	.970		.900	3.500	99.212
		3.625	.650		.603	3.750	99.814
		3.875	.200		.186	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.810

PERCENT FINER THAN 4.00 PHI = .18 PERCENT COARSER THAN -1.00 PHI = .00

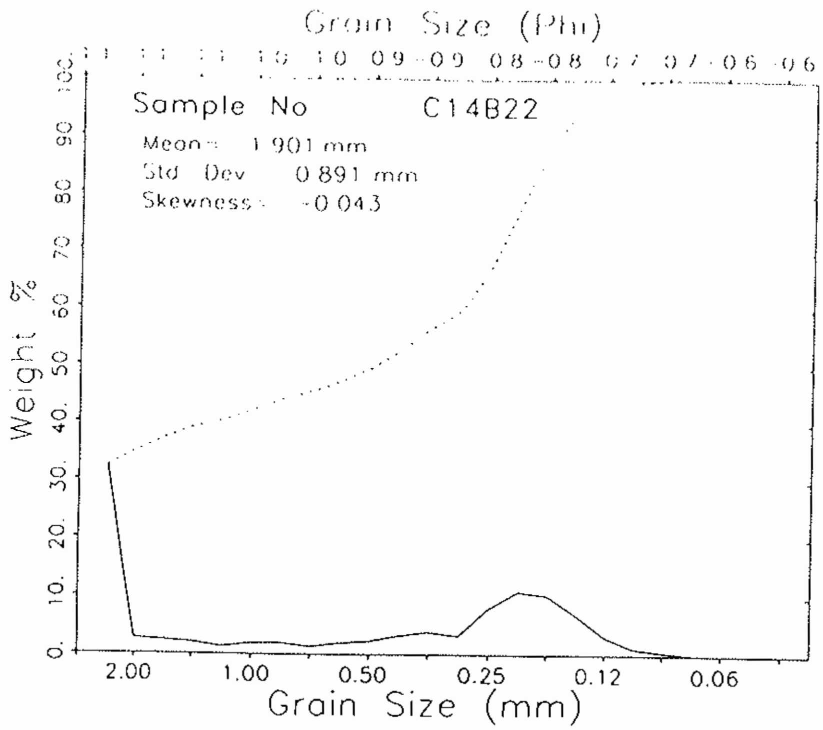
MOMENT MEASURES:

MEAN = 1.161 STANDARD DEVIATION = 1.645 SKEWNESS = -.203 KURTOSIS = -1.535
DISPERSION = .452 STANDARD DEVIATION = .686 DEVIATION FROM NORMAL DISTR. = -58.31%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.203	-1.098	-1.013	2.002	2.552	2.718	3.008	3.441

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.810	1.207	MEDIUM SAND
STANDARD DEVIATION	1.908	1.592	POORLY SORTED
SKEWNESS(1)	-.625	-.574	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.576		
KURTOSIS	.103	.404	VERY PLATYKURTIC
1.592			POORLY SORTED
SKEWNESS(1)	-.625		



SAMPLE NO. DATE

C14822 060699

Bogue Banks C14B2 Part 2, 0-1.8

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	34.510	32.334	-1.112	32.334
-1.100	2.770	2.595	-1.087	34.929
-1.075	2.440	2.286	-1.063	37.215
-1.050	2.070	1.939	-1.038	39.155
-1.025	1.300	1.218	-1.013	40.373
-1.000	1.960	1.836	-.988	42.209
-.975	2.020	1.893	-.963	44.102
-.950	1.420	1.330	-.938	45.432
-.925	1.990	1.865	-.913	47.297
-.900	2.400	2.249	-.888	49.546
-.875	3.340	3.129	-.863	52.675
-.850	4.040	3.785	-.838	56.460
-.825	3.390	3.176	-.813	59.636
-.800	8.380	7.852	-.788	67.488
-.775	11.570	10.840	-.763	78.328
-.750	10.870	10.185	-.738	88.513
-.725	7.280	6.821	-.713	95.334
-.700	3.290	3.083	-.688	98.417
-.675	1.150	1.077	-.663	99.494
-.650	.500	.468	-.638	99.963
-.625	.040	.037	-.613	100.000

TOTAL WEIGHT (GRAMS) = 106.730

PERCENT FINER THAN -.61 PHI = .41 PERCENT COARSER THAN -1.11 PHI = .00

MOMENT MEASURES:

MEAN = -.927 STANDARD DEVIATION = .166 SKEWNESS = -.043 KURTOSIS = -1.699

DISPERSION = -.549 STANDARD DEVIATION = .068 DEVIATION FROM NORMAL DISTR. = -58.85%

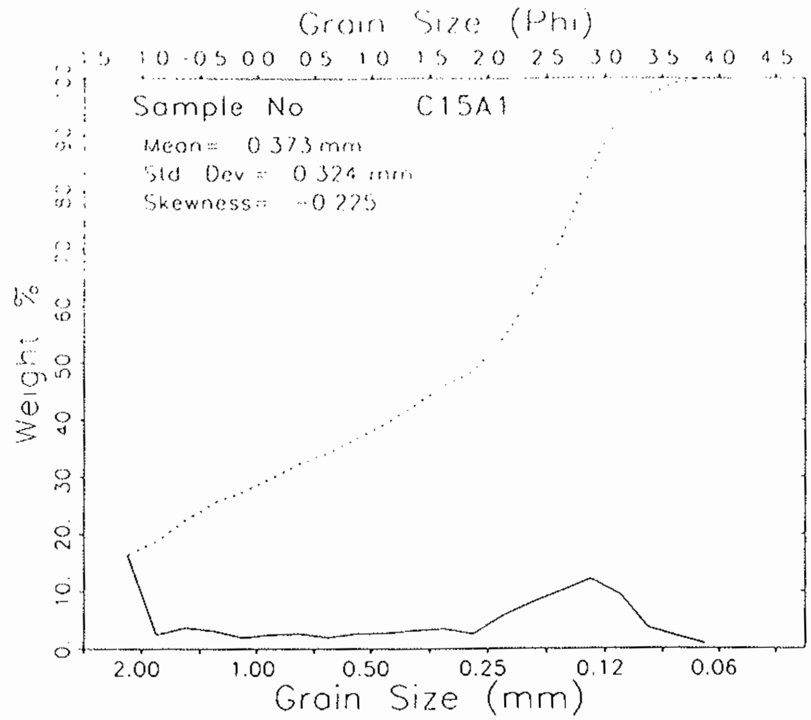
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.137	-1.134	-1.125	-1.118	-.884	-.770	-.749	-.714	-.674

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	-.937	-.919	VERY COARSE SAND
STANDARD DEVIATION	.188	.158	VERY WELL SORTED
SKEWNESS(1)	-.281	-.236	COARSE-SKEWED
SKEWNESS(2)	-.211		
KURTOSIS	.115	.495	VERY PLATYKURTIC

.158 VERY WELL SORTED

SKEWNESS(1) -.281



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C15A1	060699					
Bogue Banks C15A1 0-2.0						
		-1.125	17.140	16.366	-1.000	16.366
		-.875	2.460	2.349	-.750	18.715
		-.625	3.850	3.676	-.500	22.391
		-.375	3.240	3.094	-.250	25.485
		-.125	1.950	1.862	.000	27.347
		.125	2.540	2.425	.250	29.772
		.375	2.640	2.521	.500	32.293
		;625	1.950	1.862	.750	34.154
		.875	2.690	2.569	1.000	36.723
		1.125	2.780	2.654	1.250	39.377
		1.375	3.270	3.122	1.500	42.500
		1.625	3.570	3.409	1.750	45.909
		1.875	2.600	2.483	2.000	48.391
		2.125	5.890	5.624	2.250	54.015
		2.375	8.370	7.992	2.500	62.007
		2.625	10.460	9.988	2.750	71.995
		2.875	12.610	12.040	3.000	84.035
		3.125	9.860	9.415	3.250	93.450
		3.375	3.750	3.581	3.500	97.030
		3.625	2.250	2.148	3.750	99.179
		3.875	.860	.821	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.730

PERCENT FINER THAN 4.00 PHI = 1.35 PERCENT COARSER THAN -1.00 PHI = .00

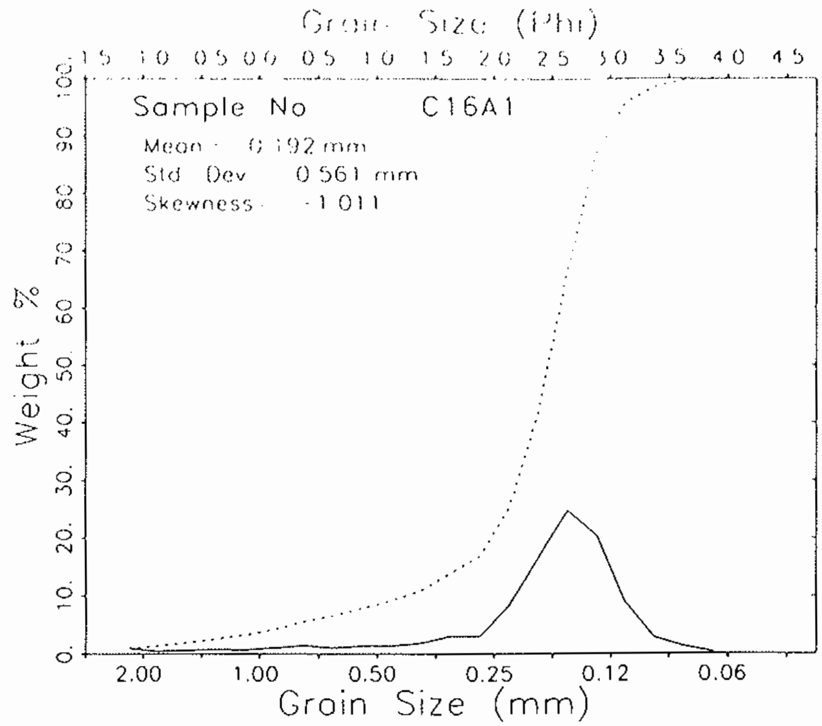
MOMENT MEASURES:

MEAN = 1.422 STANDARD DEVIATION = 1.626 SKEWNESS = -.225 KURTOSIS = -1.330
DISPERSION = .598 STANDARD DEVIATION = .958 DEVIATION FROM NORMAL DISTR. = -41.06%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.174	-1.006	-.289	2.072	2.812	2.999	3.358	3.729

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.997	1.355	MEDIUM SAND
STANDARD DEVIATION	2.002	1.688	POORLY SORTED
SKEWNESS(1)	-.537	-.484	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.489		
KURTOSIS	.132	.599	VERY PLATYKURTIC
1.688			POORLY SORTED
SKEWNESS(1)	-.537		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C16A1	060699						
Bogue Bank C16A1 D-1.9							
		-1.125	.940	.910		-1.000	.910
		-.875	.410	.397		-.750	1.307
		-.625	.530	.513		-.500	1.820
		-.375	.730	.707		-.250	2.527
		-.125	.650	.629		.000	3.157
		.125	1.030	.997		.250	4.154
		.375	1.410	1.365		.500	5.520
		.625	1.040	1.007		.750	6.527
		.875	1.320	1.278		1.000	7.805
		1.125	1.380	1.336		1.250	9.141
		1.375	1.820	1.762		1.500	10.903
		1.625	3.100	3.002		1.750	13.905
		1.875	3.040	2.944		2.000	16.849
		2.125	8.640	8.366		2.250	25.215
		2.375	17.170	16.626		2.500	41.842
		2.625	25.470	24.664		2.750	66.505
		2.875	21.120	20.451		3.000	86.957
		3.125	9.070	8.783		3.250	95.739
		3.375	2.830	2.740		3.500	98.480
		3.625	1.260	1.220		3.750	99.700
		3.875	.310	.300		4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.270

PERCENT FINER THAN 4.00 PHI = .16 PERCENT COARSER THAN -1.00 PHI = .00

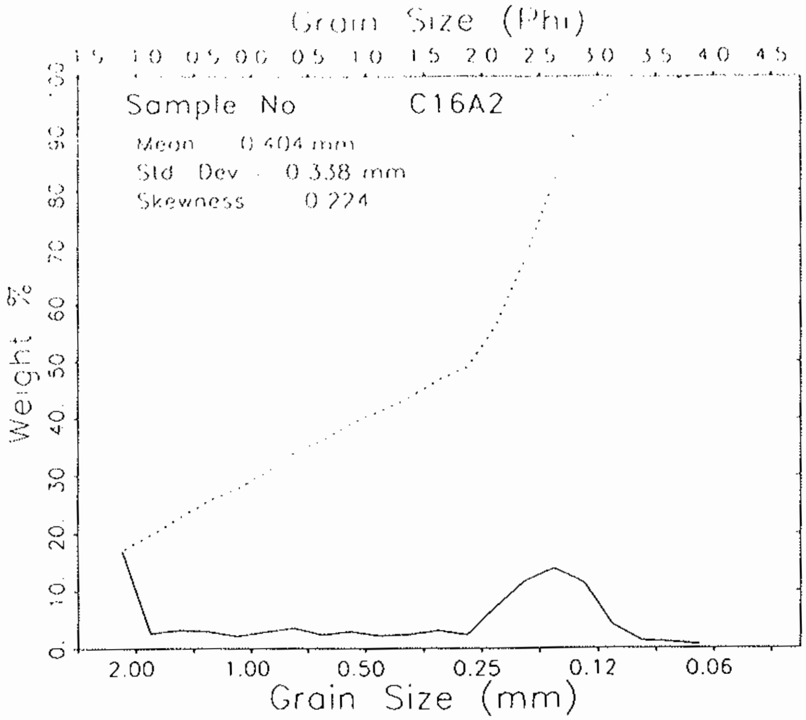
MOMENT MEASURES:

MEAN = 2.378 STANDARD DEVIATION = .833 SKEWNESS = -1.011 KURTOSIS = 4.668
DISPERSION = .380 STANDARD DEVIATION = .581 DEVIATION FROM NORMAL DISTR. = -30.27%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.943	.405	1.928	2.244	2.583	2.854	2.964	3.229	3.607

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.446	2.491	FINE SAND
STANDARD DEVIATION	.518	.687	MODERATELY WELL SORTED
SKEWNESS(1)	-.264	-.403	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.478		
KURTOSIS	1.726	1.897	VERY LEPTOKURTIC
.687			MODERATELY WELL SORTED
SKEWNESS(1)	-.264		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C16A2	060699						
Bogue Banks C16A2 0-2.1							
		-1.125	17.190		17.047	-1.000	17.047
		-.875	2.580		2.559	-.750	19.605
		-.625	3.140		3.114	-.500	22.719
		-.375	2.920		2.896	-.250	25.615
		-.125	2.110		2.092	.000	27.707
		.125	2.800		2.777	.250	30.484
		.375	3.480		3.451	.500	33.935
		.625	2.300		2.281	.750	36.216
		.875	2.930		2.906	1.000	39.121
		1.125	2.150		2.132	1.250	41.253
		1.375	2.390		2.370	1.500	43.624
		1.625	3.040		3.015	1.750	46.638
		1.875	2.360		2.340	2.000	48.979
		2.125	7.370		7.309	2.250	56.287
		2.375	11.780		11.682	2.500	67.969
		2.625	13.890		13.774	2.750	81.743
		2.875	11.600		11.503	3.000	93.247
		3.125	4.060		4.026	3.250	97.273
		3.375	1.260		1.250	3.500	98.522
		3.625	.940		.932	3.750	99.455
		3.875	.550		.545	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.840

PERCENT FINER THAN 4.00 PHI = .78 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

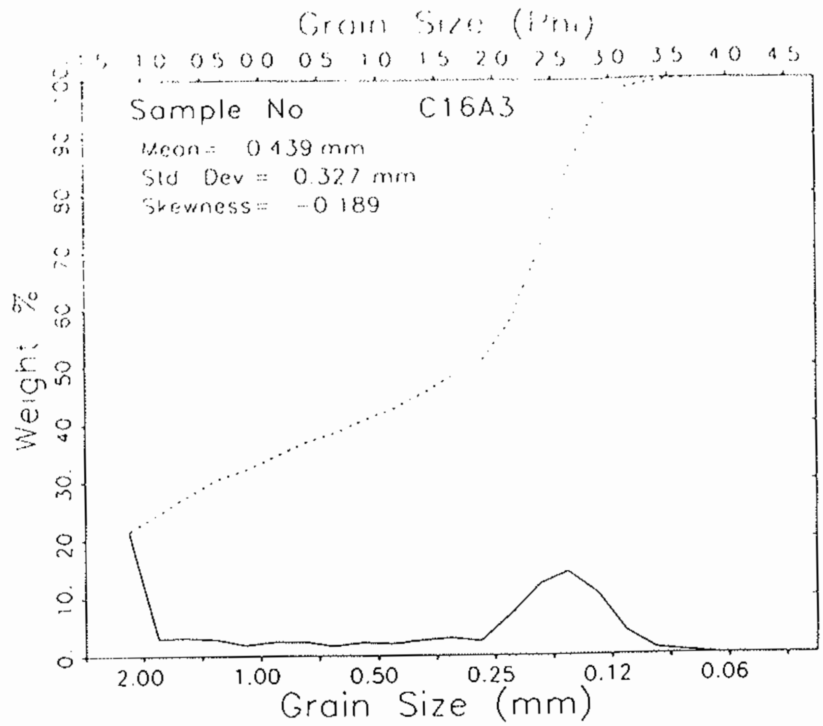
MEAN = 1.306 STANDARD DEVIATION = 1.563 SKEWNESS = -.224 KURTOSIS = -1.351

DISPERSION = .560 STANDARD DEVIATION = .879 DEVIATION FROM NORMAL DISTR. = -43.80%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.177	-1.015	-.303	2.035	2.628	2.799	3.109	3.628

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.892	1.273	MEDIUM SAND
STANDARD DEVIATION	1.907	1.603	POORLY SORTED
SKEWNESS(1)	-.599	-.549	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.560		
KURTOSIS	.124	.599	VERY PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C16A3 060699						
Bogue Banks C16A5 0-1.6						
	-1.125	22.440		21.484	-1.000	21.484
	-.875	3.060		2.930	-.750	24.414
	-.625	3.190		3.054	-.500	27.468
	-.375	2.960		2.834	-.250	30.302
	-.125	1.850		1.771	.000	32.073
	.125	2.450		2.346	.250	34.418
	.375	2.470		2.365	.500	36.783
	.625	1.710		1.637	.750	38.420
	.875	2.280		2.183	1.000	40.603
	1.125	2.070		1.982	1.250	42.585
	1.375	2.690		2.575	1.500	45.160
	1.625	3.100		2.968	1.750	48.128
	1.875	2.490		2.384	2.000	50.512
	2.125	7.230		6.922	2.250	57.434
	2.375	12.690		12.149	2.500	69.584
	2.625	14.850		14.217	2.750	83.801
	2.875	11.090		10.618	3.000	94.418
	3.125	4.150		3.973	3.250	98.392
	3.375	1.030		.986	3.500	99.378
	3.625	.500		.479	3.750	99.856
	3.875	.150		.144	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.450

PERCENT FINER THAN 4.00 PHI = .20 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

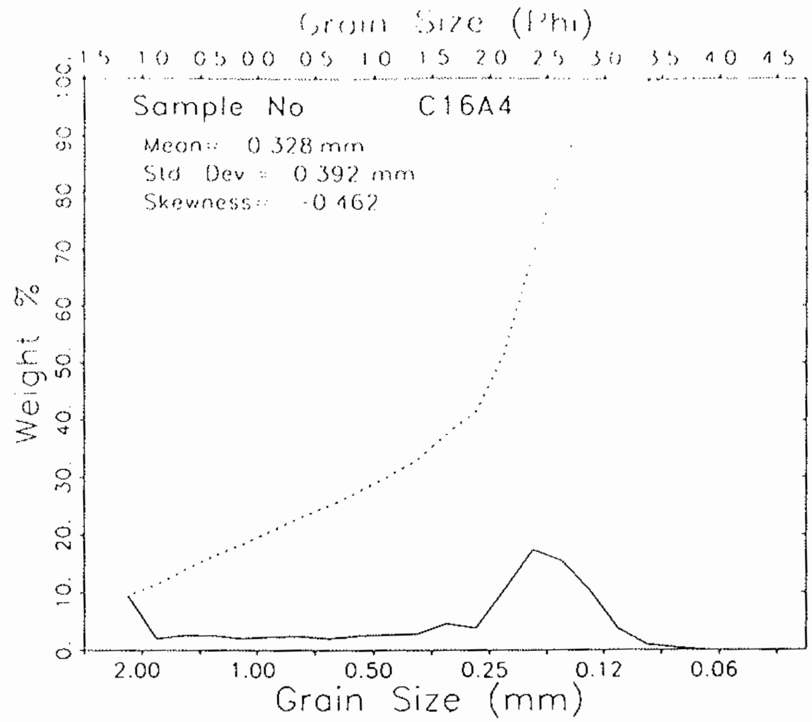
MEAN = 1.187 STANDARD DEVIATION = 1.614 SKEWNESS = -.189 KURTOSIS = -1.516

DISPERSION = .514 STANDARD DEVIATION = .791 DEVIATION FROM NORMAL DISTR. = -50.99%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.192	-1.064	-.702	1.946	2.595	2.755	3.037	3.404

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.845	1.212	MEDIUM SAND
STANDARD DEVIATION	1.909	1.595	POORLY SORTED
SKEWNESS(1)	-.577	-.530	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.536		
KURTOSIS	.107	.526	VERY PLATYKURTIC



SAMPLE NO. DATE

C16A4 060699

Bogue Bank C16A4 0-0.8

MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
-1.125	9.710	9.446	-1.000	9.446
-.875	1.990	1.936	-.750	11.382
-.625	2.660	2.588	-.500	13.970
-.375	2.550	2.481	-.250	16.451
-.125	2.030	1.975	.000	18.426
.125	2.350	2.286	.250	20.712
.375	2.470	2.403	.500	23.115
.625	2.010	1.955	.750	25.071
.875	2.500	2.432	1.000	27.503
1.125	2.700	2.627	1.250	30.129
1.375	2.910	2.831	1.500	32.960
1.625	4.690	4.563	1.750	37.523
1.875	3.930	3.823	2.000	41.346
2.125	10.790	10.497	2.250	51.844
2.375	17.910	17.424	2.500	69.267
2.625	15.940	15.507	2.750	84.775
2.875	10.560	10.273	3.000	95.048
3.125	3.780	3.677	3.250	98.726
3.375	.900	.876	3.500	99.601
3.625	.370	.360	3.750	99.961
3.875	.040	.039	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.790

PERCENT FINER THAN 4.00 PHI = .26 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.607 STANDARD DEVIATION = 1.351 SKEWNESS = -.462 KURTOSIS = -.524

DISPERSION = .535 STANDARD DEVIATION = .830 DEVIATION FROM NORMAL DISTR. = -38.57%

PERCENTILES:

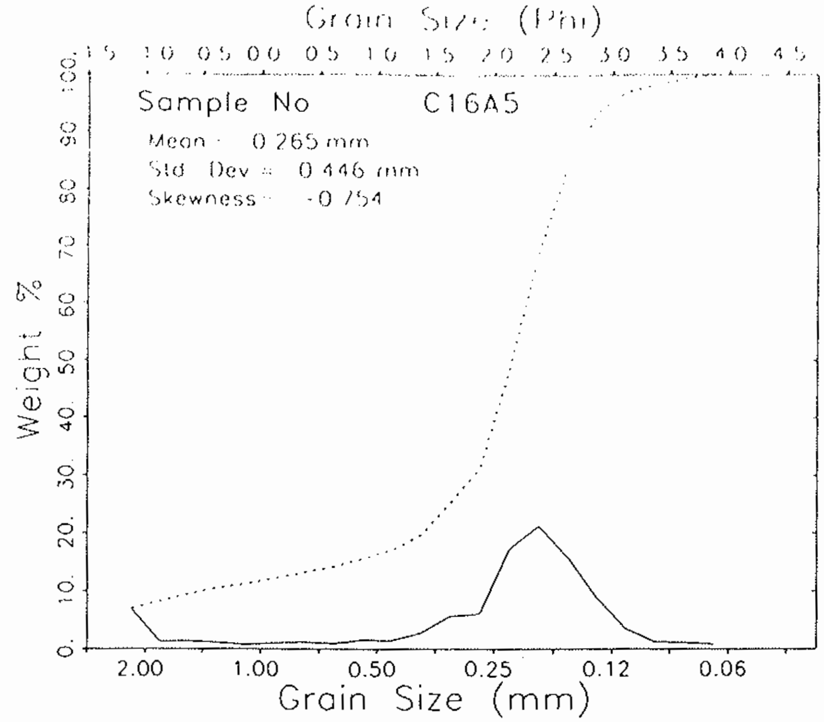
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.118	-.295	.741	2.206	2.592	2.738	2.999	3.328

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.221	1.549	MEDIUM SAND
STANDARD DEVIATION	1.516	1.382	POORLY SORTED
SKEWNESS(1)	-.650	-.632	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.835		
KURTOSIS	.357	.911	MESOKURTIC

1.382

POORLY SORTED

SKEWNESS(1) -.650



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C16A5	060699					
Bogue Banks C16A5 0-1.6						
		-1.125	22.440	21.484	-1.000	21.484
		-.875	3.060	2.930	-.750	24.414
		-.625	3.190	3.054	-.500	27.468
		-.375	2.960	2.834	-.250	30.302
		-.125	1.850	1.771	.000	32.073
		.125	2.450	2.346	.250	34.418
		.375	2.470	2.365	.500	36.783
		.625	1.710	1.637	.750	38.420
		.875	2.280	2.183	1.000	40.603
		1.125	2.070	1.982	1.250	42.585
		1.375	2.690	2.575	1.500	45.160
		1.625	3.100	2.968	1.750	48.128
		1.875	2.490	2.384	2.000	50.512
		2.125	7.230	6.922	2.250	57.434
		2.375	12.690	12.149	2.500	69.584
		2.625	14.850	14.217	2.750	83.801
		2.875	11.090	10.618	3.000	94.418
		3.125	4.150	3.973	3.250	98.392
		3.375	1.030	.986	3.500	99.378
		3.625	.500	.479	3.750	99.856
		3.875	.150	.144	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.450

PERCENT FINER THAN 4.00 PHI = .20 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

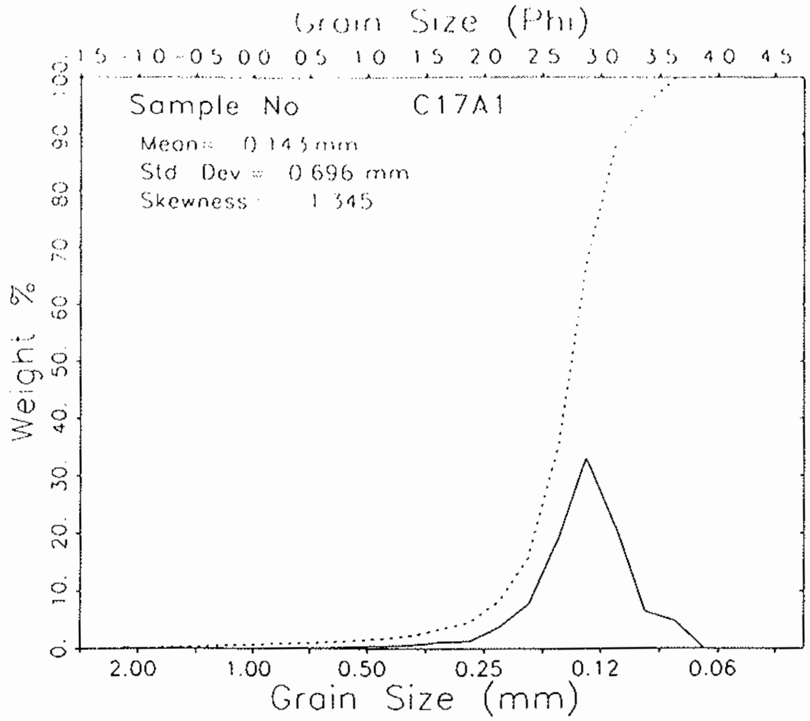
MEAN = 1.187 STANDARD DEVIATION = 1.614 SKEWNESS = -.189 KURTOSIS = -1.516

DISPERSION = .514 STANDARD DEVIATION = .791 DEVIATION FROM NORMAL DISTR. = -50.99%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.192	-1.064	-.702	1.946	2.595	2.755	3.037	3.404

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.845	1.212	MEDIUM SAND
STANDARD DEVIATION	1.909	1.595	POORLY SORTED
SKEWNESS(1)	-.577	-.530	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.536		
KURTOSIS	.107	.526	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C17A1	060699						
Bogue Bank C17A1 COMP							
		-1.125	.190		.187	-1.000	.187
		-.875	.070		.069	-.750	.256
		-.625	.130		.128	-.500	.385
		-.375	.140		.138	-.250	.523
		-.125	.080		.079	.000	.601
		.125	.160		.158	.250	.759
		.375	.160		.158	.500	.917
		.625	.150		.148	.750	1.065
		.875	.270		.266	1.000	1.331
		1.125	.350		.345	1.250	1.676
		1.375	.570		.562	1.500	2.238
		1.625	1.080		1.065	1.750	3.303
		1.875	1.200		1.183	2.000	4.486
		2.125	3.700		3.648	2.250	8.134
		2.375	7.770		7.660	2.500	15.794
		2.625	18.940		18.673	2.750	34.467
		2.875	33.580		33.107	3.000	67.574
		3.125	21.380		21.079	3.250	88.652
		3.375	6.440		6.349	3.500	95.001
		3.625	4.910		4.841	3.750	99.842
		3.875	.160		.158	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.430

PERCENT FINER THAN 4.00 PHI = 1.50 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.807 STANDARD DEVIATION = .523 SKEWNESS = -1.345 KURTOSIS = 14.197

DISPERSION = .220 STANDARD DEVIATION = .401 DEVIATION FROM NORMAL DISTR. = -23.22%

PERCENTILES:

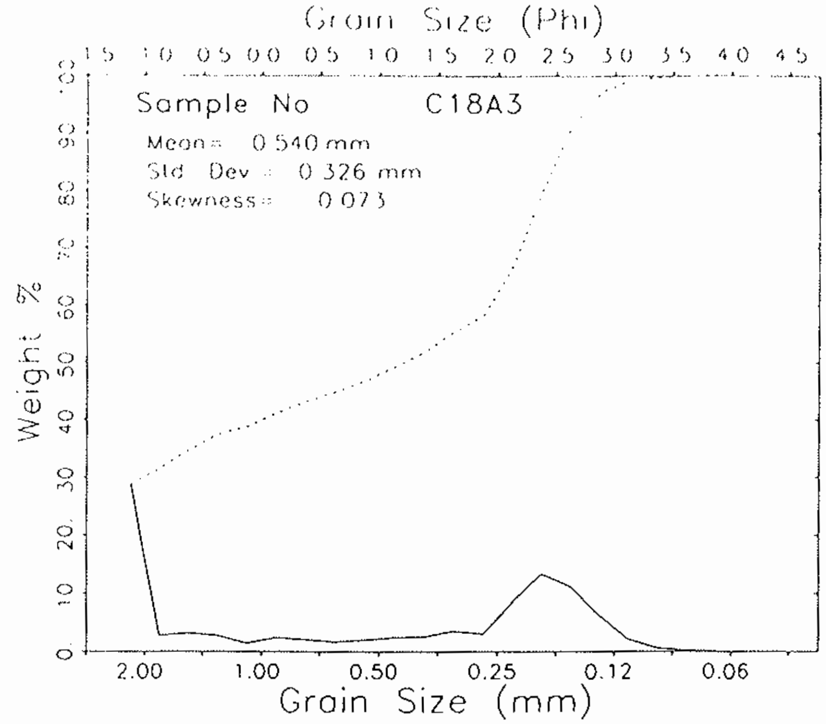
1.	5.	16.	25.	50.	75.	84.	95.	99.
.641	2.035	2.503	2.623	2.867	3.088	3.195	3.500	3.707

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.849	2.855	FINE SAND
STANDARD DEVIATION	.346	.395	WELL SORTED
SKEWNESS(1)	-.053	-.095	NEAR SYMMETRICAL
SKEWNESS(2)	-.288		
KURTOSIS	1.116	1.291	LEPTOKURTIC

346 .395

WELL SORTED

SKEWNESS(1) -.053



SAMPLE NO. DATE

C18A3 060699
Bogue Bank C18A3 0-0.9

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	31.000	28.728	-1.000	28.728
-.875	2.940	2.724	-.750	31.452
-.625	3.410	3.160	-.500	34.612
-.375	2.950	2.734	-.250	37.346
-.125	1.510	1.399	.000	38.745
.125	2.530	2.345	.250	41.090
.375	2.230	2.067	.500	43.156
.625	1.740	1.612	.750	44.769
.875	2.140	1.983	1.000	46.752
1.125	2.550	2.363	1.250	49.115
1.375	2.680	2.484	1.500	51.599
1.625	3.760	3.484	1.750	55.083
1.875	3.260	3.021	2.000	58.104
2.125	9.120	8.451	2.250	66.555
2.375	14.370	13.317	2.500	79.872
2.625	12.000	11.120	2.750	90.992
2.875	6.610	6.125	3.000	97.118
3.125	2.190	2.029	3.250	99.147
3.375	.560	.519	3.500	99.666
3.625	.260	.241	3.750	99.907
3.875	.100	.093	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.910

PERCENT FINER THAN 4.00 PHI = .13 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = .890 STANDARD DEVIATION = 1.617 SKEWNESS = -.073 KURTOSIS = -1.682
DISPERSION = .466 STANDARD DEVIATION = .708 DEVIATION FROM NORMAL DISTR. = -56.26%

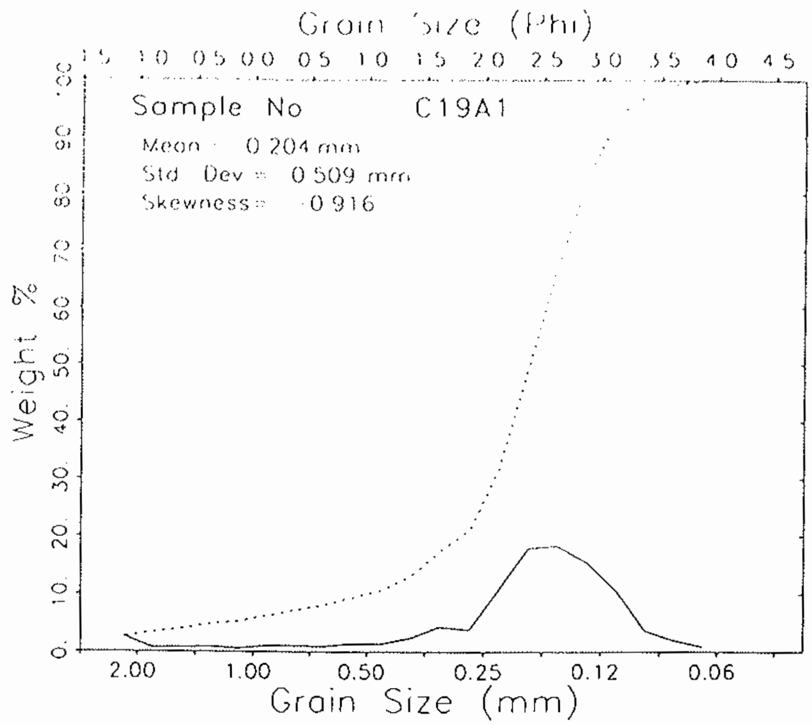
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.206	-1.111	-1.032	1.339	2.409	2.593	2.914	3.232

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.741	.940	COARSE SAND
STANDARD DEVIATION	1.852	1.550	POORLY SORTED
SKEWNESS(1)	-.323	-.279	COARSE-SKEWED
SKEWNESS(2)	-.262		
KURTOSIS	.112	.491	VERY PLATYKURTIC

1.550 POORLY SORTED

SKEWNESS(1) -.323



SAMPLE NO. DATE
C19A1 060699
Bogue Banks C19A1 0-2.0

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	2.890	2.598	-1.000	2.598
-.875	.670	.602	-.750	3.201
-.625	.770	.692	-.500	3.893
-.375	.850	.764	-.250	4.657
-.125	.570	.512	.000	5.170
.125	1.090	.980	.250	6.150
.375	1.110	.998	.500	7.148
.625	.960	.863	.750	8.011
.875	1.450	1.304	1.000	9.315
1.125	1.480	1.331	1.250	10.646
1.375	2.590	2.329	1.500	12.974
1.625	4.730	4.253	1.750	17.227
1.875	4.120	3.704	2.000	20.931
2.125	11.930	10.726	2.250	31.658
2.375	19.800	17.803	2.500	49.461
2.625	20.240	18.198	2.750	67.659
2.875	17.220	15.483	3.000	83.142
3.125	11.820	10.628	3.250	93.769
3.375	3.970	3.570	3.500	97.339
3.625	2.080	1.870	3.750	99.209
3.875	.880	.791	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.220

PERCENT FINER THAN 4.00 PHI = 1.00 PERCENT COARSER THAN -1.00 PHI = .00

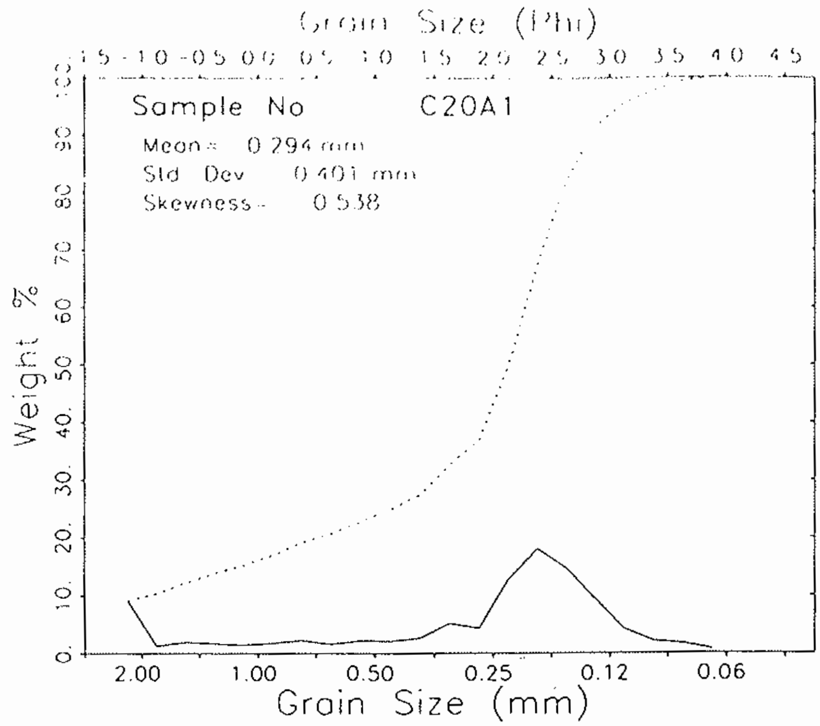
MOMENT MEASURES:

MEAN = 2.290 STANDARD DEVIATION = .974 SKEWNESS = -.916 KURTOSIS = 3.606
DISPERSION = .453 STANDARD DEVIATION = .687 DEVIATION FROM NORMAL DISTR. = -29.44%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.154	-.083	1.678	2.095	2.507	2.869	3.020	3.336	3.722

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.349	2.402	FINE SAND
STANDARD DEVIATION	.671	.054	MODERATELY SORTED
SKEWNESS(1)	-.236	-.376	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.312		
KURTOSIS	1.547	1.811	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C20A1	060699						
Bogue Banks C20A1 0-1.3							
		-1.125	10.040		9.083	-1.000	9.083
		-.875	1.310		1.185	-.750	10.268
		-.625	2.060		1.864	-.500	12.131
		-.375	1.810		1.637	-.250	13.769
		-.125	1.530		1.384	.000	15.153
		.125	1.930		1.746	.250	16.899
		.375	2.420		2.189	.500	19.088
		.625	1.710		1.547	.750	20.635
		.875	2.350		2.126	1.000	22.761
		1.125	2.290		2.072	1.250	24.833
		1.375	2.800		2.533	1.500	27.366
		1.625	5.660		5.120	1.750	32.486
		1.875	4.730		4.279	2.000	36.765
		2.125	14.060		12.719	2.250	49.484
		2.375	19.830		17.939	2.500	67.424
		2.625	16.160		14.619	2.750	82.043
		2.875	10.420		9.426	3.000	91.469
		3.125	4.580		4.143	3.250	95.612
		3.375	2.230		2.017	3.500	97.630
		3.625	1.820		1.646	3.750	99.276
		3.875	.800		.724	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.540

PERCENT FINER THAN 4.00 PHI = 2.71 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

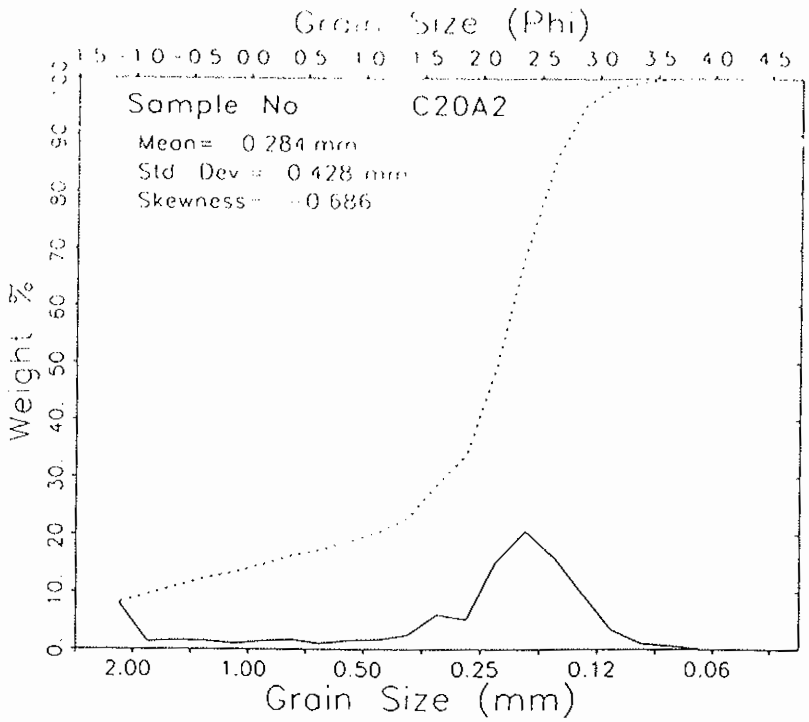
MEAN = 1.765 STANDARD DEVIATION = 1.318 SKEWNESS = -.538 KURTOSIS = .032

DISPERSION = .536 STANDARD DEVIATION = .831 DEVIATION FROM NORMAL DISTR. = -36.93%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.222	-1.112	.121	1.267	2.257	2.630	2.802	3.213	3.708

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.462	1.727	MEDIUM SAND
STANDARD DEVIATION	1.340	1.326	POORLY SORTED
SKEWNESS(1)	-.594	-.576	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.900		
KURTOSIS	.614	1.301	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C20A2	060699						
Bogue Bank C20A2 0-1.5							
		-1.125	8.570		8.143	-1.000	8.143
		-.875	1.410		1.340	-.750	9.482
		-.625	1.570		1.492	-.500	10.974
		-.375	1.420		1.349	-.250	12.323
		-.125	1.050		.998	.000	13.321
		.125	1.450		1.378	.250	14.698
		.375	1.690		1.606	.500	16.304
		.625	1.010		.960	.750	17.264
		.875	1.510		1.435	1.000	18.698
		1.125	1.750		1.663	1.250	20.361
		1.375	2.540		2.413	1.500	22.774
		1.625	6.280		5.967	1.750	28.741
		1.875	5.430		5.159	2.000	33.900
		2.125	15.950		15.154	2.250	49.055
		2.375	21.640		20.561	2.500	69.615
		2.625	16.840		16.000	2.750	85.615
		2.875	9.950		9.454	3.000	95.069
		3.125	3.450		3.278	3.250	98.347
		3.375	.980		.931	3.500	99.278
		3.625	.610		.580	3.750	99.857
		3.875	.150		.143	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.250

PERCENT FINER THAN 4.00, PHI = 1.21 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.815 STANDARD DEVIATION = 1.225 SKEWNESS = -.686 KURTOSIS = .750

DISPERSION = .467 STANDARD DEVIATION = .709 DEVIATION FROM NORMAL DISTR. = -42.13%

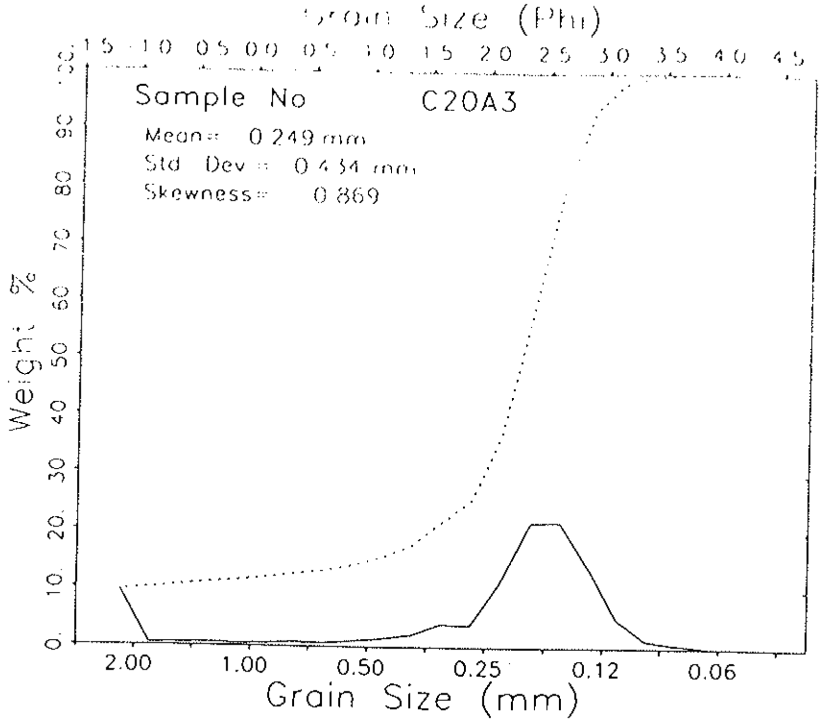
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.219	-1.096	.453	1.593	2.261	2.584	2.725	2.998	3.425

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.589	1.813	MEDIUM SAND
STANDARD DEVIATION	1.136	1.180	POORLY SORTED
SKEWNESS(1)	-.592	-.616	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.154		
KURTOSIS	.802	1.694	VERY LEPTOKURTIC

1.180 POORLY SORTED

SKEWNESS(1) -.592



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C20A3	060699						
Bogue Bank C20A3 0-0.5							
		-1.125	9.660		9.526	-1.000	9.526
		-.875	.400		.394	-.750	9.920
		-.625	.490		.483	-.500	10.403
		-.375	.550		.542	-.250	10.946
		-.125	.360		.355	.000	11.301
		.125	.510		.503	.250	11.804
		.375	.720		.710	.500	12.514
		.625	.570		.562	.750	13.076
		.875	1.000		.986	1.000	14.062
		1.125	1.430		1.410	1.250	15.472
		1.375	2.070		2.041	1.500	17.513
		1.625	3.980		3.925	1.750	21.438
		1.875	3.790		3.737	2.000	25.175
		2.125	11.360		11.202	2.250	36.377
		2.375	21.810		21.507	2.500	57.884
		2.625	21.880		21.576	2.750	79.460
		2.875	13.950		13.756	3.000	93.216
		3.125	4.910		4.842	3.250	98.057
		3.375	1.270		1.252	3.500	99.310
		3.625	.600		.592	3.750	99.901
		3.875	.100		.099	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.410

PERCENT FINER THAN 4.00 PHI = .12 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.007 STANDARD DEVIATION = 1.205 SKEWNESS = -.869 KURTOSIS = 1.910
DISPERSION = .381 STANDARD DEVIATION = .582 DEVIATION FROM NORMAL DISTR. = -51.72%

PERCENTILES:

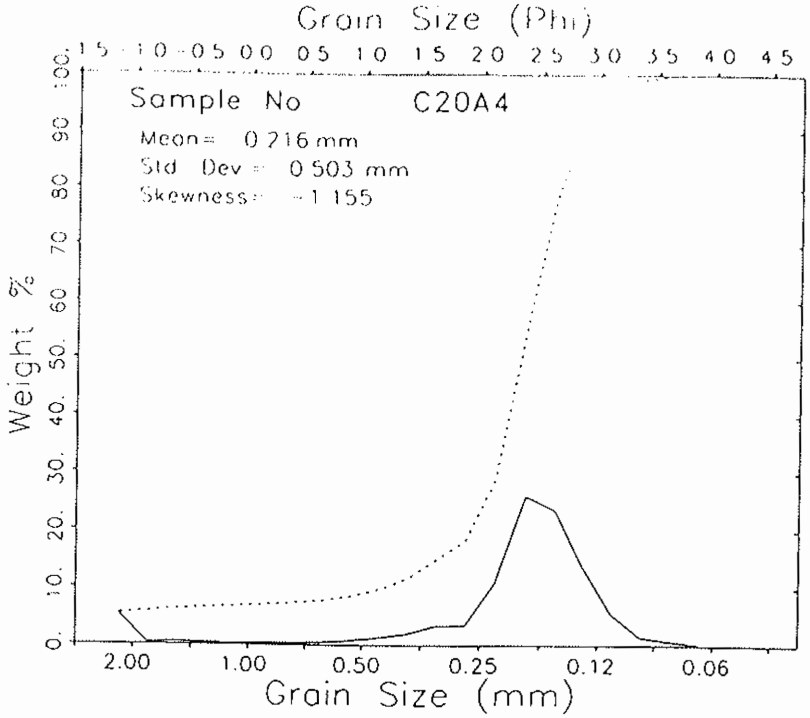
1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.119	1.315	1.988	2.408	2.698	2.833	3.092	3.438

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.074	2.185	FINE SAND
STANDARD DEVIATION	.759	1.017	POORLY SORTED
SKEWNESS(1)	-.441	-.558	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.873		
KURTOSIS	1.774	2.431	VERY LEPTOKURTIC

1.017

POORLY SORTED

SKEWNESS(1) -.441



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C20A4	060699						
Bogue Bank C20A4 COMP							
		-1.125	5.080		5.412	-1.000	5.412
		-.875	.320		.341	-.750	5.753
		-.625	.390		.415	-.500	6.168
		-.375	.300		.320	-.250	6.488
		-.125	.200		.213	.000	6.701
		.125	.280		.298	.250	6.999
		.375	.310		.330	.500	7.329
		.625	.340		.362	.750	7.691
		.875	.670		.714	1.000	8.405
		1.125	1.120		1.193	1.250	9.598
		1.375	1.750		1.864	1.500	11.463
		1.625	3.000		3.281	1.750	14.744
		1.875	3.160		3.366	2.000	18.110
		2.125	10.280		10.951	2.250	29.061
		2.375	24.490		26.089	2.500	55.151
		2.625	22.140		23.586	2.750	78.737
		2.875	12.760		13.593	3.000	92.330
		3.125	5.090		5.422	3.250	97.752
		3.375	1.280		1.364	3.500	99.116
		3.625	.690		.735	3.750	99.851
		3.875	.140		.149	4.000	100.000

TOTAL WEIGHT (GRAMS) = 93.870

PERCENT FINER THAN 4.00 PHI = .10 PERCENT COARSER THAN -1.00 PHI = .00

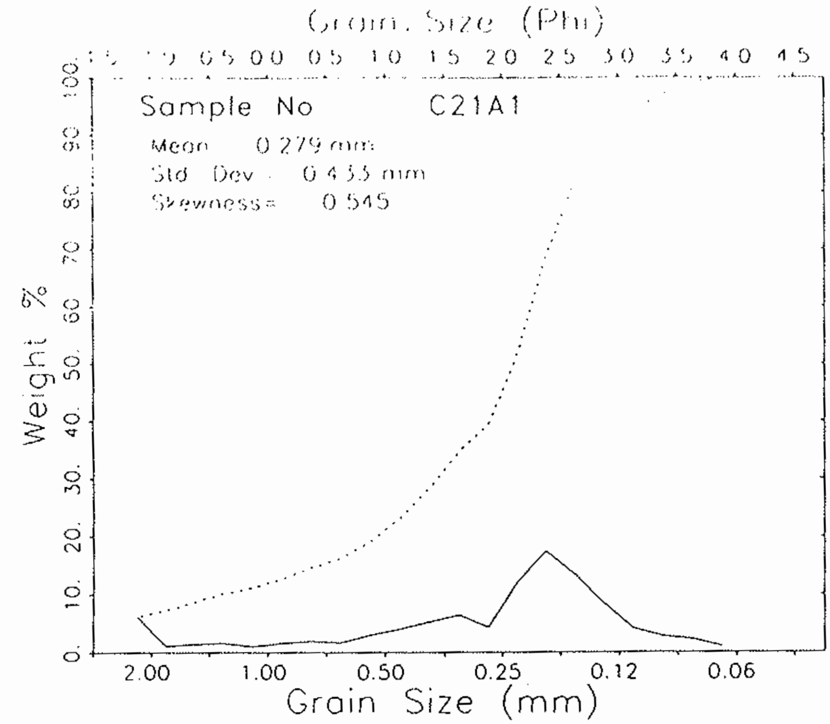
MOMENT MEASURES:

MEAN = 2.208 STANDARD DEVIATION = .990 SKEWNESS = -1.155 KURTOSIS = 5.085
DISPERSION = .329 STANDARD DEVIATION = .516 DEVIATION FROM NORMAL DISTR. = -47.87%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.204	-1.019	1.843	2.157	2.451	2.710	2.847	3.123	3.479

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.345	2.380	FINE SAND
STANDARD DEVIATION	.502	.878	MODERATELY SORTED
SKEWNESS(1)	-.210	-.443	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-2.787		
KURTOSIS	3.128	3.069	EXTREMELY LEPTOKURTIC
.878			MODERATELY SORTED
SKEWNESS(1)	-.210		



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C21A1	060699						
Bogue Banks C21A1 0-1.9							
		-1.125	6.160		6.172	-1.000	6.172
		-.875	1.080		1.082	-.750	7.255
		-.625	1.350		1.353	-.500	8.607
		-.375	1.510		1.513	-.250	10.120
		-.125	.960		.962	.000	11.082
		.125	1.580		1.583	.250	12.665
		.375	1.910		1.914	.500	14.579
		.625	1.620		1.623	.750	16.202
		.875	2.940		2.946	1.000	19.148
		1.125	3.940		3.948	1.250	23.096
		1.375	5.210		5.220	1.500	28.317
		1.625	6.400		6.413	1.750	34.729
		1.875	4.320		4.329	2.000	39.058
		2.125	11.920		11.944	2.250	51.002
		2.375	17.400		17.435	2.500	68.437
		2.625	13.270		13.297	2.750	81.733
		2.875	8.300		8.317	3.000	90.050
		3.125	4.070		4.078	3.250	94.128
		3.375	2.720		2.725	3.500	96.854
		3.625	2.210		2.214	3.750	99.068
		3.875	.930		.932	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.800

PERCENT FINER THAN 4.00 PHI = 1.61 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 1.844 STANDARD DEVIATION = 1.209 SKEWNESS = -.545 KURTOSIS = .517
DISPERSION = .563 STANDARD DEVIATION = .885 DEVIATION FROM NORMAL DISTR. = -26.77%

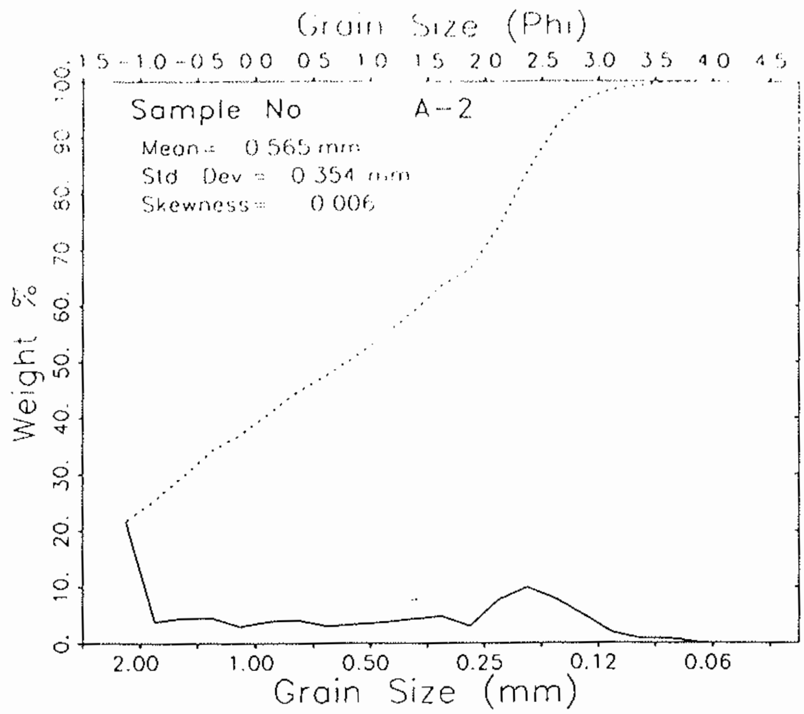
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.209	-1.047	.719	1.341	2.229	2.623	2.818	3.330	3.742

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.768	1.922	MEDIUM SAND
STANDARD DEVIATION	1.050	1.188	POORLY SORTED
SKEWNESS(1)	-.439	-.468	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.036		
KURTOSIS	1.085	1.399	LEPTOKURTIC

ANNEX E-2
Part 2

Phase II — November 1999
Sediment Sample Results
Core Logs



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-2	111199					
Bogue Banks Borrow A						
		-1.125	23.860	21.587	-1.000	21.587
		-.875	4.080	3.691	-.750	25.278
		-.625	4.830	4.370	-.500	29.648
		-.375	4.970	4.497	-.250	34.145
		-.125	3.180	2.877	.000	37.022
		.125	4.200	3.800	.250	40.821
		.375	4.360	3.945	.500	44.766
		.625	3.300	2.986	.750	47.752
		.875	3.640	3.293	1.000	51.045
		1.125	4.060	3.673	1.250	54.718
		1.375	4.650	4.207	1.500	58.925
		1.625	5.210	4.714	1.750	63.639
		1.875	3.260	2.949	2.000	66.588
		2.125	8.470	7.663	2.250	74.251
		2.375	10.850	9.816	2.500	84.068
		2.625	8.600	7.781	2.750	91.848
		2.875	5.420	4.904	3.000	96.752
		3.125	1.970	1.782	3.250	98.534
		3.375	.750	.679	3.500	99.213
		3.625	.790	.715	3.750	99.928
		3.875	.080	.072	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.530

PERCENT FINER THAN 4.00 PHI = 2.48 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

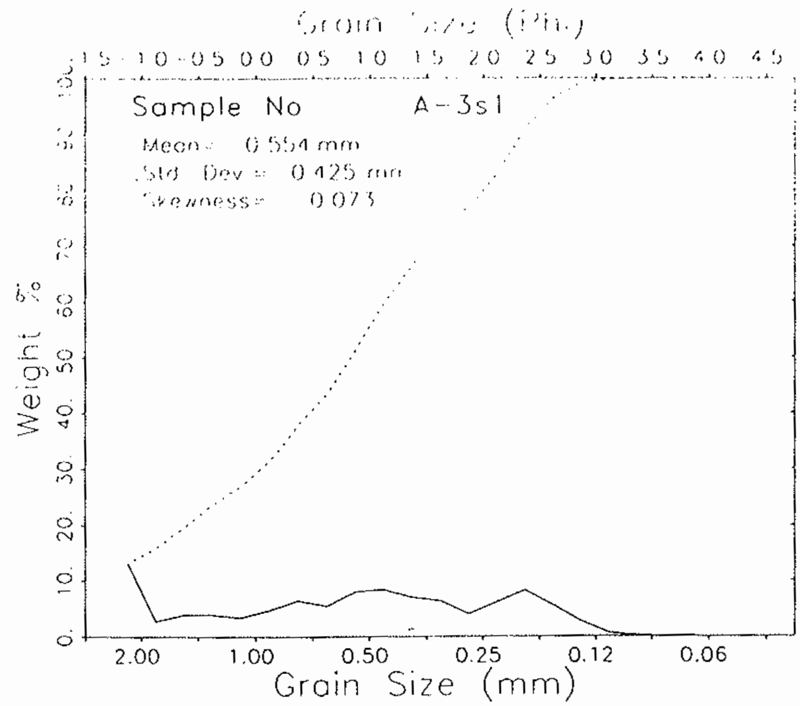
MEAN = .824 STANDARD DEVIATION = 1.497 SKEWNESS = -.006 KURTOSIS = -1.494

DISPERSION = .579 STANDARD DEVIATION = .918 DEVIATION FROM NORMAL DISTR. = -38.65%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.192	-1.065	-.769	.921	2.269	2.498	2.911	3.422

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.717	.785	COARSE SAND
STANDARD DEVIATION	1.781	1.512	POORLY SORTED
SKEWNESS(1)	-.114	-.072	NEAR SYMMETRICAL
SKEWNESS(2)	-.034		
KURTOSIS	.152	.553	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-3s1	111199					
Borrow A - A03s1						
		-1.125	14.800	13.067	-1.000	13.067
		-.875	3.080	2.719	-.750	15.787
		-.625	4.380	3.867	-.500	19.654
		-.375	4.390	3.876	-.250	23.530
		-.125	3.810	3.364	.000	26.894
		.125	5.310	4.688	.250	31.582
		.375	7.280	6.428	.500	38.010
		.625	6.160	5.439	.750	43.449
		.875	9.000	7.946	1.000	51.395
		1.125	9.370	8.273	1.250	59.668
		1.375	7.910	6.984	1.500	66.652
		1.625	7.100	6.269	1.750	72.921
		1.875	4.500	3.973	2.000	76.894
		2.125	6.920	6.110	2.250	83.004
		2.375	9.190	8.114	2.500	91.118
		2.625	6.190	5.465	2.750	96.583
		2.875	2.960	2.613	3.000	99.197
		3.125	.650	.574	3.250	99.770
		3.375	.140	.124	3.500	99.894
		3.625	.070	.062	3.750	99.956
		3.875	.050	.044	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.260

PERCENT FINER THAN 4.00 PHI = .06 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

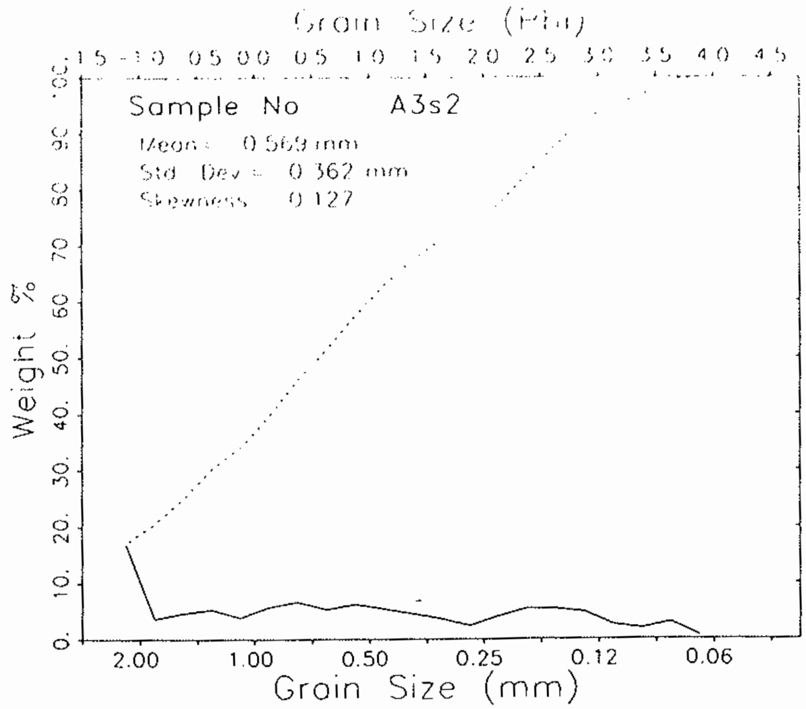
MEAN = .852 STANDARD DEVIATION = 1.235 SKEWNESS = -.073 KURTOSIS = -1.075

DISPERSION = .604 STANDARD DEVIATION = .973 DEVIATION FROM NORMAL DISTR. = -21.23%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.231	-1.154	-.736	-.141	.956	1.881	2.281	2.678	2.981

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.772	.834	COARSE SAND
STANDARD DEVIATION	1.508	1.335	POORLY SORTED
SKEWNESS(1)	-.122	-.112	COARSE-SKEWED
SKEWNESS(2)	-.129		
KURTOSIS	.270	.777	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-3s2	111199						
Borrow A - A03s2 1.0-2.7 ft							
		-1.125	16.410	16.848		-1.000	16.848
		-.875	3.470	3.563		-.750	20.411
		-.625	4.440	4.559		-.500	24.969
		-.375	5.060	5.195		-.250	30.164
		-.125	3.690	3.789		.000	33.953
		.125	5.470	5.616		.250	39.569
		.375	6.350	6.520		.500	46.088
		.625	5.120	5.257		.750	51.345
		.875	5.940	6.099		1.000	57.444
		1.125	5.140	5.277		1.250	62.721
		1.375	4.330	4.446		1.500	67.166
		1.625	3.500	3.593		1.750	70.760
		1.875	2.220	2.279		2.000	73.039
		2.125	3.870	3.973		2.250	77.012
		2.375	5.140	5.277		2.500	82.290
		2.625	5.160	5.298		2.750	87.587
		2.875	4.560	4.682		3.000	92.269
		3.125	2.430	2.495		3.250	94.764
		3.375	1.750	1.797		3.500	96.561
		3.625	2.830	2.906		3.750	99.466
		3.875	.520	.534		4.000	100.000

TOTAL WEIGHT (GRAMS) = 97.400

PERCENT FINER THAN 4.00 PHI = 13.41 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

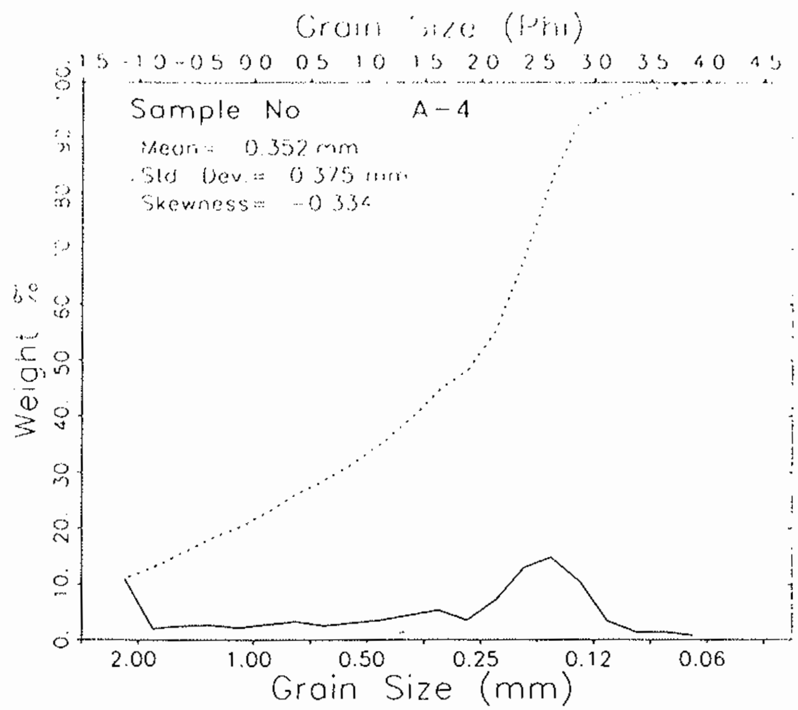
MEAN = .814 STANDARD DEVIATION = 1.465 SKEWNESS = .127 KURTOSIS = -1.116

DISPERSION = .648 STANDARD DEVIATION = 1.077 DEVIATION FROM NORMAL DISTR. = -26.50%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.176	-1.013	-.499	.686	2.123	2.581	3.283	3.710

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.784	.751	COARSE SAND
STANDARD DEVIATION	1.797	1.574	POORLY SORTED
SKEWNESS(1)	.055	.110	FINE-SKEWED
SKEWNESS(2)	.205		
KURTOSIS	.241	.697	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-4	111199					
Borrow A - A4						
		-1.125	12.710	11.023	-1.000	11.023
		-.875	2.270	1.969	-.750	12.992
		-.625	2.830	2.454	-.500	15.447
		-.375	3.050	2.645	-.250	18.092
		-.125	2.420	2.099	.000	20.191
		.125	3.120	2.706	.250	22.897
		.375	3.680	3.192	.500	26.088
		.625	2.880	2.498	.750	28.586
		.875	3.390	2.940	1.000	31.526
		1.125	4.030	3.495	1.250	35.022
		1.375	5.020	4.354	1.500	39.376
		1.625	6.130	5.317	1.750	44.692
		1.875	4.040	3.504	2.000	48.196
		2.125	8.180	7.095	2.250	55.291
		2.375	14.820	12.853	2.500	68.144
		2.625	16.940	14.692	2.750	82.836
		2.875	12.170	10.555	3.000	93.391
		3.125	3.820	3.313	3.250	96.704
		3.375	1.460	1.266	3.500	97.971
		3.625	1.550	1.344	3.750	99.315
		3.875	.790	.685	4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.300

PERCENT FINER THAN 4.00 PHI = 1.56 PERCENT COARSER THAN -1.00 PHI = .00

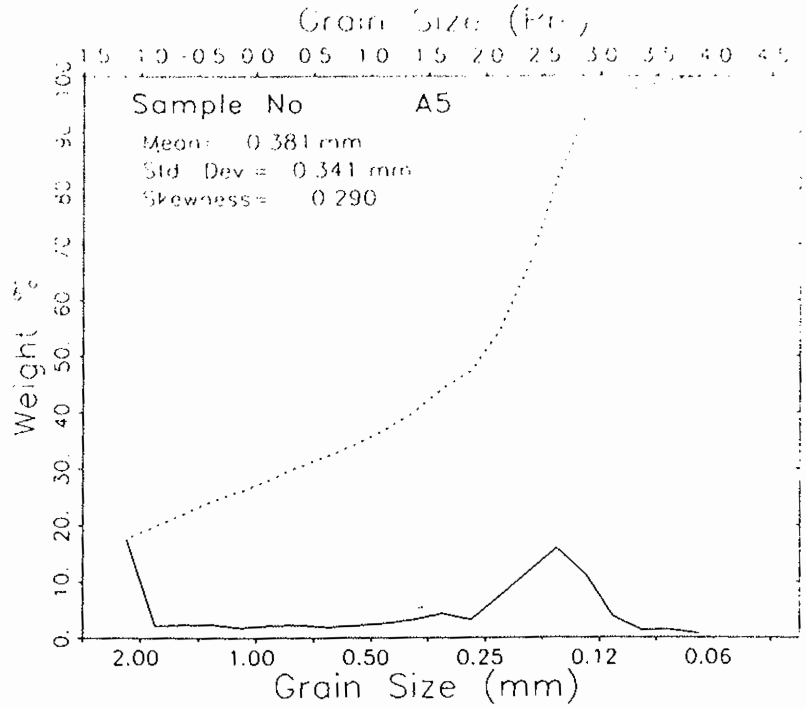
MOMENT MEASURES:

MEAN = 1.506 STANDARD DEVIATION = 1.416 SKEWNESS = -.334 KURTOSIS = -.858
DISPERSION = .592 STANDARD DEVIATION = .946 DEVIATION FROM NORMAL DISTR. = -33.20%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.137	-.448	.415	2.064	2.617	2.778	3.121	3.691

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.165	1.464	MEDIUM SAND
STANDARD DEVIATION	1.613	1.451	POORLY SORTED
SKEWNESS(1)	-.557	-.530	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.664		
KURTOSIS	.320	.793	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A5	111199					
Borrow A - A5						
		-1.125	20.440	17.653	-1.000	17.653
		-.875	2.420	2.090	-.750	19.743
		-.625	2.700	2.332	-.500	22.074
		-.375	2.630	2.271	-.250	24.346
		-.125	1.950	1.684	.000	26.030
		.125	2.470	2.133	.250	28.163
		.375	2.570	2.220	.500	30.383
		.625	2.110	1.822	.750	32.205
		.875	2.480	2.142	1.000	34.347
		1.125	2.850	2.461	1.250	36.808
		1.375	3.590	3.100	1.500	39.908
		1.625	4.910	4.240	1.750	44.149
		1.875	3.670	3.170	2.000	47.318
		2.125	8.500	7.341	2.250	54.659
		2.375	13.360	11.538	2.500	66.197
		2.625	18.280	15.787	2.750	81.985
		2.875	12.960	11.193	3.000	93.177
		3.125	4.240	3.662	3.250	96.839
		3.375	1.410	1.218	3.500	98.057
		3.625	1.480	1.278	3.750	99.335
		3.875	.770	.665	4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.790

PERCENT FINER THAN 4.00 PHI = .94 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

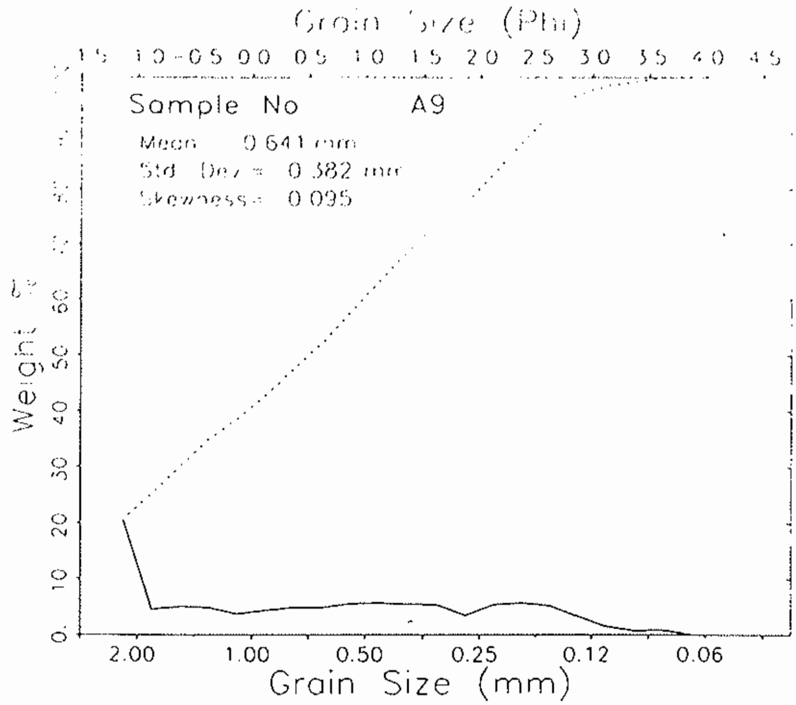
MEAN = 1.392 STANDARD DEVIATION = 1.554 SKEWNESS = -.290 KURTOSIS = -1.192

DISPERSION = .542 STANDARD DEVIATION = .843 DEVIATION FROM NORMAL DISTR. = -45.73%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.179	-1.023	-.153	2.091	2.639	2.795	3.124	3.684

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.886	1.288	MEDIUM SAND
STANDARD DEVIATION	1.909	1.607	POORLY SORTED
SKEWNESS(1)	-.631	-.576	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.586		
KURTOSIS	.127	.632	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A9	111199						
Borrow A - A9							
		-1.125	22.200		20.613	-1.000	20.613
		-.875	4.820		4.475	-.750	25.088
		-.625	5.330		4.949	-.500	30.037
		-.375	5.200		4.828	-.250	34.865
		-.125	3.960		3.677	.000	38.542
		.125	4.640		4.308	.250	42.851
		.375	5.150		4.782	.500	47.632
		.625	5.140		4.773	.750	52.405
		.875	5.860		5.441	1.000	57.846
		1.125	6.050		5.617	1.250	63.463
		1.375	5.840		5.422	1.500	68.886
		1.625	5.700		5.292	1.750	74.178
		1.875	3.650		3.389	2.000	77.567
		2.125	5.710		5.302	2.250	82.869
		2.375	6.030		5.599	2.500	88.468
		2.625	5.570		5.172	2.750	93.640
		2.875	3.590		3.333	3.000	96.973
		3.125	1.590		1.476	3.250	98.449
		3.375	.810		.752	3.500	99.202
		3.625	.840		.780	3.750	99.981
		3.875	.020		.019	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.700

PERCENT FINER THAN 4.00 PHI = 2.22 PERCENT COARSER THAN -1.00 PHI = .00

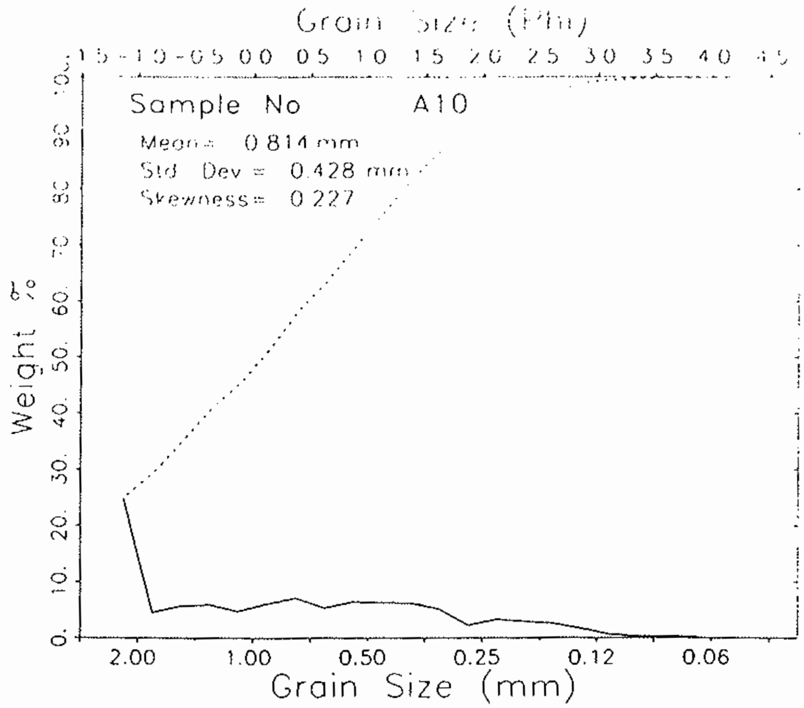
MOMENT MEASURES:

MEAN = .641 STANDARD DEVIATION = 1.390 SKEWNESS = .095 KURTOSIS = -1.234
DISPERSION = .604 STANDARD DEVIATION = .973 DEVIATION FROM NORMAL DISTR. = -30.03%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.189	-1.056	-.755	.624	1.811	2.300	2.852	3.433

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.622	.623	COARSE SAND
STANDARD DEVIATION	1.678	1.451	POORLY SORTED
SKEWNESS(1)	-.001	.051	NEAR SYMMETRICAL
SKEWNESS(2)	.124		
KURTOSIS	.204	.646	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A10	111199					
Borrow A - A10						
		-1.125	26.660	24.807	-1.000	24.807
		-.875	4.710	4.383	-.750	29.190
		-.625	5.940	5.527	-.500	34.717
		-.375	6.230	5.797	-.250	40.514
		-.125	4.950	4.606	.000	45.120
		.125	6.380	5.937	.250	51.056
		.375	7.450	6.932	.500	57.988
		.625	5.580	5.192	.750	63.180
		.875	6.740	6.272	1.000	69.452
		1.125	6.620	6.160	1.250	75.612
		1.375	6.540	6.085	1.500	81.697
		1.625	5.460	5.080	1.750	86.778
		1.875	2.320	2.159	2.000	88.936
		2.125	3.340	3.108	2.250	92.044
		2.375	2.980	2.773	2.500	94.817
		2.625	2.660	2.475	2.750	97.292
		2.875	1.700	1.582	3.000	98.874
		3.125	.590	.549	3.250	99.423
		3.375	.240	.223	3.500	99.646
		3.625	.250	.233	3.750	99.879
		3.875	.130	.121	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.470

PERCENT FINER THAN 4.00 PHI = .43 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

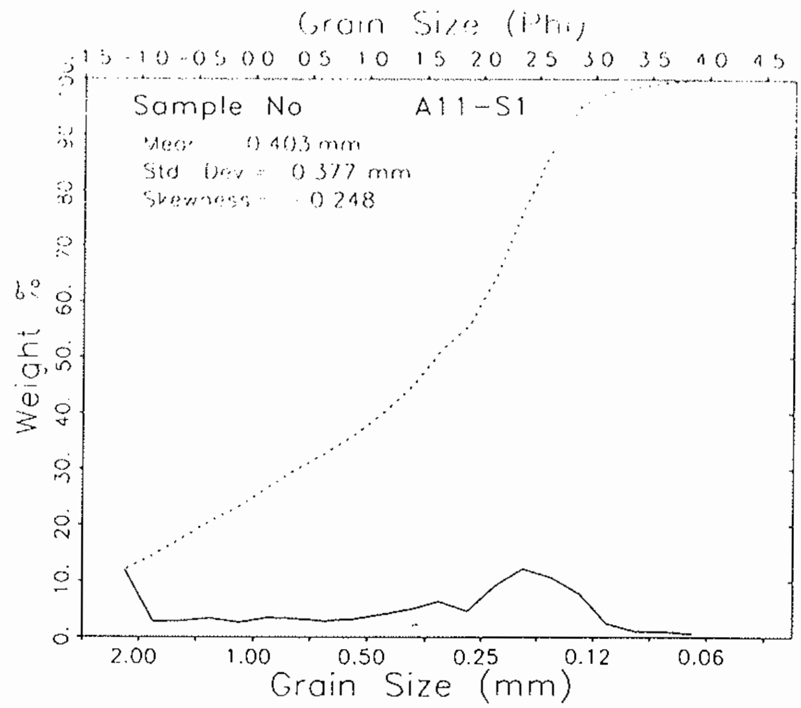
MEAN = .297 STANDARD DEVIATION = 1.224 SKEWNESS = .227 KURTOSIS = -.822

DISPERSION = .542 STANDARD DEVIATION = .843 DEVIATION FROM NORMAL DISTR. = -31.08%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.200	-1.089	-.989	.206	1.225	1.613	2.518	3.057

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.262	.243	COARSE SAND
STANDARD DEVIATION	1.351	1.239	POORLY SORTED
SKEWNESS(1)	.042	.143	FINE-SKEWED
SKEWNESS(2)	.336		
KURTOSIS	.376	.688	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A11	111199					
Borrow A - A11						
		-1.125	13.960	11.927	-1.000	11.927
		-.875	3.220	2.751	-.750	14.677
		-.625	3.310	2.828	-.500	17.505
		-.375	3.820	3.264	-.250	20.769
		-.125	2.970	2.537	.000	23.306
		.125	4.010	3.426	.250	26.732
		.375	3.780	3.229	.500	29.962
		.625	3.290	2.811	.750	32.772
		.875	3.710	3.170	1.000	35.942
		1.125	4.660	3.981	1.250	39.923
		1.375	5.690	4.861	1.500	44.784
		1.625	7.380	6.305	1.750	51.089
		1.875	5.290	4.519	2.000	55.609
		2.125	10.660	9.107	2.250	64.716
		2.375	14.250	12.174	2.500	76.890
		2.625	12.480	10.662	2.750	87.552
		2.875	9.080	7.757	3.000	95.310
		3.125	2.660	2.273	3.250	97.582
		3.375	1.130	.965	3.500	98.548
		3.625	1.020	.871	3.750	99.419
		3.875	.680	.581	4.000	100.000

TOTAL WEIGHT (GRAMS) = 117.050

PERCENT FINER THAN 4.00 PHI = .90 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

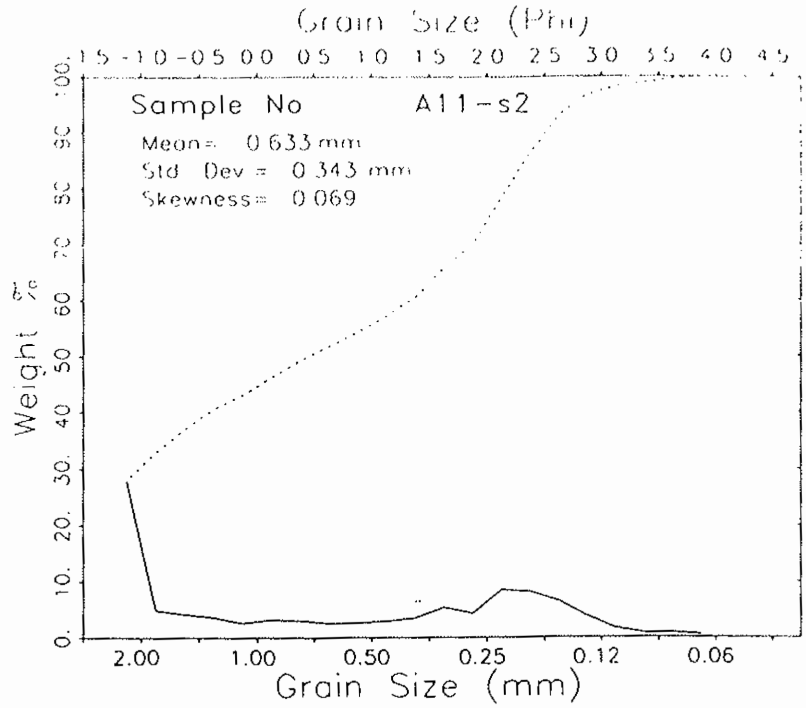
MEAN = 1.312 STANDARD DEVIATION = 1.407 SKEWNESS = -.248 KURTOSIS = -1.061

DISPERSION = .613 STANDARD DEVIATION = .992 DEVIATION FROM NORMAL DISTR. = -29.49%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.229	-1.145	-.633	.124	1.707	2.461	2.667	2.990	3.630

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.017	1.247	MEDIUM SAND
STANDARD DEVIATION	1.650	1.451	POORLY SORTED
SKEWNESS(1)	-.418	-.399	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.475		
KURTOSIS	.253	.725	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A11-s2	111199					
Borrow A - A11-s2						
		-1.125	30.610	27.926	-1.000	27.926
		-.875	5.300	4.835	-.750	32.762
		-.625	4.570	4.169	-.500	36.931
		-.375	3.930	3.585	-.250	40.516
		-.125	2.770	2.527	.000	43.044
		.125	3.470	3.166	.250	46.209
		.375	3.230	2.947	.500	49.156
		.625	2.720	2.482	.750	51.638
		.875	2.810	2.564	1.000	54.201
		1.125	3.040	2.773	1.250	56.975
		1.375	3.710	3.385	1.500	60.359
		1.625	5.830	5.319	1.750	65.678
		1.875	4.670	4.261	2.000	69.939
		2.125	9.170	8.366	2.250	78.305
		2.375	8.860	8.083	2.500	86.388
		2.625	7.110	6.487	2.750	92.875
		2.875	4.100	3.741	3.000	96.615
		3.125	1.660	1.514	3.250	98.130
		3.375	.750	.684	3.500	98.814
		3.625	.800	.730	3.750	99.544
		3.875	.500	.456	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.610

PERCENT FINER THAN 4.00 PHI = 1.14   PERCENT COARSER THAN -1.00 PHI = .00

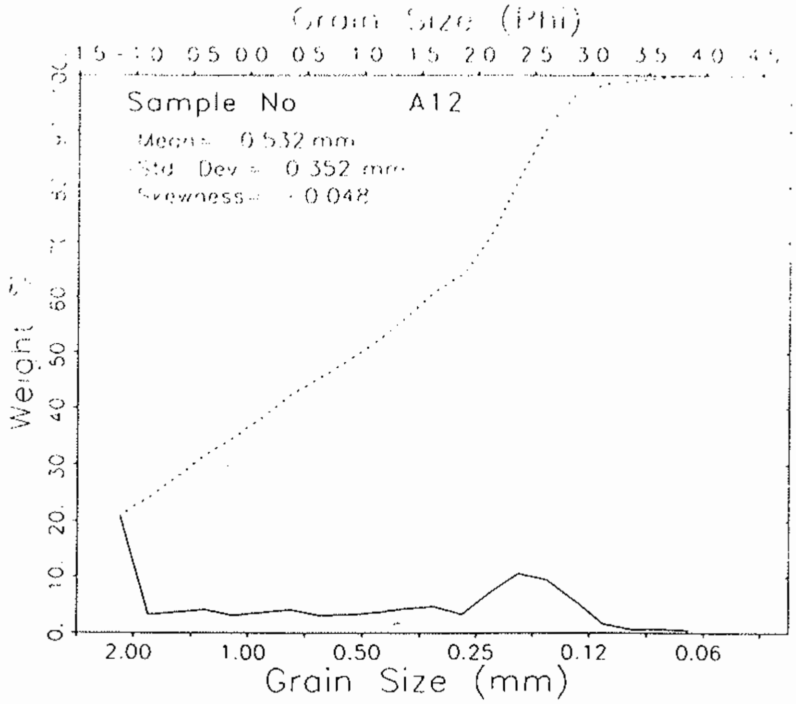
MOMENT MEASURES:

MEAN = .660   STANDARD DEVIATION = 1.543   SKEWNESS = .069   KURTOSIS = -1.525
DISPERSION = .536   STANDARD DEVIATION = .831   DEVIATION FROM NORMAL DISTR. = -46.13%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.205	-1.107	-1.026	.585	2.151	2.426	2.892	3.564

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.660	.635	COARSE SAND
STANDARD DEVIATION	1.766	1.504	POORLY SORTED
SKEWNESS(1)	.042	.084	NEAR SYMMETRICAL
SKEWNESS(2)	.146		
KURTOSIS	.160	.528	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A12	111199						
Borrow A -A12							
		-1.125	23.080	20.887		-1.000	20.887
		-.875	3.470	3.140		-.750	24.027
		-.625	4.040	3.656		-.500	27.683
		-.375	4.450	4.027		-.250	31.710
		-.125	3.390	3.068		.000	34.778
		.125	3.970	3.593		.250	38.371
		.375	4.470	4.045		.500	42.416
		.625	3.340	3.023		.750	45.439
		.875	3.480	3.149		1.000	48.588
		1.125	3.890	3.520		1.250	52.109
		1.375	4.650	4.208		1.500	56.317
		1.625	5.130	4.643		1.750	60.959
		1.875	3.560	3.222		2.000	64.181
		2.125	7.920	7.167		2.250	71.348
		2.375	11.610	10.507		2.500	81.855
		2.625	10.360	9.376		2.750	91.231
		2.875	6.200	5.611		3.000	96.842
		3.125	1.740	1.575		3.250	98.416
		3.375	.630	.570		3.500	98.986
		3.625	.660	.597		3.750	99.584
		3.875	.460	.416		4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.500

PERCENT FINER THAN 4.00 PHI = .73 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

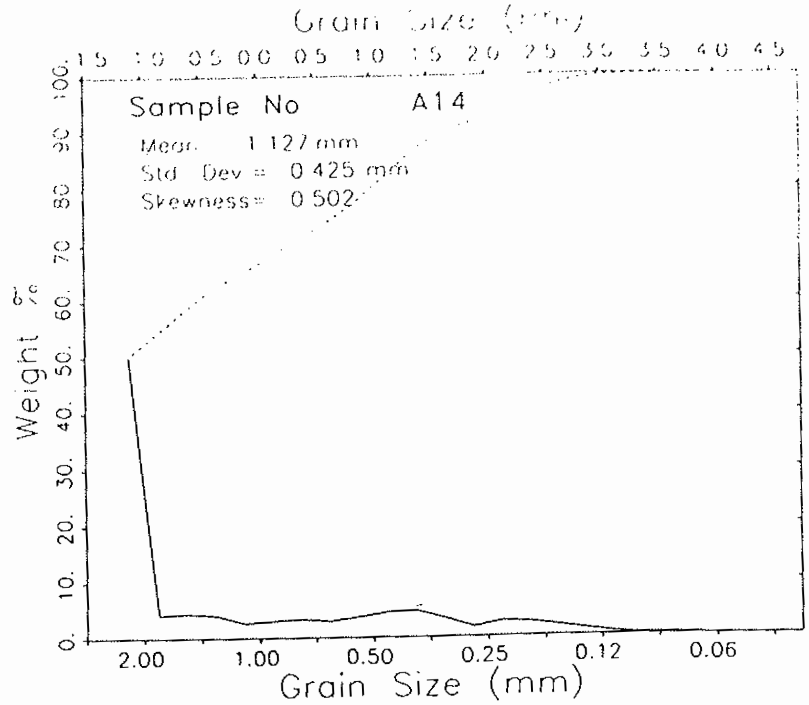
MEAN = .911 STANDARD DEVIATION = 1.506 SKEWNESS = -.048 KURTOSIS = -1.477

DISPERSION = .579 STANDARD DEVIATION = .917 DEVIATION FROM NORMAL DISTR. = -39.10%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.190	-1.058	-.683	1.100	2.337	2.557	2.918	3.506

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.749	.866	COARSE SAND
STANDARD DEVIATION	1.808	1.526	POORLY SORTED
SKEWNESS(1)	-.194	-.155	COARSE-SKEWED
SKEWNESS(2)	-.131		
KURTOSIS	.136	.557	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A14	111199					
Borrow A - A14						
		-1.125	59.210	50.085	-1.000	50.085
		-.875	4.790	4.052	-.750	54.136
		-.625	5.100	4.314	-.500	58.450
		-.375	4.720	3.993	-.250	62.443
		-.125	2.990	2.529	.000	64.972
		.125	3.540	2.994	.250	67.967
		.375	3.830	3.240	.500	71.206
		.625	3.370	2.851	.750	74.057
		.875	4.240	3.587	1.000	77.643
		1.125	5.180	4.382	1.250	82.025
		1.375	5.460	4.619	1.500	86.644
		1.625	3.840	3.248	1.750	89.892
		1.875	1.980	1.675	2.000	91.567
		2.125	3.140	2.656	2.250	94.223
		2.375	2.780	2.352	2.500	96.574
		2.625	2.050	1.734	2.750	98.308
		2.875	1.220	1.032	3.000	99.340
		3.125	.420	.355	3.250	99.695
		3.375	.160	.135	3.500	99.831
		3.625	.130	.110	3.750	99.941
		3.875	.070	.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 118.220

PERCENT FINER THAN 4.00 PHI = .08 PERCENT COARSER THAN -1.00 PHI = .00

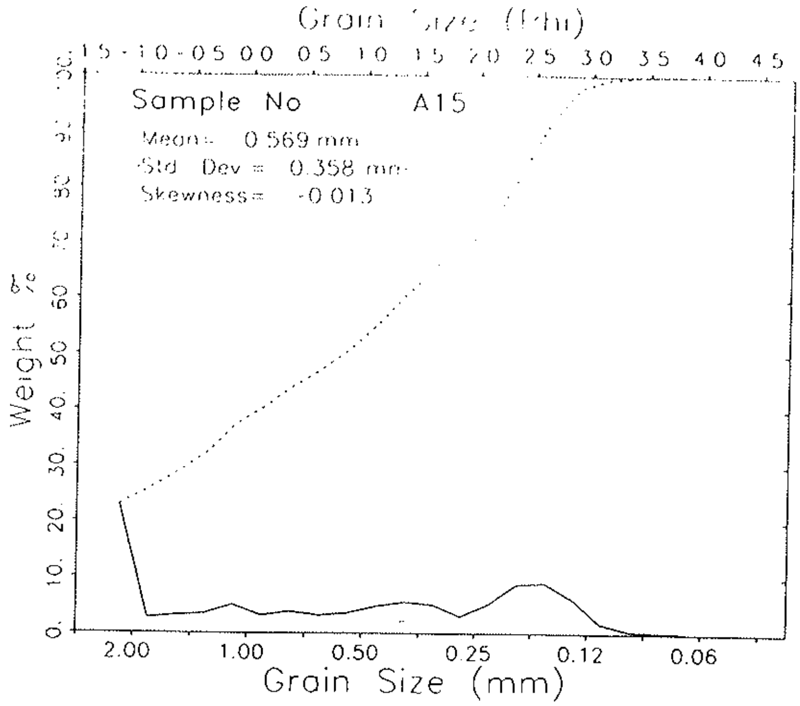
MOMENT MEASURES:

MEAN = -.172 STANDARD DEVIATION = 1.233 SKEWNESS = .502 KURTOSIS = -.312
DISPERSION = .298 STANDARD DEVIATION = .480 DEVIATION FROM NORMAL DISTR. = -61.03%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.245	-1.225	-1.170	-1.125	-1.000	.816	1.357	2.333	2.918

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.093	-.271	VERY COARSE SAND
STANDARD DEVIATION	1.264	1.171	POORLY SORTED
SKEWNESS(1)	.866	.870	STRONGLY FINE-SKEWED
SKEWNESS(2)	1.230		
KURTOSIS	.408	.751	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A15	111199						
Borrow A - A15							
		-1.125	25.490		22.882	-1.000	22.882
		-.875	2.940		2.639	-.750	25.521
		-.625	3.460		3.106	-.500	28.627
		-.375	3.820		3.429	-.250	32.056
		-.125	5.580		5.009	.000	37.065
		.125	3.510		3.151	.250	40.215
		.375	4.230		3.797	.500	44.013
		.625	3.510		3.151	.750	47.163
		.875	3.980		3.573	1.000	50.736
		1.125	5.240		4.704	1.250	55.440
		1.375	6.060		5.440	1.500	60.880
		1.625	5.660		5.081	1.750	65.960
		1.875	3.320		2.980	2.000	68.941
		2.125	5.730		5.144	2.250	74.084
		2.375	9.610		8.627	2.500	82.711
		2.625	9.910		8.896	2.750	91.607
		2.875	6.760		6.068	3.000	97.675
		3.125	1.870		1.679	3.250	99.354
		3.375	.440		.395	3.500	99.749
		3.625	.220		.197	3.750	99.946
		3.875	.060		.054	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.400

PERCENT FINER THAN 4.00 PHI = .04 PERCENT COARSER THAN -1.00 PHI = .00

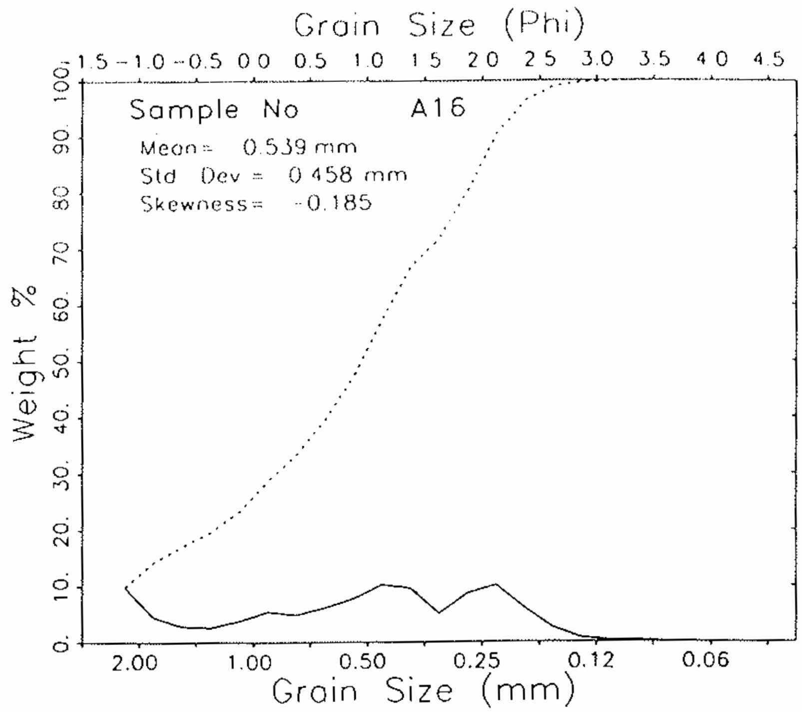
MOMENT MEASURES:

MEAN = .813 STANDARD DEVIATION = 1.480 SKEWNESS = -.013 KURTOSIS = -1.477
DISPERSION = .563 STANDARD DEVIATION = .884 DEVIATION FROM NORMAL DISTR. = -40.23%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.195	-1.075	-.799	.948	2.277	2.536	2.890	3.197

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.731	.803	COARSE SAND
STANDARD DEVIATION	1.806	1.522	POORLY SORTED
SKEWNESS(1)	-.121	-.085	NEAR SYMMETRICAL
SKEWNESS(2)	-.056		
KURTOSIS	.131	.544	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT (PHI)	CLASS LIMITS	CUM PERCENT
A16	111199						
Borrow A - A16							
		-1.125	12.180	9.736	-1.000	9.736	
		-.875	5.530	4.420	-.750	14.157	
		-.625	3.520	2.814	-.500	16.970	
		-.375	3.190	2.550	-.250	19.520	
		-.125	4.610	3.685	.000	23.205	
		.125	6.700	5.356	.250	28.561	
		.375	5.960	4.764	.500	33.325	
		.625	7.530	6.019	.750	39.345	
		.875	9.600	7.674	1.000	47.018	
		1.125	12.680	10.136	1.250	57.154	
		1.375	11.990	9.584	1.500	66.739	
		1.625	6.310	5.044	1.750	71.783	
		1.875	10.770	8.609	2.000	80.392	
		2.125	12.620	10.088	2.250	90.480	
		2.375	7.450	5.955	2.500	96.435	
		2.625	3.110	2.486	2.750	98.921	
		2.875	.780	.624	3.000	99.544	
		3.125	.310	.248	3.250	99.792	
		3.375	.260	.208	3.500	100.000	
		3.625	.000	.000	3.750	100.000	
		3.875	.000	.000	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 125.100

PERCENT FINER THAN 4.00 PHI = .31 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

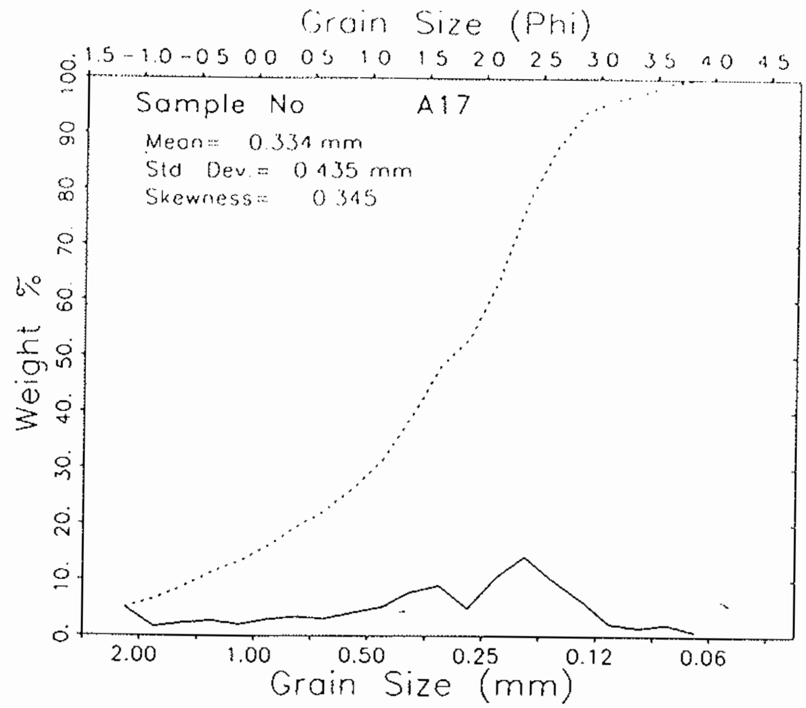
MEAN = .892 STANDARD DEVIATION = 1.128 SKEWNESS = -.185 KURTOSIS = -.902

DISPERSION = .578 STANDARD DEVIATION = .916 DEVIATION FROM NORMAL DISTR. = -18.83%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.122	-.586	.084	1.074	1.843	2.089	2.440	2.782

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.752	.859	COARSE SAND
STANDARD DEVIATION	1.338	1.209	POORLY SORTED
SKEWNESS(1)	-.241	-.237	COARSE-SKEWED
SKEWNESS(2)	-.310		
KURTOSIS	.331	.829	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A17	111199					
Borrow A - A17						
		-1.125	5.380	4.965	-1.000	4.965
		-.875	1.650	1.523	-.750	6.488
		-.625	2.400	2.215	-.500	8.702
		-.375	2.820	2.602	-.250	11.305
		-.125	2.150	1.984	.000	13.289
		.125	3.100	2.861	.250	16.150
		.375	3.590	3.313	.500	19.463
		.625	3.200	2.953	.750	22.416
		.875	4.410	4.070	1.000	26.486
		1.125	5.450	5.030	1.250	31.515
		1.375	8.400	7.752	1.500	39.267
		1.625	9.650	8.905	1.750	48.173
		1.875	5.330	4.919	2.000	53.092
		2.125	11.270	10.401	2.250	63.492
		2.375	15.310	14.129	2.500	77.621
		2.625	10.720	9.893	2.750	87.514
		2.875	6.830	6.303	3.000	93.817
		3.125	2.330	2.150	3.250	95.967
		3.375	1.470	1.357	3.500	97.324
		3.625	2.100	1.938	3.750	99.262
		3.875	.800	.738	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.360

PERCENT FINER THAN 4.00 PHI = .97 PERCENT COARSER THAN -1.00 PHI = .00

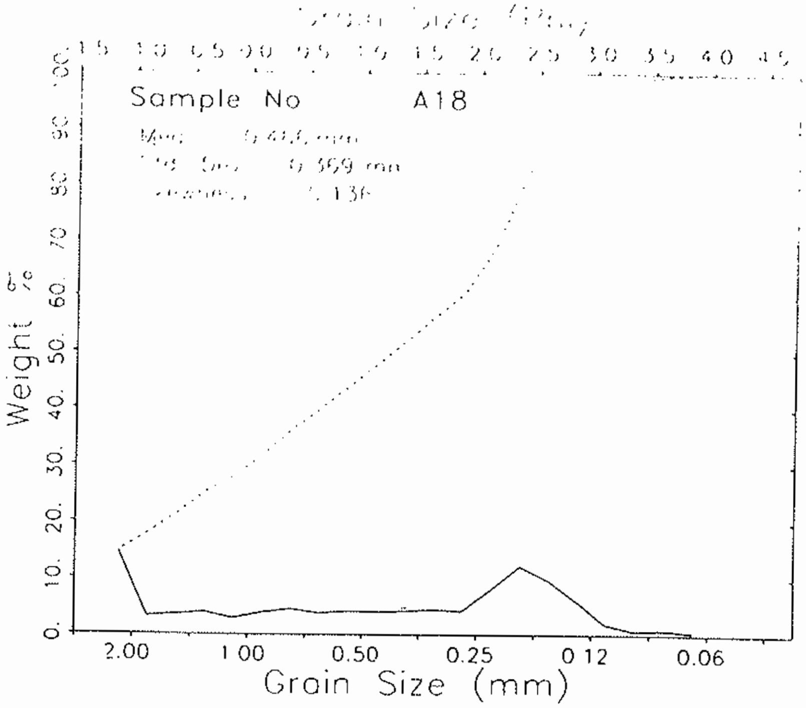
MOMENT MEASURES:

MEAN = 1.584 STANDARD DEVIATION = 1.201 SKEWNESS = -.345 KURTOSIS = -.259
DISPERSION = .614 STANDARD DEVIATION = .994 DEVIATION FROM NORMAL DISTR. = -17.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.200	-.994	.237	.909	1.843	2.454	2.661	3.138	3.716

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.449	1.580	MEDIUM SAND
STANDARD DEVIATION	1.212	1.232	POORLY SORTED
SKEWNESS(1)	-.325	-.349	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.636		
KURTOSIS	.704	1.096	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A18	111199					
Borrow A - A18						
		-1.125	15.410	14.646	-1.000	14.646
		-.875	3.300	3.136	-.750	17.782
		-.625	3.640	3.459	-.500	21.241
		-.375	4.120	3.916	-.250	25.157
		-.125	2.970	2.823	.000	27.979
		.125	4.020	3.821	.250	31.800
		.375	4.680	4.448	.500	36.248
		.625	3.880	3.688	.750	39.935
		.875	4.290	4.077	1.000	44.013
		1.125	4.180	3.973	1.250	47.985
		1.375	4.320	4.106	1.500	52.091
		1.625	4.630	4.400	1.750	56.491
		1.875	4.390	4.172	2.000	60.663
		2.125	8.400	7.983	2.250	68.647
		2.375	12.710	12.079	2.500	80.726
		2.625	10.170	9.665	2.750	90.392
		2.875	6.270	5.959	3.000	96.351
		3.125	1.930	1.834	3.250	98.185
		3.375	.650	.618	3.500	98.803
		3.625	.860	.817	3.750	99.620
		3.875	.400	.380	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.220

PERCENT FINER THAN 4.00 PHI = .68 PERCENT COARSER THAN -1.00 PHI = .00

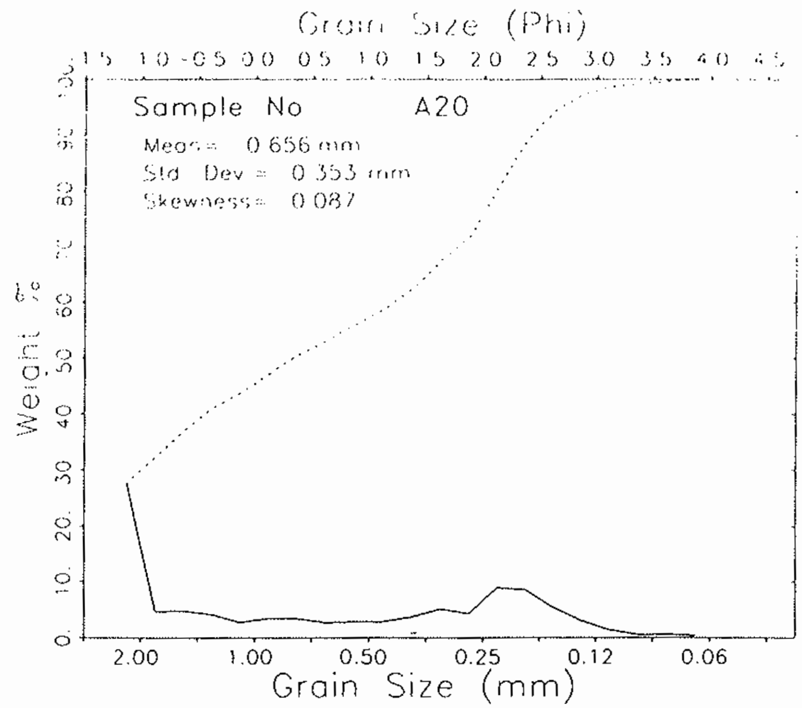
MOMENT MEASURES:

MEAN = 1.103 STANDARD DEVIATION = 1.439 SKEWNESS = -.136 KURTOSIS = -1.307
DISPERSION = .612 STANDARD DEVIATION = .990 DEVIATION FROM NORMAL DISTR. = -31.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.233	-1.165	-.892	-.260	1.373	2.381	2.585	2.943	3.560

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.846	1.022	MEDIUM SAND
STANDARD DEVIATION	1.738	1.492	POORLY SORTED
SKEWNESS(1)	-.303	-.269	COARSE-SKEWED
SKEWNESS(2)	-.278		
KURTOSIS	.182	.637	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A20	111199					
Borrow A - A20						
		-1.125	29.190	27.527	-1.000	27.527
		-.875	4.930	4.649	-.750	32.177
		-.625	4.970	4.687	-.500	36.863
		-.375	4.370	4.121	-.250	40.985
		-.125	2.910	2.744	.000	43.729
		.125	3.620	3.414	.250	47.143
		.375	3.630	3.423	.500	50.566
		.625	2.770	2.612	.750	53.178
		.875	2.990	2.820	1.000	55.998
		1.125	2.940	2.773	1.250	58.770
		1.375	3.890	3.668	1.500	62.439
		1.625	5.370	5.064	1.750	67.503
		1.875	4.480	4.225	2.000	71.728
		2.125	9.350	8.817	2.250	80.545
		2.375	8.950	8.440	2.500	88.985
		2.625	5.660	5.338	2.750	94.323
		2.875	3.130	2.952	3.000	97.275
		3.125	1.370	1.292	3.250	98.567
		3.375	.510	.481	3.500	99.048
		3.625	.580	.547	3.750	99.594
		3.875	.430	.406	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.040

PERCENT FINER THAN 4.00 PHI = .93 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

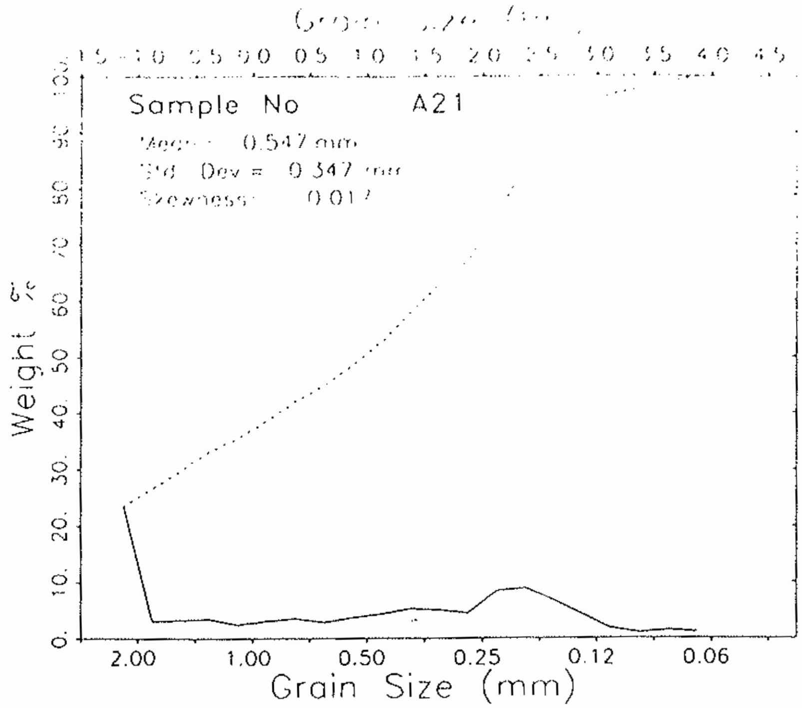
MEAN = .608 STANDARD DEVIATION = 1.504 SKEWNESS = .087 KURTOSIS = -1.494

DISPERSION = .535 STANDARD DEVIATION = .830 DEVIATION FROM NORMAL DISTR. = -44.81%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.205	-1.105	-1.023	.459	2.093	2.352	2.807	3.475

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.624	.569	COARSE SAND
STANDARD DEVIATION	1.729	1.472	POORLY SORTED
SKEWNESS(1)	.096	.133	FINE-SKEWED
SKEWNESS(2)	.198		
KURTOSIS	.161	.528	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A21	111199					
Borrow A - A21						
		-1.125	27.340	23.518	-1.000	23.518
		-.875	3.520	3.028	-.750	26.546
		-.625	3.750	3.226	-.500	29.772
		-.375	3.920	3.372	-.250	33.144
		-.125	2.820	2.426	.000	35.570
		.125	3.530	3.037	.250	38.606
		.375	4.040	3.475	.500	42.082
		.625	3.240	2.787	.750	44.869
		.875	4.180	3.596	1.000	48.465
		1.125	4.860	4.181	1.250	52.645
		1.375	5.950	5.118	1.500	57.763
		1.625	5.800	4.989	1.750	62.753
		1.875	5.070	4.361	2.000	67.114
		2.125	9.700	8.344	2.250	75.458
		2.375	10.190	8.766	2.500	84.224
		2.625	7.710	6.632	2.750	90.856
		2.875	4.850	4.172	3.000	95.028
		3.125	1.990	1.712	3.250	96.740
		3.375	1.060	.912	3.500	97.652
		3.625	1.480	1.273	3.750	98.925
		3.875	1.250	1.075	4.000	100.000

TOTAL WEIGHT (GRAMS) = 116.250

PERCENT FINER THAN 4.00 PHI = 2.01 PERCENT COARSER THAN -1.00 PHI = .00

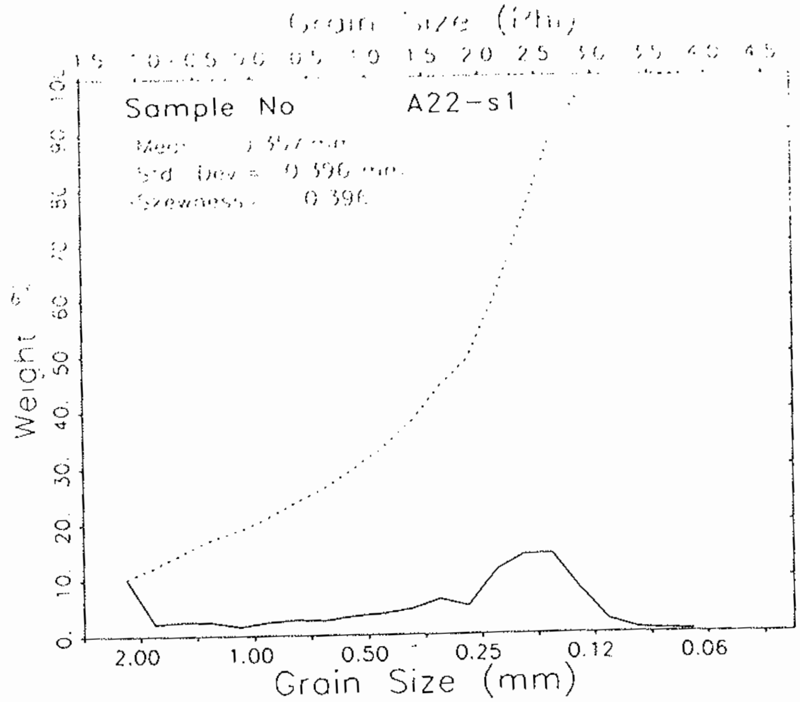
MOMENT MEASURES:

MEAN = .871 STANDARD DEVIATION = 1.527 SKEWNESS = -.017 KURTOSIS = -1.396
DISPERSION = .581 STANDARD DEVIATION = .923 DEVIATION FROM NORMAL DISTR. = -39.58%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.197	-1.080	-.878	1.092	2.236	2.494	2.998	3.767

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.707	.835	COARSE SAND
STANDARD DEVIATION	1.787	1.529	POORLY SORTED
SKEWNESS(1)	-.215	-.153	COARSE-SKEWED
SKEWNESS(2)	-.107		
KURTOSIS	.174	.552	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A22-s1	111199					
Borrow A - A22-s1						
		-1.125	10.600	10.184	-1.000	10.184
		-.875	2.260	2.171	-.750	12.356
		-.625	2.530	2.431	-.500	14.787
		-.375	2.490	2.392	-.250	17.179
		-.125	1.640	1.576	.000	18.755
		.125	2.410	2.316	.250	21.070
		.375	2.800	2.690	.500	23.761
		.625	2.670	2.565	.750	26.326
		.875	3.440	3.305	1.000	29.631
		1.125	3.830	3.680	1.250	33.311
		1.375	4.690	4.506	1.500	37.817
		1.625	6.510	6.255	1.750	44.072
		1.875	5.140	4.939	2.000	49.010
		2.125	11.730	11.270	2.250	60.281
		2.375	14.660	14.085	2.500	74.366
		2.625	14.690	14.114	2.750	88.480
		2.875	8.020	7.706	3.000	96.186
		3.125	2.350	2.258	3.250	98.444
		3.375	.770	.740	3.500	99.183
		3.625	.490	.471	3.750	99.654
		3.875	.360	.346	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.080

PERCENT FINER THAN 4.00 PHI = .54 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

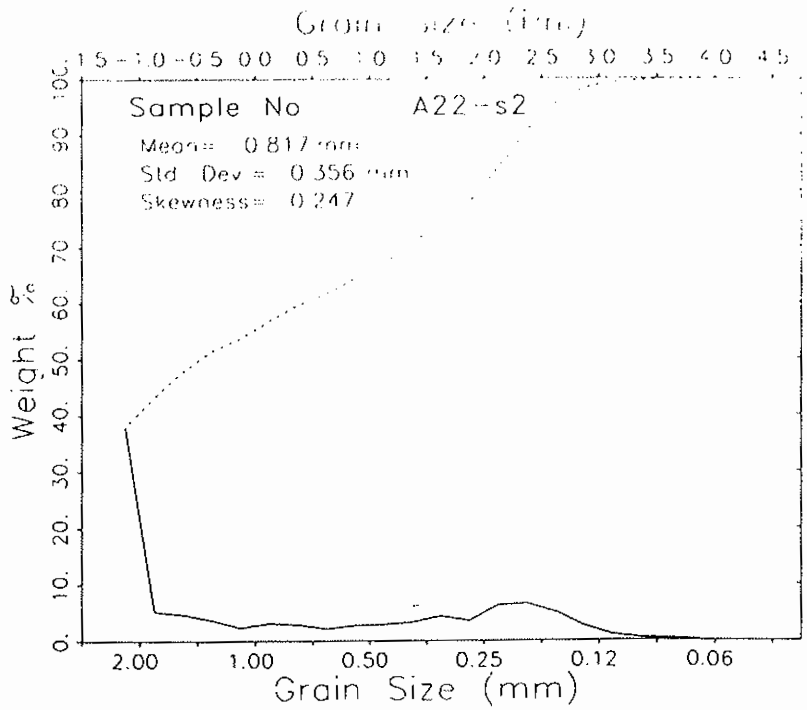
MEAN = 1.488 STANDARD DEVIATION = 1.337 SKEWNESS = -.396 KURTOSIS = -.638

DISPERSION = .570 STANDARD DEVIATION = .898 DEVIATION FROM NORMAL DISTR. = -32.80%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.225	-1.127	-.373	.621	2.022	2.511	2.671	2.962	3.438

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.149	1.440	MEDIUM SAND
STANDARD DEVIATION	1.522	1.380	POORLY SORTED
SKEWNESS(1)	-.574	-.557	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.726		
KURTOSIS	.343	.886	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A22-s2	111199					
Borrow A - A22-s2						
		-1.125	40.900	38.025	-1.000	38.025
		-.875	5.490	5.104	-.750	43.129
		-.625	4.960	4.611	-.500	47.741
		-.375	3.930	3.654	-.250	51.395
		-.125	2.470	2.296	.000	53.691
		.125	3.320	3.087	.250	56.778
		.375	3.000	2.789	.500	59.567
		.625	2.220	2.064	.750	61.631
		.875	2.840	2.640	1.000	64.271
		1.125	3.020	2.808	1.250	67.079
		1.375	3.420	3.180	1.500	70.258
		1.625	4.610	4.286	1.750	74.544
		1.875	3.710	3.449	2.000	77.994
		2.125	6.670	6.201	2.250	84.195
		2.375	6.950	6.462	2.500	90.656
		2.625	5.350	4.974	2.750	95.630
		2.875	2.790	2.594	3.000	98.224
		3.125	1.080	1.004	3.250	99.228
		3.375	.400	.372	3.500	99.600
		3.625	.330	.307	3.750	99.907
		3.875	.100	.093	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.560

PERCENT FINER THAN 4.00 PHI = .53 PERCENT COARSER THAN -1.00 PHI = .00

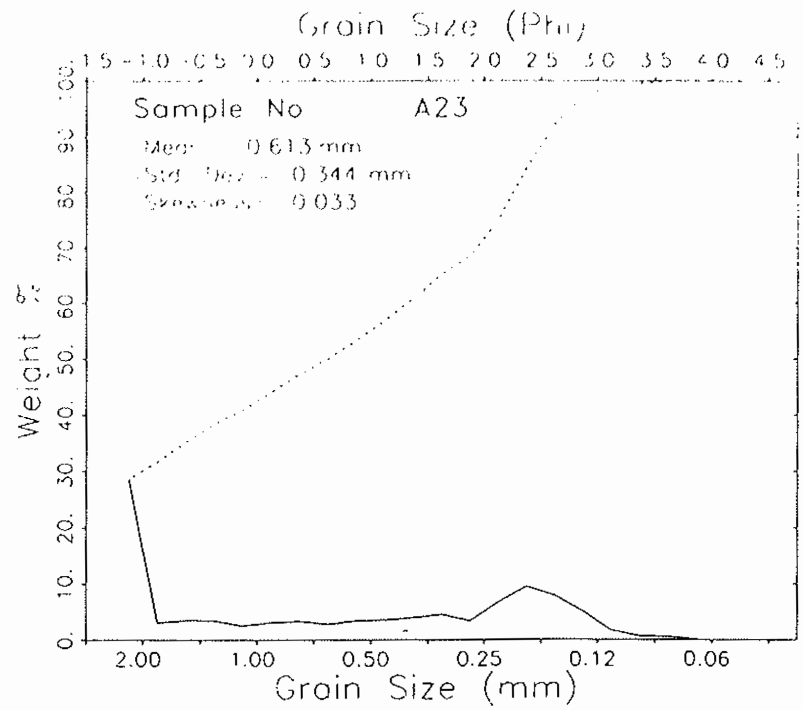
MOMENT MEASURES:

MEAN = .291 STANDARD DEVIATION = 1.489 SKEWNESS = .247 KURTOSIS = -1.344
DISPERSION = .439 STANDARD DEVIATION = .665 DEVIATION FROM NORMAL DISTR. = -55.32%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.243	-1.217	-1.145	-1.086	-.345	1.783	2.242	2.718	3.193

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.549	.251	COARSE SAND
STANDARD DEVIATION	1.693	1.443	POORLY SORTED
SKEWNESS(1)	.528	.542	STRONGLY FINE-SKEWED
SKEWNESS(2)	.647		
KURTOSIS	.162	.562	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A23	111199					
Borrow A -A23						
		-1.125	33.920	28.617	-1.000	28.617
		-.875	3.520	2.970	-.750	31.587
		-.625	4.110	3.467	-.500	35.054
		-.375	4.000	3.375	-.250	38.429
		-.125	2.940	2.480	.000	40.909
		.125	3.610	3.046	.250	43.955
		.375	3.910	3.299	.500	47.254
		.625	3.210	2.708	.750	49.962
		.875	4.020	3.392	1.000	53.354
		1.125	4.160	3.510	1.250	56.863
		1.375	4.590	3.872	1.500	60.736
		1.625	5.290	4.463	1.750	65.199
		1.875	3.900	3.290	2.000	68.489
		2.125	7.820	6.597	2.250	75.086
		2.375	11.110	9.373	2.500	84.460
		2.625	9.300	7.846	2.750	92.306
		2.875	5.940	5.011	3.000	97.317
		3.125	1.890	1.595	3.250	98.912
		3.375	.670	.565	3.500	99.477
		3.625	.590	.498	3.750	99.975
		3.875	.030	.025	4.000	100.000

TOTAL WEIGHT (GRAMS) = 118.530

PERCENT FINER THAN 4.00 PHI = 1.12 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

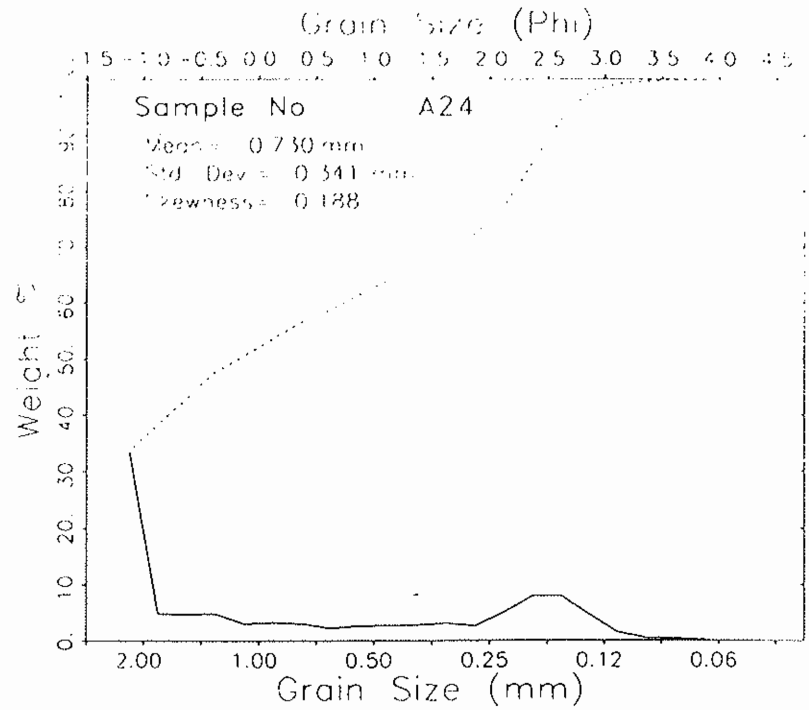
MEAN = .705 STANDARD DEVIATION = 1.539 SKEWNESS = .033 KURTOSIS = -1.564

DISPERSION = .521 STANDARD DEVIATION = .803 DEVIATION FROM NORMAL DISTR. = -47.84%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.206	-1.110	-1.032	.753	2.247	2.488	2.884	3.289

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.689	.710	COARSE SAND
STANDARD DEVIATION	1.799	1.519	POORLY SORTED
SKEWNESS(1)	-.036	.003	NEAR SYMMETRICAL
SKEWNESS(2)	.048		
KURTOSIS	.137	.511	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A24	111199					
Borrow A -A24						
		-1.125	38.220	33.553	-1.000	33.553
		-.875	5.340	4.688	-.750	38.241
		-.625	5.290	4.644	-.500	42.885
		-.375	5.390	4.732	-.250	47.617
		-.125	3.340	2.932	.000	50.549
		.125	3.540	3.108	.250	53.656
		.375	3.430	3.011	.500	56.668
		.625	2.450	2.151	.750	58.818
		.875	2.940	2.581	1.000	61.399
		1.125	3.010	2.642	1.250	64.042
		1.375	3.100	2.721	1.500	66.763
		1.625	3.480	3.055	1.750	69.818
		1.875	2.950	2.590	2.000	72.408
		2.125	5.690	4.995	2.250	77.403
		2.375	8.960	7.866	2.500	85.269
		2.625	9.020	7.919	2.750	93.188
		2.875	5.230	4.591	3.000	97.779
		3.125	1.560	1.370	3.250	99.148
		3.375	.450	.395	3.500	99.544
		3.625	.350	.307	3.750	99.851
		3.875	.170	.149	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.910

PERCENT FINER THAN 4.00 PHI = .54 PERCENT COARSER THAN -1.00 PHI = .00

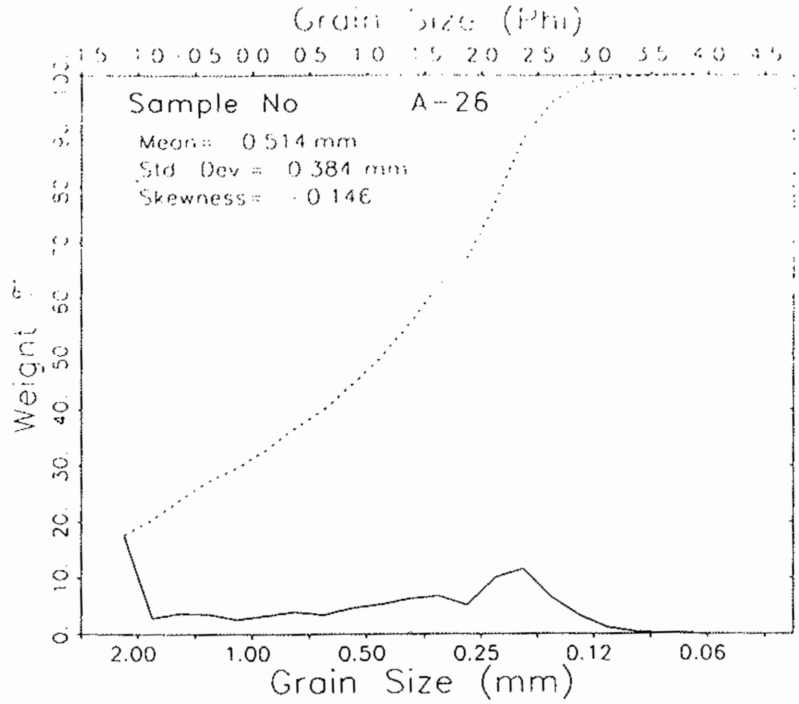
MOMENT MEASURES:

MEAN = .454 STANDARD DEVIATION = 1.551 SKEWNESS = .188 KURTOSIS = -1.478
DISPERSION = .478 STANDARD DEVIATION = .727 DEVIATION FROM NORMAL DISTR. = -53.15%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.243	-1.213	-1.131	-1.064	-.047	2.130	2.460	2.849	3.223

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.664	.427	COARSE SAND
STANDARD DEVIATION	1.795	1.513	POORLY SORTED
SKEWNESS(1)	.396	.411	STRONGLY FINE-SKEWED
SKEWNESS(2)	.482		
KURTOSIS	.131	.521	VERY PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-26 111199					
Borrow A - A26					
	-1.125	21.200	17.583	-1.000	17.583
	-.875	3.240	2.687	-.750	20.270
	-.625	4.250	3.525	-.500	23.795
	-.375	4.060	3.367	-.250	27.163
	-.125	2.950	2.447	.000	29.609
	.125	3.810	3.160	.250	32.769
	.375	4.590	3.807	.500	36.576
	.625	4.030	3.342	.750	39.919
	.875	5.410	4.487	1.000	44.406
	1.125	6.150	5.101	1.250	49.507
	1.375	7.430	6.162	1.500	55.669
	1.625	8.030	6.660	1.750	62.329
	1.875	6.040	5.010	2.000	67.338
	2.125	12.030	9.978	2.250	77.316
	2.375	13.820	11.462	2.500	88.778
	2.625	7.750	6.428	2.750	95.206
	2.875	3.770	3.127	3.000	98.333
	3.125	1.240	1.028	3.250	99.361
	3.375	.380	.315	3.500	99.677
	3.625	.260	.216	3.750	99.892
	3.875	.130	.108	4.000	100.000

TOTAL WEIGHT (GRAMS) = 120.570

PERCENT FINER THAN 4.00 PHI = .17 PERCENT COARSER THAN -1.00 PHI = .00

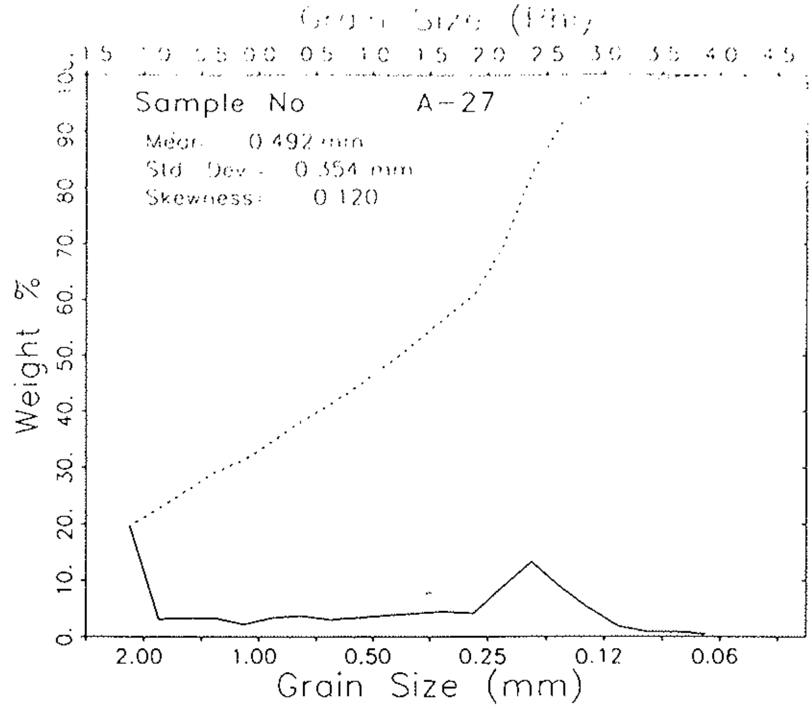
MOMENT MEASURES:

MEAN = .961 STANDARD DEVIATION = 1.380 SKEWNESS = -.146 KURTOSIS = -1.305
DISPERSION = .577 STANDARD DEVIATION = .914 DEVIATION FROM NORMAL DISTR. = -33.78%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.179	-1.023	-.411	1.270	2.192	2.396	2.742	3.162

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.687	.881	COARSE SAND
STANDARD DEVIATION	1.709	1.449	POORLY SORTED
SKEWNESS(1)	-.341	-.295	COARSE-SKEWED
SKEWNESS(2)	-.286		
KURTOSIS	.147	.617	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-27	111199						
Borrow A - A27							
		-1.125	22.630		19.629	-1.000	19.629
		-.875	3.530		3.062	-.750	22.691
		-.625	3.750		3.253	-.500	25.943
		-.375	3.710		3.218	-.250	29.161
		-.125	2.500		2.168	.000	31.330
		.125	3.810		3.305	.250	34.634
		.375	4.150		3.600	.500	38.234
		.625	3.470		3.010	.750	41.244
		.875	3.800		3.296	1.000	44.540
		1.125	4.250		3.686	1.250	48.226
		1.375	4.650		4.033	1.500	52.260
		1.625	5.040		4.372	1.750	56.631
		1.875	4.670		4.051	2.000	60.682
		2.125	10.020		8.691	2.250	69.373
		2.375	15.260		13.236	2.500	82.609
		2.625	10.010		8.682	2.750	91.292
		2.875	5.740		4.979	3.000	96.270
		3.125	2.110		1.830	3.250	98.100
		3.375	.880		.763	3.500	98.864
		3.625	.890		.772	3.750	99.636
		3.875	.420		.364	4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.290

PERCENT FINER THAN 4.00 PHI = .87 PERCENT COARSER THAN -1.00 PHI = .00

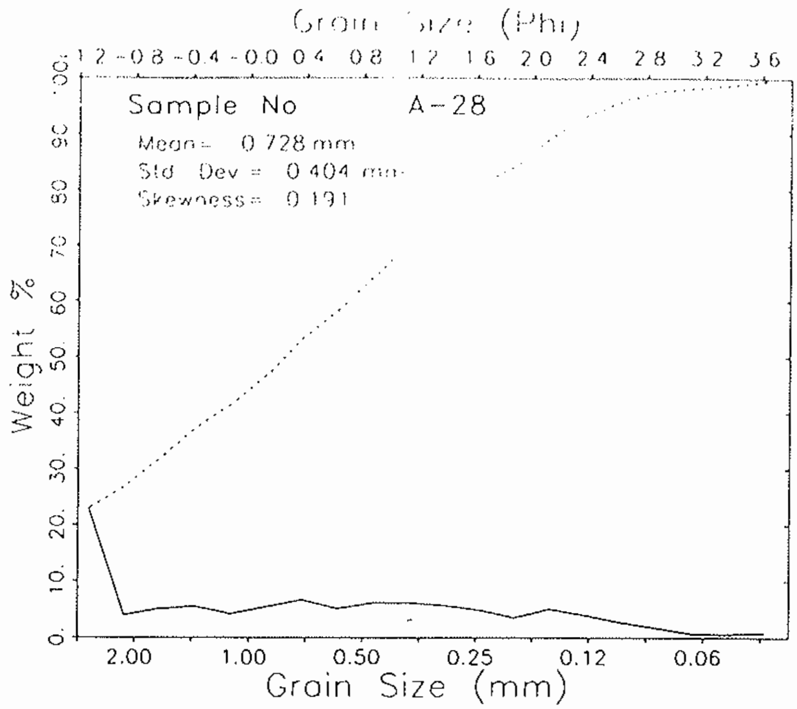
MOMENT MEASURES:

MEAN = 1.022 STANDARD DEVIATION = 1.497 SKEWNESS = -.120 KURTOSIS = -1.417
DISPERSION = .575 STANDARD DEVIATION = .909 DEVIATION FROM NORMAL DISTR. = -39.28%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.237	-1.186	-1.046	-.573	1.360	2.356	2.540	2.936	3.544

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.747	.951	COARSE SAND
STANDARD DEVIATION	1.793	1.521	POORLY SORTED
SKEWNESS(1)	-.342	-.289	COARSE-SKEWED
SKEWNESS(2)	-.270		
KURTOSIS	.150	.577	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-28	111199						
Borrow A - A28							
		-1.125	25.120		22.868	-1.000	22.868
		-.875	4.280		3.896	-.750	26.764
		-.625	5.520		5.025	-.500	31.789
		-.375	6.020		5.480	-.250	37.269
		-.125	4.570		4.160	.000	41.429
		.125	5.880		5.353	.250	46.782
		.375	7.160		6.518	.500	53.300
		.625	5.550		5.052	.750	58.352
		.875	6.660		6.063	1.000	64.415
		1.125	6.670		6.072	1.250	70.487
		1.375	6.200		5.644	1.500	76.131
		1.625	5.250		4.779	1.750	80.910
		1.875	3.840		3.496	2.000	84.406
		2.125	5.430		4.943	2.250	89.349
		2.375	4.250		3.869	2.500	93.218
		2.625	2.920		2.658	2.750	95.876
		2.875	1.790		1.629	3.000	97.506
		3.125	.720		.655	3.250	98.161
		3.375	.610		.555	3.500	98.716
		3.625	.850		.774	3.750	99.490
		3.875	.560		.510	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.850

PERCENT FINER THAN 4.00 PHI = 1.04 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

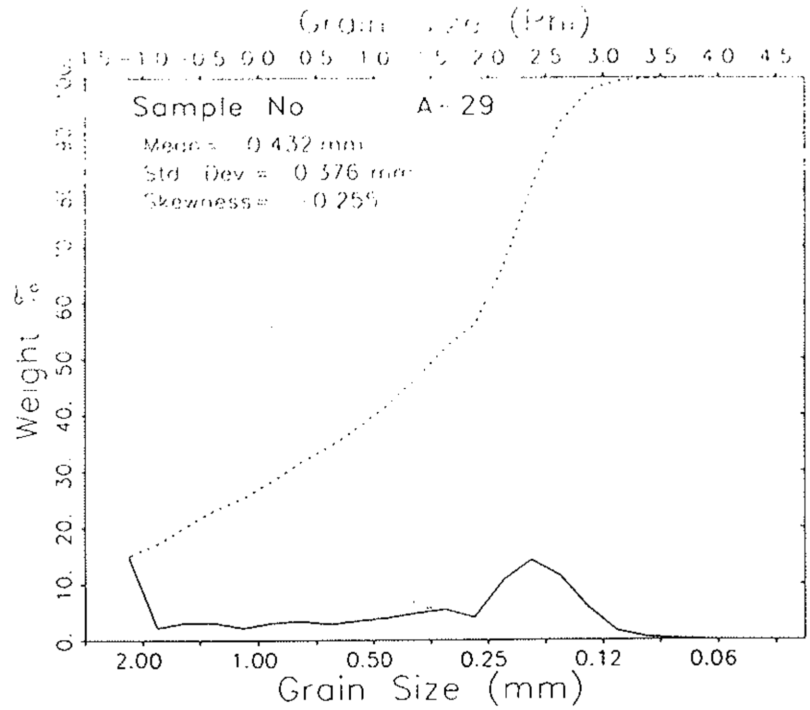
MEAN = .457 STANDARD DEVIATION = 1.308 SKEWNESS = .191 KURTOSIS = -.885

DISPERSION = .579 STANDARD DEVIATION = .918 DEVIATION FROM NORMAL DISTR. = -29.80%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.195	-1.075	-.863	.373	1.450	1.971	2.668	3.592

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.448	.423	COARSE SAND
STANDARD DEVIATION	1.523	1.347	POORLY SORTED
SKEWNESS(1)	.049	.118	FINE-SKEWED
SKEWNESS(2)	.238		
KURTOSIS	.268	.684	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-29	111199					
Borrow A - A29						
		-1.125	15.270	14.956	-1.000	14.956
		-.875	2.190	2.145	-.750	17.101
		-.625	3.100	3.036	-.500	20.137
		-.375	3.090	3.026	-.250	23.164
		-.125	2.210	2.165	.000	25.328
		.125	3.150	3.085	.250	28.413
		.375	3.370	3.301	.500	31.714
		.625	2.860	2.801	.750	34.515
		.875	3.450	3.379	1.000	37.894
		1.125	3.970	3.888	1.250	41.783
		1.375	4.860	4.760	1.500	46.543
		1.625	5.540	5.426	1.750	51.969
		1.875	4.040	3.957	2.000	55.926
		2.125	10.780	10.558	2.250	66.484
		2.375	14.440	14.143	2.500	80.627
		2.625	11.650	11.410	2.750	92.037
		2.875	5.770	5.651	3.000	97.689
		3.125	1.590	1.557	3.250	99.246
		3.375	.470	.460	3.500	99.706
		3.625	.250	.245	3.750	99.951
		3.875	.050	.049	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.100

PERCENT FINER THAN 4.00 PHI = .27 PERCENT COARSER THAN -1.00 PHI = .00

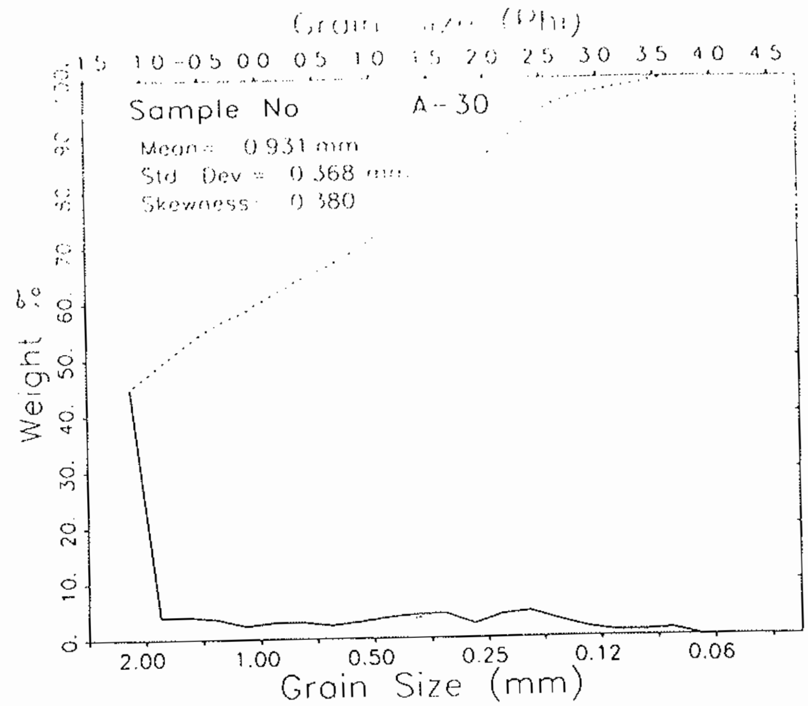
MOMENT MEASURES:

MEAN = 1.212 STANDARD DEVIATION = 1.410 SKEWNESS = -.255 KURTOSIS = -1.183
DISPERSION = .564 STANDARD DEVIATION = .887 DEVIATION FROM NORMAL DISTR. = -37.10%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.233	-1.166	-.878	-.038	1.659	2.401	2.574	2.081	3.211

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.848	1.118	MEDIUM SAND
STANDARD DEVIATION	1.726	1.476	POORLY SORTED
SKEWNESS(1)	-.470	-.433	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.465		
KURTOSIS	.172	.680	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-30	111199					
Borrow A - A30						
		-1.125	50.380	44.822	-1.000	44.822
		-.875	4.400	3.915	-.750	48.737
		-.625	4.430	3.941	-.500	52.678
		-.375	3.920	3.488	-.250	56.165
		-.125	2.630	2.340	.000	58.505
		.125	3.270	2.909	.250	61.415
		.375	3.260	2.900	.500	64.315
		.625	2.620	2.331	.750	66.646
		.875	3.230	2.874	1.000	69.520
		1.125	4.120	3.665	1.250	73.185
		1.375	4.680	4.164	1.500	77.349
		1.625	4.730	4.208	1.750	81.557
		1.875	2.700	2.402	2.000	83.959
		2.125	4.550	4.048	2.250	88.007
		2.375	5.080	4.520	2.500	92.527
		2.625	3.340	2.972	2.750	95.498
		2.875	1.820	1.619	3.000	97.117
		3.125	.960	.854	3.250	97.972
		3.375	.960	.854	3.500	98.826
		3.625	1.310	1.165	3.750	99.991
		3.875	.010	.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 112.400

PERCENT FINER THAN 4.00 PHI = 1.69 PERCENT COARSER THAN -1.00 PHI = .00

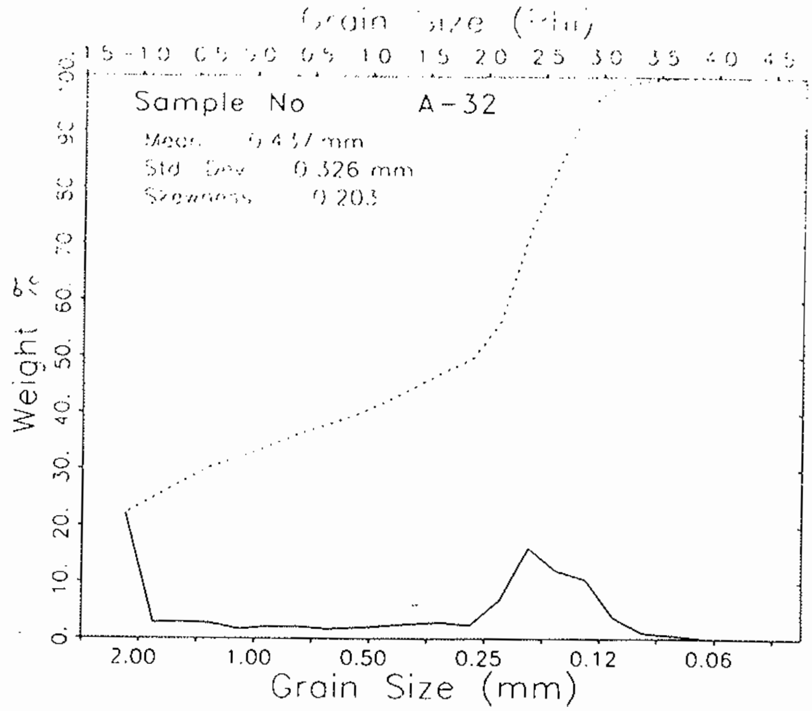
MOMENT MEASURES:

MEAN = .103 STANDARD DEVIATION = 1.441 SKEWNESS = .380 KURTOSIS = -.856
DISPERSION = .382 STANDARD DEVIATION = .583 DEVIATION FROM NORMAL DISTR. = -59.53%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.244	-1.222	-1.161	-1.111	-.670	1.359	2.003	2.708	3.537

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.421	.057	COARSE SAND
STANDARD DEVIATION	1.582	1.386	POORLY SORTED
SKEWNESS(1)	.690	.704	STRONGLY FINE-SKEWED
SKEWNESS(2)	.893		
KURTOSIS	.242	.652	VERY PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-32 111199					
Borrow A - A32					
	-1.125	23.410	22.206	-1.000	22.206
	-.875	2.840	2.694	-.750	24.900
	-.625	3.000	2.846	-.500	27.746
	-.375	2.820	2.675	-.250	30.421
	-.125	1.730	1.641	.000	32.062
	.125	2.140	2.030	.250	34.092
	.375	2.190	2.077	.500	36.170
	.625	1.730	1.641	.750	37.811
	.875	1.900	1.802	1.000	39.613
	1.125	2.270	2.153	1.250	41.766
	1.375	2.700	2.561	1.500	44.327
	1.625	2.990	2.836	1.750	47.164
	1.875	2.440	2.315	2.000	49.478
	2.125	7.030	6.669	2.250	56.147
	2.375	16.940	16.069	2.500	72.216
	2.625	12.610	11.962	2.750	84.178
	2.875	11.080	10.510	3.000	94.688
	3.125	3.840	3.643	3.250	98.330
	3.375	1.020	.968	3.500	99.298
	3.625	.600	.569	3.750	99.867
	3.875	.140	.133	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.420

PERCENT FINER THAN 4.00 PHI = .07 PERCENT COARSER THAN -1.00 PHI = .00

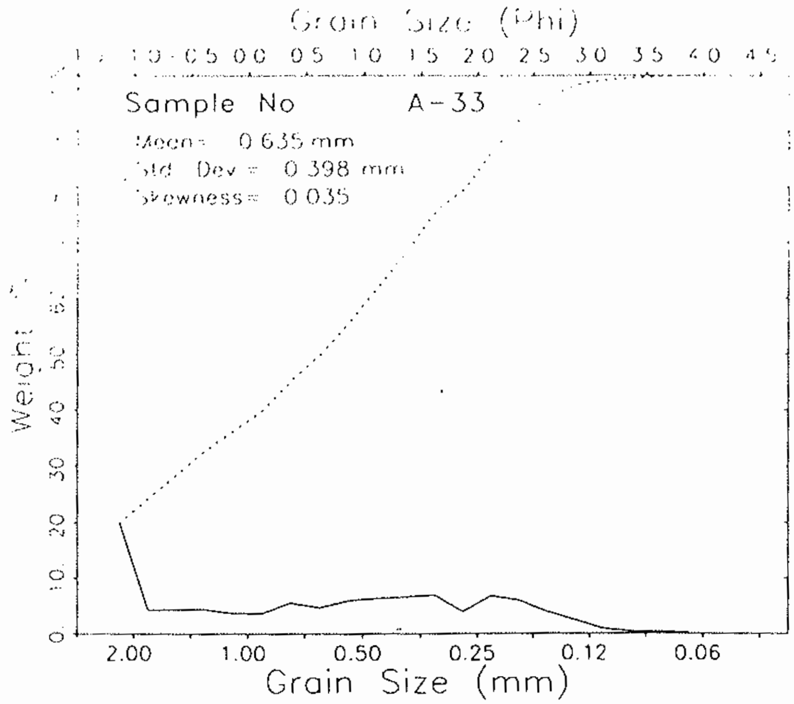
MOMENT MEASURES:

MEAN = 1.194 STANDARD DEVIATION = 1.615 SKEWNESS = -.203 KURTOSIS = -1.504
DISPERSION = .497 STANDARD DEVIATION = .760 DEVIATION FROM NORMAL DISTR. = -52.97%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.194	-1.070	-.741	2.020	2.558	2.746	3.021	3.423

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.838	1.232	MEDIUM SAND
STANDARD DEVIATION	1.908	1.593	POORLY SORTED
SKEWNESS(1)	-.619	-.572	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.579		
KURTOSIS	.105	.524	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-33	111199					
Borrow A - A33						
		-1.125	21.470	19.863	-1.000	19.863
		-.875	4.540	4.200	-.750	24.063
		-.625	4.630	4.283	-.500	28.347
		-.375	4.680	4.330	-.250	32.676
		-.125	3.900	3.608	.000	36.285
		.125	3.800	3.516	.250	39.800
		.375	5.890	5.449	.500	45.249
		.625	5.020	4.644	.750	49.894
		.875	6.330	5.856	1.000	55.750
		1.125	6.780	6.273	1.250	62.022
		1.375	7.130	6.596	1.500	68.619
		1.625	7.480	6.920	1.750	75.539
		1.875	4.200	3.886	2.000	79.425
		2.125	7.270	6.726	2.250	86.150
		2.375	6.350	5.875	2.500	92.025
		2.625	4.180	3.867	2.750	95.892
		2.875	2.540	2.350	3.000	98.242
		3.125	.910	.842	3.250	99.084
		3.375	.370	.342	3.500	99.426
		3.625	.360	.333	3.750	99.759
		3.875	.260	.241	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.090

PERCENT FINER THAN 4.00 PHI = .50 PERCENT COARSER THAN -1.00 PHI = .00

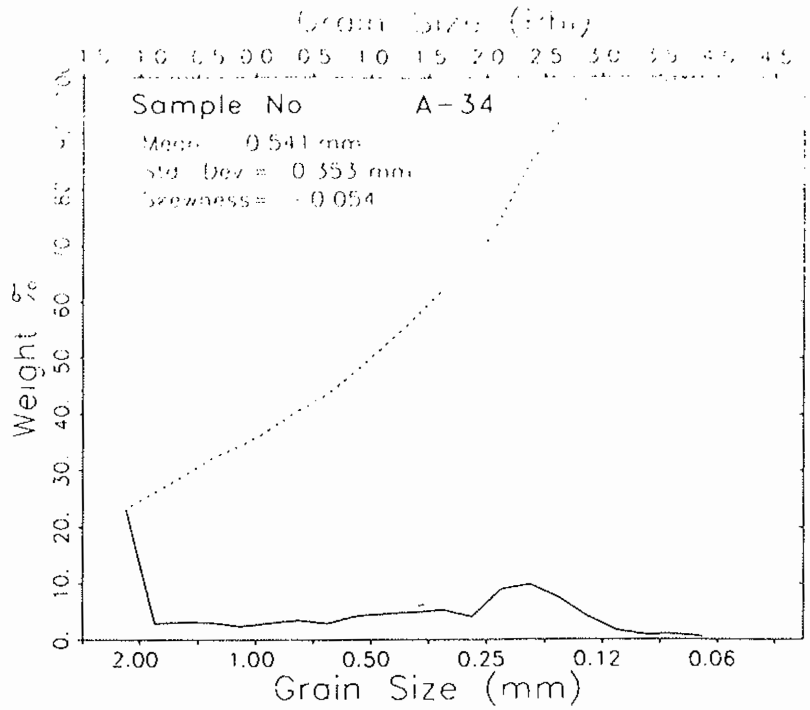
MOMENT MEASURES:

MEAN = .655 STANDARD DEVIATION = 1.330 SKEWNESS = .035 KURTOSIS = -1.221
DISPERSION = .592 STANDARD DEVIATION = .945 DEVIATION FROM NORMAL DISTR. = -28.93%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.237	-1.187	-1.049	-.695	.755	1.731	2.170	2.692	3.225

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.561	.625	COARSE SAND
STANDARD DEVIATION	1.609	1.392	POORLY SORTED
SKEWNESS(1)	-.120	-.061	NEAR SYMMETRICAL
SKEWNESS(2)	-.001		
KURTOSIS	.205	.655	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-34	111199					
Borrow A - A34						
		-1.125	24.170	23.176	-1.000	23.176
		-.875	2.950	2.829	-.750	26.004
		-.625	3.170	3.040	-.500	29.044
		-.375	3.120	2.992	-.250	32.036
		-.125	2.420	2.320	.000	34.356
		.125	3.030	2.905	.250	37.261
		.375	3.560	3.414	.500	40.675
		.625	2.950	2.829	.750	43.504
		.875	4.310	4.133	1.000	47.636
		1.125	4.750	4.555	1.250	52.191
		1.375	5.020	4.814	1.500	57.005
		1.625	5.420	5.197	1.750	62.202
		1.875	4.180	4.008	2.000	66.210
		2.125	9.270	8.889	2.250	75.098
		2.375	10.100	9.685	2.500	84.783
		2.625	7.670	7.354	2.750	92.137
		2.875	4.270	4.094	3.000	96.232
		3.125	1.590	1.525	3.250	97.756
		3.375	.880	.844	3.500	98.600
		3.625	.930	.892	3.750	99.492
		3.875	.530	.508	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.290

PERCENT FINER THAN 4.00 PHI = 1.13 PERCENT COARSER THAN -1.00 PHI = .00

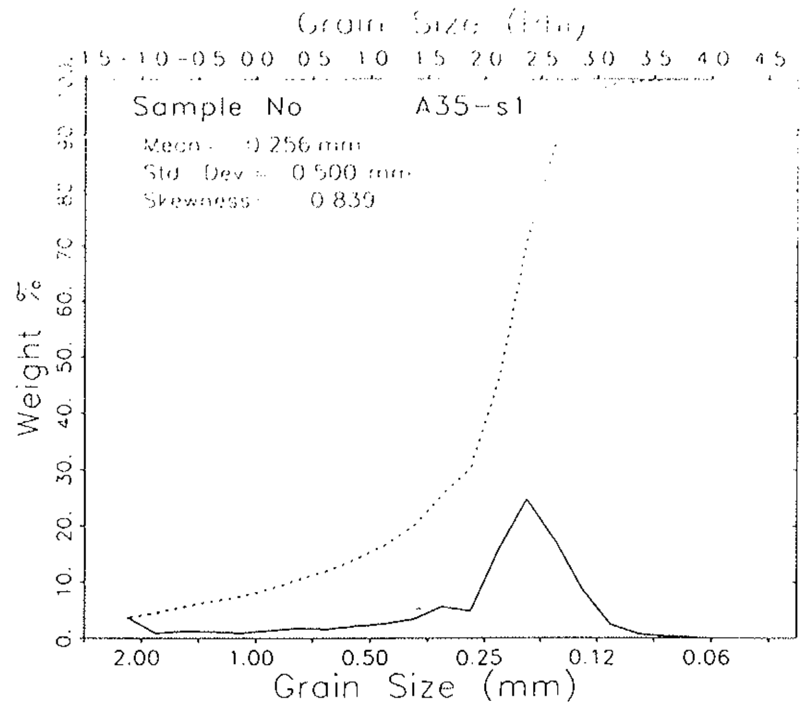
MOMENT MEASURES:

MEAN = .887 STANDARD DEVIATION = 1.501 SKEWNESS = -.054 KURTOSIS = -1.421
DISPERSION = .568 STANDARD DEVIATION = .896 DEVIATION FROM NORMAL DISTR. = -40.30%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.196	-1.077	-.839	1.130	2.247	2.480	2.925	3.612

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.701	.844	COARSE SAND
STANDARD DEVIATION	1.779	1.514	POORLY SORTED
SKEWNESS(1)	-.241	-.185	COARSE-SKEWED
SKEWNESS(2)	-.149		
KURTOSIS	.158	.547	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-35-s	111199					
Borrow A - A-35s1						
		-1.125	4.140	3.606	-1.000	3.606
		-.875	.890	.775	-.750	4.381
		-.625	1.280	1.115	-.500	5.496
		-.375	1.200	1.045	-.250	6.541
		-.125	.990	.862	.000	7.404
		.125	1.500	1.307	.250	8.710
		.375	1.970	1.716	.500	10.426
		.625	1.750	1.524	.750	11.950
		.875	2.340	2.038	1.000	13.988
		1.125	2.880	2.508	1.250	16.497
		1.375	3.820	3.327	1.500	19.824
		1.625	6.340	5.522	1.750	25.346
		1.875	5.520	4.808	2.000	30.154
		2.125	18.280	15.922	2.250	46.076
		2.375	28.330	24.676	2.500	70.752
		2.625	20.050	17.464	2.750	88.215
		2.875	9.680	8.431	3.000	96.647
		3.125	2.670	2.326	3.250	98.972
		3.375	.740	.645	3.500	99.617
		3.625	.330	.287	3.750	99.904
		3.875	.110	.096	4.000	100.000

TOTAL WEIGHT (GRAMS) = 114.810

PERCENT FINER THAN 4.00 PHI = .12 PERCENT COARSER THAN -1.00 PHI = .00

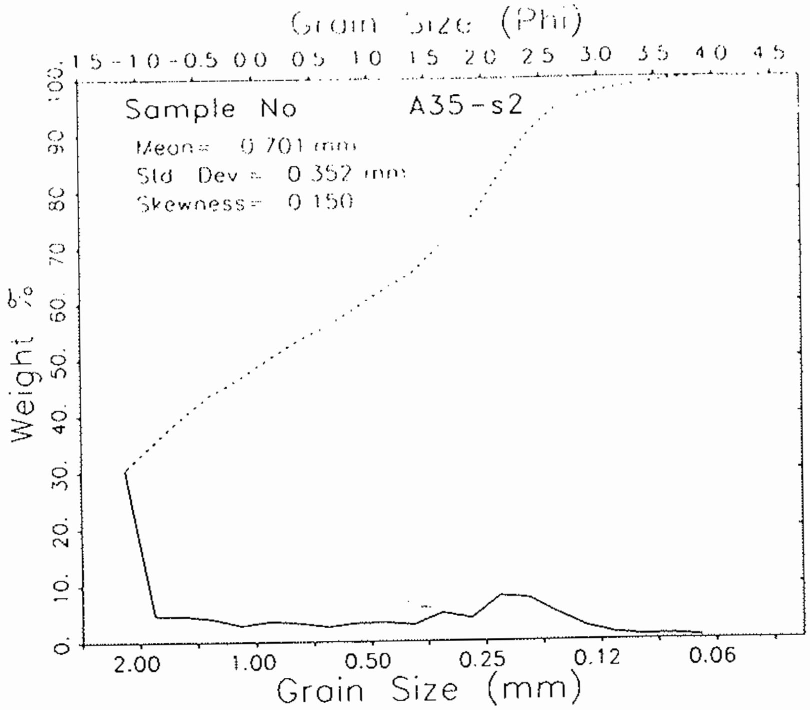
MOMENT MEASURES:

MEAN = 1.964 STANDARD DEVIATION = .999 SKEWNESS = -.839 KURTOSIS = 2.331
DISPERSION = .428 STANDARD DEVIATION = .648 DEVIATION FROM NORMAL DISTR. = -35.12%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.181	-.611	1.200	1.734	2.290	2.561	2.690	2.951	3.261

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.945	2.060	FINE SAND
STANDARD DEVIATION	.745	.912	MODERATELY SORTED
SKEWNESS(1)	-.463	-.546	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.504		
KURTOSIS	1.392	1.767	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-35s-	111199					
Borrow A - A-35s2						
		-1.125	33.380	30.440	-1.000	30.440
		-.875	5.060	4.614	-.750	35.054
		-.625	5.080	4.632	-.500	39.686
		-.375	4.450	4.058	-.250	43.744
		-.125	3.120	2.845	.000	46.589
		.125	3.870	3.529	.250	50.119
		.375	3.550	3.237	.500	53.356
		.625	2.770	2.526	.750	55.882
		.875	3.540	3.228	1.000	59.110
		1.125	3.620	3.301	1.250	62.411
		1.375	3.140	2.863	1.500	65.274
		1.625	5.460	4.979	1.750	70.253
		1.875	4.400	4.012	2.000	74.266
		2.125	8.620	7.861	2.250	82.127
		2.375	8.230	7.505	2.500	89.632
		2.625	5.190	4.733	2.750	94.364
		2.875	2.660	2.426	3.000	96.790
		3.125	1.260	1.149	3.250	97.939
		3.375	.800	.730	3.500	98.669
		3.625	.910	.830	3.750	99.498
		3.875	.550	.502	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.660

PERCENT FINER THAN 4.00 PHI = 1.02 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

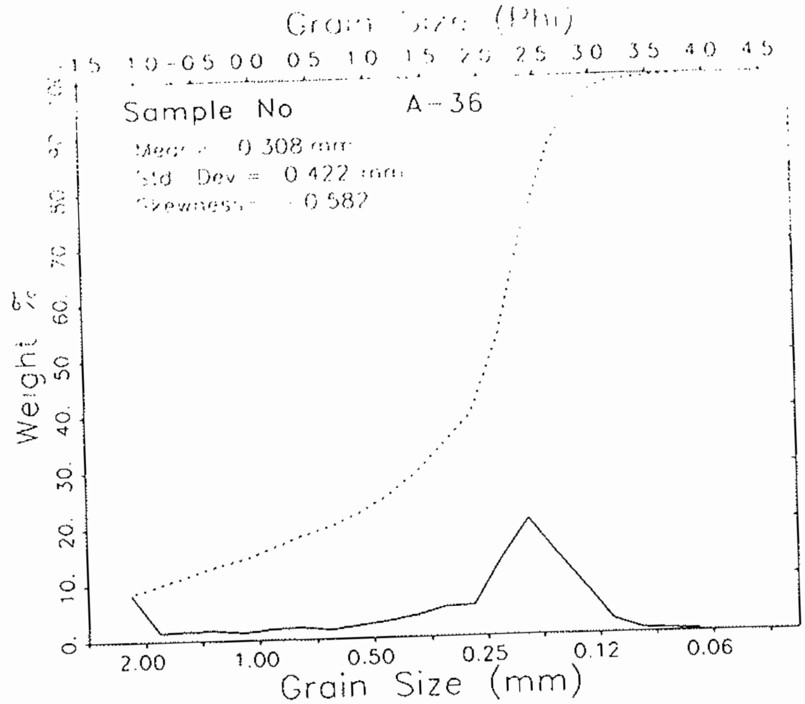
MEAN = .512 STANDARD DEVIATION = 1.508 SKEWNESS = .150 KURTOSIS = -1.400

DISPERSION = .521 STANDARD DEVIATION = .803 DEVIATION FROM NORMAL DISTR. = -46.78%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.209	-1.119	-1.045	.242	2.023	2.312	2.816	3.600

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.597	.478	COARSE SAND
STANDARD DEVIATION	1.715	1.468	POORLY SORTED
SKEWNESS(1)	.207	.243	FINE-SKEWED
SKEWNESS(2)	.327		
KURTOSIS	.173	.538	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-36	111199						
Borrow A - A36							
		-1.125	9.080		8.304	-1.000	8.304
		-.875	1.570		1.436	-.750	9.739
		-.625	1.820		1.664	-.500	11.404
		-.375	1.850		1.692	-.250	13.096
		-.125	1.380		1.262	.000	14.358
		.125	2.100		1.920	.250	16.278
		.375	2.250		2.058	.500	18.336
		.625	1.700		1.555	.750	19.890
		.875	2.410		2.204	1.000	22.094
		1.125	3.200		2.926	1.250	25.021
		1.375	4.200		3.841	1.500	28.861
		1.625	5.750		5.258	1.750	34.120
		1.875	5.880		5.377	2.000	39.497
		2.125	14.880		13.608	2.250	53.105
		2.375	22.450		20.530	2.500	73.635
		2.625	15.660		14.321	2.750	87.956
		2.875	9.140		8.358	3.000	96.315
		3.125	2.500		2.286	3.250	98.601
		3.375	.690		.631	3.500	99.232
		3.625	.520		.476	3.750	99.707
		3.875	.320		.293	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.350

PERCENT FINER THAN 4.00 PHI = .86 PERCENT COARSER THAN -1.00 PHI = .00

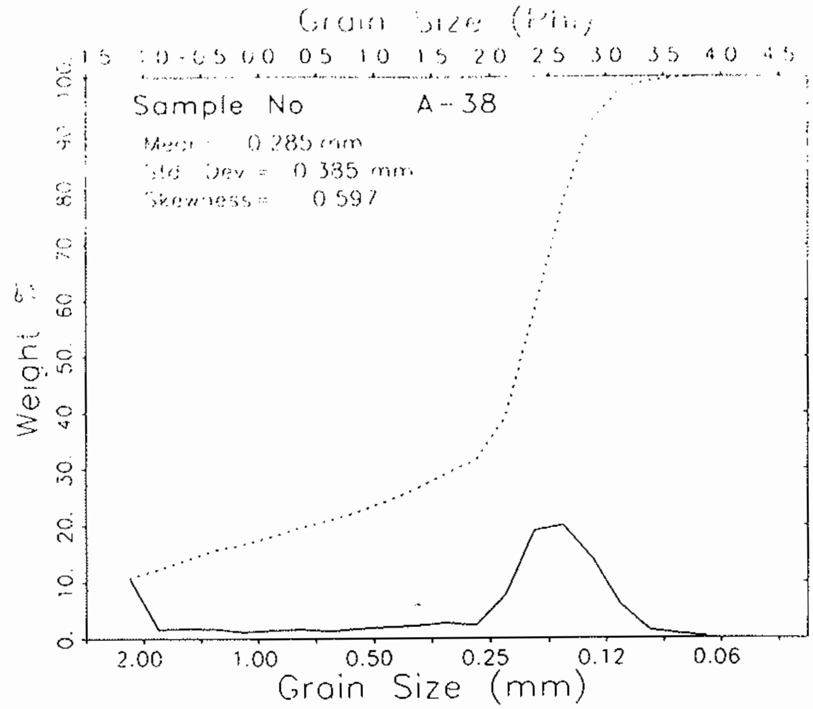
MOMENT MEASURES:

MEAN = 1.701 STANDARD DEVIATION = 1.244 SKEWNESS = -.582 KURTOSIS = .207
DISPERSION = .505 STANDARD DEVIATION = .773 DEVIATION FROM NORMAL DISTR. = -37.82%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.220	-1.099	.214	1.248	2.193	2.524	2.681	2.961	3.408

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.447	1.696	MEDIUM SAND
STANDARD DEVIATION	1.234	1.232	POORLY SORTED
SKEWNESS(1)	-.604	-.613	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.023		
KURTOSIS	.646	1.304	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-38	111199						
Borrow A - A38							
		-1.125	11.430	10.700		-1.000	10.700
		-.875	1.670	1.563		-.750	12.264
		-.625	1.830	1.713		-.500	13.977
		-.375	1.750	1.638		-.250	15.615
		-.125	1.110	1.039		.000	16.654
		.125	1.490	1.395		.250	18.049
		.375	1.690	1.582		.500	19.631
		.625	1.290	1.208		.750	20.839
		.875	1.710	1.601		1.000	22.440
		1.125	2.010	1.882		1.250	24.321
		1.375	2.290	2.144		1.500	26.465
		1.625	2.850	2.668		1.750	29.133
		1.875	2.410	2.256		2.000	31.389
		2.125	8.030	7.517		2.250	38.907
		2.375	20.310	19.013		2.500	57.920
		2.625	21.210	19.856		2.750	77.776
		2.875	15.220	14.248		3.000	92.024
		3.125	6.190	5.795		3.250	97.819
		3.375	1.380	1.292		3.500	99.111
		3.625	.730	.683		3.750	99.794
		3.875	.220	.206		4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.820

PERCENT FINER THAN 4.00 PHI = .33 PERCENT COARSER THAN -1.00 PHI = .00

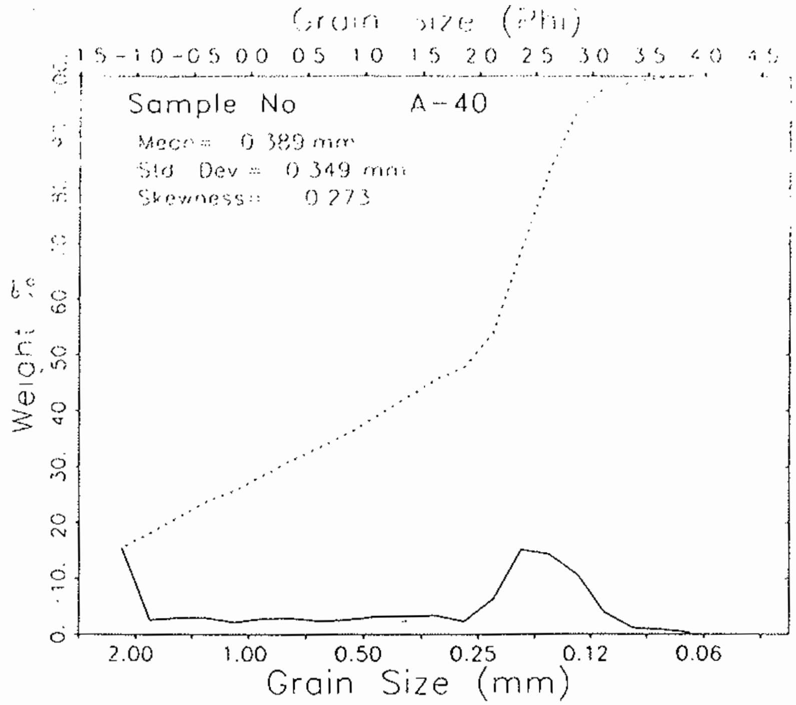
MOMENT MEASURES:

MEAN = 1.813 STANDARD DEVIATION = 1.377 SKEWNESS = -.597 KURTOSIS = .003
DISPERSION = .462 STANDARD DEVIATION = .701 DEVIATION FROM NORMAL DISTR. = -49.10%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.133	-.157	1.329	2.396	2.715	2.859	3.128	3.479

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.351	1.699	MEDIUM SAND
STANDARD DEVIATION	1.508	1.400	POORLY SORTED
SKEWNESS(1)	-.693	-.675	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.927		
KURTOSIS	.413	1.260	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-40	111199					
Borrow A - A40						
		-1.125	17.290	15.512	-1.000	15.512
		-.875	2.770	2.485	-.750	17.997
		-.625	3.200	2.871	-.500	20.868
		-.375	3.230	2.898	-.250	23.766
		-.125	2.250	2.019	.000	25.785
		.125	2.990	2.683	.250	28.468
		.375	3.100	2.781	.500	31.249
		.625	2.550	2.288	.750	33.537
		.875	2.860	2.566	1.000	36.103
		1.125	3.480	3.122	1.250	39.225
		1.375	3.530	3.167	1.500	42.392
		1.625	3.640	3.266	1.750	45.658
		1.875	2.520	2.261	2.000	47.919
		2.125	6.850	6.146	2.250	54.064
		2.375	16.750	15.028	2.500	69.092
		2.625	15.940	14.301	2.750	83.393
		2.875	11.960	10.730	3.000	94.123
		3.125	4.220	3.786	3.250	97.910
		3.375	1.140	1.023	3.500	98.932
		3.625	.890	.798	3.750	99.731
		3.875	.300	.269	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.460

PERCENT FINER THAN 4.00 PHI = .22 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

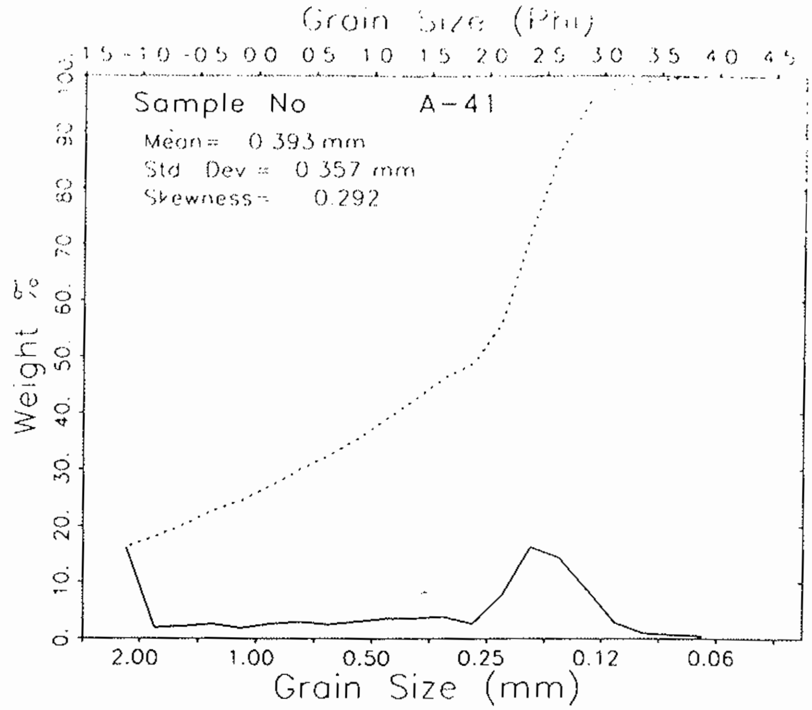
MEAN = 1.361 STANDARD DEVIATION = 1.519 SKEWNESS = -.273 KURTOSIS = -1.231

DISPERSION = .551 STANDARD DEVIATION = .861 DEVIATION FROM NORMAL DISTR. = -43.31%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.234	-1.169	-.951	-.097	2.085	2.603	2.764	3.058	3.521

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.907	1.299	MEDIUM SAND
STANDARD DEVIATION	1.858	1.569	POORLY SORTED
SKEWNESS(1)	-.634	-.587	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.614		
KURTOSIS	.138	.642	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-41	111199						
Borrow A - A41							
		-1.125	19.260	16.147	-1.000	16.147	
		-.875	2.240	1.878	-.750	18.025	
		-.625	2.530	2.121	-.500	20.146	
		-.375	3.000	2.515	-.250	22.661	
		-.125	2.200	1.844	.000	24.505	
		.125	3.040	2.549	.250	27.054	
		.375	3.470	2.909	.500	29.963	
		.625	2.940	2.465	.750	32.428	
		.875	3.590	3.010	1.000	35.438	
		1.125	4.130	3.462	1.250	38.900	
		1.375	4.200	3.521	1.500	42.421	
		1.625	4.560	3.823	1.750	46.244	
		1.875	3.070	2.574	2.000	48.818	
		2.125	8.870	7.436	2.250	56.254	
		2.375	19.330	16.206	2.500	72.460	
		2.625	17.120	14.353	2.750	86.813	
		2.875	10.250	8.593	3.000	95.406	
		3.125	3.200	2.683	3.250	98.089	
		3.375	1.070	.897	3.500	98.986	
		3.625	.770	.646	3.750	99.631	
		3.875	.440	.369	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 119.280

PERCENT FINER THAN 4.00 PHI = .89 PERCENT COARSER THAN -1.00 PHI = .00

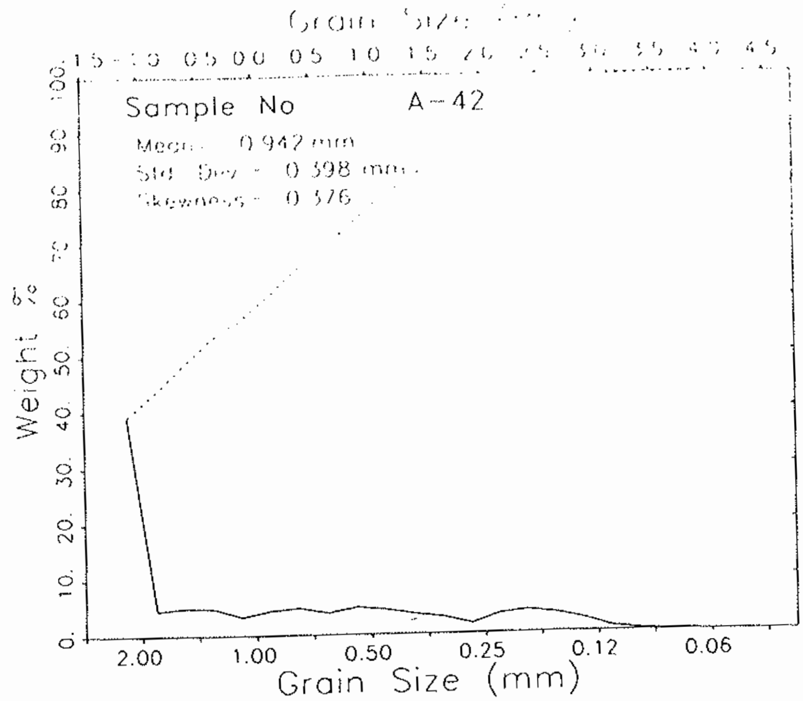
MOMENT MEASURES:

MEAN = 1.349 STANDARD DEVIATION = 1.484 SKEWNESS = -.292 KURTOSIS = -1.141
DISPERSION = .542 STANDARD DEVIATION = .842 DEVIATION FROM NORMAL DISTR. = -43.25%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.173	-1.002	.049	2.040	2.544	2.701	2.988	3.506

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.849	1.246	MEDIUM SAND
STANDARD DEVIATION	1.852	1.556	POORLY SORTED
SKEWNESS(1)	-.643	-.593	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.611		
KURTOSIS	.124	.683	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-42	111199					
Borrow A - A42						
		-1.125	43.190	38.973	-1.000	38.973
		-.875	4.820	4.349	-.750	43.323
		-.625	5.400	4.873	-.500	48.195
		-.375	5.270	4.755	-.250	52.951
		-.125	3.590	3.239	.000	56.190
		.125	4.770	4.304	.250	60.494
		.375	5.260	4.746	.500	65.241
		.625	4.180	3.772	.750	69.013
		.875	5.290	4.774	1.000	73.786
		1.125	4.810	4.340	1.250	78.127
		1.375	3.850	3.474	1.500	81.601
		1.625	3.200	2.888	1.750	84.488
		1.875	1.800	1.624	2.000	86.113
		2.125	3.620	3.267	2.250	89.379
		2.375	4.330	3.907	2.500	93.286
		2.625	3.640	3.285	2.750	96.571
		2.875	2.480	2.238	3.000	98.809
		3.125	.790	.713	3.250	99.522
		3.375	.280	.253	3.500	99.774
		3.625	.170	.153	3.750	99.928
		3.875	.080	.072	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.820

PERCENT FINER THAN 4.00 PHI = .17 PERCENT COARSER THAN -1.00 PHI = .00

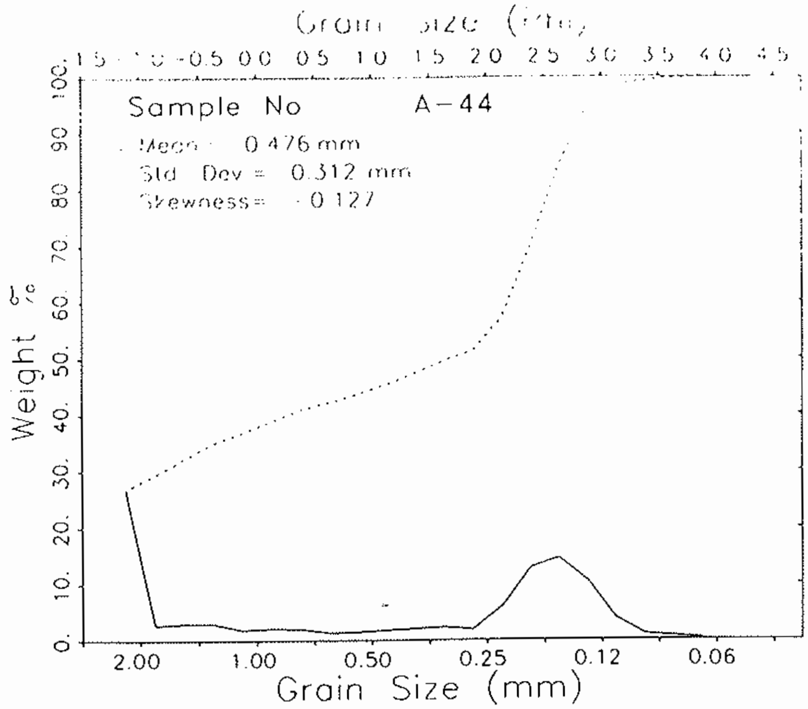
MOMENT MEASURES:

MEAN = .086 STANDARD DEVIATION = 1.329 SKEWNESS = .376 KURTOSIS = -.745
DISPERSION = .431 STANDARD DEVIATION = .653 DEVIATION FROM NORMAL DISTR. = -50.87%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.244	-1.218	-1.147	-1.090	-.405	1.070	1.708	2.630	3.067

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.280	.052	COARSE SAND
STANDARD DEVIATION	1.428	1.297	POORLY SORTED
SKEWNESS(1)	.480	.529	STRONGLY FINE-SKEWED
SKEWNESS(2)	.779		
KURTOSIS	.348	.730	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-44	111199					
Borrow A - A44						
		-1.125	31.120	26.619	-1.000	26.619
		-.875	3.100	2.652	-.750	29.270
		-.625	3.350	2.865	-.500	32.136
		-.375	3.360	2.874	-.250	35.010
		-.125	2.110	1.805	.000	36.815
		.125	2.380	2.036	.250	38.850
		.375	2.340	2.002	.500	40.852
		.625	1.570	1.343	.750	42.195
		.875	1.630	1.394	1.000	43.589
		1.125	2.040	1.745	1.250	45.334
		1.375	2.290	1.959	1.500	47.293
		1.625	2.590	2.215	1.750	49.508
		1.875	2.070	1.771	2.000	51.279
		2.125	6.810	5.825	2.250	57.104
		2.375	14.860	12.711	2.500	69.814
		2.625	16.840	14.404	2.750	84.219
		2.875	12.150	10.393	3.000	94.611
		3.125	4.390	3.755	3.250	98.366
		3.375	.990	.847	3.500	99.213
		3.625	.680	.582	3.750	99.795
		3.875	.240	.205	4.000	100.000

TOTAL WEIGHT (GRAMS) = 116.910

PERCENT FINER THAN 4.00 PHI = .23　　PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

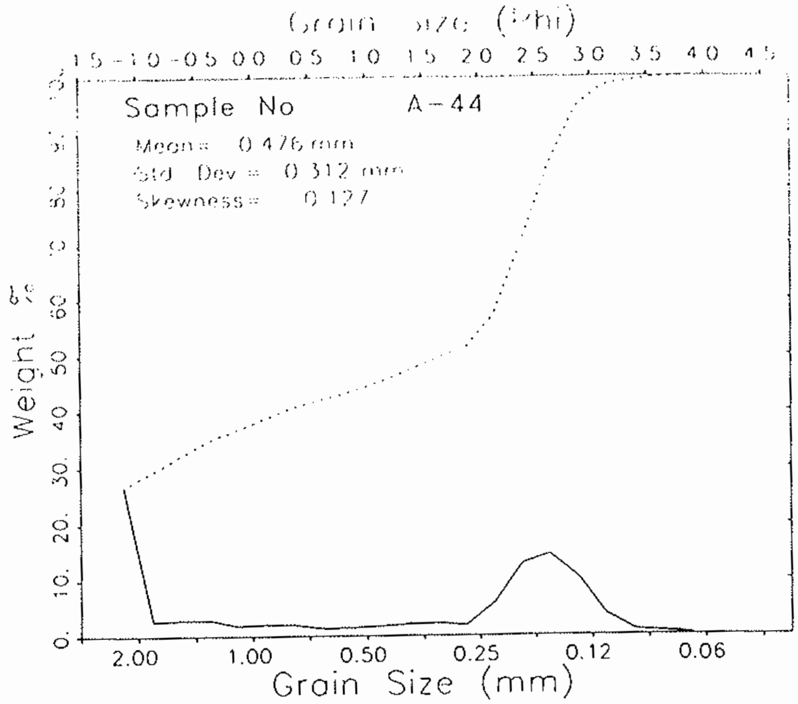
MEAN = 1.070　STANDARD DEVIATION = 1.682　SKEWNESS = -.127　KURTOSIS = -1.667

DISPERSION = .463　STANDARD DEVIATION = .702　DEVIATION FROM NORMAL DISTR. = -58.24%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.203	-1.100	-1.015	1.819	2.590	2.746	3.026	3.437

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.823	1.155	MEDIUM SAND
STANDARD DEVIATION	1.923	1.602	POORLY SORTED
SKEWNESS(1)	-.518	-.474	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.472		
KURTOSIS	.100	.481	VERY PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-44 111199					
Borrow A - A44					
	-1.125	31.120	26.619	-1.000	26.619
	-.875	3.100	2.652	-.750	29.270
	-.625	3.350	2.865	-.500	32.136
	-.375	3.360	2.874	-.250	35.010
	-.125	2.110	1.805	.000	36.815
	.125	2.380	2.036	.250	38.850
	.375	2.340	2.002	.500	40.852
	.625	1.570	1.343	.750	42.195
	.875	1.630	1.394	1.000	43.589
	1.125	2.040	1.745	1.250	45.334
	1.375	2.290	1.959	1.500	47.293
	1.625	2.590	2.215	1.750	49.508
	1.875	2.070	1.771	2.000	51.279
	2.125	6.810	5.825	2.250	57.104
	2.375	14.860	12.711	2.500	69.814
	2.625	16.840	14.404	2.750	84.219
	2.875	12.150	10.393	3.000	94.611
	3.125	4.390	3.755	3.250	98.366
	3.375	.990	.847	3.500	99.213
	3.625	.680	.582	3.750	99.795
	3.875	.240	.205	4.000	100.000

TOTAL WEIGHT (GRAMS) = 116.910

PERCENT FINER THAN 4.00 PHI = .23 PERCENT COARSER THAN -1.00 PHI = .00

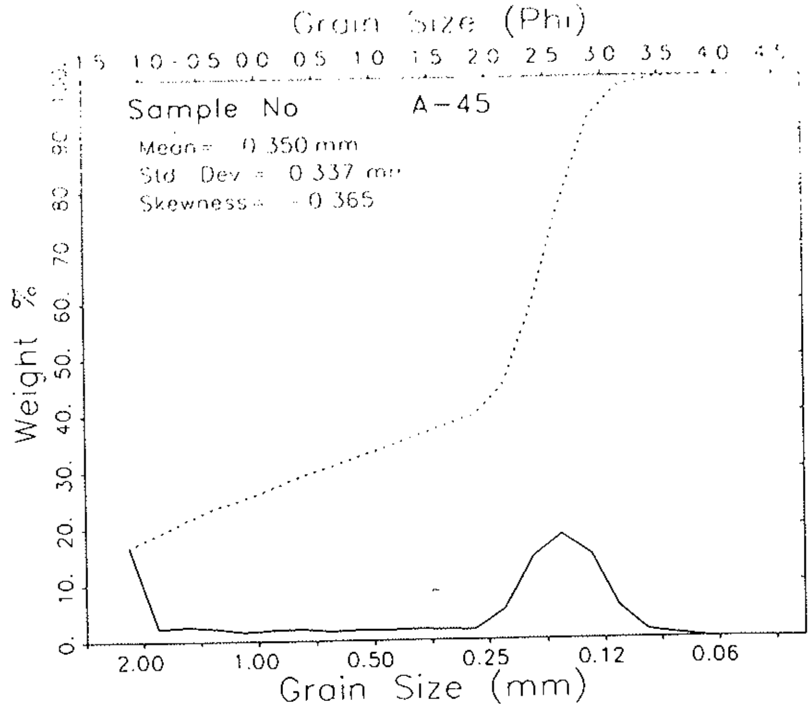
MOMENT MEASURES:

MEAN = 1.070 STANDARD DEVIATION = 1.682 SKEWNESS = -.127 KURTOSIS = -1.667
DISPERSION = .463 STANDARD DEVIATION = .702 DEVIATION FROM NORMAL DISTR. = -58.24%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.203	-1.100	-1.015	1.819	2.590	2.746	3.026	3.437

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.823	1.155	MEDIUM SAND
STANDARD DEVIATION	1.923	1.602	POORLY SORTED
SKEWNESS(1)	-.518	-.474	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.472		
KURTOSIS	.100	.481	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-45	111199						
Borrow A -A45							
		-1.125	19.750		16.671	-1.000	16.671
		-.875	2.610		2.203	-.750	18.874
		-.625	2.990		2.524	-.500	21.398
		-.375	2.590		2.186	-.250	23.584
		-.125	1.810		1.528	.000	25.112
		.125	2.270		1.916	.250	27.028
		.375	2.460		2.076	.500	29.104
		.625	1.820		1.536	.750	30.641
		.875	2.180		1.840	1.000	32.481
		1.125	2.060		1.739	1.250	34.220
		1.375	2.260		1.908	1.500	36.127
		1.625	2.140		1.806	1.750	37.934
		1.875	1.990		1.680	2.000	39.613
		2.125	6.110		5.157	2.250	44.771
		2.375	17.020		14.367	2.500	59.137
		2.625	21.690		18.308	2.750	77.446
		2.875	17.760		14.991	3.000	92.437
		3.125	6.620		5.588	3.250	98.025
		3.375	1.510		1.275	3.500	99.299
		3.625	.740		.625	3.750	99.924
		3.875	.090		.076	4.000	100.000

TOTAL WEIGHT (GRAMS) = 118.470

PERCENT FINER THAN 4.00 PHI = .44 PERCENT COARSER THAN -1.00 PHI = .00

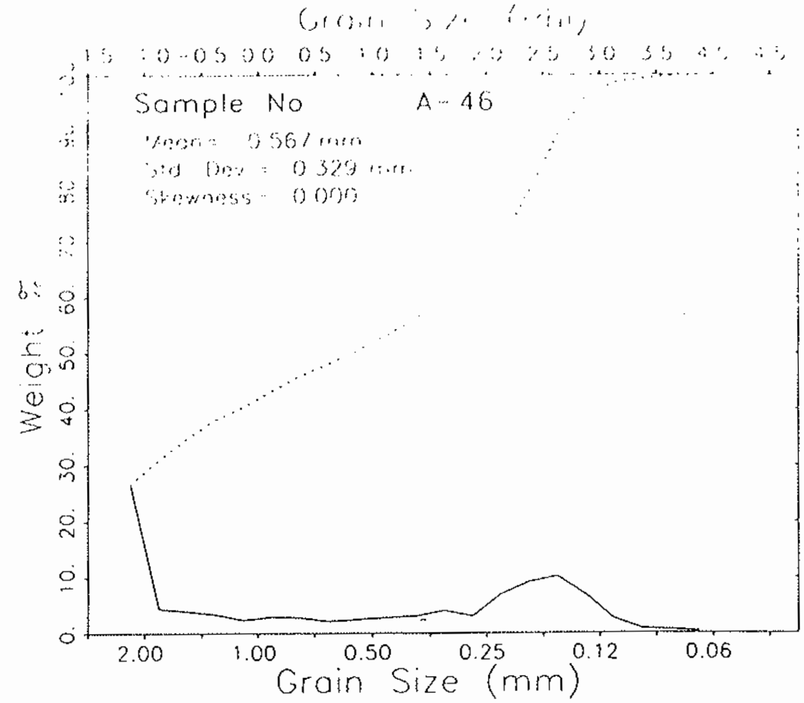
MOMENT MEASURES:

MEAN = 1.515 STANDARD DEVIATION = 1.569 SKEWNESS = -.365 KURTOSIS = -1.116
DISPERSION = .477 STANDARD DEVIATION = .726 DEVIATION FROM NORMAL DISTR. = -53.72%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.175	-1.010	-.018	2.341	2.717	2.859	3.115	3.441

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.925	1.397	MEDIUM SAND
STANDARD DEVIATION	1.935	1.617	POORLY SORTED
SKEWNESS(1)	-.732	-.686	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.709		
KURTOSIS	.109	.643	VERY PLATYKURTIC



SAMPLE NO. DATE

A-46 111199

Borrow A - A46

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	28.400	26.604	-1.000	26.604
-.875	4.560	4.272	-.750	30.876
-.625	4.160	3.897	-.500	34.773
-.375	3.550	3.326	-.250	38.098
-.125	2.440	2.286	.000	40.384
.125	3.060	2.867	.250	43.251
.375	2.920	2.735	.500	45.986
.625	2.200	2.061	.750	48.047
.875	2.530	2.370	1.000	50.417
1.125	2.910	2.726	1.250	53.143
1.375	3.170	2.970	1.500	56.112
1.625	4.280	4.009	1.750	60.122
1.875	3.210	3.007	2.000	63.129
2.125	7.390	6.923	2.250	70.052
2.375	9.640	9.030	2.500	79.082
2.625	10.710	10.033	2.750	89.115
2.875	7.270	6.810	3.000	95.925
3.125	2.740	2.567	3.250	98.492
3.375	.750	.703	3.500	99.194
3.625	.550	.515	3.750	99.710
3.875	.310	.290	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.750

PERCENT FINER THAN 4.00 PHI = .58 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

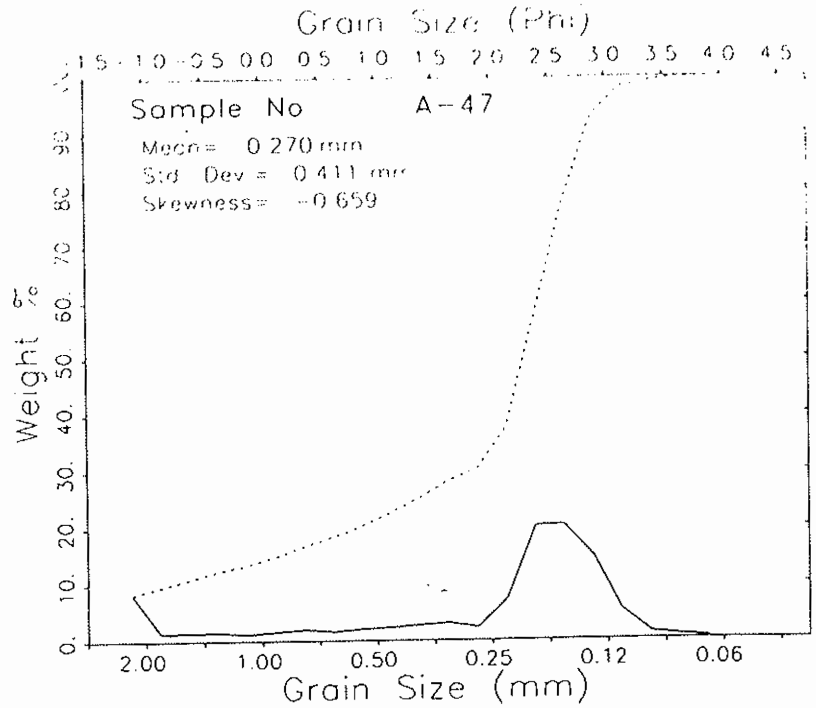
MEAN = .819 STANDARD DEVIATION = 1.603 SKEWNESS = .000 KURTOSIS = -1.625

DISPERSION = .530 STANDARD DEVIATION = .821 DEVIATION FROM NORMAL DISTR. = -48.82%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.203	-1.100	-1.015	.956	2.387	2.623	2.966	3.431

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.761	.826	COARSE SAND
STANDARD DEVIATION	1.861	1.562	POORLY SORTED
SKEWNESS(1)	-.105	-.070	NEAR SYMMETRICAL
SKEWNESS(2)	-.040		
KURTOSIS	.120	.502	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-47	111199					
Borrow A -A47						
		-1.125	8.490	8.197	-1.000	8.197
		-.875	1.340	1.294	-.750	9.491
		-.625	1.450	1.400	-.500	10.891
		-.375	1.510	1.458	-.250	12.349
		-.125	1.140	1.101	.000	13.450
		.125	1.570	1.516	.250	14.966
		.375	1.920	1.854	.500	16.820
		.625	1.650	1.593	.750	18.413
		.875	2.010	1.941	1.000	20.353
		1.125	2.330	2.250	1.250	22.603
		1.375	2.700	2.607	1.500	25.210
		1.625	3.080	2.974	1.750	28.184
		1.875	2.260	2.182	2.000	30.366
		2.125	7.450	7.193	2.250	37.559
		2.375	20.830	20.112	2.500	57.671
		2.625	21.040	20.315	2.750	77.986
		2.875	15.450	14.917	3.000	92.903
		3.125	5.340	5.156	3.250	98.059
		3.375	1.150	1.110	3.500	99.170
		3.625	.660	.637	3.750	99.807
		3.875	.200	.193	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.570

PERCENT FINER THAN 4.00 PHI = .16 PERCENT COARSER THAN -1.00 PHI = .00

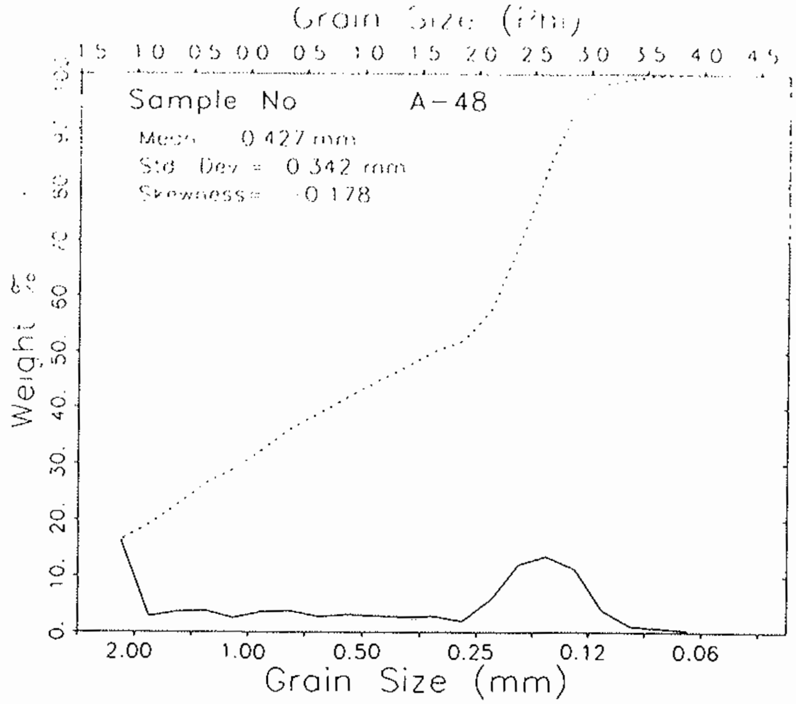
MOMENT MEASURES:

MEAN = 1.889 STANDARD DEVIATION = 1.283 SKEWNESS = -.659 KURTOSIS = .484
DISPERSION = .461 STANDARD DEVIATION = .699 DEVIATION FROM NORMAL DISTR. = -45.50%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.220	-1.098	.389	1.480	2.405	2.713	2.851	3.102	3.462

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.620	1.882	MEDIUM SAND
STANDARD DEVIATION	1.231	1.252	POORLY SORTED
SKEWNESS(1)	-.637	-.653	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.140		
KURTOSIS	.706	1.395	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-48	111199					
Borrow A - A48						
		-1.125	16.550	16.357	-1.000	16.357
		-.875	2.760	2.728	-.750	19.085
		-.625	3.600	3.558	-.500	22.643
		-.375	3.800	3.756	-.250	26.398
		-.125	2.530	2.500	.000	28.899
		.125	3.570	3.528	.250	32.427
		.375	3.780	3.736	.500	36.163
		.625	2.780	2.748	.750	38.911
		.875	3.070	3.034	1.000	41.945
		1.125	2.800	2.767	1.250	44.712
		1.375	2.650	2.619	1.500	47.331
		1.625	2.850	2.817	1.750	50.148
		1.875	1.900	1.878	2.000	52.026
		2.125	5.770	5.703	2.250	57.729
		2.375	12.110	11.969	2.500	69.698
		2.625	13.580	13.422	2.750	83.119
		2.875	11.350	11.218	3.000	94.337
		3.125	3.860	3.815	3.250	98.152
		3.375	.970	.959	3.500	99.110
		3.625	.620	.613	3.750	99.723
		3.875	.280	.277	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.180

PERCENT FINER THAN 4.00 PHI = .51 PERCENT COARSER THAN -1.00 PHI = .00

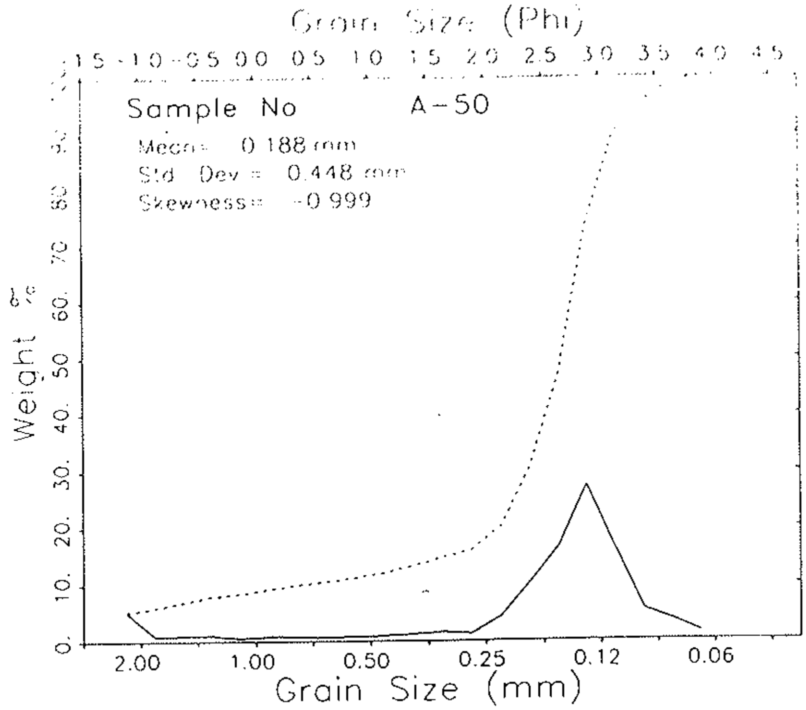
MOMENT MEASURES:

MEAN = 1.228 STANDARD DEVIATION = 1.547 SKEWNESS = -.178 KURTOSIS = -1.430
DISPERSION = .568 STANDARD DEVIATION = .894 DEVIATION FROM NORMAL DISTR. = -42.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.174	-1.005	-.343	1.737	2.599	2.770	3.043	3.471

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.882	1.167	MEDIUM SAND
STANDARD DEVIATION	1.888	1.583	POORLY SORTED
SKEWNESS(1)	-.453	-.417	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.425		
KURTOSIS	.117	.587	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-50	111199						
Borrow A - A50							
		-1.125	5.190		5.088	-1.000	5.088
		-.875	.780		.765	-.750	5.853
		-.625	1.010		.990	-.500	6.843
		-.375	1.010		.990	-.250	7.833
		-.125	.490		.480	.000	8.314
		.125	.840		.824	.250	9.137
		.375	.730		.716	.500	9.853
		.625	.620		.608	.750	10.461
		.875	.700		.686	1.000	11.147
		1.125	.900		.882	1.250	12.029
		1.375	1.190		1.167	1.500	13.196
		1.625	1.530		1.500	1.750	14.696
		1.875	1.240		1.216	2.000	15.912
		2.125	4.220		4.137	2.250	20.049
		2.375	10.370		10.167	2.500	30.216
		2.625	16.650		16.324	2.750	46.539
		2.875	27.840		27.294	3.000	73.833
		3.125	16.420		16.098	3.250	89.931
		3.375	5.380		5.275	3.500	95.206
		3.625	3.530		3.461	3.750	98.667
		3.875	1.360		1.333	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.000

PERCENT FINER THAN 4.00 PHI = 1.86 PERCENT COARSER THAN -1.00 PHI = .00

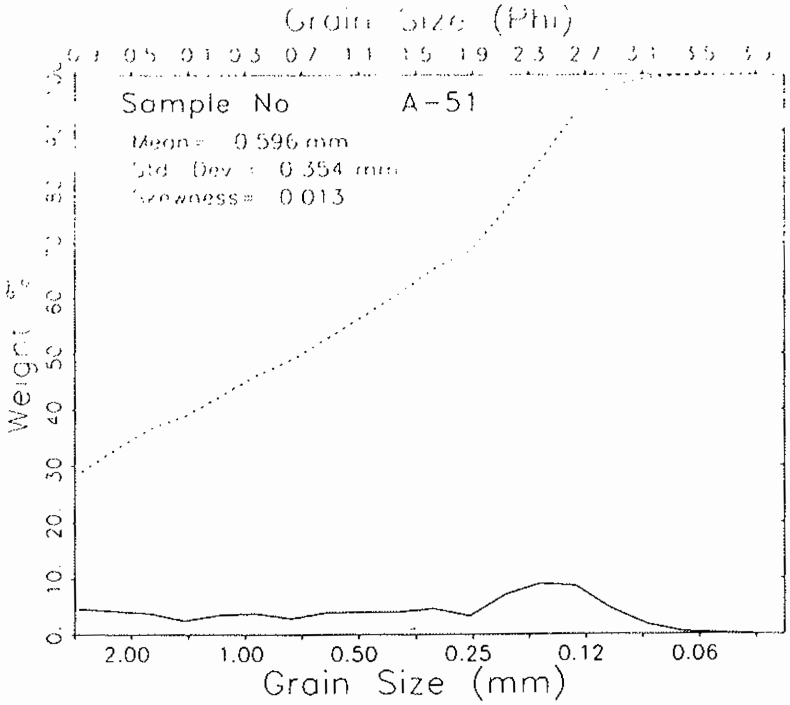
MOMENT MEASURES:

MEAN = 2.413 STANDARD DEVIATION = 1.160 SKEWNESS = -.999 KURTOSIS = 3.199
DISPERSION = .394 STANDARD DEVIATION = .600 DEVIATION FROM NORMAL DISTR. = -48.32%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.201	-1.004	2.005	2.372	2.782	3.018	3.158	3.490	3.812

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.582	2.648	FINE SAND
STANDARD DEVIATION	.576	.969	MODERATELY SORTED
SKEWNESS(1)	-.347	-.516	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-2.670		
KURTOSIS	2.900	2.850	VERY LEPTOKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-51 111199					
Bogue Banks - Borrow A					
	-1.125	24.400	24.002	-1.000	24.002
	-.875	4.660	4.584	-.750	28.585
	-.625	4.170	4.102	-.500	32.687
	-.375	3.820	3.758	-.250	36.445
	-.125	2.440	2.400	.000	38.845
	.125	3.560	3.502	.250	42.347
	.375	3.750	3.689	.500	46.036
	.625	2.880	2.833	.750	48.869
	.875	3.940	3.876	1.000	52.744
	1.125	4.050	3.984	1.250	56.728
	1.375	4.050	3.984	1.500	60.712
	1.625	4.670	4.594	1.750	65.306
	1.875	3.280	3.226	2.000	68.532
	2.125	7.100	6.984	2.250	75.516
	2.375	9.100	8.951	2.500	84.468
	2.625	8.760	8.617	2.750	93.085
	2.875	4.620	4.545	3.000	97.629
	3.125	1.760	1.731	3.250	99.361
	3.375	.370	.364	3.500	99.725
	3.625	.220	.216	3.750	99.941
	3.875	.060	.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.660

PERCENT FINER THAN 4.00 PHI = .10 PERCENT COARSER THAN -1.00 PHI = .00

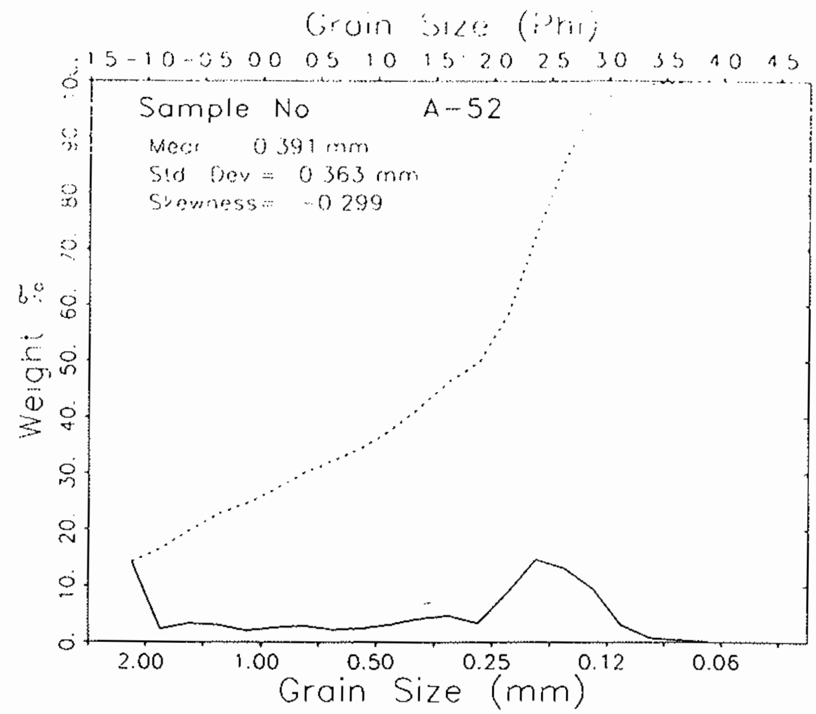
MOMENT MEASURES:

MEAN = .746 STANDARD DEVIATION = 1.499 SKEWNESS = .013 KURTOSIS = -1.538
DISPERSION = .555 STANDARD DEVIATION = .869 DEVIATION FROM NORMAL DISTR. = -42.05%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.198	-1.083	-.946	.823	2.232	2.487	2.855	3.198

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	.702	.742	COARSE SAND
STANDARD DEVIATION	1.785	1.507	POORLY SORTED
SKEWNESS(1)	-.068	-.033	NEAR SYMMETRICAL
SKEWNESS(2)	.003		
KURTOSIS	.135	.523	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-52	111199					
Borrow A - A52						
		-1.125	15.520	14.203	-1.000	14.203
		-.875	2.450	2.242	-.750	16.446
		-.625	3.530	3.231	-.500	19.676
		-.375	3.280	3.002	-.250	22.678
		-.125	2.150	1.968	.000	24.645
		.125	2.790	2.553	.250	27.199
		.375	3.060	2.800	.500	29.999
		.625	2.370	2.169	.750	32.168
		.875	2.570	2.352	1.000	34.520
		1.125	3.380	3.093	1.250	37.613
		1.375	4.460	4.082	1.500	41.695
		1.625	5.060	4.631	1.750	46.326
		1.875	3.620	3.313	2.000	49.639
		2.125	9.530	8.722	2.250	58.360
		2.375	15.980	14.624	2.500	72.984
		2.625	14.400	13.178	2.750	86.163
		2.875	10.410	9.527	3.000	95.690
		3.125	3.250	2.974	3.250	98.664
		3.375	.820	.750	3.500	99.414
		3.625	.450	.412	3.750	99.826
		3.875	.190	.174	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.270

PERCENT FINER THAN 4.00 PHI = .36 PERCENT COARSER THAN -1.00 PHI = .00

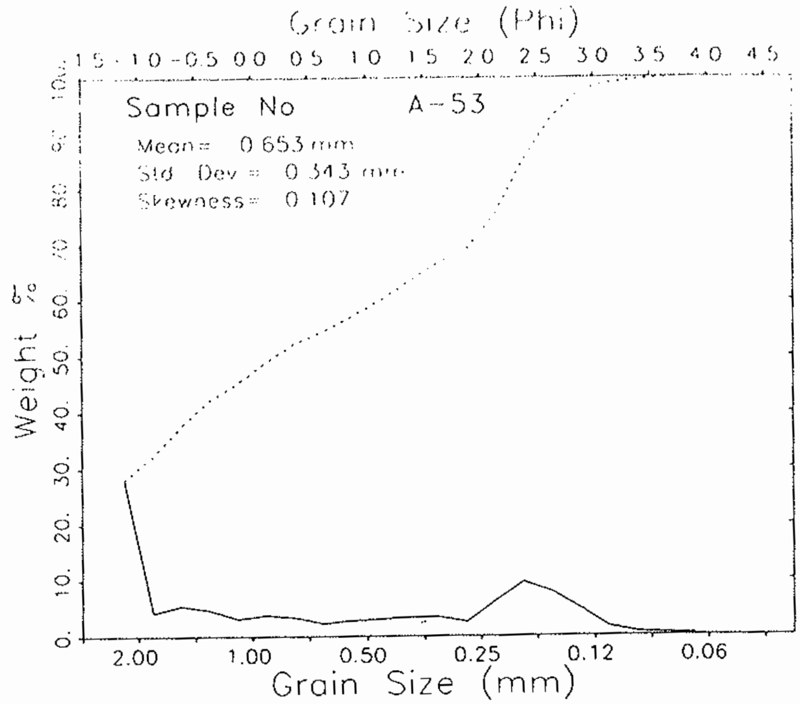
HOMENT MEASURES:

MEAN = 1.355 STANDARD DEVIATION = 1.461 SKEHNESS = -.299 KURTOSIS = -1.129
DISPERSION = .559 STANDARD DEVIATION = .877 DEVIATION FROM NORMAL DISTR. = -39.96%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.232	-1.162	-.800	.035	2.010	2.538	2.709	2.982	3.362

GRAPHIC PHI PARAMETER	INHAN (1952)	FOLK AND HARD (1957)	
MEAN	.955	1.307	MEDIUM SAND
STANDARD DEVIATION	1.754	1.505	POORLY SORTED
SKEHNESS(1)	-.602	-.566	STRONGLY COARSE-SKEWED
SKEHNESS(2)	-.627		
KURTOSIS	.181	.678	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-53	111199					
Borrow A - A53						
		-1.125	30.830	27.987	-1.000	27.987
		-.875	4.540	4.121	-.750	32.108
		-.625	5.910	5.365	-.500	37.473
		-.375	5.140	4.666	-.250	42.139
		-.125	3.370	3.059	.000	45.198
		.125	4.100	3.722	.250	48.920
		.375	3.660	3.322	.500	52.242
		.625	2.410	2.188	.750	54.430
		.875	2.960	2.687	1.000	57.117
		1.125	3.250	2.950	1.250	60.067
		1.375	3.630	3.295	1.500	63.362
		1.625	3.610	3.277	1.750	66.639
		1.875	2.680	2.433	2.000	69.072
		2.125	6.720	6.100	2.250	75.172
		2.375	10.510	9.541	2.500	84.713
		2.625	8.620	7.825	2.750	92.538
		2.875	5.250	4.766	3.000	97.304
		3.125	1.730	1.570	3.250	98.874
		3.375	.570	.517	3.500	99.392
		3.625	.400	.363	3.750	99.755
		3.875	.270	.245	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.160

PERCENT FINER THAN 4.00 PHI = .51 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

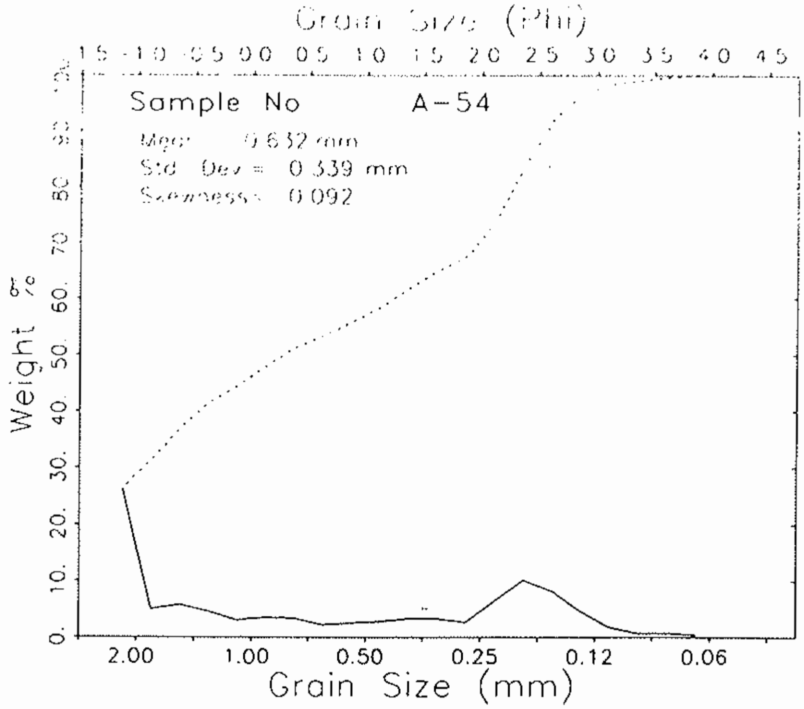
MEAN = .614 STANDARD DEVIATION = 1.545 SKEWNESS = .107 KURTOSIS = -1.540

DISPERSION = .526 STANDARD DEVIATION = .812 DEVIATION FROM NORMAL DISTR. = -47.47%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.205	-1.107	-1.027	.331	2.243	2.481	2.879	3.311

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.687	.569	COARSE SAND
STANDARD DEVIATION	1.794	1.516	POORLY SORTED
SKEWNESS(1)	.190	.223	FINE-SKEWED
SKEWNESS(2)	.282		
KURTOSIS	.138	.512	VERY PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-54 111199					
Borrow A - A54					
	-1.125	27.370	26.305	-1.000	26.305
	-.875	5.090	4.892	-.750	31.197
	-.625	5.940	5.709	-.500	36.905
	-.375	4.770	4.584	-.250	41.490
	-.125	3.090	2.970	.000	44.459
	.125	3.640	3.498	.250	47.958
	.375	3.410	3.277	.500	51.235
	.625	2.210	2.124	.750	53.359
	.875	2.540	2.441	1.000	55.800
	1.125	2.800	2.691	1.250	58.491
	1.375	3.390	3.258	1.500	61.749
	1.625	3.330	3.200	1.750	64.950
	1.875	2.700	2.595	2.000	67.544
	2.125	6.660	6.401	2.250	73.945
	2.375	10.440	10.034	2.500	83.979
	2.625	8.490	8.160	2.750	92.138
	2.875	4.710	4.527	3.000	96.665
	3.125	1.760	1.691	3.250	98.357
	3.375	.650	.625	3.500	98.981
	3.625	.640	.615	3.750	99.596
	3.875	.420	.404	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.050

PERCENT FINER THAN 4.00 PHI = .89 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

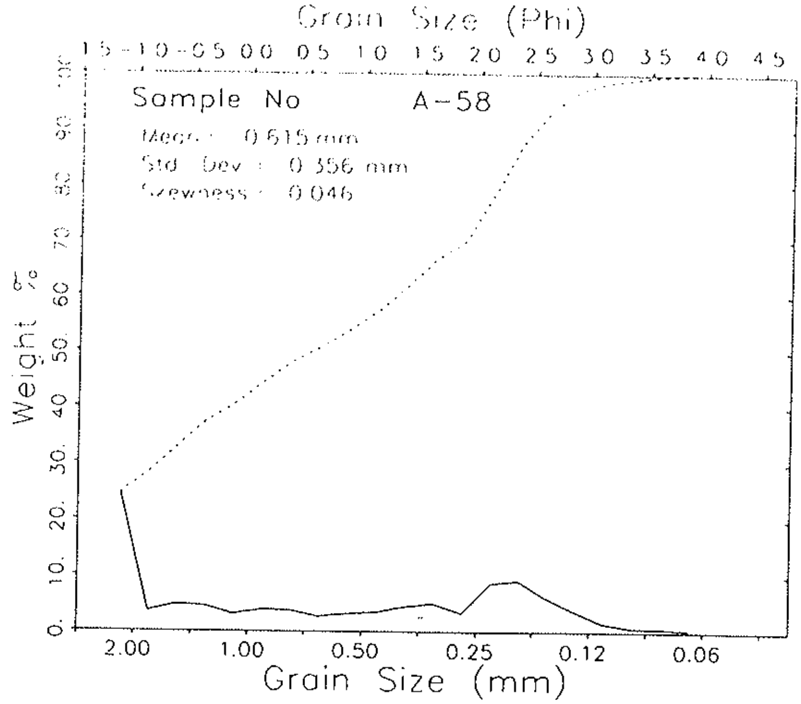
MEAN = .662 STANDARD DEVIATION = 1.560 SKEWNESS = .092 KURTOSIS = -1.549

DISPERSION = .540 STANDARD DEVIATION = .839 DEVIATION FROM NORMAL DISTR. = -46.25%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.202	-1.098	-1.012	.406	2.276	2.501	2.908	3.508

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.701	.603	COARSE SAND
STANDARD DEVIATION	1.799	1.522	POORLY SORTED
SKEWNESS(1)	.164	.191	FINE-SKEWED
SKEWNESS(2)	.248		
KURTOSIS	.142	.512	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-58 Borrow A - A58	111199					
		-1.125	26.050	24.655	-1.000	24.655
		-.875	3.770	3.568	-.750	28.223
		-.625	4.970	4.704	-.500	32.926
		-.375	4.760	4.505	-.250	37.431
		-.125	3.250	3.076	.000	40.507
		.125	4.010	3.795	.250	44.302
		.375	3.920	3.710	.500	48.012
		.625	2.820	2.669	.750	50.681
		.875	3.290	3.114	1.000	53.795
		1.125	3.610	3.417	1.250	57.212
		1.375	4.640	4.391	1.500	61.603
		1.625	5.210	4.931	1.750	66.534
		1.875	3.510	3.322	2.000	69.856
		2.125	9.070	8.584	2.250	78.440
		2.375	9.580	9.067	2.500	87.507
		2.625	6.280	5.944	2.750	93.451
		2.875	3.830	3.625	3.000	97.076
		3.125	1.540	1.458	3.250	98.533
		3.375	.690	.653	3.500	99.186
		3.625	.560	.530	3.750	99.716
		3.875	.300	.284	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.660

PERCENT FINER THAN 4.00 PHI = .70 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

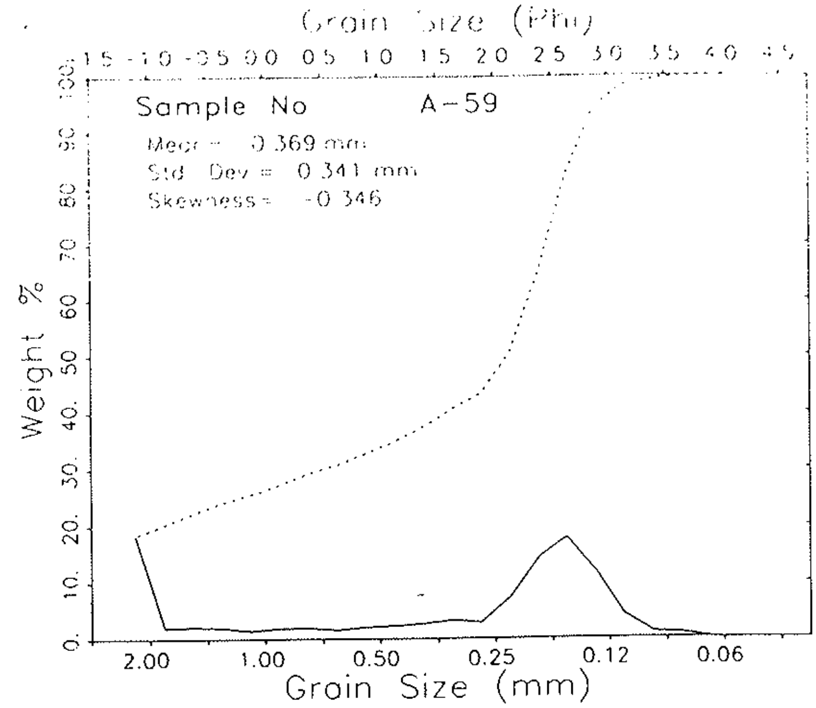
MEAN = .701 STANDARD DEVIATION = 1.491 SKEWNESS = .046 KURTOSIS = -1.484

DISPERSION = .560 STANDARD DEVIATION = .878 DEVIATION FROM NORMAL DISTR. = -41.12%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.199	-1.088	-.976	.686	2.150	2.403	2.857	3.429

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.658	.667	COARSE SAND
STANDARD DEVIATION	1.746	1.487	POORLY SORTED
SKEWNESS(1)	-.016	.027	NEAR SYMMETRICAL
SKEWNESS(2)	.082		
KURTOSIS	.162	.532	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-59	111199					
Borrow A - A59						
		-1.125	20.330	18.291	-1.000	18.291
		-.875	2.130	1.916	-.750	20.207
		-.625	2.290	2.060	-.500	22.267
		-.375	2.130	1.916	-.250	24.184
		-.125	1.510	1.359	.000	25.542
		.125	2.000	1.799	.250	27.341
		.375	2.110	1.898	.500	29.240
		.625	1.650	1.484	.750	30.724
		.875	2.170	1.952	1.000	32.677
		1.125	2.360	2.123	1.250	34.800
		1.375	2.880	2.591	1.500	37.391
		1.625	3.470	3.122	1.750	40.513
		1.875	3.010	2.708	2.000	43.221
		2.125	7.930	7.135	2.250	50.355
		2.375	15.780	14.197	2.500	64.552
		2.625	19.680	17.706	2.750	82.258
		2.875	13.210	11.885	3.000	94.143
		3.125	4.520	4.067	3.250	98.210
		3.375	1.100	.990	3.500	99.199
		3.625	.800	.720	3.750	99.919
		3.875	.090	.081	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.150

PERCENT FINER THAN 4.00 PHI = .44 PERCENT COARSER THAN -1.00 PHI = .00

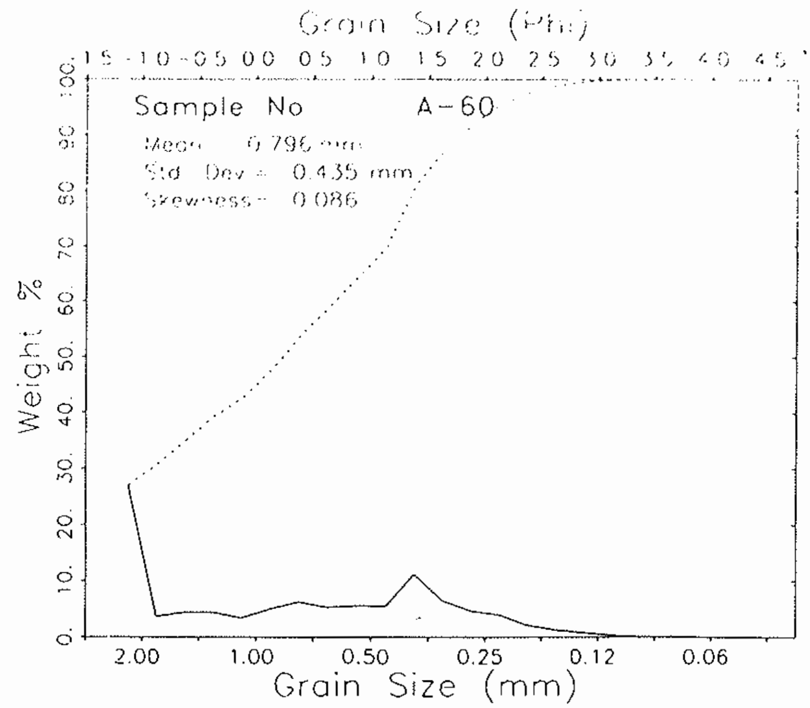
MOMENT MEASURES:

MEAN = 1.437 STANDARD DEVIATION = 1.552 SKEWNESS = -.346 KURTOSIS = -1.136
DISPERSION = .489 STANDARD DEVIATION = .746 DEVIATION FROM NORMAL DISTR. = -51.94%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.236	-1.182	-1.031	-.100	2.238	2.648	2.787	3.053	3.450

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.878	1.331	MEDIUM SAND
STANDARD DEVIATION	1.909	1.596	POORLY SORTED
SKEWNESS(1)	-.712	-.664	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.682		
KURTOSIS	.109	.632	VERY PLATYKURTIC



SAMPLE NO. DATE

A-60 111199

Borrow A - A60

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	32.260	26.946	-1.000	26.946
-.875	4.260	3.558	-.750	30.505
-.625	5.130	4.285	-.500	34.790
-.375	5.190	4.335	-.250	39.125
-.125	4.000	3.341	.000	42.466
.125	5.880	4.911	.250	47.377
.375	7.320	6.114	.500	53.491
.625	6.270	5.237	.750	58.729
.875	6.550	5.471	1.000	64.200
1.125	6.490	5.421	1.250	69.621
1.375	13.300	11.109	1.500	80.730
1.625	7.670	6.407	1.750	87.137
1.875	5.420	4.527	2.000	91.664
2.125	4.620	3.859	2.250	95.523
2.375	2.490	2.080	2.500	97.603
2.625	1.480	1.236	2.750	98.839
2.875	.900	.752	3.000	99.591
3.125	.350	.292	3.250	99.883
3.375	.080	.067	3.500	99.950
3.625	.060	.050	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 119.720

PERCENT FINER THAN 4.00 PHI = .03 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

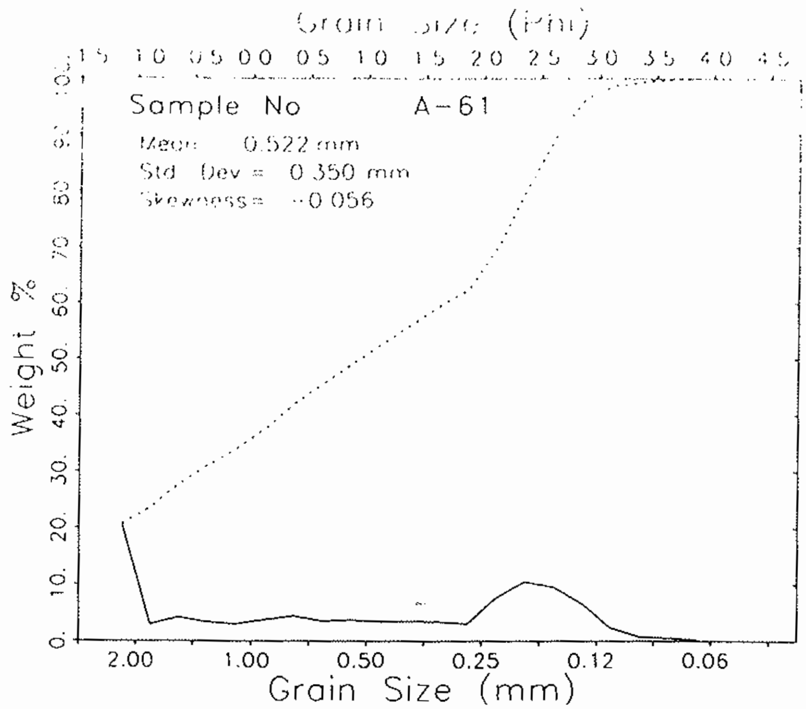
MEAN = .330 STANDARD DEVIATION = 1.201 SKEWNESS = .086 KURTOSIS = -1.250

DISPERSION = .497 STANDARD DEVIATION = .760 DEVIATION FROM NORMAL DISTR. = -36.78%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.204	-1.102	-1.018	.357	1.371	1.628	2.216	2.604

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.263	.294	COARSE SAND
STANDARD DEVIATION	1.365	1.200	POORLY SORTED
SKEWNESS(1)	-.069	.009	NEAR SYMMETRICAL
SKEWNESS(2)	.109		
KURTOSIS	.253	.587	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
A-61	111199					
Bogue Banks - Borrow A						
		-1.125	23.790	20.635	-1.000	20.635
		-.875	3.330	2.888	-.750	23.523
		-.625	4.730	4.103	-.500	27.626
		-.375	3.820	3.313	-.250	30.939
		-.125	3.400	2.949	.000	33.888
		.125	4.270	3.704	.250	37.592
		.375	5.100	4.424	.500	42.016
		.625	4.020	3.487	.750	45.503
		.875	4.160	3.608	1.000	49.111
		1.125	3.910	3.391	1.250	52.502
		1.375	3.980	3.452	1.500	55.955
		1.625	3.930	3.409	1.750	59.363
		1.875	3.470	3.010	2.000	62.373
		2.125	8.710	7.555	2.250	69.928
		2.375	11.960	10.374	2.500	80.302
		2.625	10.910	9.463	2.750	89.765
		2.875	7.580	6.575	3.000	96.340
		3.125	2.650	2.299	3.250	98.638
		3.375	.840	.729	3.500	99.367
		3.625	.510	.442	3.750	99.809
		3.875	.220	.191	4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.290

PERCENT FINER THAN 4.00 PHI = .71 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

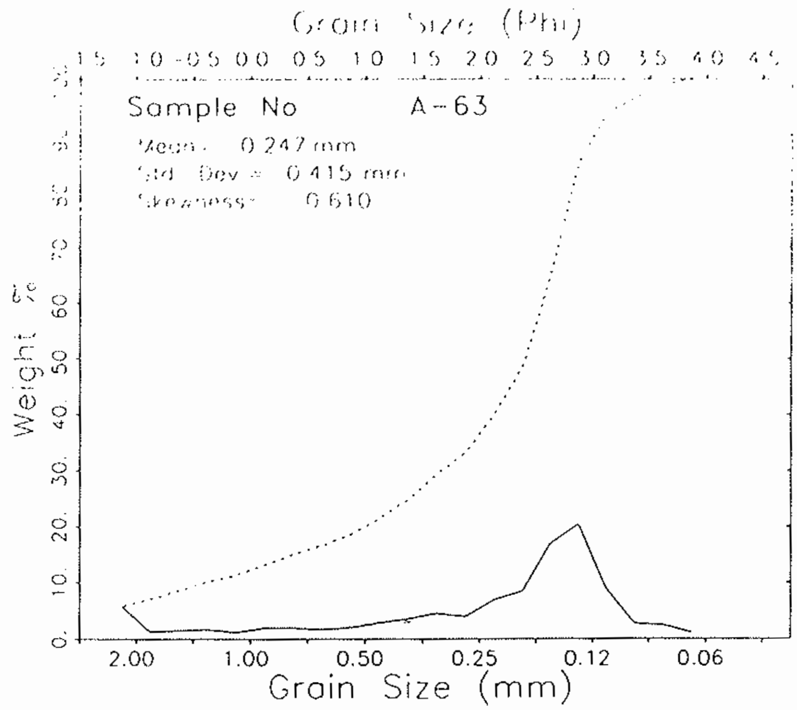
MEAN = .937 STANDARD DEVIATION = 1.515 SKEWNESS = -.056 KURTOSIS = -1.495

DISPERSION = .577 STANDARD DEVIATION = .914 DEVIATION FROM NORMAL DISTR. = -39.67%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.238	-1.189	-1.056	-.660	1.066	2.372	2.598	2.949	3.374

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.771	.869	COARSE SAND
STANDARD DEVIATION	1.827	1.541	POORLY SORTED
SKEWNESS(1)	-.161	-.126	COARSE-SKEWED
SKEWNESS(2)	-.102		
KURTOSIS	.133	.559	VERY PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-63 111199						
Borrow A - A63						
	-1.125	5.920		5.713	-1.000	5.713
	-.875	1.280		1.235	-.750	6.948
	-.625	1.540		1.486	-.500	8.434
	-.375	1.710		1.650	-.250	10.084
	-.125	1.190		1.148	.000	11.232
	.125	1.920		1.853	.250	13.085
	.375	1.920		1.853	.500	14.938
	.625	1.660		1.602	.750	16.540
	.875	2.070		1.997	1.000	18.537
	1.125	2.880		2.779	1.250	21.316
	1.375	3.560		3.435	1.500	24.752
	1.625	4.630		4.468	1.750	29.219
	1.875	4.040		3.898	2.000	33.118
	2.125	7.090		6.842	2.250	39.959
	2.375	8.610		8.308	2.500	48.268
	2.625	17.380		16.771	2.750	65.039
	2.875	20.960		20.226	3.000	85.265
	3.125	9.030		8.714	3.250	93.979
	3.375	2.690		2.596	3.500	96.574
	3.625	2.470		2.383	3.750	98.958
	3.875	1.080		1.042	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.630

PERCENT FINER THAN 4.00 PHI = 1.50 PERCENT COARSER THAN -1.00 PHI = .00

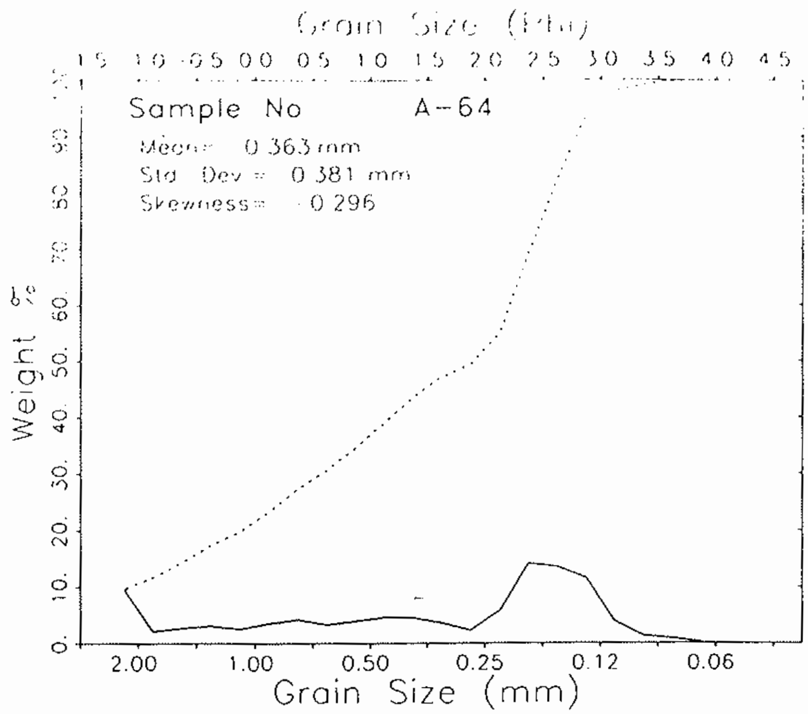
MOMENT MEASURES:

MEAN = 2.020 STANDARD DEVIATION = 1.269 SKEWNESS = -.610 KURTOSIS = .508
DISPERSION = .540 STANDARD DEVIATION = .839 DEVIATION FROM NORMAL DISTR. = -33.91%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.206	-1.031	.666	1.514	2.526	2.873	2.984	3.348	3.760

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.825	2.059	FINE SAND
STANDARD DEVIATION	1.159	1.243	POORLY SORTED
SKEWNESS(1)	-.604	-.614	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.179		
KURTOSIS	.889	1.321	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-64	111199						
Borrow A - A64							
		-1.125	9.970	9.608	-1.000	9.608	
		-.875	2.120	2.043	-.750	11.651	
		-.625	2.760	2.660	-.500	14.310	
		-.375	3.160	3.045	-.250	17.356	
		-.125	2.580	2.486	.000	19.842	
		.125	3.590	3.460	.250	23.302	
		.375	4.280	4.125	.500	27.426	
		.625	3.310	3.190	.750	30.616	
		.875	4.070	3.922	1.000	34.538	
		1.125	4.720	4.549	1.250	39.086	
		1.375	4.610	4.443	1.500	43.529	
		1.625	3.710	3.575	1.750	47.104	
		1.875	2.280	2.197	2.000	49.301	
		2.125	5.920	5.705	2.250	55.006	
		2.375	14.600	14.070	2.500	69.076	
		2.625	13.970	13.462	2.750	82.538	
		2.875	12.000	11.564	3.000	94.102	
		3.125	3.940	3.797	3.250	97.899	
		3.375	1.240	1.195	3.500	99.094	
		3.625	.820	.790	3.750	99.884	
		3.875	.120	.116	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 103.770

PERCENT FINER THAN 4.00 PHI = 1.28 PERCENT COARSER THAN -1.00 PHI = .00

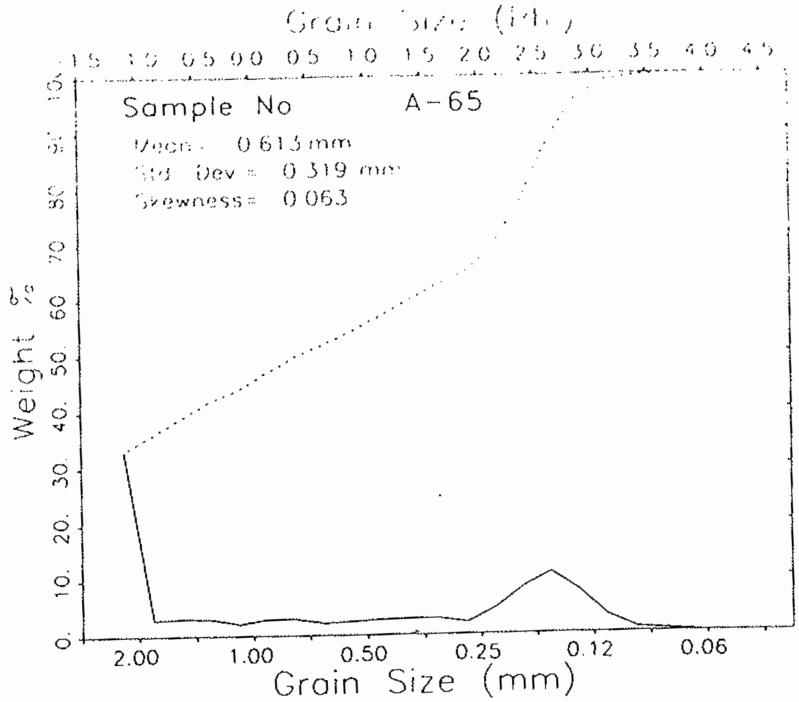
MOMENT MEASURES:

MEAN = 1.462 STANDARD DEVIATION = 1.393 SKEWNESS = -.296 KURTOSIS = -.984
DISPERSION = .591 STANDARD DEVIATION = .944 DEVIATION FROM NORMAL DISTR. = -32.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.120	-.361	.353	2.031	2.610	2.782	3.059	3.480

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.210	1.484	MEDIUM SAND
STANDARD DEVIATION	1.571	1.419	POORLY SORTED
SKEWNESS(1)	-.522	-.515	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.675		
KURTOSIS	.330	.759	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-65	111199					
Borrow A - A65						
		-1.125	35.900	33.030	-1.000	33.030
		-.875	3.070	2.825	-.750	35.854
		-.625	3.330	3.064	-.500	38.918
		-.375	3.200	2.944	-.250	41.862
		-.125	2.220	2.043	.000	43.905
		.125	3.150	2.898	.250	46.803
		.375	3.150	2.898	.500	49.701
		.625	2.340	2.153	.750	51.854
		.875	2.550	2.346	1.000	54.200
		1.125	2.850	2.622	1.250	56.822
		1.375	3.020	2.779	1.500	59.601
		1.625	3.020	2.779	1.750	62.379
		1.875	2.260	2.079	2.000	64.459
		2.125	5.050	4.646	2.250	69.105
		2.375	8.990	8.271	2.500	77.376
		2.625	11.750	10.811	2.750	88.187
		2.875	8.170	7.517	3.000	95.703
		3.125	3.230	2.972	3.250	98.675
		3.375	.790	.727	3.500	99.402
		3.625	.460	.423	3.750	99.825
		3.875	.190	.175	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.690

PERCENT FINER THAN 4.00 PHI = .30   PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

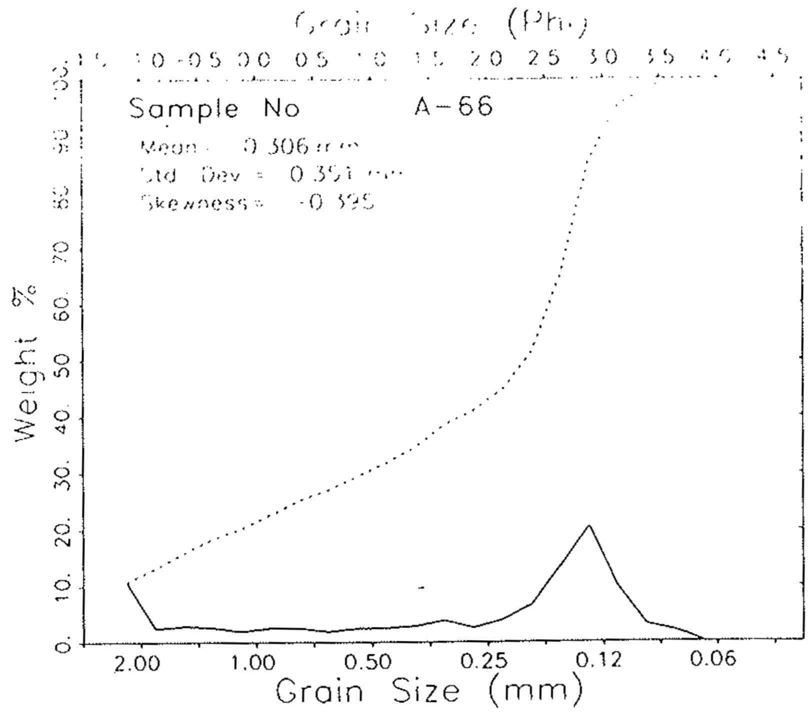
MEAN = .706   STANDARD DEVIATION = 1.649   SKEWNESS = .063   KURTOSIS = -1.656

DISPERSION = .469   STANDARD DEVIATION = .712   DEVIATION FROM NORMAL DISTR. = -56.79%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.212	-1.129	-1.061	.535	2.428	2.653	2.977	3.362

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.762	.686	COARSE SAND
STANDARD DEVIATION	1.891	1.580	POORLY SORTED
SKEWNESS(1)	.120	.143	FINE-SKEWED
SKEWNESS(2)	.104		
KURTOSIS	.108	.492	VERY PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-66 111199					
Borrow A - ATHB14					
	-1.125	11.040	10.673	-1.000	10.673
	-.875	2.490	2.407	-.750	13.080
	-.625	2.890	2.794	-.500	15.874
	-.375	2.610	2.523	-.250	18.397
	-.125	1.940	1.875	.000	20.273
	.125	2.520	2.436	.250	22.709
	.375	2.550	2.465	.500	25.174
	.625	1.880	1.817	.750	26.991
	.875	2.480	2.398	1.000	29.389
	1.125	2.520	2.436	1.250	31.825
	1.375	2.880	2.784	1.500	34.609
	1.625	3.970	3.838	1.750	38.447
	1.875	2.520	2.436	2.000	40.884
	2.125	3.990	3.857	2.250	44.741
	2.375	6.770	6.545	2.500	51.286
	2.625	13.880	13.418	2.750	64.704
	2.875	21.270	20.563	3.000	85.267
	3.125	10.070	9.735	3.250	95.002
	3.375	3.140	3.036	3.500	98.038
	3.625	2.000	1.933	3.750	99.971
	3.875	.030	.029	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.440

PERCENT FINER THAN 4.00 PHI = 1.24 PERCENT COARSER THAN -1.00 PHI = .00

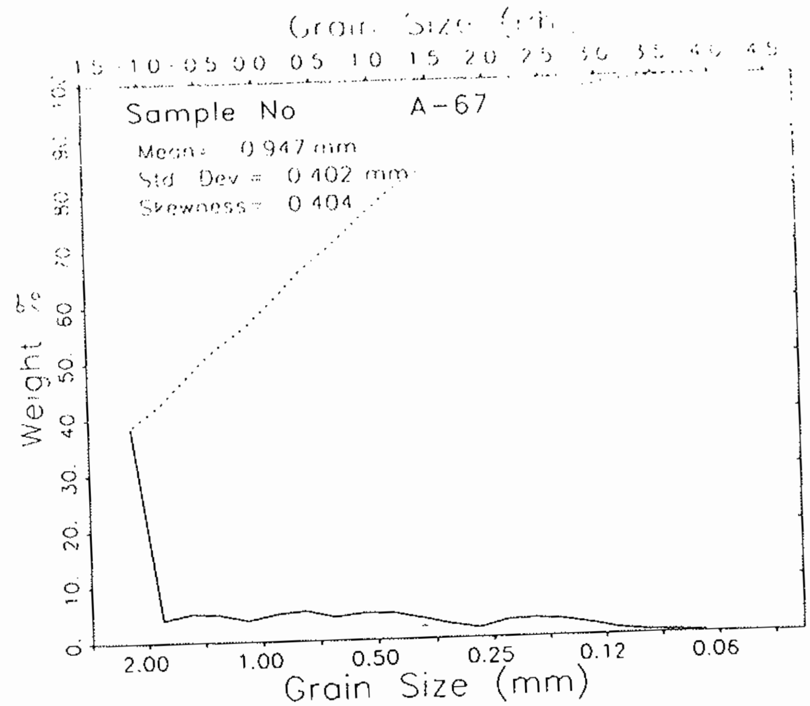
MOMENT MEASURES:

MEAN = 1.707 STANDARD DEVIATION = 1.509 SKEWNESS = -.395 KURTOSIS = -.860
DISPERSION = .551 STANDARD DEVIATION = .861 DEVIATION FROM NORMAL DISTR. = -42.92%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.133	-.488	.482	2.451	2.875	2.985	3.250	3.624

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.249	1.649	MEDIUM SAND
STANDARD DEVIATION	1.736	1.532	POORLY SORTED
SKEWNESS(1)	-.693	-.664	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.802		
KURTOSIS	.262	.751	PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-67 111199					
Borrow A - A67					
	-1.125	41.550	38.316	-1.000	38.316
	-.875	4.280	3.947	-.750	42.263
	-.625	5.510	5.081	-.500	47.344
	-.375	5.210	4.805	-.250	52.149
	-.125	4.000	3.689	.000	55.837
	.125	5.210	4.805	.250	60.642
	.375	5.760	5.312	.500	65.954
	.625	4.520	4.168	.750	70.122
	.875	5.130	4.731	1.000	74.852
	1.125	5.040	4.648	1.250	79.500
	1.375	3.930	3.624	1.500	83.124
	1.625	2.650	2.444	1.750	85.568
	1.875	1.780	1.641	2.000	87.210
	2.125	3.200	2.951	2.250	90.160
	2.375	3.410	3.145	2.500	93.305
	2.625	3.020	2.785	2.750	96.090
	2.875	2.160	1.992	3.000	98.082
	3.125	1.010	.931	3.250	99.013
	3.375	.480	.443	3.500	99.456
	3.625	.400	.369	3.750	99.825
	3.875	.190	.175	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.440

PERCENT FINER THAN 4.00 PHI = .18 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

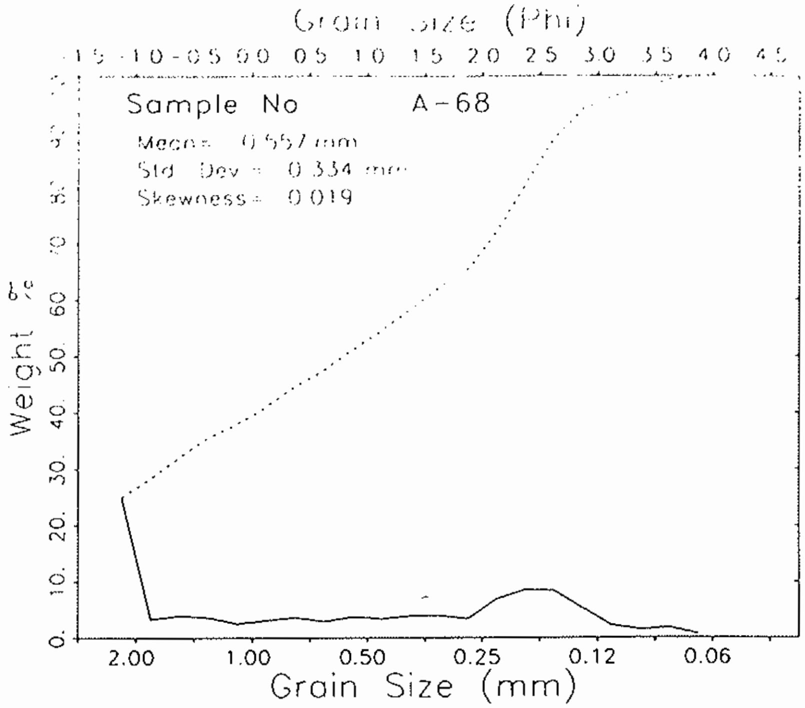
MEAN = .078 STANDARD DEVIATION = 1.315 SKEWNESS = .404 KURTOSIS = -.527

DISPERSION = .442 STANDARD DEVIATION = .669 DEVIATION FROM NORMAL DISTR. = -49.12%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.243	-1.217	-1.146	-1.087	-.362	1.008	1.590	2.652	3.246

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.222	.027	COARSE SAND
STANDARD DEVIATION	1.368	1.270	POORLY SORTED
SKEWNESS(1)	.427	.492	STRONGLY FINE-SKEWED
SKEWNESS(2)	.789		
KURTOSIS	.415	.757	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT (PHI)	CLASS LIMITS	CUM PERCENT
A-68	111199						
Borrow A - A68							
		-1.125	25.940	24.930	-1.000	24.930	
		-.875	3.370	3.239	-.750	28.169	
		-.625	4.010	3.854	-.500	32.023	
		-.375	3.700	3.556	-.250	35.579	
		-.125	2.550	2.451	.000	38.030	
		.125	3.160	3.037	.250	41.067	
		.375	3.700	3.556	.500	44.623	
		.625	2.960	2.845	.750	47.468	
		.875	3.800	3.652	1.000	51.120	
		1.125	3.440	3.306	1.250	54.426	
		1.375	3.940	3.787	1.500	58.212	
		1.625	4.040	3.883	1.750	62.095	
		1.875	3.410	3.277	2.000	65.372	
		2.125	7.070	6.795	2.250	72.167	
		2.375	8.830	8.486	2.500	80.654	
		2.625	8.610	8.275	2.750	88.928	
		2.875	5.350	5.142	3.000	94.070	
		3.125	2.210	2.124	3.250	96.194	
		3.375	1.450	1.394	3.500	97.588	
		3.625	1.820	1.749	3.750	99.337	
		3.875	.690	.663	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 104.050

PERCENT FINER THAN 4.00 PHI = 1.18 PERCENT COARSER THAN -1.00 PHI = .00

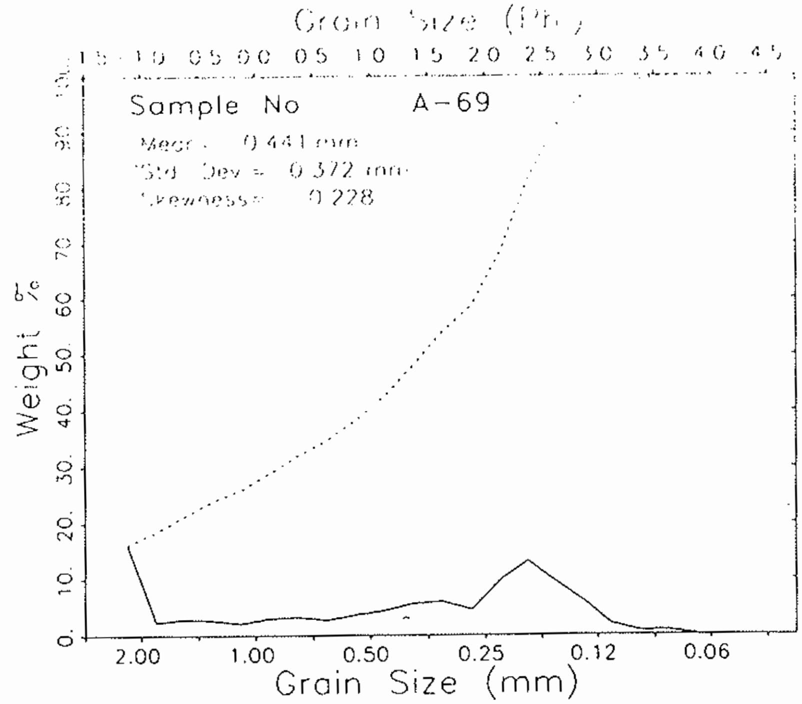
MOMENT MEASURES:

MEAN = .845 STANDARD DEVIATION = 1.581 SKEWNESS = .019 KURTOSIS = -1.481
DISPERSION = .575 STANDARD DEVIATION = .910 DEVIATION FROM NORMAL DISTR. = -42.46%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.200	-1.090	-.995	.923	2.333	2.601	3.109	3.702

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.756	.812	COARSE SAND
STANDARD DEVIATION	1.845	1.576	POORLY SORTED
SKEWNESS(1)	-.091	-.038	NEAR SYMMETRICAL
SKEWNESS(2)	.017		
KURTOSIS	.168	.531	VERY PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A-69 111199					
Borrow A - A69					
	-1.125	18.280	16.150	-1.000	16.150
	-.875	2.570	2.271	-.750	18.420
	-.625	3.200	2.827	-.500	21.247
	-.375	2.950	2.606	-.250	23.854
	-.125	2.350	2.076	.000	25.930
	.125	3.400	3.004	.250	28.934
	.375	3.510	3.101	.500	32.035
	.625	3.020	2.668	.750	34.703
	.875	3.980	3.516	1.000	38.219
	1.125	4.900	4.329	1.250	42.548
	1.375	6.280	5.548	1.500	48.096
	1.625	6.690	5.910	1.750	54.007
	1.875	5.060	4.470	2.000	58.477
	2.125	10.890	9.621	2.250	68.098
	2.375	14.920	13.181	2.500	81.279
	2.625	10.620	9.382	2.750	90.662
	2.875	6.780	5.990	3.000	96.652
	3.125	2.180	1.926	3.250	98.578
	3.375	.730	.645	3.500	99.223
	3.625	.800	.707	3.750	99.929
	3.875	.080	.071	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.190

PERCENT FINER THAN 4.00 PHI = 1.04　　PERCENT COARSER THAN -1.00 PHI = .00

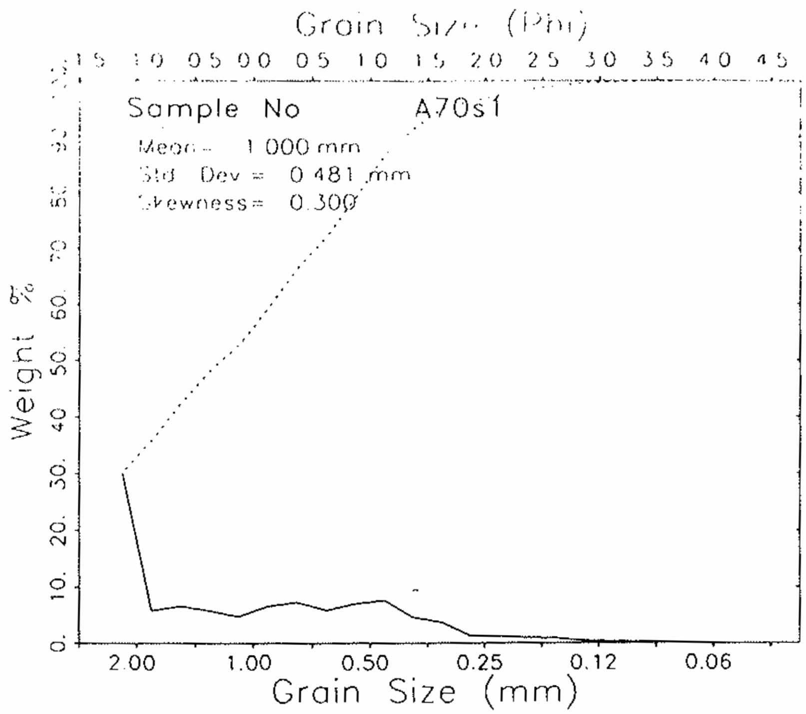
MOMENT MEASURES:

MEAN = 1.182　STANDARD DEVIATION = 1.428　SKEWNESS = -.228　KURTOSIS = -1.190
DISPERSION = .578　STANDARD DEVIATION = .917　DEVIATION FROM NORMAL DISTR. = -35.79%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.235	-1.173	-1.002	-.112	1.581	2.381	2.572	2.931	3.414

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.785	1.050	MEDIUM SAND
STANDARD DEVIATION	1.787	1.515	POORLY SORTED
SKEWNESS(1)	-.445	-.393	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.392		
KURTOSIS	.148	.675	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A70s1	111199					
Bogue Banks - Borrow A						
		-1.125	30.670	30.101	-1.000	30.101
		-.875	5.790	5.683	-.750	35.784
		-.625	6.660	6.536	-.500	42.320
		-.375	5.850	5.741	-.250	48.062
		-.125	4.820	4.731	.000	52.792
		.125	6.680	6.556	.250	59.348
		.375	7.320	7.184	.500	66.533
		.625	5.910	5.800	.750	72.333
		.875	7.090	6.958	1.000	79.291
		1.125	7.690	7.547	1.250	86.839
		1.375	4.660	4.574	1.500	91.412
		1.625	3.690	3.622	1.750	95.034
		1.875	1.230	1.207	2.000	96.241
		2.125	1.200	1.178	2.250	97.419
		2.375	.870	.854	2.500	98.273
		2.625	.850	.834	2.750	99.107
		2.875	.430	.422	3.000	99.529
		3.125	.190	.186	3.250	99.715
		3.375	.110	.108	3.500	99.823
		3.625	.120	.118	3.750	99.941
		3.875	.060	.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.890

PERCENT FINER THAN 4.00 PHI = .33 PERCENT COARSER THAN -1.00 PHI = .00

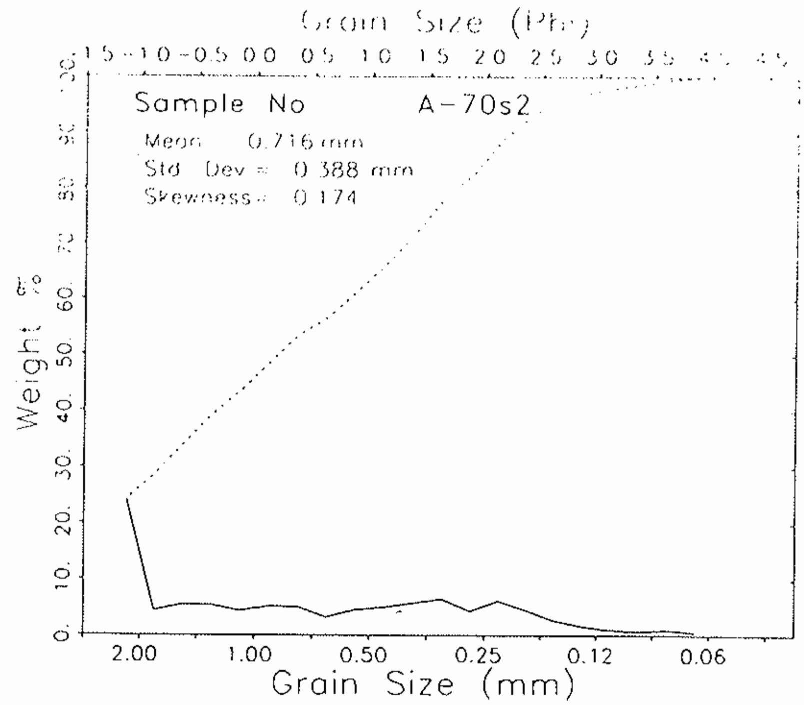
MOMENT MEASURES:

MEAN = .000 STANDARD DEVIATION = 1.056 SKEWNESS = .300 KURTOSIS = -.493
DISPERSION = .452 STANDARD DEVIATION = .685 DEVIATION FROM NORMAL DISTR. = -35.14%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.208	-1.117	-1.042	-.148	.846	1.156	1.748	2.718

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.019	-.036	VERY COARSE SAND
STANDARD DEVIATION	1.137	1.016	POORLY SORTED
SKEWNESS(1)	.147	.215	FINE-SKEWED
SKEWNESS(2)	.367		
KURTOSIS	.300	.642	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT (PHI)	CLASS LIMITS	CUM PERCENT
A-70s2	111199						
Bogue Banks - Borrow A							
		-1.125	11.030	24.242	-1.000	24.242	
		-.875	1.960	4.308	-.750	28.549	
		-.625	2.440	5.363	-.500	33.912	
		-.375	2.420	5.319	-.250	39.231	
		-.125	1.950	4.286	.000	43.516	
		.125	2.310	5.077	.250	48.593	
		.375	2.260	4.967	.500	53.560	
		.625	1.440	3.165	.750	56.725	
		.875	2.050	4.505	1.000	61.231	
		1.125	2.210	4.857	1.250	66.088	
		1.375	2.570	5.648	1.500	71.736	
		1.625	2.920	6.418	1.750	78.154	
		1.875	1.930	4.242	2.000	82.396	
		2.125	2.760	6.066	2.250	88.462	
		2.375	1.990	4.374	2.500	92.835	
		2.625	1.180	2.593	2.750	95.429	
		2.875	.720	1.582	3.000	97.011	
		3.125	.420	.923	3.250	97.934	
		3.375	.290	.637	3.500	98.571	
		3.625	.420	.923	3.750	99.495	
		3.875	.230	.505	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 45.500

PERCENT FINER THAN 4.00 PHI = 1.11 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

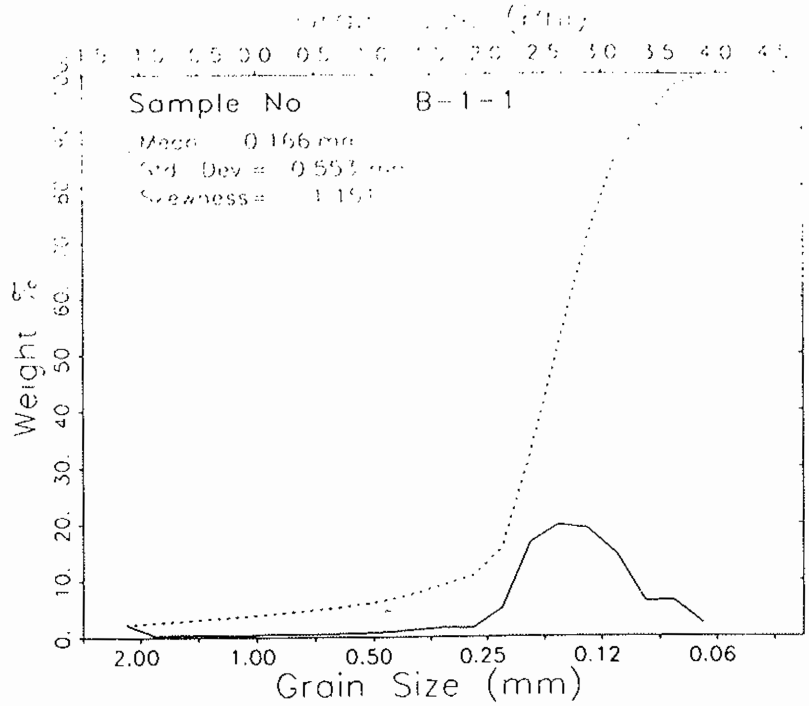
MEAN = .481 STANDARD DEVIATION = 1.367 SKEWNESS = .174 KURTOSIS = -1.073

DISPERSION = .574 STANDARD DEVIATION = .908 DEVIATION FROM NORMAL DISTR. = -33.60%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.198	-1.085	-.956	.321	1.627	2.066	2.709	3.616

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	.491	.434	COARSE SAND
STANDARD DEVIATION	1.576	1.300	POORLY SORTED
SKEWNESS(1)	.108	.165	FINE-SKEWED
SKEWNESS(2)	.276		
KURTOSIS	.240	.620	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-1-1	111199					
Borrow 81 - 01						
		-1.125	2.500	2.202	-1.000	2.202
		-.875	.370	.326	-.750	2.528
		-.625	.400	.352	-.500	2.880
		-.375	.420	.370	-.250	3.250
		-.125	.390	.344	.000	3.594
		.125	.500	.440	.250	4.034
		.375	.530	.467	.500	4.501
		.625	.560	.493	.750	4.994
		.875	.710	.625	1.000	5.620
		1.125	.950	.837	1.250	6.456
		1.375	1.370	1.207	1.500	7.663
		1.625	1.780	1.568	1.750	9.231
		1.875	1.660	1.462	2.000	10.693
		2.125	5.410	4.765	2.250	15.458
		2.375	18.820	16.577	2.500	32.036
		2.625	22.290	19.634	2.750	51.669
		2.875	21.670	19.087	3.000	70.757
		3.125	16.630	14.648	3.250	85.405
		3.375	6.990	6.157	3.500	91.562
		3.625	7.080	6.236	3.750	97.798
		3.875	2.500	2.202	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.530

PERCENT FINER THAN 4.00 PHI = 2.31 PERCENT COARSER THAN -1.00 PHI = .00

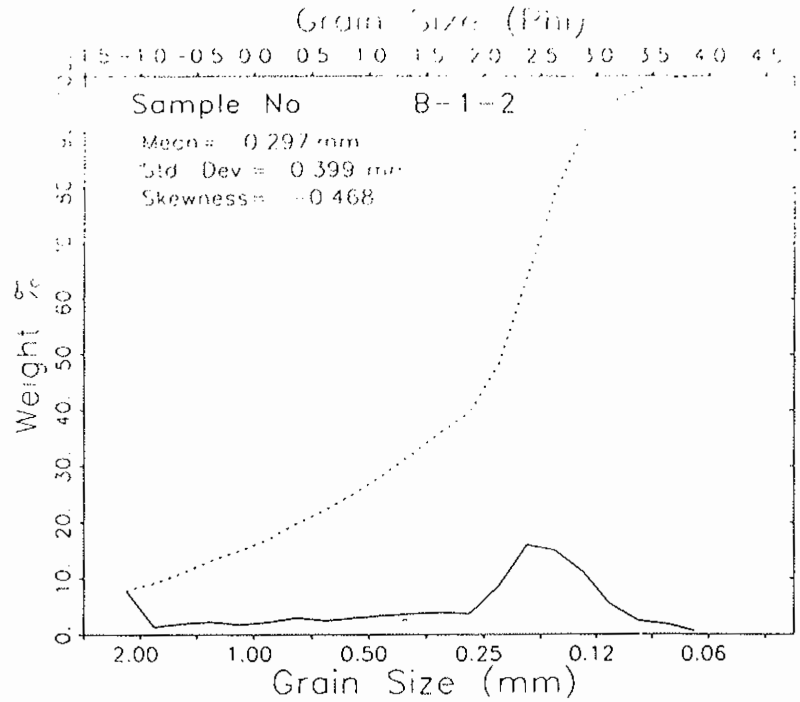
MOMENT MEASURES:

MEAN = 2.594 STANDARD DEVIATION = .894 SKEWNESS = -1.151 KURTOSIS = 6.706
DISPERSION = .388 STANDARD DEVIATION = .591 DEVIATION FROM NORMAL DISTR. = -33.92%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.136	.752	2.258	2.394	2.729	3.072	3.226	3.638	3.886

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.742	2.738	FINE SAND
STANDARD DEVIATION	.484	.679	MODERATELY WELL SORTED
SKEWNESS(1)	.028	-.171	COARSE-SKEWED
SKEWNESS(2)	-1.103		
KURTOSIS	1.981	1.743	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-1-2	111199						
Borrow 81 - 2							
		-1.125	8.010		7.762	-1.000	7.762
		-.875	1.330		1.289	-.750	9.051
		-.625	1.910		1.851	-.500	10.902
		-.375	2.270		2.200	-.250	13.102
		-.125	1.790		1.735	.000	14.837
		.125	2.200		2.132	.250	16.969
		.375	2.940		2.849	.500	19.818
		.625	2.460		2.384	.750	22.202
		.875	2.970		2.878	1.000	25.080
		1.125	3.430		3.324	1.250	28.404
		1.375	3.770		3.653	1.500	32.057
		1.625	4.030		3.905	1.750	35.963
		1.875	3.750		3.634	2.000	39.597
		2.125	8.670		8.402	2.250	47.999
		2.375	16.370		15.864	2.500	63.863
		2.625	15.410		14.934	2.750	78.796
		2.875	11.480		11.125	3.000	89.922
		3.125	5.500		5.330	3.250	95.251
		3.375	2.460		2.384	3.500	97.635
		3.625	1.880		1.822	3.750	99.457
		3.875	.560		.543	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.190

PERCENT FINER THAN 4.00 PHI = 1.30 PERCENT COARSER THAN -1.00 PHI = .00

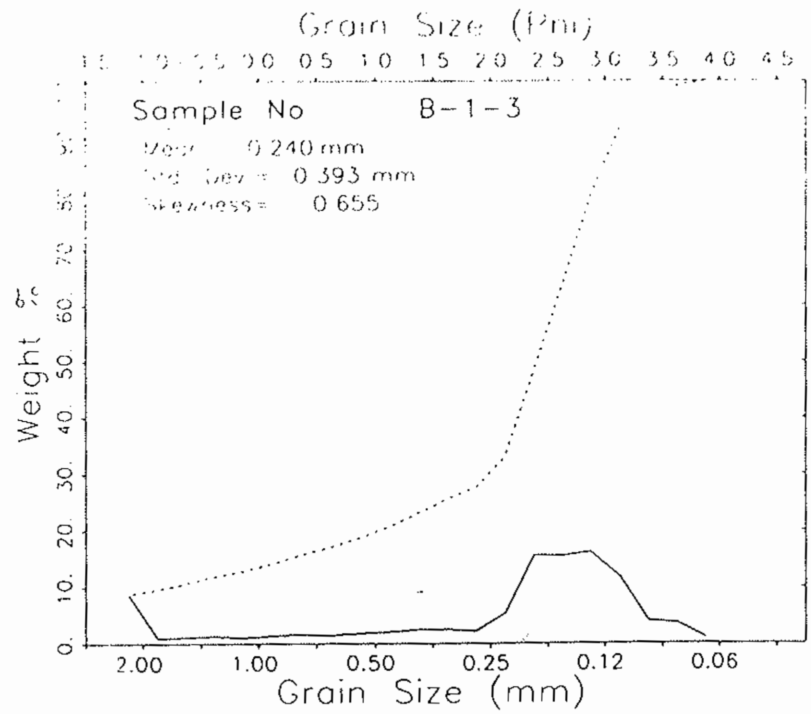
MOMENT MEASURES:

MEAN = 1.753 STANDARD DEVIATION = 1.326 SKEWNESS = -.468 KURTOSIS = -.252
DISPERSION = .576 STANDARD DEVIATION = .912 DEVIATION FROM NORMAL DISTR. = -31.19%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.089	.136	.993	2.282	2.686	2.867	3.238	3.687

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.502	1.762	MEDIUM SAND
STANDARD DEVIATION	1.365	1.338	POORLY SORTED
SKEWNESS(1)	-.571	-.565	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.804		
KURTOSIS	.585	1.047	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-1-3 Borrow B1 - 3	111199					
		-1.125	9.930	8.654	-1.000	8.654
		-.875	1.010	.880	-.750	9.535
		-.625	1.240	1.081	-.500	10.615
		-.375	1.400	1.220	-.250	11.835
		-.125	1.150	1.002	.000	12.838
		.125	1.480	1.290	.250	14.128
		.375	1.760	1.534	.500	15.661
		.625	1.560	1.360	.750	17.021
		.875	1.930	1.682	1.000	18.703
		1.125	2.270	1.978	1.250	20.682
		1.375	2.760	2.405	1.500	23.087
		1.625	2.760	2.405	1.750	25.492
		1.875	2.460	2.144	2.000	27.636
		2.125	6.010	5.238	2.250	32.874
		2.375	17.730	15.452	2.500	48.327
		2.625	17.670	15.400	2.750	63.727
		2.875	18.380	16.019	3.000	79.746
		3.125	13.580	11.835	3.250	91.581
		3.375	4.470	3.896	3.500	95.477
		3.625	4.120	3.591	3.750	99.067
		3.875	1.070	.933	4.000	100.000

TOTAL WEIGHT (GRAMS) = 114.740

PERCENT FINER THAN 4.00 PHI = .87 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

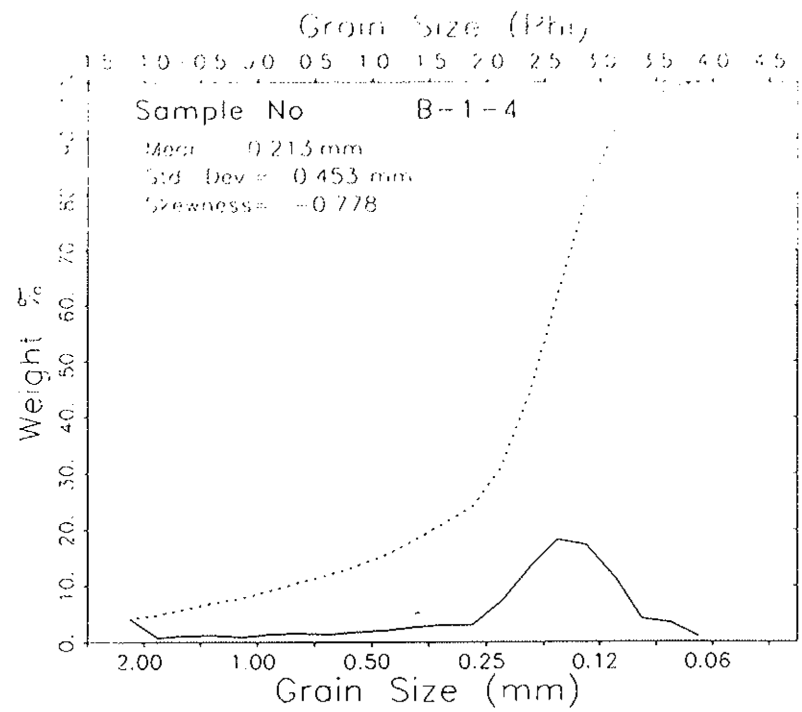
MEAN = 2.058 STANDARD DEVIATION = 1.349 SKEWNESS = -.655 KURTOSIS = .574

DISPERSION = .508 STANDARD DEVIATION = .779 DEVIATION FROM NORMAL DISTR. = -42.27%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.221	-1.106	.562	1.699	2.527	2.926	3.090	3.469	3.745

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.826	2.060	FINE SAND
STANDARD DEVIATION	1.264	1.325	POORLY SORTED
SKEWNESS(1)	-.555	-.571	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.064		
KURTOSIS	.810	1.528	VERY LEPTOKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-1-4 111199					
Borrow B1 - 4					
	-1.125	4.690	4.068	-1.000	4.068
	-.875	.810	.703	-.750	4.771
	-.625	1.210	1.050	-.500	5.821
	-.375	1.290	1.119	-.250	6.940
	-.125	.940	.815	.000	7.755
	.125	1.560	1.353	.250	9.108
	.375	1.690	1.466	.500	10.574
	.625	1.510	1.310	.750	11.884
	.875	1.950	1.692	1.000	13.576
	1.125	2.240	1.943	1.250	15.519
	1.375	2.920	2.533	1.500	18.052
	1.625	3.460	3.001	1.750	21.053
	1.875	3.420	2.967	2.000	24.020
	2.125	8.230	7.139	2.250	31.159
	2.375	15.210	13.194	2.500	44.353
	2.625	20.940	18.164	2.750	62.517
	2.875	19.840	17.210	3.000	79.728
	3.125	13.550	11.754	3.250	91.482
	3.375	4.720	4.094	3.500	95.576
	3.625	3.950	3.426	3.750	99.002
	3.875	1.150	.998	4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.280

PERCENT FINER THAN 4.00 PHI = 1.30 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

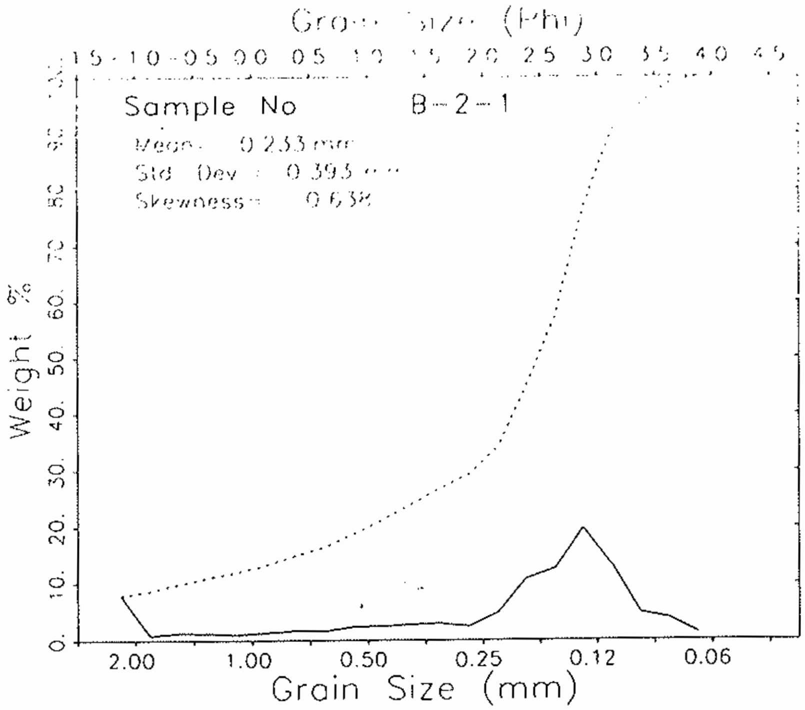
MEAN = 2.233 STANDARD DEVIATION = 1.144 SKEWNESS = -.778 KURTOSIS = 1.845

DISPERSION = .501 STANDARD DEVIATION = .767 DEVIATION FROM NORMAL DISTR. = -32.97%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.189	-.695	1.298	2.034	2.578	2.931	3.091	3.465	3.750

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.194	2.322	FINE SAND
STANDARD DEVIATION	.897	1.079	POORLY SORTED
SKEWNESS(1)	-.428	-.501	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.330		
KURTOSIS	1.320	1.901	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-1	111199					
Bogue Banks - Borrow B2						
		-1.125	7.920	7.827	-1.000	7.827
		-.875	.800	.791	-.750	8.617
		-.625	1.250	1.235	-.500	9.853
		-.375	1.190	1.176	-.250	11.029
		-.125	.980	.968	.000	11.997
		.125	1.320	1.304	.250	13.302
		.375	1.660	1.640	.500	14.942
		.625	1.530	1.512	.750	16.454
		.875	2.350	2.322	1.000	18.777
		1.125	2.410	2.382	1.250	21.158
		1.375	2.770	2.737	1.500	23.896
		1.625	2.940	2.905	1.750	26.801
		1.875	2.420	2.392	2.000	29.193
		2.125	4.810	4.753	2.250	33.946
		2.375	10.870	10.742	2.500	44.688
		2.625	12.650	12.501	2.750	57.189
		2.875	19.950	19.715	3.000	76.905
		3.125	13.490	13.331	3.250	90.236
		3.375	4.810	4.753	3.500	94.990
		3.625	3.810	3.765	3.750	98.755
		3.875	1.260	1.245	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.190

PERCENT FINER THAN 4.00 PHI = .07 PERCENT COARSER THAN -1.00 PHI = .00

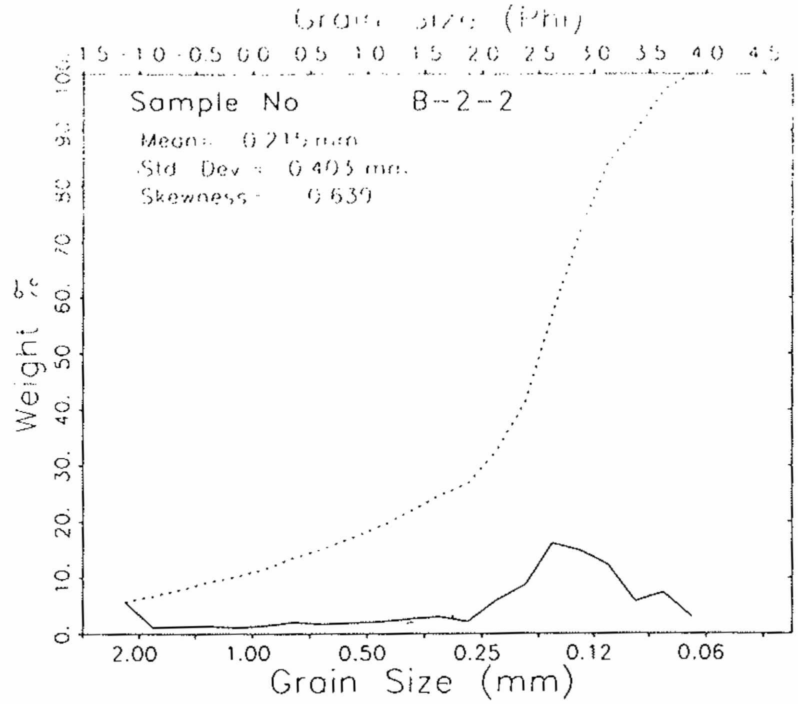
MOMENT MEASURES:

MEAN = 2.099 STANDARD DEVIATION = 1.347 SKEWNESS = -.638 KURTOSIS = .531
DISPERSION = .527 STANDARD DEVIATION = .814 DEVIATION FROM NORMAL DISTR. = -39.54%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.090	.675	1.595	2.606	2.976	3.133	3.501	3.799

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.904	2.138	FINE SAND
STANDARD DEVIATION	1.229	1.310	POORLY SORTED
SKEWNESS(1)	-.571	-.591	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.140		
KURTOSIS	.868	1.363	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-2	111199					
Borrow B2 - 2						
		-1.125	5.840	5.627	-1.000	5.627
		-.875	1.080	1.041	-.750	6.668
		-.625	1.240	1.195	-.500	7.863
		-.375	1.360	1.310	-.250	9.173
		-.125	1.080	1.041	.000	10.214
		.125	1.470	1.416	.250	11.630
		.375	2.030	1.956	.500	13.586
		.625	1.680	1.619	.750	15.205
		.875	1.990	1.918	1.000	17.123
		1.125	2.170	2.091	1.250	19.214
		1.375	2.620	2.525	1.500	21.738
		1.625	3.050	2.939	1.750	24.677
		1.875	2.120	2.043	2.000	26.720
		2.125	6.050	5.830	2.250	32.550
		2.375	8.880	8.557	2.500	41.106
		2.625	16.670	16.063	2.750	57.169
		2.875	15.360	14.801	3.000	71.970
		3.125	12.740	12.276	3.250	84.246
		3.375	5.890	5.675	3.500	89.921
		3.625	7.460	7.188	3.750	97.109
		3.875	3.000	2.891	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.780

PERCENT FINER THAN 4.00 PHI = 3.08 PERCENT COARSER THAN -1.00 PHI = .00

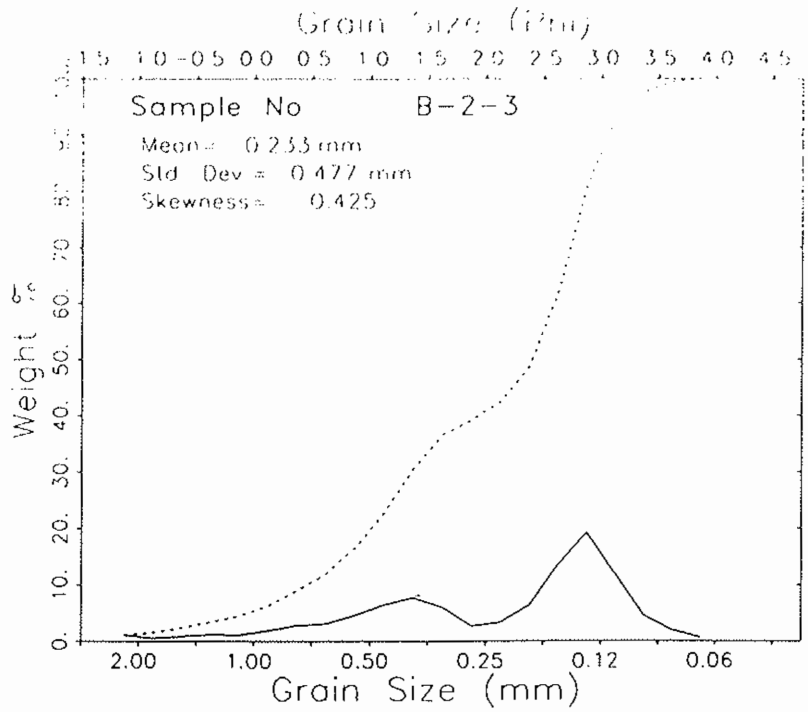
MOMENT MEASURES:

MEAN = 2.216 STANDARD DEVIATION = 1.312 SKEWNESS = -.639 KURTOSIS = .735
DISPERSION = .557 STANDARD DEVIATION = .872 DEVIATION FROM NORMAL DISTR. = -33.57%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.206	-1.028	.854	1.790	2.638	3.062	3.245	3.677	3.914

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARO (1957)	
MEAN	2.049	2.246	FINE SAND
STANDARD DEVIATION	1.196	1.311	POORLY SORTED
SKEWNESS(1)	-.493	-.526	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.099		
KURTOSIS	.967	1.516	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
8-2-3	111199					
Borrow 82 - 3						
		-1.125	1.140	1.025	-1.000	1.025
		-.875	.480	.432	-.750	1.456
		-.625	.900	.809	-.500	2.266
		-.375	1.220	1.097	-.250	3.362
		-.125	1.180	1.061	.000	4.423
		.125	1.980	1.780	.250	6.203
		.375	3.050	2.742	.500	8.945
		.625	3.350	3.012	.750	11.957
		.875	5.070	4.558	1.000	16.515
		1.125	7.070	6.356	1.250	22.872
		1.375	8.520	7.660	1.500	30.531
		1.625	6.660	5.988	1.750	36.519
		1.875	2.900	2.607	2.000	39.126
		2.125	3.590	3.228	2.250	42.354
		2.375	6.910	6.212	2.500	48.566
		2.625	15.000	13.486	2.750	62.052
		2.875	21.310	19.158	3.000	81.210
		3.125	13.270	11.930	3.250	93.140
		3.375	4.990	4.486	3.500	97.627
		3.625	2.060	1.852	3.750	99.479
		3.875	.580	.521	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.230

PERCENT FINER THAN 4.00 PHI = .30 PERCENT COARSER THAN -1.00 PHI = .00

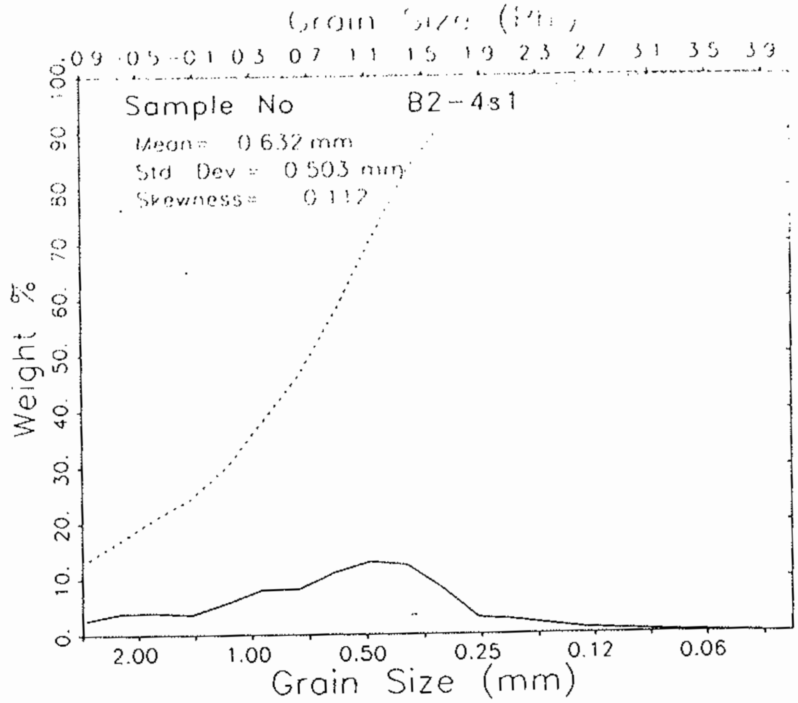
MOMENT MEASURES:

MEAN = 2.101 STANDARD DEVIATION = 1.068 SKEWNESS = -.425 KURTOSIS = -.005
DISPERSION = .537 STANDARD DEVIATION = .834 DEVIATION FROM NORMAL DISTR. = -21.68%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.006	.081	.972	1.319	2.527	2.919	3.058	3.354	3.685

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.015	2.186	FINE SAND
STANDARD DEVIATION	1.043	1.018	POORLY SORTED
SKEWNESS(1)	-.490	-.492	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.776		
KURTOSIS	.568	.839	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-4	111199					
Borrow B2 - 4 S1 Top						
		-1.125	11.400	10.570	-1.000	10.570
		-.875	2.770	2.568	-.750	13.139
		-.625	4.090	3.792	-.500	16.931
		-.375	4.230	3.922	-.250	20.853
		-.125	3.820	3.542	.000	24.395
		.125	6.050	5.610	.250	30.005
		.375	8.680	8.048	.500	38.053
		.625	8.780	8.141	.750	46.194
		.875	11.950	11.080	1.000	57.274
		1.125	13.960	12.944	1.250	70.218
		1.375	13.330	12.360	1.500	82.578
		1.625	8.780	8.141	1.750	90.719
		1.875	3.070	2.847	2.000	93.565
		2.125	2.680	2.485	2.250	96.050
		2.375	1.790	1.660	2.500	97.710
		2.625	.940	.872	2.750	98.581
		2.875	.660	.612	3.000	99.193
		3.125	.430	.399	3.250	99.592
		3.375	.260	.241	3.500	99.833
		3.625	.140	.130	3.750	99.963
		3.875	.040	.037	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.850

PERCENT FINER THAN 4.00 PHI = .04 PERCENT COARSER THAN -1.00 PHI = .00

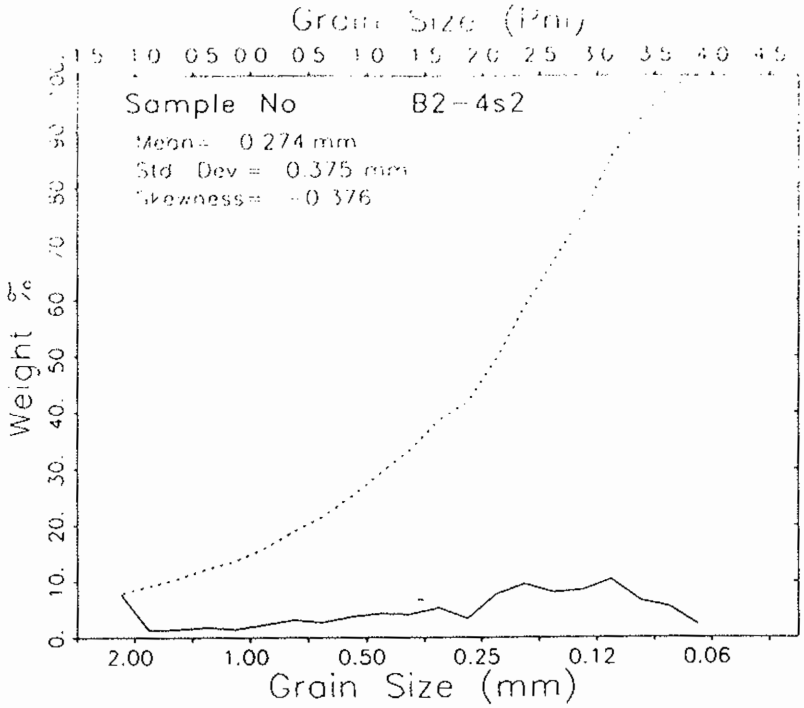
MOMENT MEASURES:

MEAN = .661 STANDARD DEVIATION = .992 SKEWNESS = -.112 KURTOSIS = -.407
DISPERSION = .537 STANDARD DEVIATION = .833 DEVIATION FROM NORMAL DISTR. = -16.02%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.226	-1.132	-.561	.027	.836	1.347	1.544	2.144	2.921

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.491	.606	COARSE SAND
STANDARD DEVIATION	1.053	1.023	POORLY SORTED
SKEWNESS(1)	-.328	-.264	COARSE-SKEWED
SKEWNESS(2)	-.313		
KURTOSIS	.556	1.017	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-4s	111199					
Borrow B2 - 4s2 Bottom						
		-1.125	8.260	7.793	-1.000	7.793
		-.875	1.300	1.227	-.750	9.020
		-.625	1.510	1.425	-.500	10.444
		-.375	1.850	1.745	-.250	12.190
		-.125	1.480	1.396	.000	13.586
		.125	2.360	2.227	.250	15.813
		.375	3.230	3.047	.500	18.860
		.625	2.800	2.642	.750	21.502
		.875	3.860	3.642	1.000	25.144
		1.125	4.440	4.189	1.250	29.333
		1.375	4.270	4.029	1.500	33.362
		1.625	5.540	5.227	1.750	38.589
		1.875	3.490	3.293	2.000	41.881
		2.125	8.080	7.623	2.250	49.505
		2.375	10.000	9.435	2.500	58.940
		2.625	8.480	8.001	2.750	66.940
		2.875	8.890	8.388	3.000	75.328
		3.125	10.880	10.265	3.250	85.593
		3.375	6.980	6.586	3.500	92.179
		3.625	5.820	5.491	3.750	97.670
		3.875	2.470	2.330	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.990

PERCENT FINER THAN 4.00 PHI = 2.84 PERCENT COARSER THAN -1.00 PHI = .00

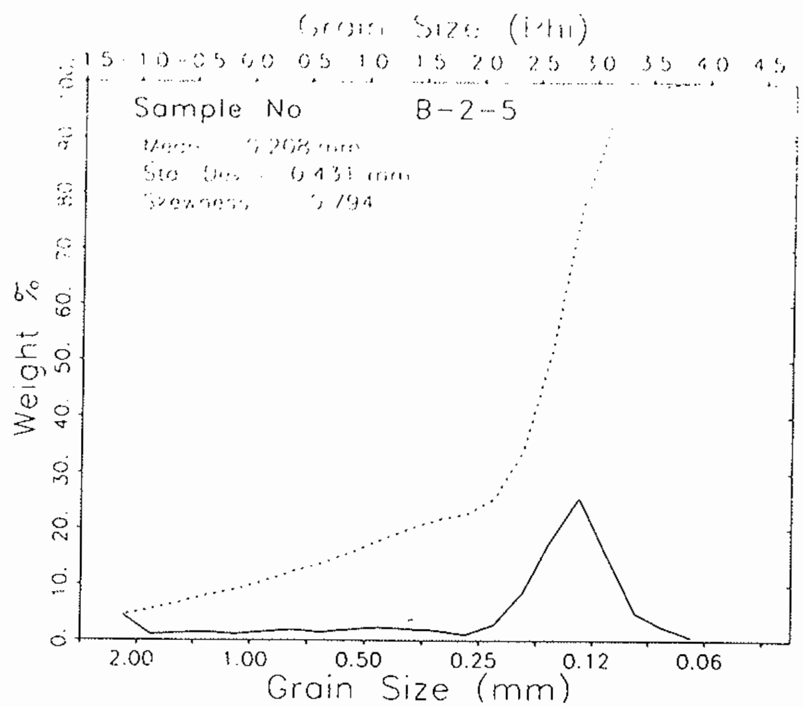
MOMENT MEASURES:

MEAN = 1.866 STANDARD DEVIATION = 1.416 SKEWNESS = -.376 KURTOSIS = -.458
DISPERSION = .644 STANDARD DEVIATION = 1.066 DEVIATION FROM NORMAL DISTR. = -24.74%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.090	.265	.990	2.263	2.990	3.211	3.628	3.893

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.738	1.913	MEDIUM SAND
STANDARD DEVIATION	1.473	1.451	POORLY SORTED
SKEWNESS(1)	-.356	-.389	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.675		
KURTOSIS	.602	.967	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-5	111199					
Borrow B2 - 5						
		-1.125	4.720	4.427	-1.000	4.427
		-.875	1.050	.985	-.750	5.412
		-.625	1.290	1.210	-.500	6.622
		-.375	1.500	1.407	-.250	8.029
		-.125	1.150	1.079	.000	9.108
		.125	1.570	1.473	.250	10.581
		.375	1.880	1.763	.500	12.344
		.625	1.520	1.426	.750	13.770
		.875	1.970	1.848	1.000	15.618
		1.125	2.380	2.232	1.250	17.850
		1.375	2.110	1.979	1.500	19.829
		1.625	1.870	1.754	1.750	21.583
		1.875	1.050	.985	2.000	22.568
		2.125	2.930	2.748	2.250	25.317
		2.375	9.010	8.451	2.500	33.768
		2.625	19.070	17.888	2.750	51.656
		2.875	27.130	25.448	3.000	77.103
		3.125	16.110	15.111	3.250	92.215
		3.375	5.180	4.859	3.500	97.073
		3.625	2.490	2.336	3.750	99.409
		3.875	.630	.591	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.610

PERCENT FINER THAN 4.00 PHI = .53 PERCENT COARSER THAN -1.00 PHI = .00

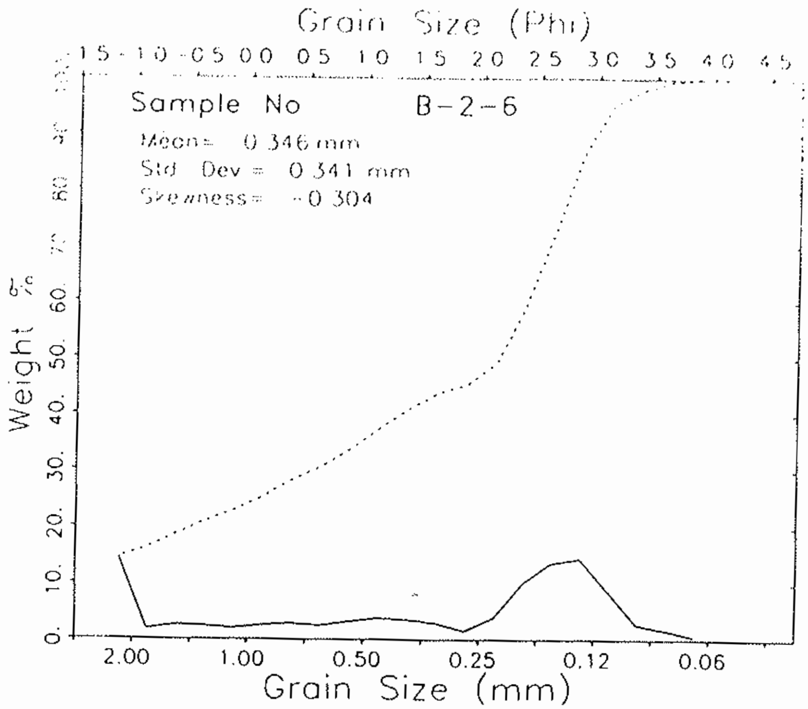
MOMENT MEASURES:

MEAN = 2.264 STANDARD DEVIATION = 1.214 SKEWNESS = -.794 KURTOSIS = 1.487
DISPERSION = .443 STANDARD DEVIATION = .671 DEVIATION FROM NORMAL DISTR. = -44.71%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.194	-.855	1.043	2.221	2.727	2.979	3.114	3.393	3.706

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	2.078	2.295	FINE SAND
STANDARD DEVIATION	1.036	1.161	POORLY SORTED
SKEWNESS(1)	-.626	-.656	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.407		
KURTOSIS	1.051	2.296	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT (PHI)	CLASS LIMITS	CUM PERCENT
B-2-6	111199						
Borrow B2 - 6							
		-1.125	15.020	14.409	-1.000	14.409	
		-.875	1.830	1.756	-.750	16.165	
		-.625	2.580	2.475	-.500	18.640	
		-.375	2.420	2.322	-.250	20.961	
		-.125	1.960	1.880	.000	22.842	
		.125	2.570	2.465	.250	25.307	
		.375	2.940	2.820	.500	28.127	
		.625	2.480	2.379	.750	30.507	
		.875	3.240	3.108	1.000	33.615	
		1.125	3.890	3.732	1.250	37.347	
		1.375	3.610	3.463	1.500	40.810	
		1.625	2.970	2.849	1.750	43.659	
		1.875	1.570	1.506	2.000	45.165	
		2.125	3.970	3.809	2.250	48.974	
		2.375	10.310	9.891	2.500	58.864	
		2.625	14.080	13.507	2.750	72.371	
		2.875	14.880	14.275	3.000	86.646	
		3.125	8.980	8.615	3.250	95.261	
		3.375	2.710	2.600	3.500	97.861	
		3.625	1.700	1.631	3.750	99.492	
		3.875	.530	.508	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 104.240

PERCENT FINER THAN 4.00 PHI = .66 PERCENT COARSER THAN -1.00 PHI = .00

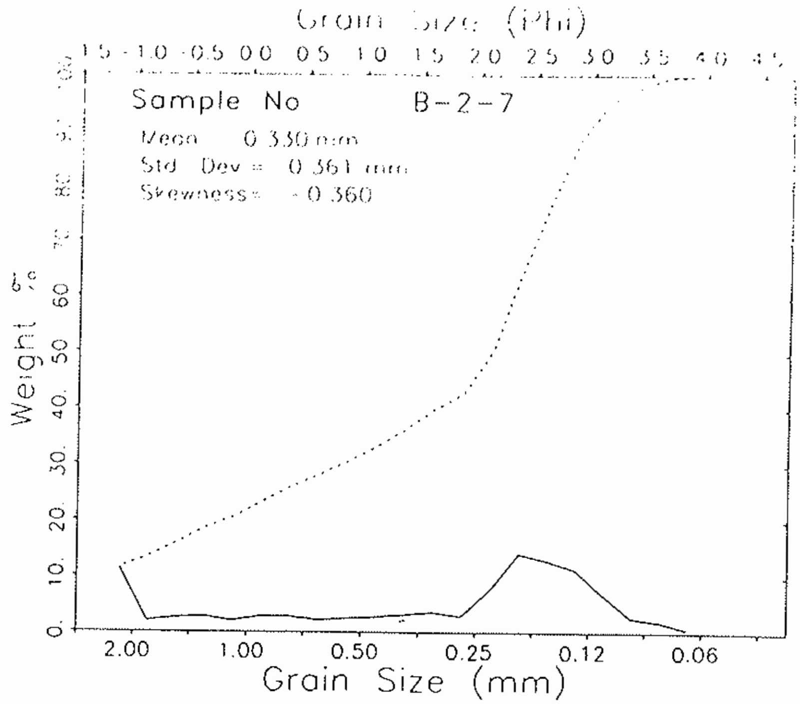
MOMENT MEASURES:

MEAN = 1.532 STANDARD DEVIATION = 1.552 SKEWNESS = -.304 KURTOSIS = -1.109
DISPERSION = .570 STANDARD DEVIATION = .898 DEVIATION FROM NORMAL DISTR. = -42.11%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.233	-1.163	-.773	.219	2.276	2.796	2.954	3.242	3.675

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.090	1.485	MEDIUM SAND
STANDARD DEVIATION	1.864	1.599	POORLY SORTED
SKEWNESS(1)	-.636	-.599	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.663		
KURTOSIS	.182	.701	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B-2-7	111199						
Borrow B2 - 7							
		-1.125	12.960	11.425		-1.000	11.425
		-.875	2.170	1.913		-.750	13.337
		-.625	2.770	2.442		-.500	15.779
		-.375	3.060	2.697		-.250	18.477
		-.125	2.220	1.957		.000	20.434
		.125	3.100	2.733		.250	23.166
		.375	3.130	2.759		.500	25.926
		.625	2.460	2.169		.750	28.094
		.875	2.740	2.415		1.000	30.510
		1.125	3.010	2.653		1.250	33.163
		1.375	3.490	3.077		1.500	36.239
		1.625	4.030	3.553		1.750	39.792
		1.875	3.180	2.803		2.000	42.595
		2.125	8.610	7.590		2.250	50.185
		2.375	15.980	14.087		2.500	64.272
		2.625	14.490	12.773		2.750	77.045
		2.875	12.690	11.187		3.000	88.232
		3.125	7.660	6.752		3.250	94.984
		3.375	2.890	2.548		3.500	97.532
		3.625	2.150	1.895		3.750	99.427
		3.875	.650	.573		4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.440

PERCENT FINER THAN 4.00 PHI = .85 PERCENT COARSER THAN -1.00 PHI = .00

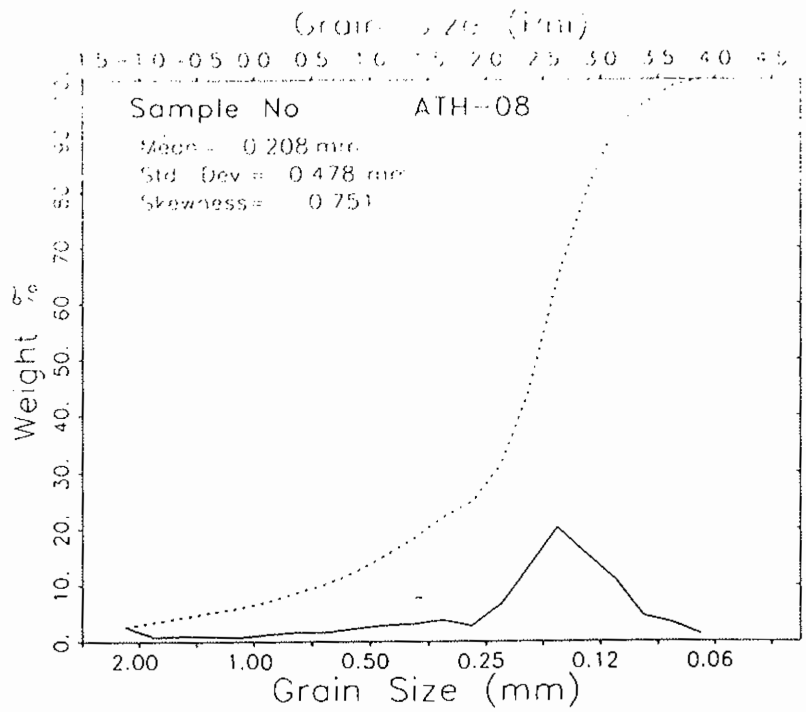
MOMENT MEASURES:

MEAN = 1.598 STANDARD DEVIATION = 1.470 SKEWNESS = -.360 KURTOSIS = -.859
DISPERSION = .588 STANDARD DEVIATION = .938 DEVIATION FROM NORMAL DISTR. = -36.18%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.228	-1.141	-.480	.416	2.244	2.710	2.905	3.252	3.694

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.213	1.557	MEDIUM SAND
STANDARD DEVIATION	1.692	1.512	POORLY SORTED
SKEWNESS(1)	-.609	-.575	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.702		
KURTOSIS	.298	.785	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
ATH-08	111199					
Borrow B1 - ATH08						
		-1.125	2.810	2.563	-1.000	2.563
		-.875	.860	.784	-.750	3.347
		-.625	.940	.857	-.500	4.204
		-.375	.960	.876	-.250	5.080
		-.125	.830	.757	.000	5.837
		.125	1.320	1.204	.250	7.041
		.375	1.730	1.578	.500	8.618
		.625	1.700	1.550	.750	10.169
		.875	2.410	2.198	1.000	12.367
		1.125	3.080	2.809	1.250	15.176
		1.375	3.370	3.073	1.500	18.249
		1.625	4.120	3.757	1.750	22.006
		1.875	2.960	2.699	2.000	24.706
		2.125	7.100	6.475	2.250	31.181
		2.375	14.520	13.242	2.500	44.423
		2.625	22.100	20.155	2.750	64.578
		2.875	17.000	15.504	3.000	80.082
		3.125	12.140	11.072	3.250	91.154
		3.375	4.870	4.441	3.500	95.595
		3.625	3.510	3.201	3.750	98.796
		3.875	1.320	1.204	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.650

PERCENT FINER THAN 4.00 PHI = .75 PERCENT COARSER THAN -1.00 PHI = .00

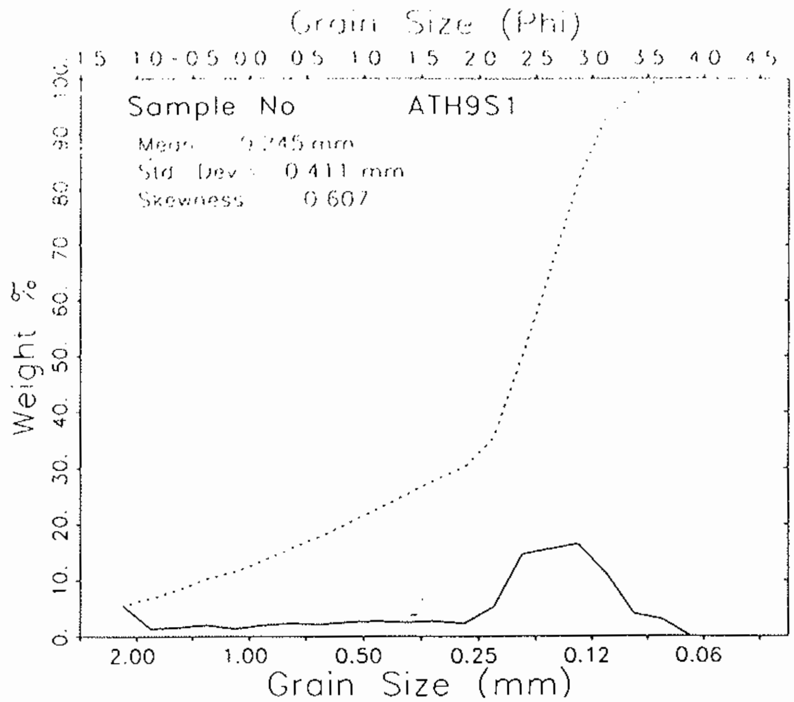
MOMENT MEASURES:

MEAN = 2.262 STANDARD DEVIATION = 1.066 SKEWNESS = -.751 KURTOSIS = 1.994
DISPERSION = .505 STANDARD DEVIATION = .774 DEVIATION FROM NORMAL DISTR. = -27.45%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.152	-.273	1.317	2.011	2.569	2.918	3.088	3.467	3.792

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.203	2.325	FINE SAND
STANDARD DEVIATION	.886	1.009	POORLY SORTED
SKEWNESS(1)	-.414	-.467	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.098		
KURTOSIS	1.111	1.690	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-09	111199						
Borrow B1 - ATH09s1							
		-1.125	5.940		5.465	-1.000	5.465
		-.875	1.380		1.270	-.750	6.735
		-.625	1.650		1.518	-.500	8.253
		-.375	2.110		1.941	-.250	10.194
		-.125	1.430		1.316	.000	11.510
		.125	2.170		1.997	.250	13.506
		.375	2.420		2.227	.500	15.733
		.625	2.230		2.052	.750	17.785
		.875	2.660		2.447	1.000	20.232
		1.125	2.840		2.613	1.250	22.845
		1.375	2.680		2.466	1.500	25.311
		1.625	2.880		2.650	1.750	27.960
		1.875	2.380		2.190	2.000	30.150
		2.125	5.600		5.152	2.250	35.302
		2.375	15.860		14.592	2.500	49.894
		2.625	16.830		15.484	2.750	65.379
		2.875	17.800		16.377	3.000	81.755
		3.125	12.240		11.261	3.250	93.017
		3.375	4.270		3.929	3.500	96.945
		3.625	3.260		2.999	3.750	99.945
		3.875	.060		.055	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.690

PERCENT FINER THAN 4.00 PHI = 1.33 PERCENT COARSER THAN -1.00 PHI = .00

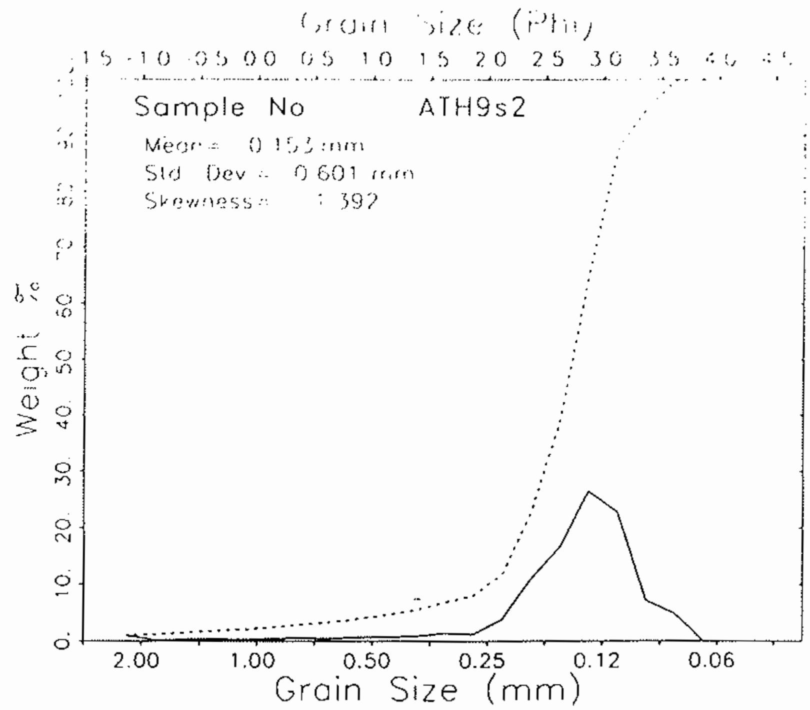
MOMENT MEASURES:

MEAN = 2.030 STANDARD DEVIATION = 1.284 SKEWNESS = -.607 KURTOSIS = .377
DISPERSION = .532 STANDARD DEVIATION = .825 DEVIATION FROM NORMAL DISTR. = -35.78%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.204	-1.021	.533	1.469	2.502	2.897	3.050	3.376	3.671

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.791	2.028	FINE SAND
STANDARD DEVIATION	1.259	1.296	POORLY SORTED
SKEWNESS(1)	-.565	-.503	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.052		
KURTOSIS	.747	1.262	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-09	111199					
Borrow B1 - ATH09s2						
		-1.125	1.010	.999	-1.000	.999
		-.875	.170	.168	-.750	1.167
		-.625	.300	.297	-.500	1.463
		-.375	.310	.307	-.250	1.770
		-.125	.240	.237	.000	2.007
		.125	.370	.366	.250	2.373
		.375	.450	.445	.500	2.818
		.625	.400	.395	.750	3.213
		.875	.640	.633	1.000	3.846
		1.125	.730	.722	1.250	4.568
		1.375	.840	.831	1.500	5.398
		1.625	1.360	1.345	1.750	6.743
		1.875	1.170	1.157	2.000	7.900
		2.125	3.740	3.698	2.250	11.598
		2.375	10.910	10.787	2.500	22.385
		2.625	16.660	16.472	2.750	38.857
		2.875,	26.730	26.429	3.000	65.286
		3.125	23.050	22.790	3.250	88.076
		3.375	7.170	7.089	3.500	95.165
		3.625	4.830	4.776	3.750	99.941
		3.875	.060	.059	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.140

PERCENT FINER THAN 4.00 PHI = 2.31 PERCENT COARSER THAN -1.00 PHI = .00

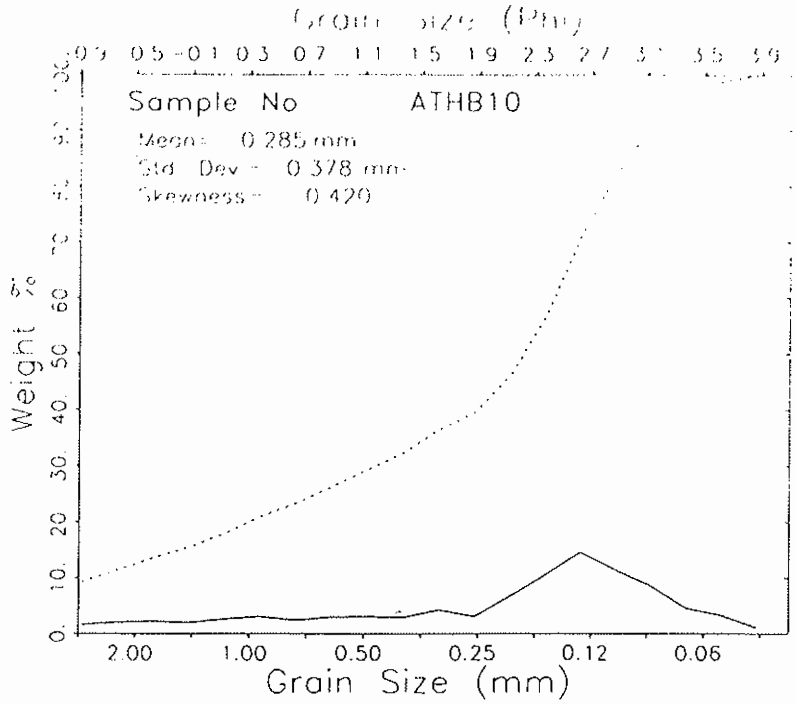
MOMENT MEASURES:

MEAN = 2.711 STANDARD DEVIATION = .734 SKEWNESS = -1.392 KURTOSIS = 10.252
DISPERSION = .299 STANDARD DEVIATION = .482 DEVIATION FROM NORMAL DISTR. = -34.35%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.998	1.380	2.352	2.540	2.855	3.107	3.205	3.494	3.701

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.779	2.604	FINE SAND
STANDARD DEVIATION	.427	.534	MODERATELY WELL SORTED
SKEWNESS(1)	-.180	-.288	COARSE-SKEWED
SKEWNESS(2)	-.980		
KURTOSIS	1.478	1.528	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-B1	111199					
Borrow B1 - ATHB10						
		-1.125	9.050	7.744	-1.000	7.744
		-.875	1.820	1.557	-.750	9.302
		-.625	2.330	1.994	-.500	11.296
		-.375	2.540	2.174	-.250	13.469
		-.125	2.160	1.848	.000	15.317
		.125	2.950	2.524	.250	17.842
		.375	3.530	3.021	.500	20.863
		.625	2.830	2.422	.750	23.284
		.875	3.450	2.952	1.000	26.237
		1.125	3.610	3.089	1.250	29.326
		1.375	3.360	2.875	1.500	32.201
		1.625	4.950	4.236	1.750	36.437
		1.875	3.540	3.029	2.000	39.466
		2.125	7.860	6.726	2.250	46.192
		2.375	12.280	10.508	2.500	56.700
		2.625	16.950	14.505	2.750	71.205
		2.875	13.180	11.278	3.000	82.483
		3.125	10.020	8.574	3.250	91.058
		3.375	5.350	4.578	3.500	95.636
		3.625	3.830	3.277	3.750	98.913
		3.875	1.270	1.087	4.000	100.000

TOTAL WEIGHT (GRAMS) = 116.860

PERCENT FINER THAN 4.00 PHI = .79 PERCENT COARSER THAN -1.00 PHI = .00

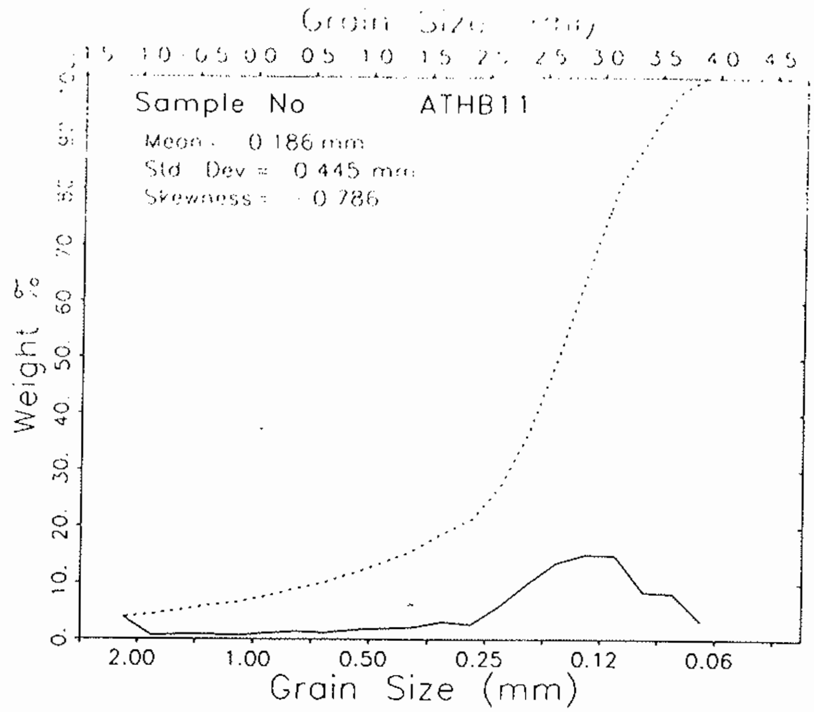
MOMENT MEASURES:

MEAN = 1.813 STANDARD DEVIATION = 1.402 SKEWNESS = -.420 KURTOSIS = -.475
DISPERSION = .613 STANDARD DEVIATION = .992 DEVIATION FROM NORMAL DISTR. = -29.22%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.089	.068	.895	2.341	2.834	3.044	3.465	3.770

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.556	1.817	MEDIUM SAND
STANDARD DEVIATION	1.408	1.434	POORLY SORTED
SKEWNESS(1)	-.527	-.517	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.774		
KURTOSIS	.530	.963	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT / WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-B- Borrow B1 - B11	111199					
		-1.125	4.000	3.868	-1.000	3.868
		-.875	.530	.512	-.750	4.380
		-.625	.830	.803	-.500	5.183
		-.375	.860	.832	-.250	6.014
		-.125	.640	.619	.000	6.633
		.125	1.070	1.035	.250	7.668
		.375	1.360	1.315	.500	8.983
		.625	1.210	1.170	.750	10.153
		.875	1.710	1.653	1.000	11.806
		1.125	1.940	1.876	1.250	13.682
		1.375	2.090	2.021	1.500	15.703
		1.625	3.120	3.017	1.750	18.720
		1.875	2.620	2.533	2.000	21.253
		2.125	6.120	5.918	2.250	27.171
		2.375	10.310	9.969	2.500	37.140
		2.625	14.020	13.556	2.750	50.696
		2.875	15.470	14.958	3.000	65.655
		3.125	15.300	14.794	3.250	80.449
		3.375	8.600	8.316	3.500	88.764
		3.625	8.380	8.103	3.750	96.867
		3.875	3.240	3.133	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.420

PERCENT FINER THAN 4.00 PHI = 2.22   PERCENT COARSER THAN -1.00 PHI = .00

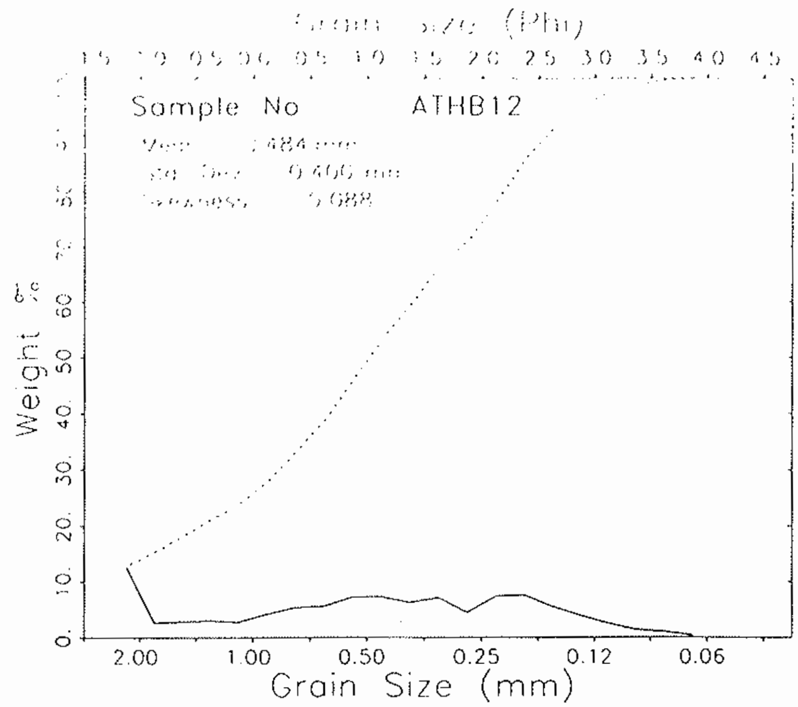
MOMENT MEASURES:

MEAN = 2.423 STANDARD DEVIATION = 1.168 SKEWNESS = -.786 KURTOSIS = 2.083
DISPERSION = .524 STANDARD DEVIATION = .809 DEVIATION FROM NORMAL DISTR. = -30.73%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.185	-.557	1.525	2.158	2.737	3.158	3.357	3.692	3.920

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.441	2.540	FINE SAND
STANDARD DEVIATION	.916	1.102	POORLY SORTED
SKEWNESS(1)	-.324	-.437	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.277		
KURTOSIS	1.319	1.742	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-B-	111199						
Borrow B1 - ATHB12							
		-1.125	13.920		12.663	-1.000	12.663
		-.875	2.780		2.529	-.750	15.191
		-.625	3.080		2.802	-.500	17.993
		-.375	3.300		3.002	-.250	20.995
		-.125	2.970		2.702	.000	23.697
		.125	4.540		4.130	.250	27.827
		.375	5.810		5.285	.500	33.112
		.625	6.130		5.576	.750	38.688
		.875	7.880		7.168	1.000	45.856
		1.125	7.980		7.259	1.250	53.116
		1.375	6.870		6.249	1.500	59.365
		1.625	7.760		7.059	1.750	66.424
		1.875	4.830		4.394	2.000	70.818
		2.125	8.030		7.305	2.250	78.122
		2.375	8.180		7.441	2.500	85.564
		2.625	6.010		5.467	2.750	91.031
		2.875	4.280		3.893	3.000	94.924
		3.125	2.720		2.474	3.250	97.398
		3.375	1.430		1.301	3.500	98.699
		3.625	1.110		1.010	3.750	99.709
		3.875	.320		.291	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.930

PERCENT FINER THAN 4.00 PHI = .44 PERCENT COARSER THAN -1.00 PHI = .00

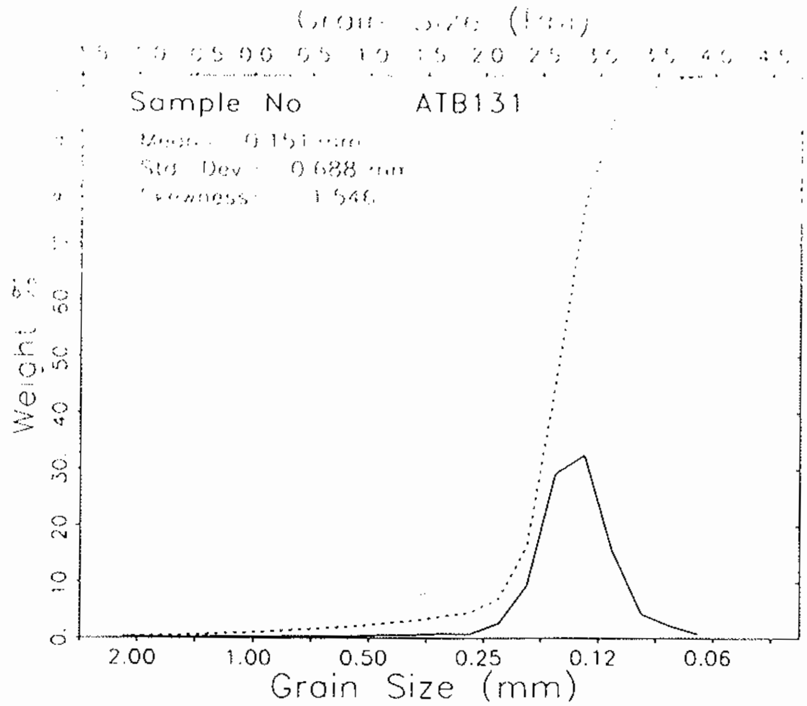
MOMENT MEASURES:

MEAN = 1.047 STANDARD DEVIATION = 1.322 SKEWNESS = -.088 KURTOSIS = -.971
DISPERSION = .642 STANDARD DEVIATION = 1.060 DEVIATION FROM NORMAL DISTR. = -19.82%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.230	-1.151	-.678	.079	1.143	2.143	2.447	3.008	3.574

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.885	.971	COARSE SAND
STANDARD DEVIATION	1.563	1.411	POORLY SORTED
SKEWNESS(1)	-.165	-.134	COARSE-SKEWED
SKEWNESS(2)	-.137		
KURTOSIS	.331	.826	PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
ATH-B-135\ 111199						
Borrow B1 - ATHB135\						
	-1.125	.240		.228	-1.000	.228
	-.875	.140		.133	-.750	.361
	-.625	.150		.142	-.500	.503
	-.375	.210		.199	-.250	.702
	-.125	.190		.180	.000	.883
	.125	.230		.218	.250	1.101
	.375	.340		.323	.500	1.424
	.625	.280		.266	.750	1.689
	.875	.360		.342	1.000	2.031
	1.125	.510		.484	1.250	2.515
	1.375	.490		.465	1.500	2.980
	1.625	.800		.759	1.750	3.739
	1.875	.710		.674	2.000	4.413
	2.125	2.590		2.458	2.250	6.871
	2.375	9.840		9.339	2.500	16.210
	2.625	30.670		29.107	2.750	45.317
	2.875	34.180		32.438	3.000	77.755
	3.125	16.040		15.223	3.250	92.977
	3.375	4.460		4.233	3.500	97.210
	3.625	2.240		2.126	3.750	99.336
	3.875	.700		.664	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.370

PERCENT FINER THAN 4.00 PHI = .27 PERCENT COARSER THAN -1.00 PHI = .00

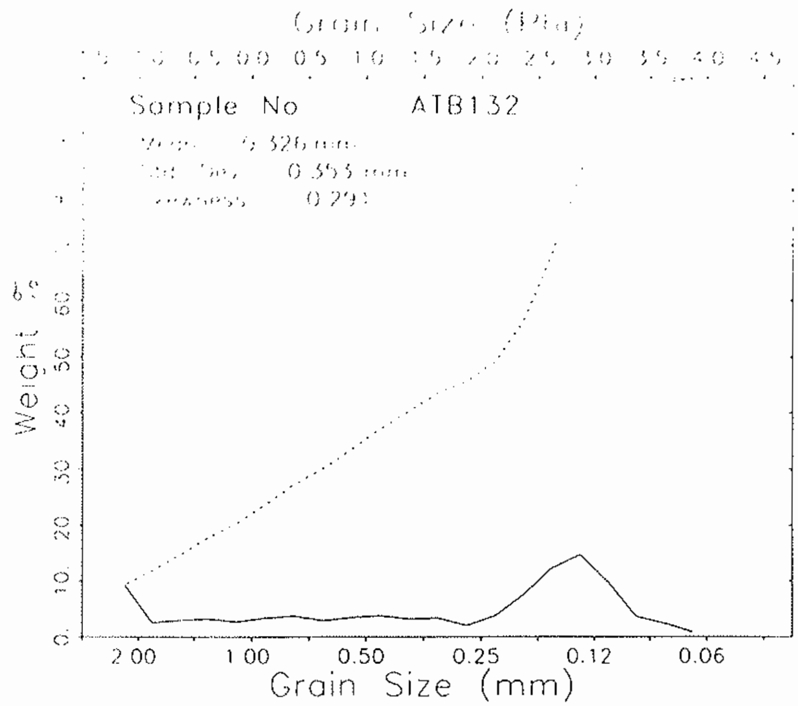
MOMENT MEASURES:

MEAN = 2.729 STANDARD DEVIATION = .539 SKEWNESS = -1.546 KURTOSIS = 16.067
DISPERSION = .187 STANDARD DEVIATION = .372 DEVIATION FROM NORMAL DISTR. = -30.93%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.134	2.060	2.494	2.576	2.786	2.979	3.103	3.369	3.711

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.798	2.794	FINE SAND
STANDARD DEVIATION	.304	.350	WELL SORTED
SKEWNESS(1)	.041	-.034	NEAR SYMMETRICAL
SKEWNESS(2)	-.235		
KURTOSIS	1.154	1.331	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
ATHB13	111199					
Borrow B1 - ATHB13-s2						
		-1.125	10.280	9.265	-1.000	9.265
		-.875	2.760	2.487	-.750	11.752
		-.625	3.250	2.929	-.500	14.681
		-.375	3.450	3.109	-.250	17.790
		-.125	2.880	2.596	.000	20.386
		.125	3.640	3.280	.250	23.666
		.375	4.000	3.605	.500	27.271
		.625	3.070	2.767	.750	30.038
		.875	3.790	3.416	1.000	33.453
		1.125	4.090	3.686	1.250	37.140
		1.375	3.520	3.172	1.500	40.312
		1.625	3.630	3.271	1.750	43.583
		1.875	2.140	1.929	2.000	45.512
		2.125	4.150	3.740	2.250	49.252
		2.375	8.290	7.471	2.500	56.723
		2.625	13.600	12.257	2.750	68.980
		2.875,	16.170	14.573	3.000	83.553
		3.125	10.830	9.760	3.250	93.313
		3.375	3.940	3.551	3.500	96.864
		3.625	2.610	2.352	3.750	99.216
		3.875	.870	.784	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.960

PERCENT FINER THAN 4.00 PHI = .45 PERCENT COARSER THAN -1.00 PHI = .00

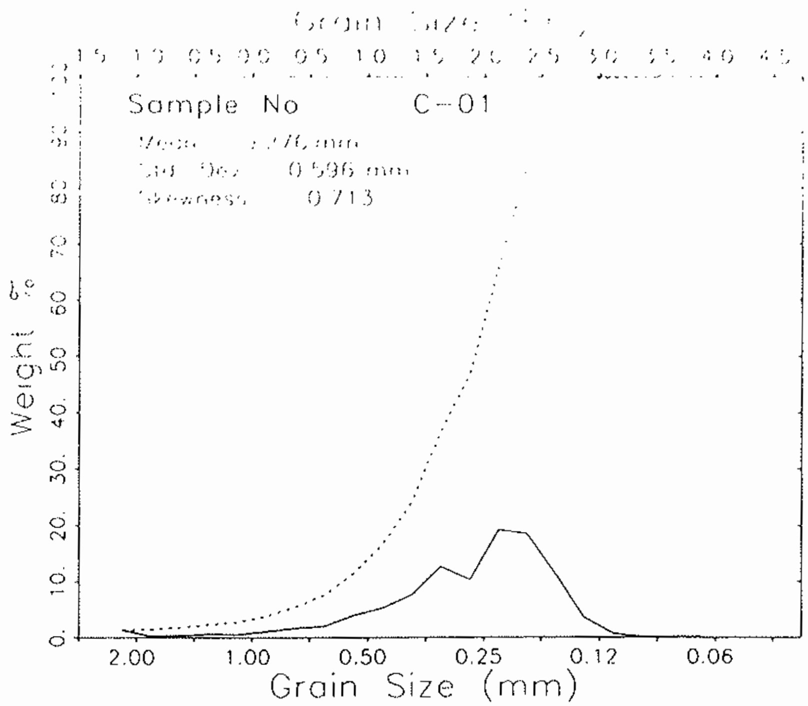
MOMENT MEASURES:

MEAN = 1.618 STANDARD DEVIATION = 1.504 SKEWNESS = -.291 KURTOSIS = -1.062
DISPERSION = .619 STANDARD DEVIATION = 1.005 DEVIATION FROM NORMAL DISTR. = -33.15%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.223	-1.115	-.394	.343	2.275	2.853	3.011	3.369	3.727

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.309	1.631	MEDIUM SAND
STANDARD DEVIATION	1.703	1.531	POORLY SORTED
SKEWNESS(1)	-.567	-.540	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.674		
KURTOSIS	.317	.732	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-01	111199						
Borrow C - 01							
		-1.125	1.130		1.263	-1.000	1.263
		-.875	.170		.190	-.750	1.453
		-.625	.280		.313	-.500	1.765
		-.375	.460		.514	-.250	2.279
		-.125	.430		.480	.000	2.760
		.125	.930		1.039	.250	3.799
		.375	1.500		1.676	.500	5.475
		.625	1.790		2.000	.750	7.475
		.875	3.450		3.855	1.000	11.330
		1.125	4.670		5.218	1.250	16.547
		1.375	6.770		7.564	1.500	24.112
		1.625	11.210		12.525	1.750	36.637
		1.875	9.170		10.246	2.000	46.883
		2.125	17.150		19.162	2.250	66.045
		2.375	16.540		18.480	2.500	84.525
		2.625	10.060		11.240	2.750	95.765
		2.875	3.130		3.497	3.000	99.263
		3.125	.540		.603	3.250	99.866
		3.375	.080		.089	3.500	99.955
		3.625	.020		.022	3.750	99.978
		3.875	.020		.022	4.000	100.000

TOTAL WEIGHT (GRAMS) = 89.500

PERCENT FINER THAN 4.00 PHI = .02 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

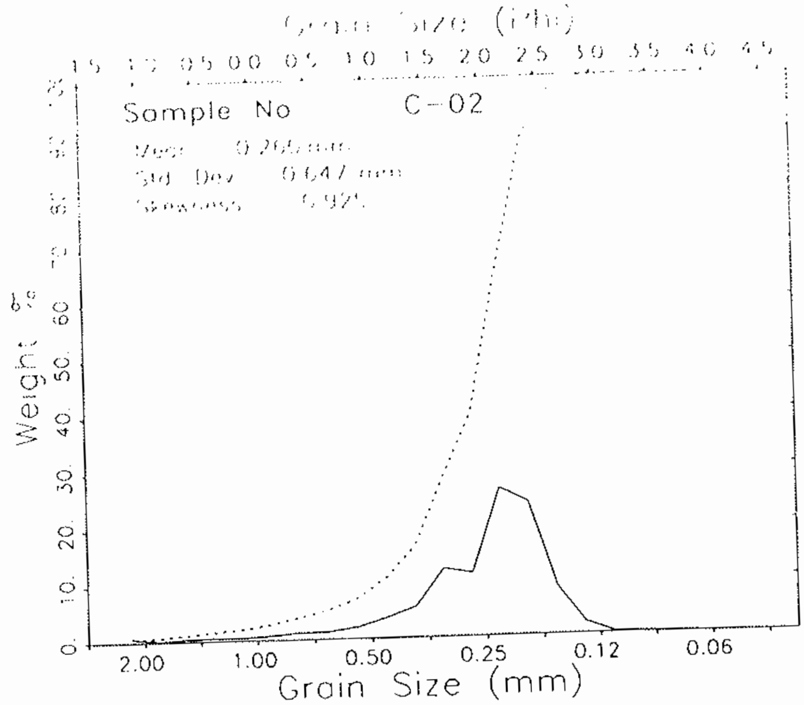
MEAN = 1.857 STANDARD DEVIATION = .747 SKEWNESS = -.713 KURTOSIS = 2.853

DISPERSION = .411 STANDARD DEVIATION = .624 DEVIATION FROM NORMAL DISTR. = -16.46%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.052	.429	1.224	1.518	2.041	2.371	2.493	2.733	2.981

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.858	1.919	MEDIUM SAND
STANDARD DEVIATION	.635	.666	MODERATELY WELL SORTED
SKEWNESS(1)	-.287	-.343	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.724		
KURTOSIS	.815	1.106	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-02	111199					
Borrown C - 02						
		-1.125	.530	.530	-1.000	.530
		-.875	.160	.160	-.750	.690
		-.625	.380	.380	-.500	1.071
		-.375	.460	.460	-.250	1.531
		-.125	.450	.450	.000	1.981
		.125	.760	.760	.250	2.741
		.375	1.140	1.141	.500	3.882
		.625	1.240	1.241	.750	5.123
		.875	1.990	1.991	1.000	7.114
		1.125	3.530	3.532	1.250	10.645
		1.375	5.410	5.413	1.500	16.058
		1.625	12.120	12.126	1.750	28.184
		1.875	11.200	11.206	2.000	39.390
		2.125	26.300	26.313	2.250	65.703
		2.375	23.680	23.692	2.500	89.395
		2.625	8.390	8.394	2.750	97.789
		2.875	1.940	1.941	3.000	99.730
		3.125	.220	.220	3.250	99.950
		3.375	.030	.030	3.500	99.980
		3.625	.010	.010	3.750	99.990
		3.875	.010	.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.950

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

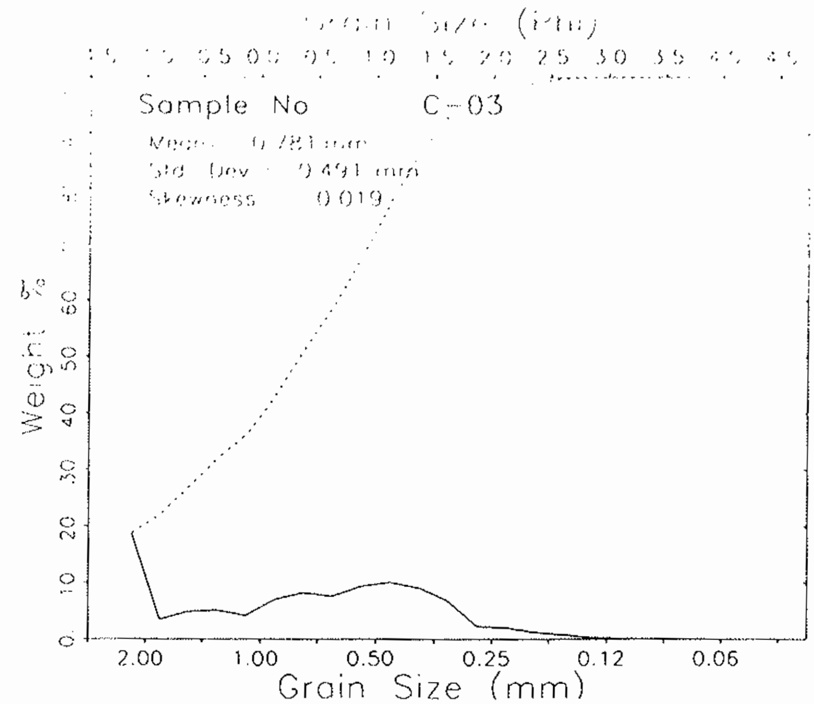
MEAN = 1.946 STANDARD DEVIATION = .629 SKEWNESS = -.925 KURTOSIS = 4.930

DISPERSION = .310 STANDARD DEVIATION = .494 DEVIATION FROM NORMAL DISTR. = -21.46%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.546	.725	1.497	1.684	2.101	2.348	2.443	2.667	2.906

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.970	2.014	FINE SAND
STANDARD DEVIATION	.473	.531	MODERATELY WELL SORTED
SKEWNESS(1)	-.276	-.347	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.856		
KURTOSIS	1.053	1.199	LEPTOKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-03 111199					
Borrow C - 03					
	-1.125	19.210	18.634	-1.000	18.634
	-.875	3.470	3.366	-.750	22.000
	-.625	4.990	4.840	-.500	26.841
	-.375	5.200	5.044	-.250	31.885
	-.125	4.290	4.161	.000	36.046
	.125	7.200	6.984	.250	43.030
	.375	8.380	8.129	.500	51.159
	.625	7.820	7.586	.750	58.745
	.875	9.590	9.303	1.000	68.047
	1.125	10.260	9.952	1.250	78.000
	1.375	9.290	9.012	1.500	87.011
	1.625	6.870	6.664	1.750	93.675
	1.875	2.330	2.260	2.000	95.936
	2.125	2.060	1.998	2.250	97.934
	2.375	1.160	1.125	2.500	99.059
	2.625	.710	.689	2.750	99.748
	2.875	.210	.204	3.000	99.951
	3.125	.040	.039	3.250	99.990
	3.375	.010	.010	3.500	100.000
	3.625	.000	.000	3.750	100.000
	3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.090

PERCENT FINER THAN 4.00 PHI = .00   PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

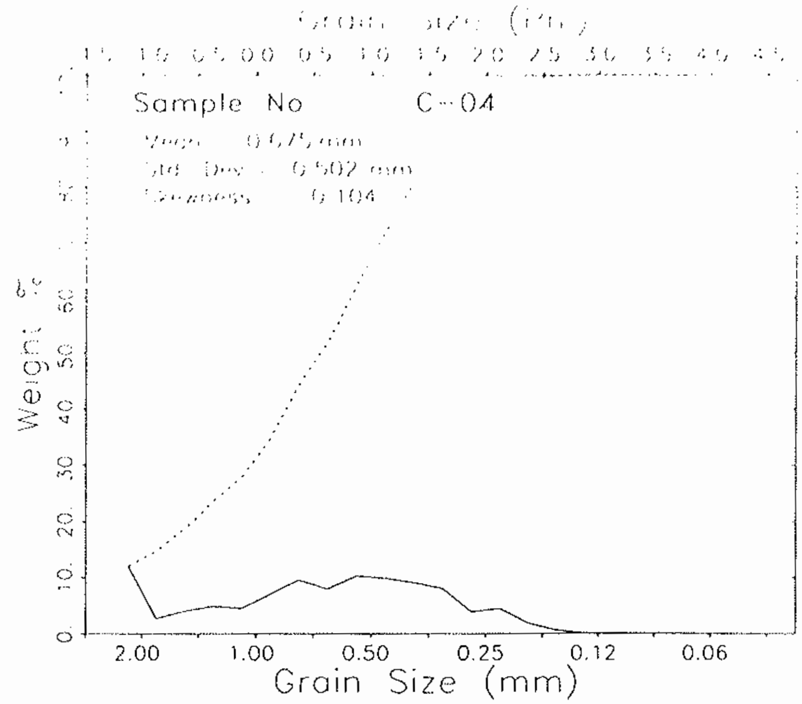
MEAN = .356   STANDARD DEVIATION = 1.025   SKEWNESS = -.019   KURTOSIS = -1.053

DISPERSION = .508   STANDARD DEVIATION = .779   DEVIATION FROM NORMAL DISTR. = -23.97%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.237	-1.183	-1.035	-.595	.464	1.175	1.416	1.897	2.487

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.191	.282	COARSE SAND
STANDARD DEVIATION	1.226	1.080	POORLY SORTED
SKEWNESS(1)	-.223	-.147	COARSE-SKEWED
SKEWNESS(2)	-.088		
KURTOSIS	.256	.713	PLATYKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-04 111199					
Borrow C - 04					
	-1.125	12.040	12.038	-1.000	12.038
	-.875	2.630	2.629	-.750	14.667
	-.625	3.930	3.929	-.500	18.596
	-.375	4.800	4.799	-.250	23.395
	-.125	4.440	4.439	.000	27.834
	.125	7.010	7.009	.250	34.843
	.375	9.450	9.448	.500	44.291
	.625	7.890	7.888	.750	52.180
	.875	10.260	10.258	1.000	62.438
	1.125	9.840	9.838	1.250	72.276
	1.375	9.070	9.068	1.500	81.344
	1.625	7.970	7.968	1.750	89.312
	1.875	3.790	3.789	2.000	93.101
	2.125	4.410	4.409	2.250	97.510
	2.375	1.800	1.800	2.500	99.310
	2.625	.550	.550	2.750	99.860
	2.875	.090	.090	3.000	99.950
	3.125	.050	.050	3.250	100.000
	3.375	.000	.000	3.500	100.000
	3.625	.000	.000	3.750	100.000
	3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.020

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

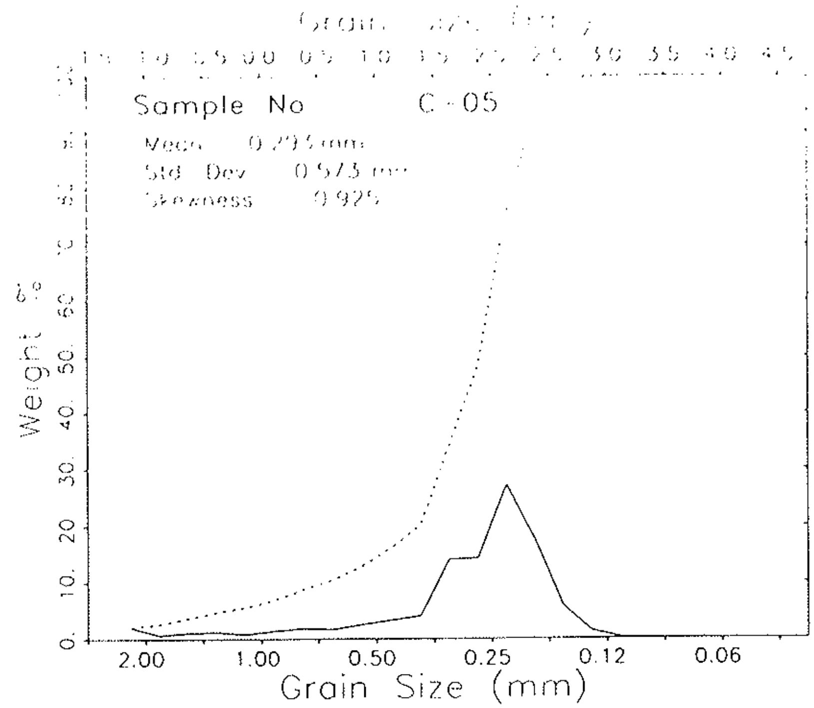
MOMENT MEASURES:

MEAN = .568 STANDARD DEVIATION = .994 SKEWNESS = -.104 KURTOSIS = -.857
DISPERSION = .538 STANDARD DEVIATION = .835 DEVIATION FROM NORMAL DISTR. = -15.96%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.229	-1.146	-.665	-.160	.681	1.325	1.583	2.108	2.457

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.459	.533	COARSE SAND
STANDARD DEVIATION	1.124	1.055	POORLY SORTED
SKEWNESS(1)	-.197	-.160	COARSE-SKEWED
SKEWNESS(2)	-.178		
KURTOSIS	.447	.898	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-05	111199					
Borrow C - 05						
		-1.125	2.110	2.004	-1.000	2.004
		-.875	.630	.598	-.750	2.603
		-.625	1.080	1.026	-.500	3.628
		-.375	1.160	1.102	-.250	4.730
		-.125	.860	.817	.000	5.547
		.125	1.460	1.387	.250	6.934
		.375	1.910	1.814	.500	8.748
		.625	1.700	1.615	.750	10.363
		.875	2.570	2.441	1.000	12.804
		1.125	3.420	3.248	1.250	16.052
		1.375	4.160	3.951	1.500	20.004
		1.625	14.700	13.963	1.750	33.967
		1.875	14.950	14.200	2.000	48.167
		2.125	28.600	27.166	2.250	75.332
		2.375	18.520	17.591	2.500	92.924
		2.625	5.960	5.661	2.750	98.585
		2.875	1.350	1.282	3.000	99.867
		3.125	.130	.123	3.250	99.991
		3.375	.010	.009	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.280

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

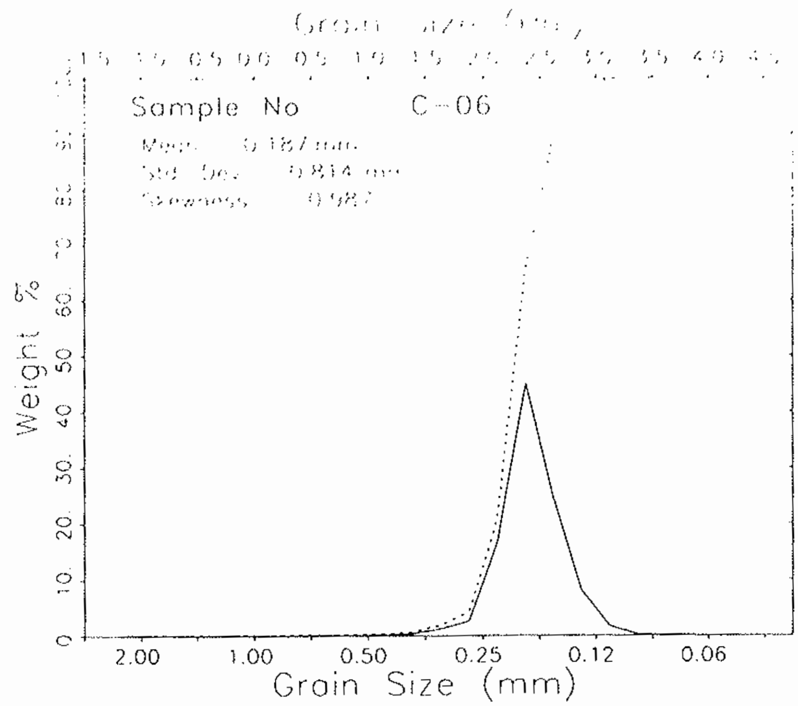
MEAN = 1.769 STANDARD DEVIATION = .803 SKEWNESS = -.925 KURTOSIS = 3.442

DISPERSION = .359 STANDARD DEVIATION = .553 DEVIATION FROM NORMAL OISTR. = -31.14%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.125	-.167	1.246	1.589	2.017	2.247	2.373	2.592	2.831

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.810	1.879	MEDIUM SAND
STANDARD DEVIATION	.564	.700	MODERATELY WELL SORTED
SKEWNESS(1)	-.368	-.476	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.428		
KURTOSIS	1.448	1.720	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
C-06	111199					
Borrow C - 06						
		-1.125	.050	.048	-1.000	.048
		-.875	.010	.010	-.750	.058
		-.625	.030	.029	-.500	.086
		-.375	.030	.029	-.250	.115
		-.125	.020	.019	.000	.135
		.125	.030	.029	.250	.163
		.375	.020	.019	.500	.183
		.625	.020	.019	.750	.202
		.875	.050	.048	1.000	.250
		1.125	.100	.096	1.250	.346
		1.375	.290	.279	1.500	.625
		1.625	1.140	1.095	1.750	1.720
		1.875	2.570	2.469	2.000	4.189
		2.125	17.460	16.777	2.250	20.967
		2.375	46.890	45.056	2.500	66.023
		2.625	25.250	24.263	2.750	90.285
		2.875	8.250	7.927	3.000	98.213
		3.125	1.660	1.595	3.250	99.808
		3.375	.180	.173	3.500	99.981
		3.625	.020	.019	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.070

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.417 STANDARD DEVIATION = .297 SKEWNESS = -.987 KURTOSIS = 19.712
DISPERSION = .035 STANDARD DEVIATION = .262 DEVIATION FROM NORMAL DISTR. = -11.73%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.586	2.012	2.176	2.272	2.411	2.592	2.685	2.899	3.123

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.431	2.424	FINE SAND
STANDARD DEVIATION	.255	.262	VERY WELL SORTED
SKEWNESS(1)	.077	.008	NEAR SYMMETRICAL
SKEWNESS(2)	.174		
KURTOSIS	.741	1.135	LEPTOKURTIC

ATHENA CORE LOG

CORE ID: ATH-01

PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 0810
PENETRATION LENGTH 6'
RECOVERY 2 83'
WATER DEPTH 49'
WEATHER Clear 45F, Lt Breeze
GPS-LAT 34 38'59 9"
GPS-LON 76 53'29 9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER JNW/WJS
DATE LOGGED 8 NOV 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION

0-0 58 Coarse grained, poorly sorted Sand mixed with up to 50% shell fragments (<1mm-7mm) (SW) CX, SH

0 58-0 92 Grey silty Mud, soft high water content (CH) MU

0 92-1 17 Coarse grained, poorly sorted Sand mixed with up to 50% shell fragments (<1mm-7mm) (SW) CX, SH

1 17-2 83 Gray Mud and fine Sand mixed with abundant shells from 0 1-7cm Large clam shells at base Occasional fine Sand lens (SC) FX, MU, SH

1 0
2 0
3 0
4 0
5 0
6 0
7 0
8 0
9 0
10 0

ATHENA CORE LOG

CORE ID: ATH-02

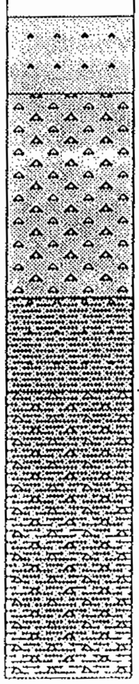
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 9 Nov 99
TIME 0847
PENETRATION LENGTH 8'
RECOVERY 7.08'
WATER DEPTH 46'
WEATHER Clear 45F
GPS-LAT 34 39'29.9"
GPS-LON 76' 53'29.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 8 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-0 83 Fine grained well sorted Sand Grey/tan Abundant small black grains and fine shell fragments (SP) FX SL
1 0			0 83-3 0 Fine grained Sand mixed with abundant shell fragments (0 1-5 0cm) Shell content varies with depth minor mud content (SW) FX SH
2 0			
3 0			3 0-4 0 Shell content decreases Fine Sand mixed with Mud (SC) FX MU SL
4 0			4 0-7 08 Fine Sand and Mud mixed with abundant shell material that increases with depth (SC) FX MU SH
5 0			
6 0			
7 0			
8 0			
9 0			
10 0			



ATHENA CORE LOG

CORE ID: ATH-03

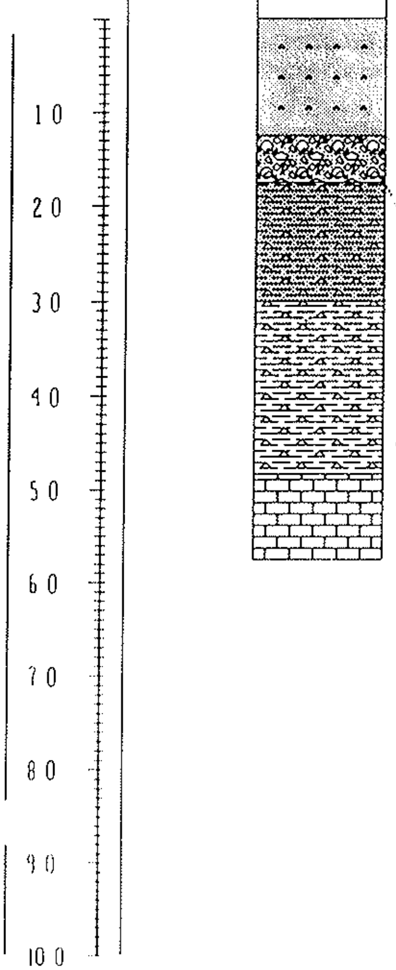
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 0940
PENETRATION LENGTH 7'
RECOVERY 5 75'
WATER DEPTH 48'
WEATHER Clear 50F
GPS-LAT 34 39'15.1"
GPS-LON 76 53'59.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 8 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-1 25 Fine grained, well sorted Sand Abundant fine black grains and fine to medium shell fragments (SP) FX SL

1 25-1 75 Mixed fine to coarse sand with abundant shell fragments (SW) CX SH

1 25-3 0 Grey mixed fine Sand and Mud with abundant shell fragments (1-15mm) (SC) FX MU SH

3 0-4 83 Mud content increases, several large thick clam shells (SC) MU SH

4 83-5 75 Tight dewatered mud Grainy texture, heavy reaction to HCL Tan in color (ML) LS

ATHENA CORE LOG

CORE ID

ATH-04

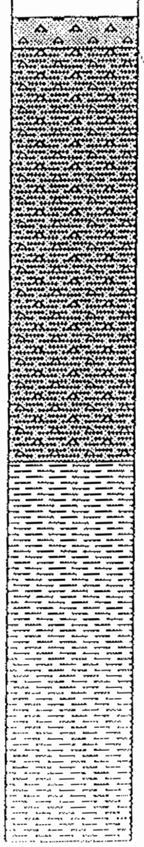
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 9 Nov 99
TIME 1115
PENETRATION LENGTH 10'
RECOVERY 8 83'
WATER DEPTH 50'
WEATHER CLEAR 55F
GPS-LAT 54 38'44.9"
GPS-LON 76 54'59.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 9 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-0 33 Fine to medium Sand mixed with abundant randomly size shell fragments (SW) FX SH
1 0			0 33-4 75 Gray fine Sand and Mud mixed with abundant shell fragments Intact 3cm olive shells at 0 83 and 1 25' Shell size and content varies with depth Mild HCl reaction (SC) FX MU SH
2 0			
3 0			
4 0			
5 0			4 75-8 83 Olive, silty Mud Very mild HCl reaction Occasional pockets of gray sediments similar to above unit Water content decreases, becomes tighter with depth (OL) MU
6 0			
7 0			
8 0			
9 0			
10 0			



ATHENA CORE LOG

CORE ID: ATH-05

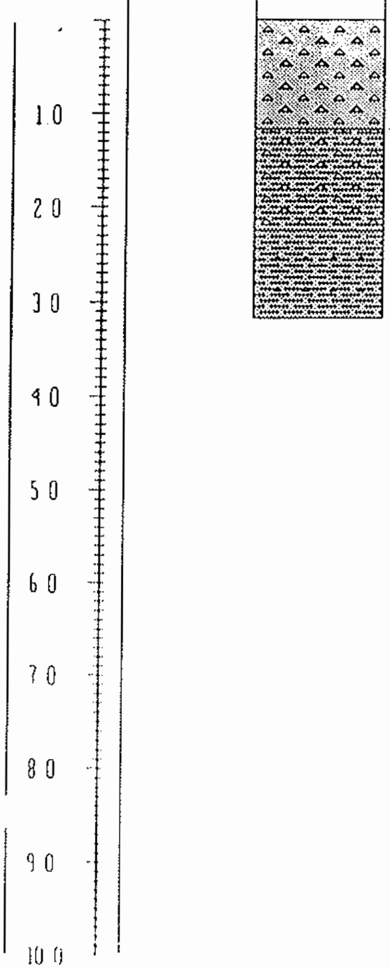
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 1210
PENETRATION LENGTH 7'
RECOVERY 3'2"
WATER DEPTH 47
WEATHER Clear 60F
GPS-LAT 34 39'59.9"
GPS-LON 76 54'29.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 8 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-1 17 Fine to medium grained Sand mixed with abundant small shell fragments (SW) FX SH

1 17-2 25 Fine grained Sand and Mud mixed with abundant shell fragments (SW) FX MU SH

2 25-3 17 Shell and sand content decreases, mud content decreases (SW) FX MU SL

ATHENA CORE LOG

CORE ID: ATH-06

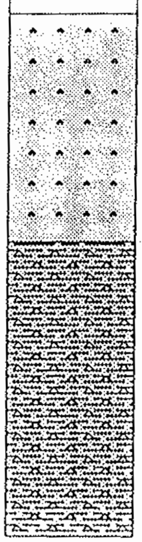
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 4 Nov 99
TIME 1301
PENETRATION LENGTH 6 5'
RECOVERY 5 58'
WATER DEPTH 49'
WEATHER Clear 60F
GPS-LAT 34 39'29 9"
GPS-LON 76 54'29 9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 9 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-2 43 Gray, well sorted, fine grained Sand mixed with moderate fine to medium shell fragments Abundant fine black grains throughout Coarse shell layer (lag?) at base of unit (SP) FX SL
1 0			
2 0			2 43-5 58 Olive gray fine Sand and Mud mix with shell content increasing with depth intact olive shell (2cm) at 3 0' Mild reaction with HCl Large intact shells at 3 5' and 4 08' Becomes light gray after 4 08' Mild HCl reaction Shell assemblage varies in size and type (SC) FX MU SH
3 0			
4 0			
5 0			
6 0			
7 0			
8 0			
9 0			
10 0			



ATHENA CORE LOG

CORE ID: ATH-07

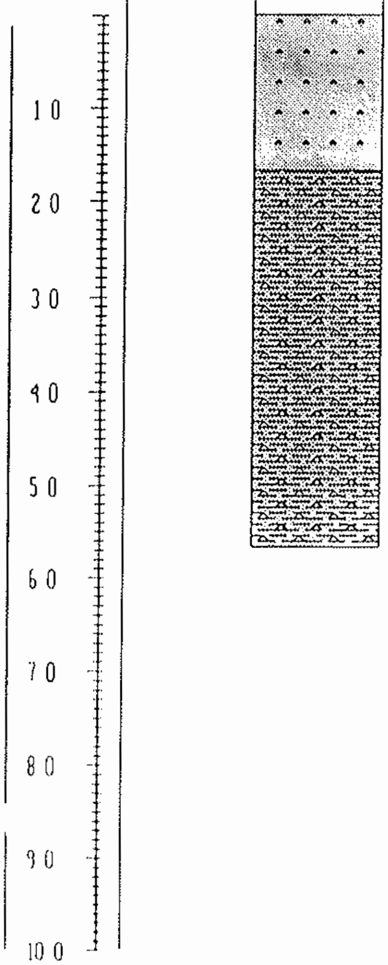
PROJECT Bogue Bonk Sond Seorch
CLIENT CSE
CORE DATE 4 Nov 99
TIME 1437
PENETRATION LENGTH 9'
RECOVERY 5 67'
WATER DEPTH 47'
WEATHER Cleor 65F
GPS-LAT 34 39'15.0"
GPS-LON 76 54'59.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 9 Nov 99
PAGE 1 OF 1

KEY

Fine Sond	Corbonote	Mud
Med Sond	Shell Hosh	Peot
Crs Sond	Muddy Sond	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-1 67 Olive/gray, fine groined, well sorted Sond Low fine shell content (SP) FX, SL

1 67-5 67 Fine groined Sond ond Mud mixed with obundont shell frogments Shells vory in type ond size (2mm-60mm) Mild HCl reoction Shell content increoses ond becomes more uniform below 3 0' (3-10mm) (SC) FX MU SH

ATHENA CORE LOG

CORE ID

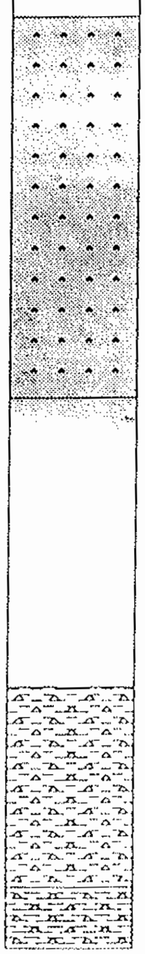
ATH-B08

PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 0755
PENETRATION LENGTH 13'
RECOVERY 11 25'
WATER DEPTH 35'
WEATHER Clear 45F
GPS-LAT 34 41'12.5"
GPS-LON 76 48'07.8"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 10 Nov 99
PAGE 1 OF 2

KEY

Fine Sand		Carbonate		Mud	
Med Sand		Shell Hash		Peat	
Crs Sand		Muddy Sand		Burrows	

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-4 08 Gray, fine grained, well sorted Sand minor shell fragments throughout Very thin muddy layers between 0 5-1 43' Shell content increases at 2 5' (SP) FX SL
1 0			
2 0			
3 0			
4 0			4 08-7 17 Slightly muddy, fine grained Sand Medium shell fragments throughout Mud content increases with depth (SC) FX
5 0			
6 0			
7 0			7 17-9 33 Slightly muddy fine to medium Sand and shell fragments ranging from 1mm-40mm Shells are of varying types and sizes (GM) MS SH
8 0			
9 0			9 33-11 25 Shell assemblage becomes all oyster Sand matrix becomes finer and muddy (GC) FX MD SH
10 0			

ATHENA CORE LOG

CORE ID: ATH-B09

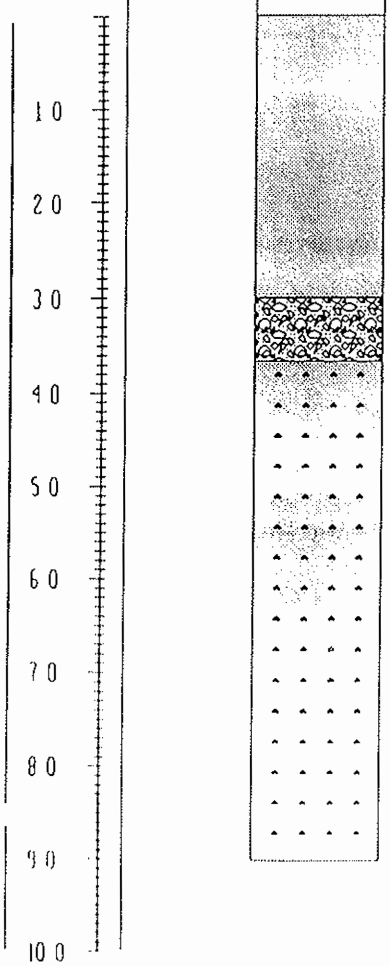
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 0850
PENETRATION LENGTH 10'
RECOVERY 9'
WATER DEPTH 32'
WEATHER Clear, 50F
GPS-LAT 34 41'10.3"
GPS-LON 76 49'10.7"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 9 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-3 0 Fine grained, well sorted gray Sand, low shell content
2" shell/fine to coarse sand horizon at 1 25' (SP) FX

3 0-3 67 Shell rich horizon, coarse Sand mixed with
abundant shell fragments ranging from 1mm-50mm (SW) CX SH
3 67-9 0 Olive gray very fine Sand Low to moderate fine
shell content Reacts with HCl Becomes muddier with depth
Shell fragments up to 1cm between 8 25-8 58' (SP) FX SL

ATHENA CORE LOG

CORE ID

ATH-B10

PROJECT Bogue Bank Sand Search

CLIENT CSE

CORE DATE 5 Nov 99

TIME 1000

PENETRATION LENGTH 10 5'

RECOVERY 7 5'

WATER DEPTH 37'

WEATHER Clear 60F

GPS-LAT 34 40'56 7"

GPS-LON 76 50'10 8"

CORED BY ATHENA TECHNOLOGIES INC

LOGGER WJS/JNW

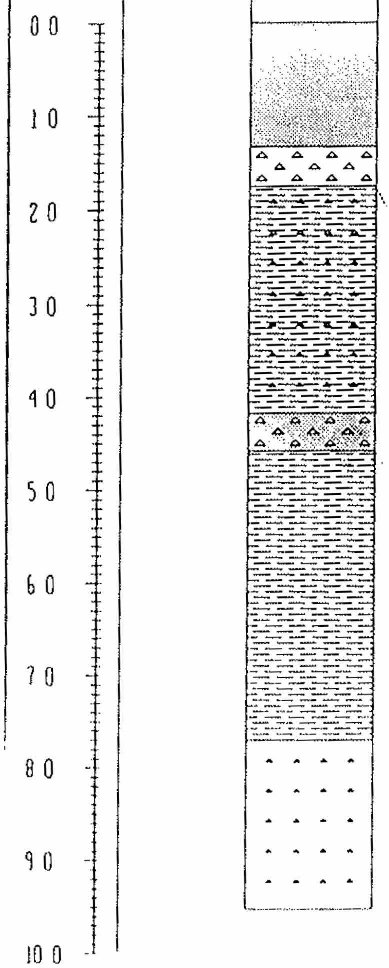
DATE LOGGED 9 Nov 99

PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-1 33 Fine grained, well sorted sand Very low shell content Black Mud lenses at 0 83' and 1 33' (SP) FX

1 33-1 75 Coarse grained, poorly sorted Sand mixed with abundant, randomly sized shell fragments (SW) LX SH

1 75-4 17 Gray, muddy, very fine sand with shell fragments present Mild HCl reaction (MH) MU SL

4 17-4 58 Very fine sandy/mud mixed with abundant shell fragments (SC) FX SH

4 58-7 67 Olive Mud Soft and moldable, moderate HCl reaction Appears burrowed in some areas Minor small shell fragments throughout (CH) MU

7 67-9 5 Muddy, fine grained Sand mixed with moderate amounts of shell fragments (SC) FX SL

ATHENA CORE LOG

CORE ID: ATH-B11

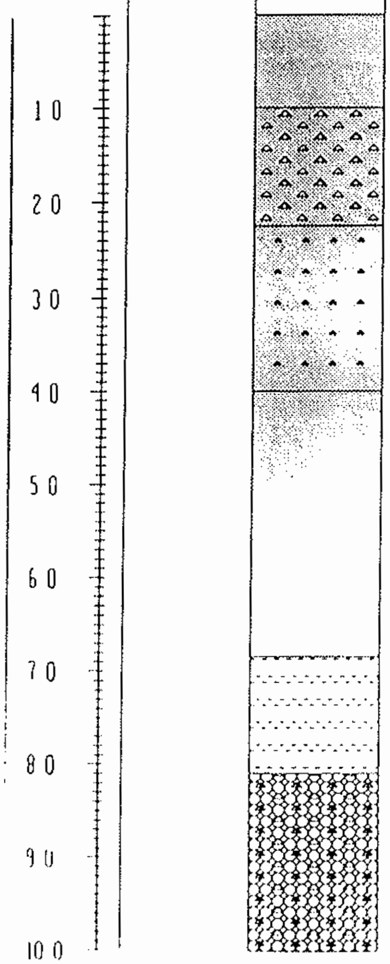
PROJECT Bogue Bonk Sond Seorch
CLIENT CSE
CORE DATE 5 Nov 99
TIME 1055
PENETRATION LENGTH 11 5'
RECOVERY 10 0'
WATER DEPTH 35'
WEATHER Cleor, 65F
GPS-LAT 34 40'33 7"
GPS-LON 76 53'50 6"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 10 Nov 99
PAGE 1 OF 1

KEY

Fine Sond	Corbonote	Mud
Med Sond	Shell Hosh	Peot
Crs Sond	Muddy Sond	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-1 0 Fine groined, well sorted, dork groy Sond Soft Mud lens from 0 08-0 17'Fine to medium shell frogments present throughout (SP) FX

1 0-2 25 Groy, fine groined, slightly muddy Sond mixed with moderote shell frogments (1-20mm) (SW) FX SH

2 25-4 0 Groy, muddy, very fine sond, low shell content Sond slightly coorsens with depth (MH) FX SL

4 0-6 83 Olive groy, fine to very fine groined, slightly muddy Sond Occosionol rondom lorge shell frogment Medium to fine shell frogments throughout Smoll mud lenses oppeor between 5' ond 6' Coorsens with depth ofter 5 5' (SP) FX

6 83-8 08 Groy Mud interbedded with fine groined Sond Low shell content (SC) FB

8 08-10 0 Fine to medium groined, Sond mixed with obundont shell frogments Shell frogments coorsen downcore (SW) MX SH

ATHENA CORE LOG

CORE ID: ATH-B12

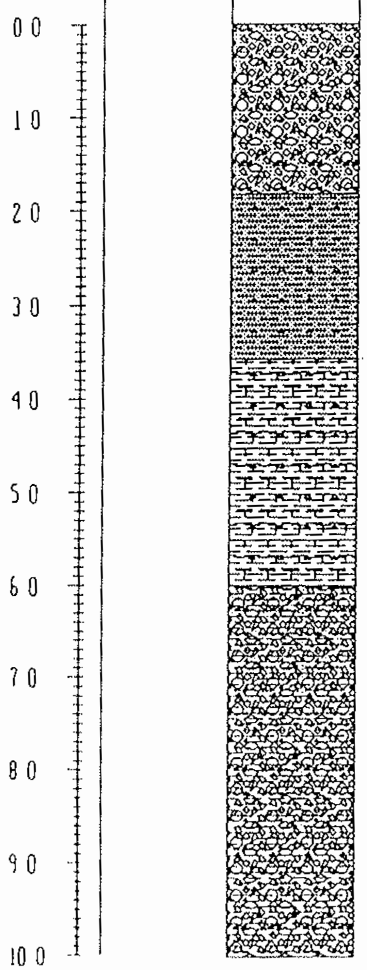
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 1147
PENETRATION LENGTH 10 5'
RECOVERY 10 25'
WATER DEPTH 37'
WEATHER Clear 65F
GPS-LAT 34 40'22.5"
GPS-LON 76 54'52.4"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 10 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-1 83 Fine to coarse grained, poorly sorted Sand with abundant small shell fragments Mud lenses present at 0 67' and 1 25' (SW) CX SH

1 83-3 58 Olive, fine to very fine grained Sand, slightly muddy moderate shell content (SC) FX MU SL

3 58-6 0 Soft mud Occasional fine sand pockets (burrows?) Reacts with HCl (OH) MU SL BR

6 0-10 25 Gray fine to coarse, poorly sorted Sand and mud mixed with abundant shell fragments of various types and sizes (GC) MU CX SH

ATHENA CORE LOG

CORE ID
ATH-B13

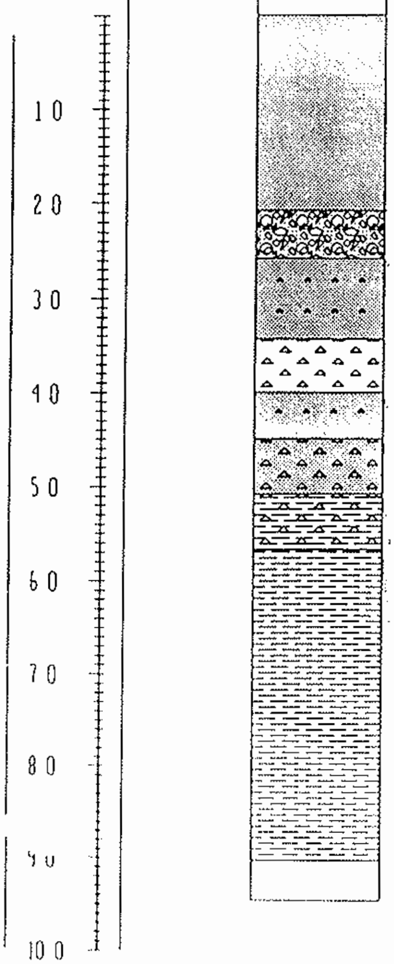
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 1242
PENETRATION LENGTH 10'
RECOVERY 9.58'
WATER DEPTH 29'
WEATHER clear, 65-70F
GPS-LAT 34 40'22.609"
GPS-LON 76 55'59.563"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 10 Nov 99
PAGE 1 OF 1

KEY

Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION



0-2 08 Tan, fine grained, well sorted Sand
Very fine shell debris throughout, reacts with HCl (SP) FX

2 08-2 58 Shell hash mixed with fine to coarse Sand and shell mix Shell fragments range from 1mm to 20mm (SW) CX SH

2 58-3 43 Very fine sand Gray in color
Moderate amount of small shell fragments (SW) FX SL

3 43-4 0 Fine to coarse grained Sand mixed with abundant shell fragments Shell fragments 1-3mm at 3 43-3 75, 1-30mm from 3 75-4 0' (SW) CS SH

4 0-4 50 Fine to medium Sand mixed with moderate amount of small shell fragments (1-10mm size) (SN) FX SL

4 50-5 08 Shell layer similar to 3 43 to 4 0' unit Fine to medium Sand mixed with abundant shell fragments of random size (SW) FX SH

5 08-5 67 Silty, Mud High amount of intact oyster shells
(OH) MU SH

5 67-9 0 Olive, soft Mud High water content, moldable Minor unidentifiable plant fragments present Some fine sand infilled burrows present Unit becomes silty down core (OH) MU

9 0-9 43 Fine grained well sorted Sand 3mm white carbonate lenses present Becomes finer with depth (SN) FX

ATHENA CORE LOG

CORE ID

ATH-19

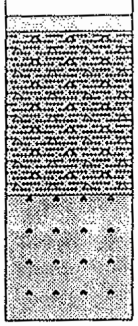
PROJECT Bogue Bank Sand Search
CLIENT CSE
CORE DATE 5 Nov 99
TIME 1355
PENETRATION LENGTH 6'
RECOVERY 3 33'
WATER DEPTH 43
WEATHER Clear 65F
GPS-LAT 34 40'19.9"
GPS-LON 76 59'59.9"

CORED BY ATHENA TECHNOLOGIES INC
LOGGER WJS/JNW
DATE LOGGED 8 Nov 99
PAGE 1 OF 1

KEY

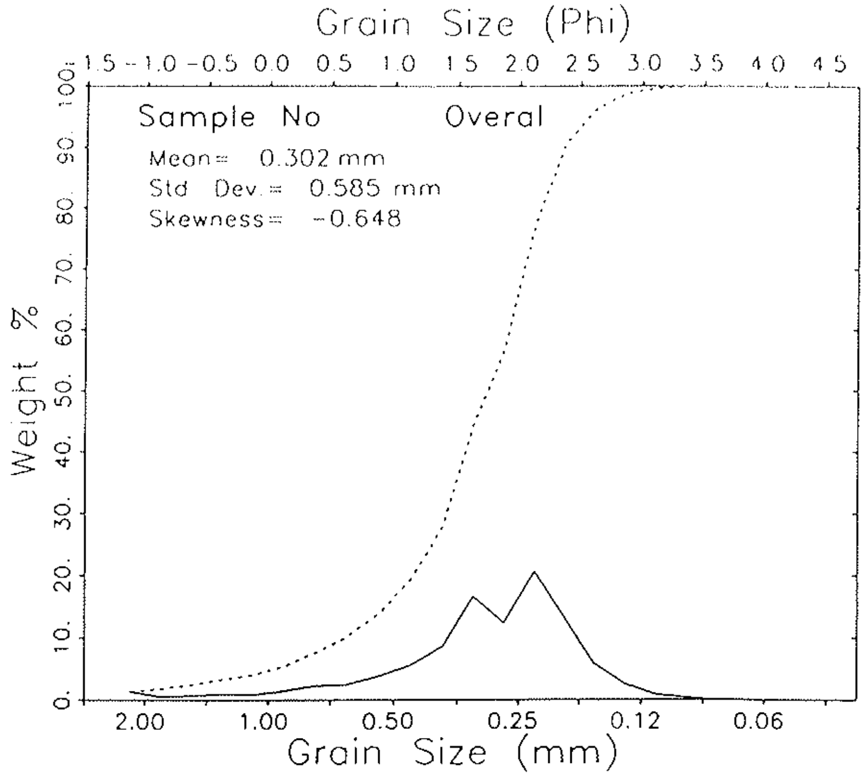
Fine Sand	Carbonate	Mud
Med Sand	Shell Hash	Peat
Crs Sand	Muddy Sand	Burrows

REC LENGTH IN FEET	SEDIMENT SAMPLED	SED PROFILE	LITHOLOGY DESCRIPTION
0 0			0-0 17 Fine well sorted Sand (SP)FX
1 0			0 17-1 93 Fine Sand and Mud mixed with abundant randomly sized shell fragments High water content, dark grey (SC)FX MU SH
2 0			1 93-3 25 Mud and water content decreases as does shell content Mostly Fx sand and silt (SC) FX SL
3 0			
4 0			
5 0			
6 0			
7 0			
8 0			
9 0			
10 0			



ANNEX E-3

Beach Composite Sediment Sample Results
Phase I Borrow Area Composites



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
A11Cmp	070699					
Bogue Banks - Overall Beach Composite -						
		-1.125	1.370	1.280	-1.000	1.280
		-.875	.470	.439	-.750	1.719
		-.625	.720	.673	-.500	2.392
		-.375	.910	.850	-.250	3.242
		-.125	.840	.785	.000	4.027
		.125	1.460	1.364	.250	5.391
		.375	2.350	2.196	.500	7.587
		.625	2.590	2.420	.750	10.007
		.875	3.970	3.709	1.000	13.716
		1.125	5.900	5.512	1.250	19.228
		1.375	9.080	8.484	1.500	27.712
		1.625	17.820	16.650	1.750	44.361
		1.875	13.240	12.370	2.000	56.732
		2.125	22.070	20.620	2.250	77.352
		2.375	14.190	13.258	2.500	90.610
		2.625	6.080	5.681	2.750	96.291
		2.875	2.650	2.476	3.000	98.767
		3.125	.900	.841	3.250	99.608
		3.375	.310	.290	3.500	99.897
		3.625	.100	.093	3.750	99.991
		3.875	.010	.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.030

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

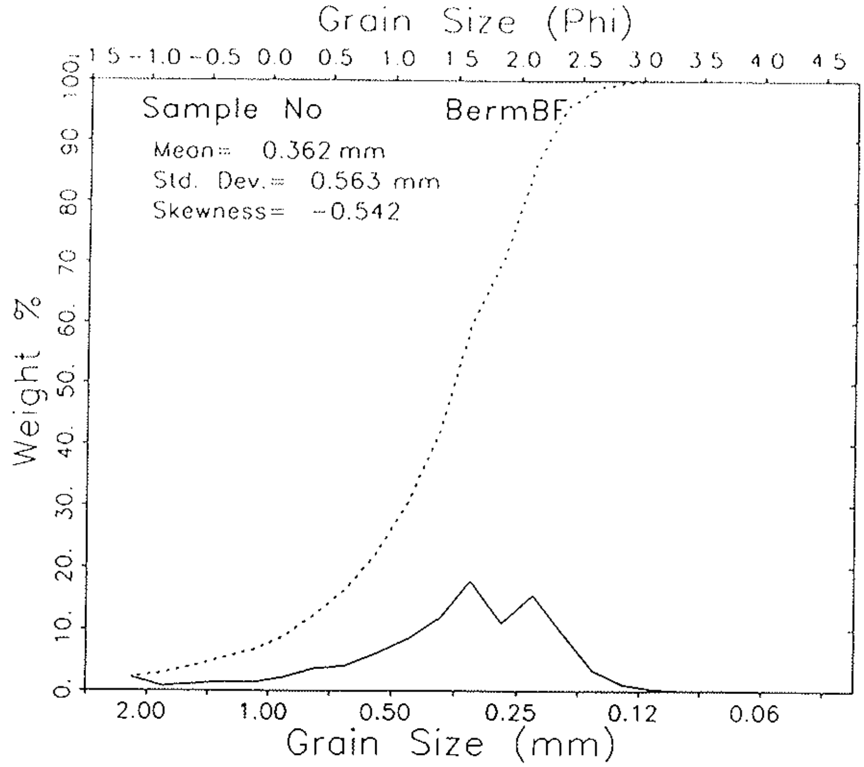
MEAN = 1.725 STANDARD DEVIATION = .773 SKEWNESS = -.648 KURTOSIS = 2.366

DISPERSION = .434 STANDARD DEVIATION = .657 DEVIATION FROM NORMAL DISTR. = -14.96%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.055	.178	1.104	1.420	1.864	2.221	2.375	2.693	3.069

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.739	1.781	MEDIUM SAND
STANDARD DEVIATION	.636	.699	MODERATELY WELL SORTED
SKEWNESS(1)	-.196	-.268	COARSE-SKEWED
SKEWNESS(2)	-.673		
KURTOSIS	.977	1.286	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BERMBF	070699					
Bogue Banks Berm & Beach Face Composite						
		-1.125	2.300	2.145	-1.000	2.145
		-.875	.770	.718	-.750	2.862
		-.625	1.160	1.082	-.500	3.944
		-.375	1.470	1.371	-.250	5.315
		-.125	1.360	1.268	.000	6.583
		.125	2.310	2.154	.250	8.737
		.375	3.820	3.562	.500	12.298
		.625	4.240	3.953	.750	16.252
		.875	6.370	5.939	1.000	22.191
		1.125	8.880	8.280	1.250	30.471
		1.375	12.480	11.636	1.500	42.107
		1.625	19.060	17.772	1.750	59.879
		1.875	11.780	10.984	2.000	70.862
		2.125	16.590	15.469	2.250	86.331
		2.375	9.820	9.156	2.500	95.487
		2.625	3.460	3.226	2.750	98.713
		2.875	1.000	.932	3.000	99.646
		3.125	.250	.233	3.250	99.879
		3.375	.090	.084	3.500	99.963
		3.625	.030	.028	3.750	99.991
		3.875	.010	.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.250

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

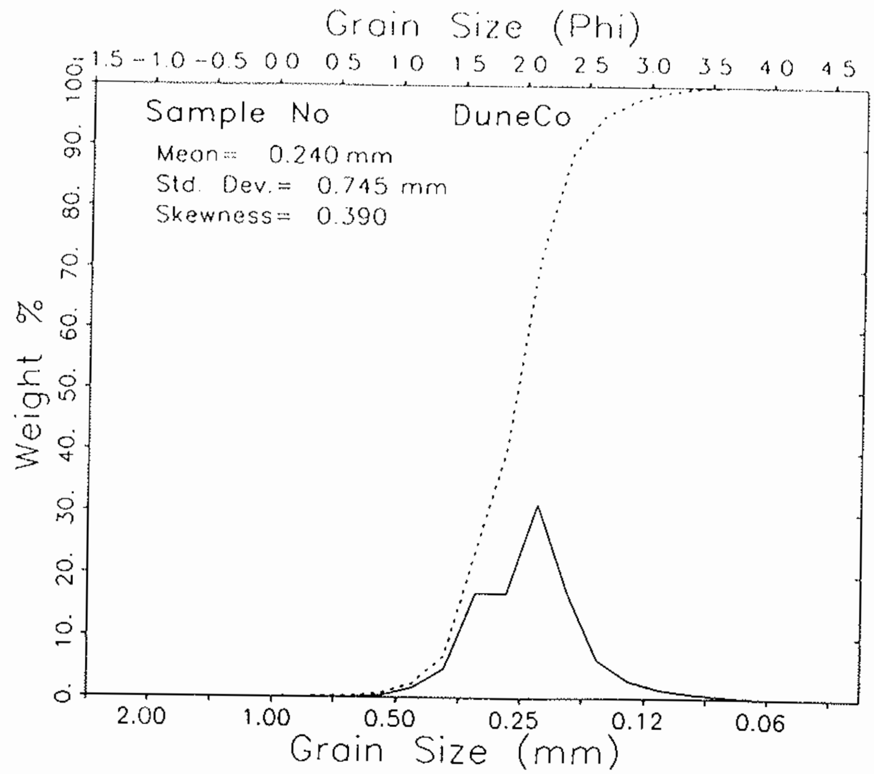
MOMENT MEASURES:

MEAN = 1.466 STANDARD DEVIATION = .830 SKEWNESS = -.542 KURTOSIS = 1.227
DISPERSION = .470 STANDARD DEVIATION = .715 DEVIATION FROM NORMAL DISTR. = -13.87%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.133	-.307	.734	1.085	1.611	2.067	2.212	2.487	2.827

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.473	1.519	MEDIUM SAND
STANDARD DEVIATION	.739	.793	MODERATELY SORTED
SKEWNESS(1)	-.186	-.280	COARSE-SKEWED
SKEWNESS(2)	-.705		
KURTOSIS	.890	1.166	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Dune-C	070699					
Bogue Banks - Dune Composite BB30 & BB90						
		-1.125	.000	.000	-1.000	.000
		-.875	.010	.010	-.750	.010
		-.625	.020	.020	-.500	.029
		-.375	.020	.020	-.250	.049
		-.125	.010	.010	.000	.059
		.125	.050	.049	.250	.108
		.375	.110	.108	.500	.216
		.625	.140	.137	.750	.353
		.875	.350	.343	1.000	.696
		1.125	1.550	1.519	1.250	2.214
		1.375	4.620	4.526	1.500	6.740
		1.625	17.260	16.910	1.750	23.650
		1.875	17.140	16.792	2.000	40.443
		2.125	31.940	31.292	2.250	71.735
		2.375	17.310	16.959	2.500	88.694
		2.625	6.290	6.162	2.750	94.856
		2.875	2.820	2.763	3.000	97.619
		3.125	1.390	1.362	3.250	98.981
		3.375	.740	.725	3.500	99.706
		3.625	.270	.265	3.750	99.971
		3.875	.030	.029	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.070

PERCENT FINER THAN 4.00 PHI = .01 PERCENT COARSER THAN -1.00 PHI = .00

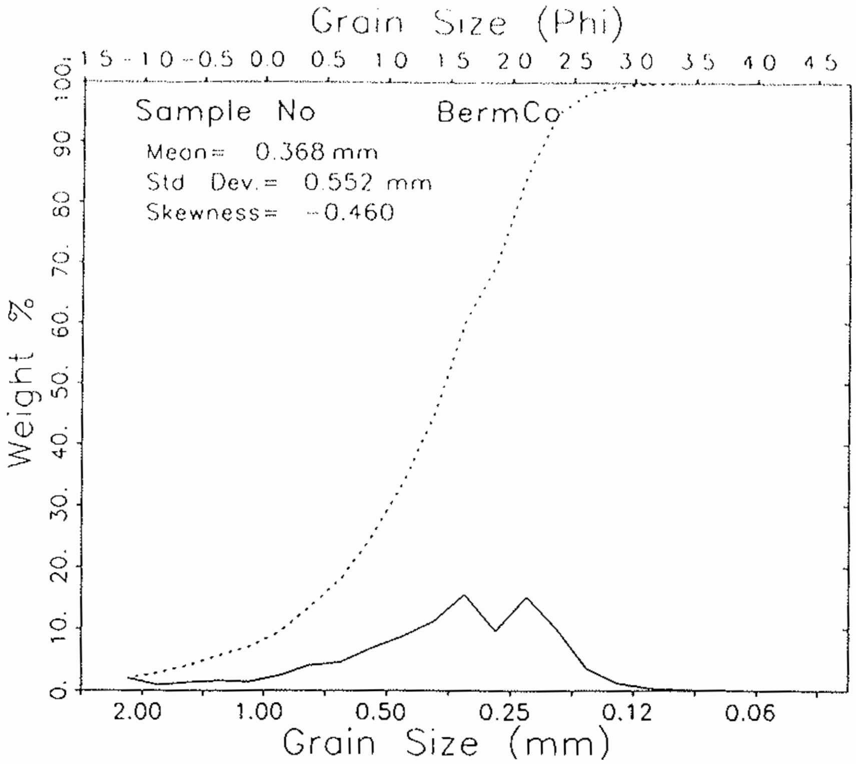
MOMENT MEASURES:

MEAN = 2.060 STANDARD DEVIATION = .425 SKEWNESS = .039 KURTOSIS = 1.952
DISPERSION = .221 STANDARD DEVIATION = .403 DEVIATION FROM NORMAL DISTR. = -5.10%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.050	1.404	1.637	1.770	2.076	2.298	2.431	2.763	3.257

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.034	2.048	FINE SAND
STANDARD DEVIATION	.397	.404	WELL SORTED
SKEWNESS(1)	-.107	-.048	NEAR SYMMETRICAL
SKEWNESS(2)	.018		
KURTOSIS	.712	1.055	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Berm C	070699						
Bogue Banks - Berm Composite - 6 Station							
		-1.125	2.070		1.962	-1.000	1.962
		-.875	.900		.853	-.750	2.815
		-.625	1.330		1.261	-.500	4.076
		-.375	1.620		1.536	-.250	5.612
		-.125	1.500		1.422	.000	7.034
		.125	2.520		2.389	.250	9.423
		.375	4.280		4.057	.500	13.480
		.625	4.800		4.550	.750	18.030
		.875	7.220		6.844	1.000	24.874
		1.125	9.160		8.683	1.250	33.558
		1.375	11.640		11.034	1.500	44.592
		1.625	16.410		15.556	1.750	60.148
		1.875	10.130		9.603	2.000	69.751
		2.125	16.000		15.167	2.250	84.918
		2.375	10.430		9.887	2.500	94.805
		2.625	3.640		3.451	2.750	98.256
		2.875	1.210		1.147	3.000	99.403
		3.125	.400		.379	3.250	99.782
		3.375	.160		.152	3.500	99.934
		3.625	.060		.057	3.750	99.991
		3.875	.010		.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.490

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

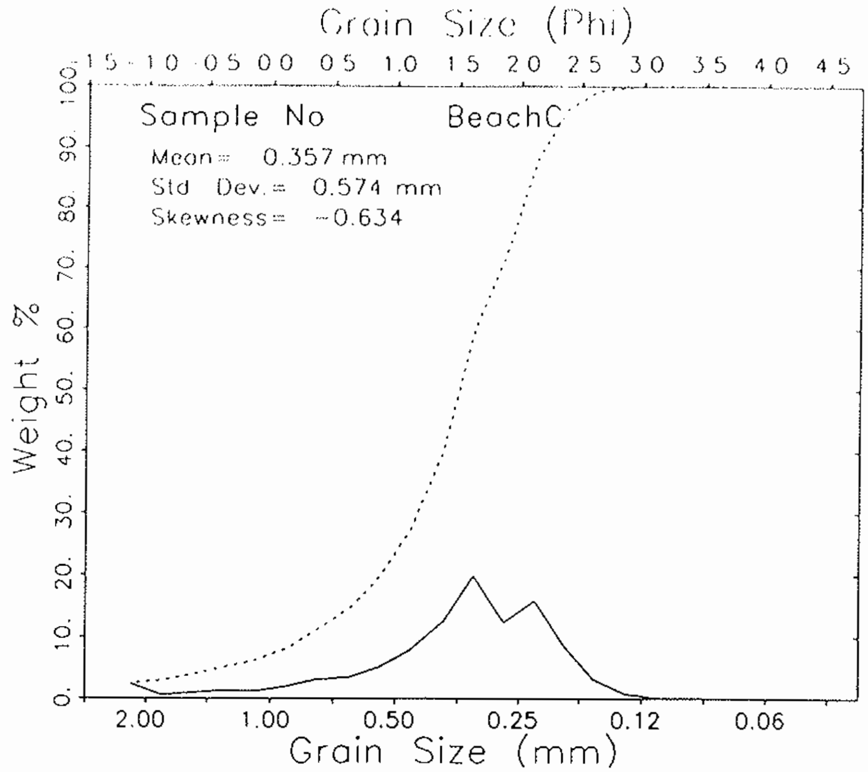
MOMENT MEASURES:

MEAN = 1.444 STANDARD DEVIATION = .858 SKEWNESS = -.460 KURTOSIS = .760
DISPERSION = .496 STANDARD DEVIATION = .759 DEVIATION FROM NORMAL DISTR. = -11.52%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.123	-.350	.638	1.004	1.587	2.087	2.235	2.514	2.912

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.437	1.487	MEDIUM SAND
STANDARD DEVIATION	.798	.833	MODERATELY SORTED
SKEWNESS(1)	-.188	-.270	COARSE-SKEWED
SKEWNESS(2)	-.632		
KURTOSIS	.794	1.084	MESOKURTIC



SAMPLE NO. DATE

BFComp 070699

Bogue Banks - Beach Face Composite - 6 S

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	2.540	2.330	-1.000	2.330
-.875	.630	.578	-.750	2.908
-.625	.990	.908	-.500	3.816
-.375	1.320	1.211	-.250	5.027
-.125	1.220	1.119	.000	6.146
.125	2.090	1.917	.250	8.063
.375	3.360	3.082	.500	11.146
.625	3.690	3.385	.750	14.531
.875	5.530	5.073	1.000	19.604
1.125	8.590	7.880	1.250	27.484
1.375	13.320	12.219	1.500	39.703
1.625	21.720	19.925	1.750	59.628
1.875	13.430	12.320	2.000	71.948
2.125	17.190	15.769	2.250	87.717
2.375	9.210	8.449	2.500	96.165
2.625	3.270	3.000	2.750	99.165
2.875	.780	.716	3.000	99.881
3.125	.100	.092	3.250	99.972
3.375	.020	.018	3.500	99.991
3.625	.000	.000	3.750	99.991
3.875	.010	.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.010

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

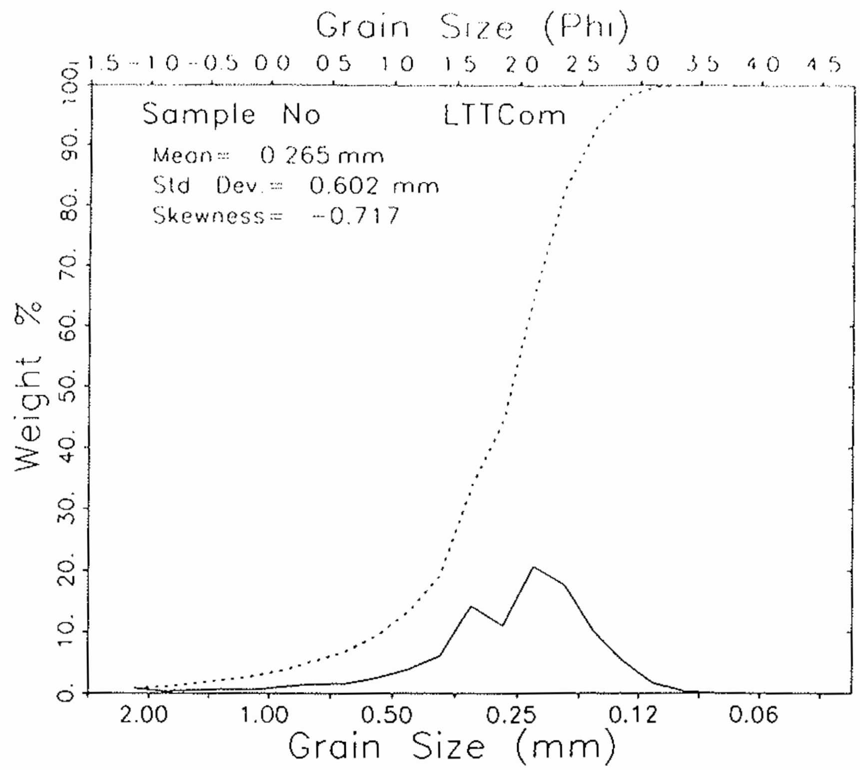
MEAN = 1.487 STANDARD DEVIATION = .801 SKEWNESS = -.634 KURTOSIS = 1.798

DISPERSION = .440 STANDARD DEVIATION = .666 DEVIATION FROM NORMAL DISTR. = -16.88%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.143	-.256	.822	1.171	1.629	2.048	2.191	2.466	2.736

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.507	1.548	MEDIUM SAND
STANDARD DEVIATION	.684	.754	MODERATELY SORTED
SKEWNESS(1)	-.179	-.202	COARSE-SKEWED
SKEWNESS(2)	-.766		
KURTOSIS	.988	1.271	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
LTTCmp	070699						
Bogue Banks - Low Tide Terrace - 6 Stati							
		-1.125	.870		.780	-1.000	.780
		-.875	.330		.296	-.750	1.075
		-.625	.560		.502	-.500	1.577
		-.375	.680		.609	-.250	2.187
		-.125	.650		.582	.000	2.769
		.125	1.170		1.048	.250	3.818
		.375	1.650		1.479	.500	5.296
		.625	1.720		1.541	.750	6.838
		.875	2.780		2.491	1.000	9.329
		1.125	4.300		3.853	1.250	13.182
		1.375	6.730		6.031	1.500	19.213
		1.625	15.910		14.258	1.750	33.471
		1.875	12.260		10.987	2.000	44.457
		2.125	23.170		20.764	2.250	65.221
		2.375	19.820		17.761	2.500	82.982
		2.625	11.110		9.956	2.750	92.938
		2.875	5.780		5.180	3.000	98.118
		3.125	1.690		1.514	3.250	99.633
		3.375	.320		.287	3.500	99.919
		3.625	.080		.072	3.750	99.991
		3.875	.010		.009	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.590

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

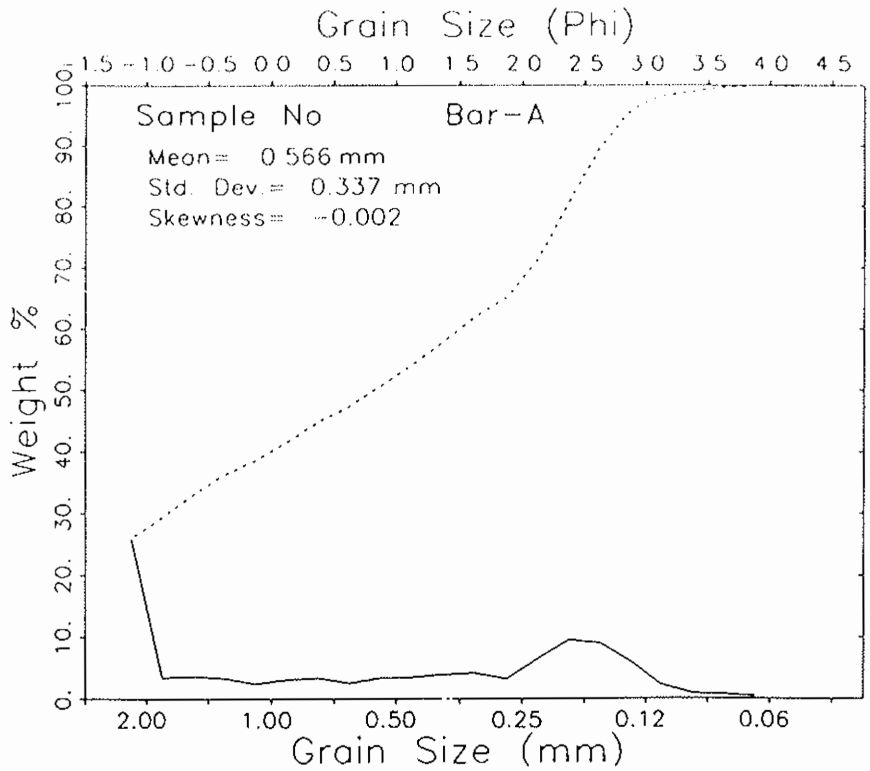
MOMENT MEASURES:

MEAN = 1.918 STANDARD DEVIATION = .731 SKEWNESS = -.717 KURTOSIS = 3.112
DISPERSION = .409 STANDARD DEVIATION = .620 DEVIATION FROM NORMAL DISTR. = -15.19%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.814	.450	1.367	1.601	2.067	2.388	2.526	2.850	3.146

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.946	1.986	MEDIUM SAND
STANDARD DEVIATION	.579	.653	MODERATELY WELL SORTED
SKEWNESS(1)	-.200	-.278	COARSE-SKEWED
SKEWNESS(2)	-.720		
KURTOSIS	1.071	1.251	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bor-A	070699					
Bogue Banks - Borrow Area A						
		-1.125	27.420	25.856	-1.000	25.856
		-.875	3.610	3.404	-.750	29.260
		-.625	3.810	3.593	-.500	32.852
		-.375	3.520	3.319	-.250	36.172
		-.125	2.520	2.376	.000	38.548
		.125	3.230	3.046	.250	41.594
		.375	3.460	3.263	.500	44.856
		.625	2.580	2.433	.750	47.289
		.875	3.490	3.291	1.000	50.580
		1.125	3.630	3.423	1.250	54.003
		1.375	4.120	3.885	1.500	57.888
		1.625	4.310	4.064	1.750	61.952
		1.875	3.370	3.178	2.000	65.130
		2.125	6.830	6.440	2.250	71.570
		2.375	10.010	9.439	2.500	81.009
		2.625	9.490	8.949	2.750	89.958
		2.875	6.350	5.988	3.000	95.945
		3.125	2.350	2.216	3.250	98.161
		3.375	.850	.802	3.500	98.963
		3.625	.680	.641	3.750	99.604
		3.875	.420	.396	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.050

PERCENT FINER THAN 4.00 PHI = 1.20 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

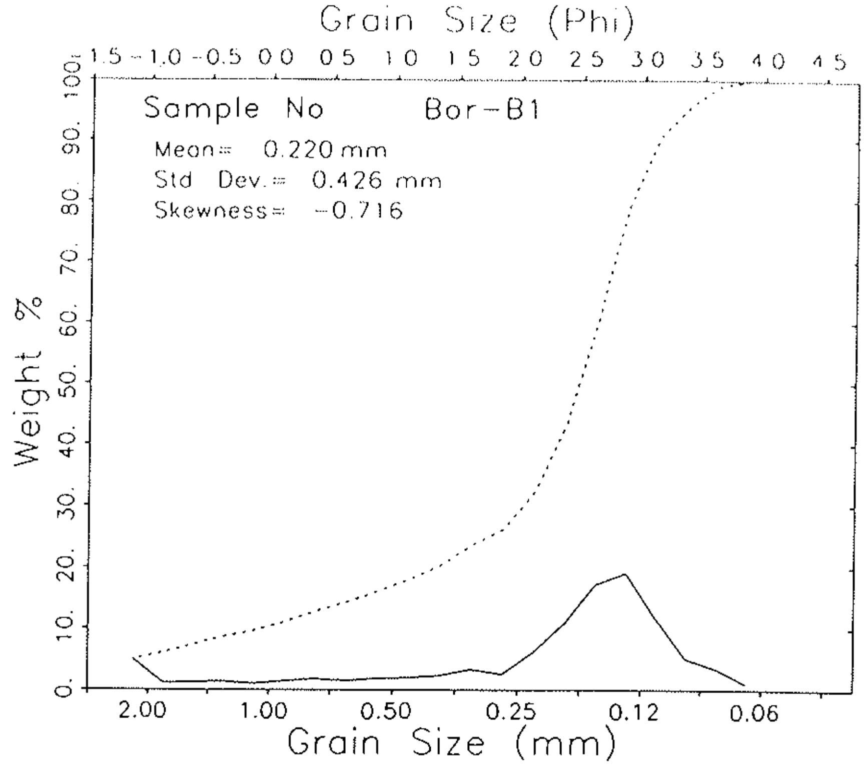
MEAN = .822 STANDARD DEVIATION = 1.568 SKEWNESS = -.002 KURTOSIS = -1.551

DISPERSION = .549 STANDARD DEVIATION = .856 DEVIATION FROM NORMAL DISTR. = -45.40%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.202	-1.095	-1.008	.956	2.341	2.584	2.961	3.515

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.744	.815	COARSE SAND
STANDARD DEVIATION	1.839	1.550	POORLY SORTED
SKEWNESS(1)	-.115	-.076	NEAR SYMMETRICAL
SKEWNESS(2)	-.042		
KURTOSIS	.131	.509	VERY PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bor-B1	070699					
Bogue Banks - Borrow Area B1						
		-1.125	5.050	4.952	-1.000	4.952
		-.875	1.130	1.108	-.750	6.060
		-.625	1.270	1.245	-.500	7.305
		-.375	1.310	1.285	-.250	8.590
		-.125	.950	.932	.000	9.521
		.125	1.440	1.412	.250	10.934
		.375	1.750	1.716	.500	12.650
		.625	1.540	1.510	.750	14.160
		.875	1.840	1.804	1.000	15.964
		1.125	1.990	1.951	1.250	17.915
		1.375	2.370	2.324	1.500	20.239
		1.625	3.330	3.265	1.750	23.505
		1.875	2.640	2.589	2.000	26.093
		2.125	6.240	6.119	2.250	32.212
		2.375	10.900	10.688	2.500	42.901
		2.625	17.500	17.160	2.750	60.061
		2.875	19.330	18.955	3.000	79.015
		3.125	11.720	11.492	3.250	90.508
		3.375	5.170	5.070	3.500	95.578
		3.625	3.520	3.452	3.750	99.029
		3.875	.990	.971	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.980

PERCENT FINER THAN 4.00 PHI = 1.71 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

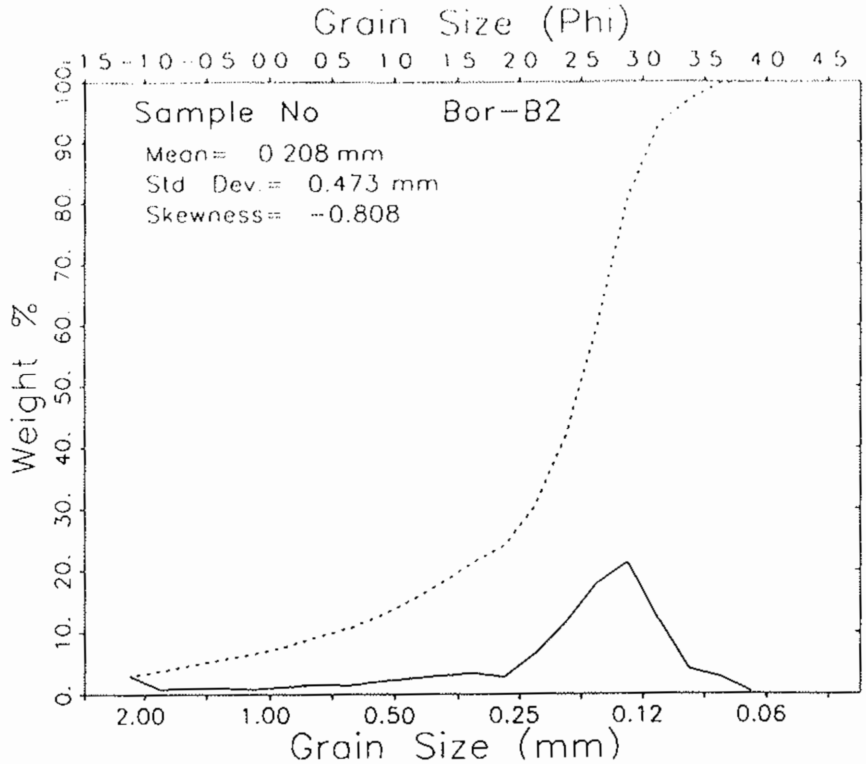
MEAN = 2.182 STANDARD DEVIATION = 1.230 SKEWNESS = -.716 KURTOSIS = 1.181

DISPERSION = .517 STANDARD DEVIATION = .797 DEVIATION FROM NORMAL DISTR. = -35.23%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.200	-.989	1.005	1.894	2.603	2.947	3.108	3.472	3.748

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.057	2.239	FINE SAND
STANDARD DEVIATION	1.052	1.202	POORLY SORTED
SKEWNESS(1)	-.520	-.565	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.295		
KURTOSIS	1.120	1.737	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bor-B2	070699					
Bogue Banks - Borrow Area B2						
		-1.125	3.110	2.979	-1.000	2.979
		-.875	.800	.766	-.750	3.746
		-.625	.970	.929	-.500	4.675
		-.375	1.020	.977	-.250	5.652
		-.125	.840	.805	.000	6.457
		.125	1.210	1.159	.250	7.616
		.375	1.600	1.533	.500	9.149
		.625	1.470	1.408	.750	10.558
		.875	2.100	2.012	1.000	12.569
		1.125	2.570	2.462	1.250	15.032
		1.375	3.070	2.941	1.500	17.973
		1.625	3.450	3.305	1.750	21.278
		1.875	2.820	2.702	2.000	23.980
		2.125	6.750	6.467	2.250	30.446
		2.375	12.150	11.640	2.500	42.087
		2.625	18.550	17.772	2.750	59.858
		2.875	22.060	21.134	3.000	80.993
		3.125	12.510	11.985	3.250	92.978
		3.375	4.140	3.966	3.500	96.944
		3.625	2.880	2.759	3.750	99.703
		3.875	.310	.297	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.380

PERCENT FINER THAN 4.00 PHI = .63 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

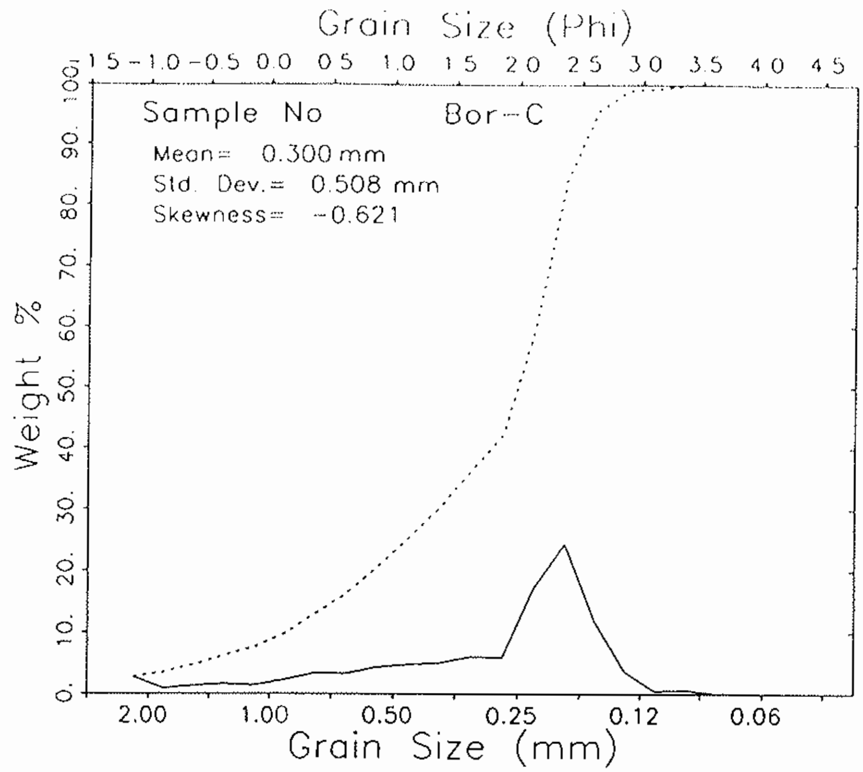
MEAN = 2.263 STANDARD DEVIATION = 1.081 SKEWNESS = -.808 KURTOSIS = 2.137

DISPERSION = .480 STANDARD DEVIATION = .730 DEVIATION FROM NORMAL DISTR. = -32.44%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.166	-.417	1.332	2.039	2.611	2.929	3.063	3.377	3.686

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.198	2.335	FINE SAND
STANDARD DEVIATION	.865	1.008	POORLY SORTED
SKEWNESS(1)	-.478	-.537	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.307		
KURTOSIS	1.193	1.748	VERY LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Bor-C	070699					
Bogue Inlet Shoal						
		-1.125	2.800	2.616	-1.000	2.616
		-.875	.850	.794	-.750	3.410
		-.625	1.300	1.214	-.500	4.624
		-.375	1.630	1.523	-.250	6.147
		-.125	1.420	1.327	.000	7.474
		.125	2.400	2.242	.250	9.716
		.375	3.550	3.317	.500	13.033
		.625	3.450	3.223	.750	16.256
		.875	4.650	4.344	1.000	20.600
		1.125	5.040	4.709	1.250	25.308
		1.375	5.330	4.979	1.500	30.288
		1.625	6.430	6.007	1.750	36.295
		1.875	6.320	5.904	2.000	42.199
		2.125	18.470	17.255	2.250	59.454
		2.375	26.150	24.430	2.500	83.885
		2.625	12.330	11.519	2.750	95.404
		2.875	3.790	3.541	3.000	98.944
		3.125	.430	.402	3.250	99.346
		3.375	.600	.561	3.500	99.907
		3.625	.100	.093	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.040

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

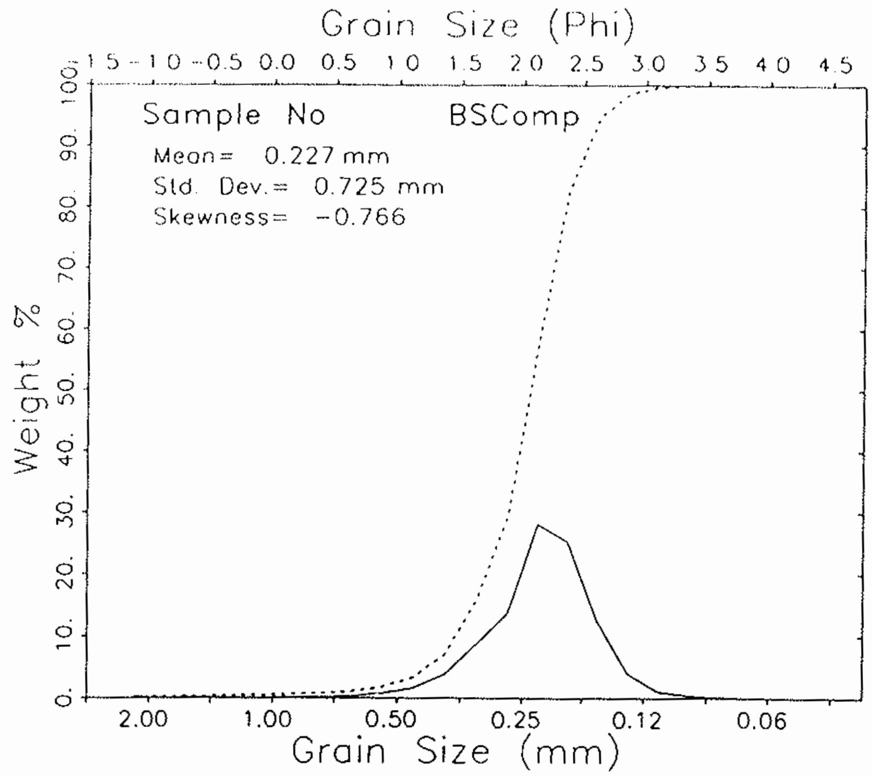
MEAN = 1.738 STANDARD DEVIATION = .978 SKEWNESS = -.621 KURTOSIS = .890

DISPERSION = .464 STANDARD DEVIATION = .705 DEVIATION FROM NORMAL DISTR. = -27.95%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.154	-.438	.730	1.234	2.113	2.409	2.503	2.741	3.035

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.616	1.782	MEDIUM SAND
STANDARD DEVIATION	.886	.925	MODERATELY SORTED
SKEWNESS(1)	-.560	-.583	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.085		
KURTOSIS	.794	1.109	MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BSComp	070699					
Bogue Sound - 3 Samples						
		-1.125	.150	.140	-1.000	.140
		-.875	.070	.065	-.750	.205
		-.625	.120	.112	-.500	.317
		-.375	.080	.075	-.250	.391
		-.125	.080	.075	.000	.466
		.125	.140	.130	.250	.596
		.375	.190	.177	.500	.773
		.625	.280	.261	.750	1.034
		.875	.760	.708	1.000	1.742
		1.125	1.630	1.519	1.250	3.261
		1.375	3.960	3.690	1.500	6.951
		1.625	9.260	8.628	1.750	15.580
		1.875	14.680	13.679	2.000	29.258
		2.125	30.150	28.094	2.250	57.352
		2.375	27.100	25.252	2.500	82.603
		2.625	13.100	12.206	2.750	94.810
		2.875	4.170	3.886	3.000	98.695
		3.125	1.030	.960	3.250	99.655
		3.375	.290	.270	3.500	99.925
		3.625	.080	.075	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.320

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

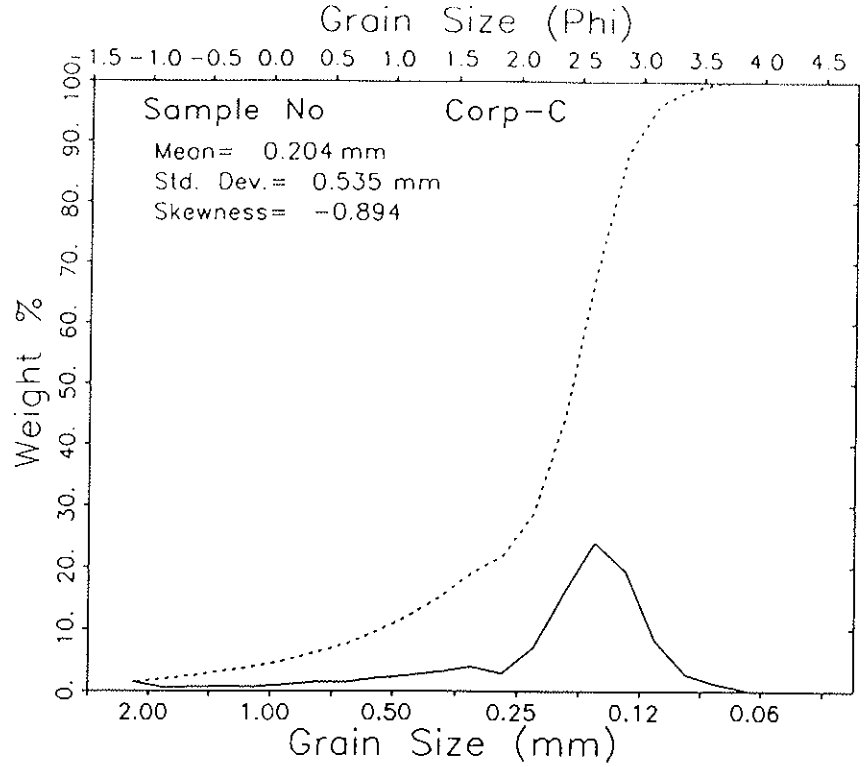
MOMENT MEASURES:

MEAN = 2.141 STANDARD DEVIATION = .463 SKEWNESS = -.766 KURTOSIS = 7.247
DISPERSION = .234 STANDARD DEVIATION = .415 DEVIATION FROM NORMAL DISTR. = -10.50%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.717	1.368	1.758	1.922	2.185	2.425	2.529	2.762	3.079

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.143	2.157	FINE SAND
STANDARD DEVIATION	.385	.404	WELL SORTED
SKEWNESS(1)	-.107	-.139	COARSE-SKEWED
SKEWNESS(2)	-.310		
KURTOSIS	.809	1.137	LEPTOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
CorpC	070699					
Corps Disposal Area - Eastern Bogue Bank						
		-1.125	1.430	1.368	-1.000	1.368
		-.875	.500	.478	-.750	1.847
		-.625	.660	.631	-.500	2.478
		-.375	.760	.727	-.250	3.205
		-.125	.690	.660	.000	3.865
		.125	1.010	.966	.250	4.832
		.375	1.420	1.359	.500	6.190
		.625	1.430	1.368	.750	7.558
		.875	2.160	2.067	1.000	9.625
		1.125	2.560	2.449	1.250	12.074
		1.375	3.200	3.062	1.500	15.136
		1.625	4.030	3.856	1.750	18.992
		1.875	2.940	2.813	2.000	21.804
		2.125	7.190	6.879	2.250	28.684
		2.375	16.590	15.873	2.500	44.556
		2.625	25.030	23.948	2.750	68.504
		2.875	20.380	19.499	3.000	88.002
		3.125	8.370	8.008	3.250	96.010
		3.375	2.790	2.669	3.500	98.680
		3.625	1.200	1.148	3.750	99.828
		3.875	.180	.172	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.520

PERCENT FINER THAN 4.00 PHI = .24 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

MEAN = 2.292 STANDARD DEVIATION = .903 SKEWNESS = -.894 KURTOSIS = 3.329
DISPERSION = .418 STANDARD DEVIATION = .634 DEVIATION FROM NORMAL DISTR. = -29.79%

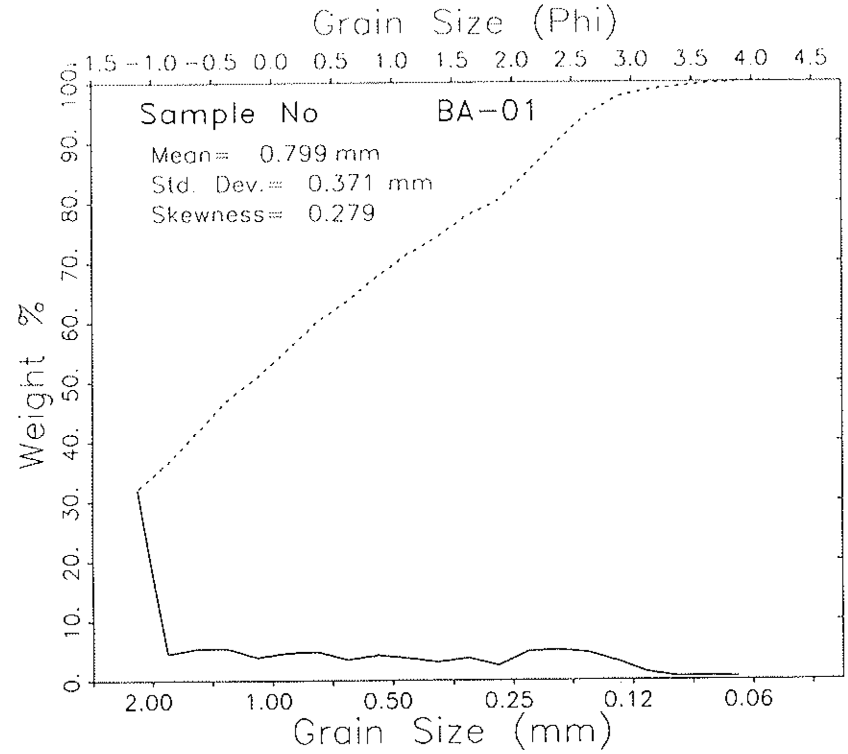
PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.067	.281	1.556	2.116	2.557	2.833	2.949	3.218	3.570

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.252	2.354	FINE SAND
STANDARD DEVIATION	.696	.793	MODERATELY SORTED
SKEWNESS(1)	-.437	-.493	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.159		
KURTOSIS	1.109	1.679	VERY LEPTOKURTIC

ANNEX E-3
Part 3

Phase III — November 2000-March 2001
Sediment Sample Results



1 SAMPLE NO. DATE

BA-01 140101

Bogue Banks Borrow Area A

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	30.010	31.902	-1.000	31.902
-.875	4.140	4.401	-.750	36.303
-.625	4.990	5.305	-.500	41.607
-.375	5.010	5.326	-.250	46.933
-.125	3.610	3.838	.000	50.771
.125	4.260	4.529	.250	55.299
.375	4.460	4.741	.500	60.040
.625	3.160	3.359	.750	63.400
.875	3.900	4.146	1.000	67.545
1.125	3.390	3.604	1.250	71.149
1.375	2.810	2.987	1.500	74.136
1.625	3.430	3.646	1.750	77.783
1.875	2.250	2.392	2.000	80.174
2.125	4.410	4.688	2.250	84.862
2.375	4.700	4.996	2.500	89.859
2.625	4.270	4.539	2.750	94.398
2.875	2.850	3.030	3.000	97.427
3.125	1.120	1.191	3.250	98.618
3.375	.460	.489	3.500	99.107
3.625	.500	.532	3.750	99.639
3.875	.340	.361	4.000	100.000

TOTAL WEIGHT (GRAMS) = 94.070

PERCENT FINER THAN 4.00 PHI = .72 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = .323 STANDARD DEVIATION = 1.432 SKEWNESS = .279 KURTOSIS = -1.058

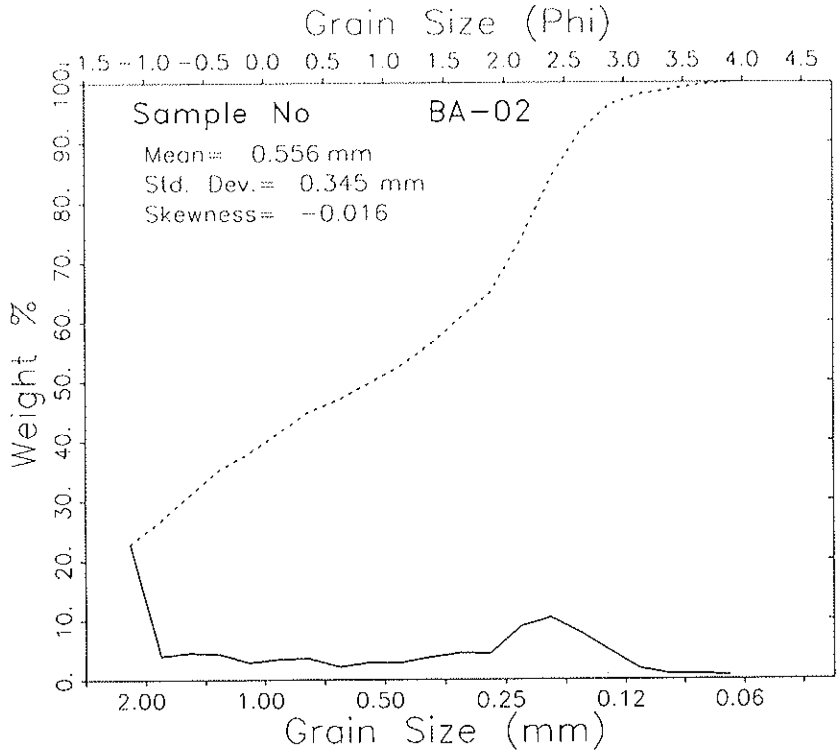
0 DISPERSION = .514 STANDARD DEVIATION = .791 DEVIATION FROM NORMAL DISTR. = -44.75%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.242	-1.211	-1.125	-1.054	-.050	1.559	2.204	2.800	3.445

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.540	.343	COARSE SAND
STANDARD DEVIATION	1.664	1.440	POORLY SORTED
SKEWNESS(1)	.354	.388	STRONGLY FINE-SKEWED
SKEWNESS(2)	.508		
KURTOSIS	.205	.629	VERY PLATYKURTIC



1 SAMPLE NO. DATE

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT

BA-02 140101
Bogue Banks Borrow Area A

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	22.930	22.674	-1.000	22.674
-.875	3.900	3.856	-.750	26.530
-.625	4.490	4.440	-.500	30.970
-.375	4.280	4.232	-.250	35.202
-.125	2.810	2.779	.000	37.981
.125	3.420	3.382	.250	41.363
.375	3.550	3.510	.500	44.873
.625	2.090	2.067	.750	46.940
.875	2.810	2.779	1.000	49.718
1.125	2.730	2.699	1.250	52.418
1.375	3.670	3.629	1.500	56.047
1.625	4.420	4.371	1.750	60.417
1.875	4.340	4.292	2.000	64.709
2.125	8.930	8.830	2.250	73.539
2.375	10.450	10.333	2.500	83.872
2.625	7.810	7.723	2.750	91.595
2.875	4.650	4.598	3.000	96.193
3.125	1.770	1.750	3.250	97.943
3.375	.780	.771	3.500	98.715
3.625	.780	.771	3.750	99.486
3.875	.520	.514	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.130

PERCENT FINER THAN 4.00 PHI = .78 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

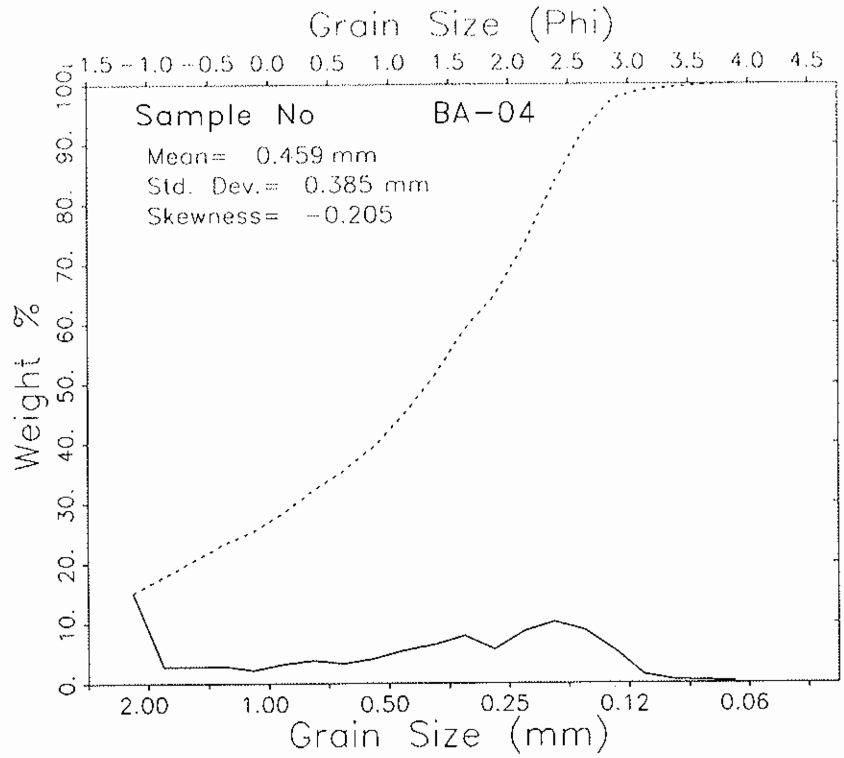
MEAN = .847 STANDARD DEVIATION = 1.535 SKEWNESS = -.016 KURTOSIS = -1.525

0 DISPERSION = .569 STANDARD DEVIATION = .897 DEVIATION FROM NORMAL DISTR. = -41.58%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.195	-1.074	-.849	1.026	2.285	2.504	2.935	3.593

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.715	.819	COARSE SAND
STANDARD DEVIATION	1.789	1.520	POORLY SORTED
SKEWNESS(1)	-.174	-.125	COARSE-SKEWED
SKEWNESS(2)	-.087		
KURTOSIS	.154	.540	VERY PLATYKURTIC



1 SAMPLE NO. DATE

BA-04 140101

Bogue Banks Borrow Area A

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	15.520	15.005	-1.000	15.005
-.875	2.780	2.688	-.750	17.693
-.625	2.820	2.726	-.500	20.420
-.375	2.860	2.765	-.250	23.185
-.125	2.200	2.127	.000	25.312
.125	3.220	3.113	.250	28.425
.375	3.870	3.742	.500	32.167
.625	3.350	3.239	.750	35.406
.875	4.200	4.061	1.000	39.466
1.125	5.590	5.405	1.250	44.871
1.375	6.490	6.275	1.500	51.146
1.625	8.040	7.773	1.750	58.919
1.875	5.720	5.530	2.000	64.449
2.125	8.890	8.595	2.250	73.045
2.375	10.520	10.171	2.500	83.216
2.625	9.100	8.798	2.750	92.014
2.875	5.700	5.511	3.000	97.525
3.125	1.410	1.363	3.250	98.888
3.375	.520	.503	3.500	99.391
3.625	.400	.387	3.750	99.778
3.875	.230	.222	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.430

PERCENT FINER THAN 4.00 PHI = .39 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

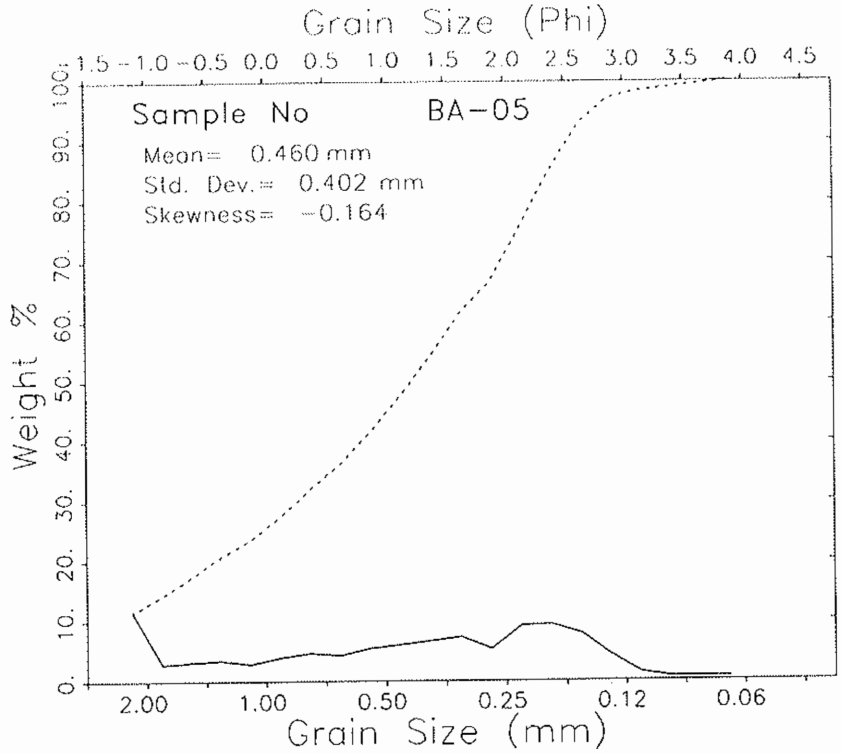
\+ MEAN = 1.124 STANDARD DEVIATION = 1.377 SKEWNESS = -.205 KURTOSIS = -1.133

0 DISPERSION = .597 STANDARD DEVIATION = .956 DEVIATION FROM NORMAL DISTR. = -30.55%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.233	-1.167	-.907	-.037	1.454	2.298	2.522	2.885	3.306

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.807	1.023	MEDIUM SAND
STANDARD DEVIATION	1.715	1.471	POORLY SORTED
SKEWNESS(1)	-.377	-.335	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.347		
KURTOSIS	.181	.711	PLATYKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BA-05	140101					
Bogue Banks Borrow Area A						
		-1.125	13.050	11.490	-1.000	11.490
		-.875	3.060	2.694	-.750	14.184
		-.625	3.580	3.152	-.500	17.336
		-.375	3.810	3.354	-.250	20.690
		-.125	3.230	2.844	.000	23.534
		.125	4.440	3.909	.250	27.443
		.375	5.180	4.561	.500	32.004
		.625	4.780	4.208	.750	36.212
		.875	6.140	5.406	1.000	41.618
		1.125	6.820	6.005	1.250	47.623
		1.375	7.400	6.515	1.500	54.138
		1.625	8.180	7.202	1.750	61.340
		1.875	5.960	5.247	2.000	66.587
		2.125	10.360	9.121	2.250	75.709
		2.375	10.610	9.341	2.500	85.050
		2.625	8.860	7.801	2.750	92.851
		2.875	4.800	4.226	3.000	97.077
		3.125	1.450	1.277	3.250	98.354
		3.375	.630	.555	3.500	98.908
		3.625	.660	.581	3.750	99.489
		3.875	.580	.511	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.580

PERCENT FINER THAN 4.00 PHI = 1.16 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

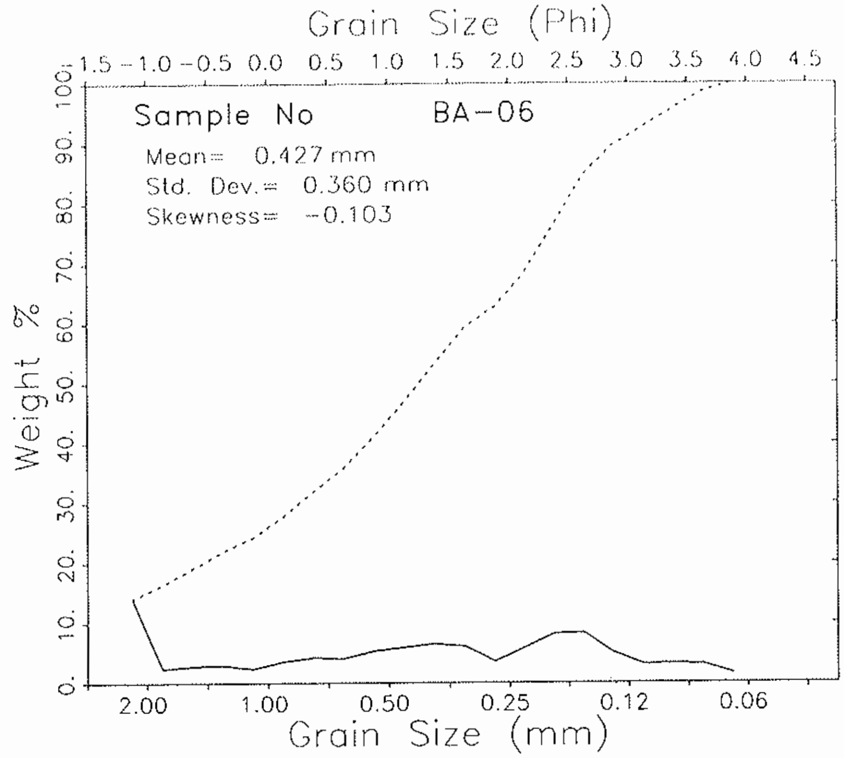
\+ MEAN = 1.121 STANDARD DEVIATION = 1.316 SKEWNESS = -.164 KURTOSIS = -1.017

0 DISPERSION = .629 STANDARD DEVIATION = 1.029 DEVIATION FROM NORMAL DISTR. = -21.84%

0 PERCENTILES:

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.228	-1.141	-.606	.094	1.341	2.231	2.472	2.877	3.539

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0 / + / 0	MEAN	.933	1.069	
+				MEDIUM SAND
0	STANDARD DEVIATION	1.539	1.378	
+				POORLY SORTED
0	SKEWNESS(1)	-.265	-.250	
+				COARSE-SKEWED
0	SKEWNESS(2)	-.308		
0	KURTOSIS	.306	.771	
+				PLATYKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BA-06	140101					
Bogue Banks Borrow Area A						
		-1.125	13.820	13.968	-1.000	13.968
		-.875	2.300	2.325	-.750	16.293
		-.625	2.700	2.729	-.500	19.022
		-.375	2.840	2.870	-.250	21.892
		-.125	2.270	2.294	.000	24.186
		.125	3.410	3.447	.250	27.633
		.375	4.120	4.164	.500	31.797
		.625	3.920	3.962	.750	35.759
		.875	5.160	5.215	1.000	40.974
		1.125	5.770	5.832	1.250	46.806
		1.375	6.330	6.398	1.500	53.204
		1.625	5.910	5.973	1.750	59.177
		1.875	3.430	3.467	2.000	62.644
		2.125	5.680	5.741	2.250	68.385
		2.375	7.950	8.035	2.500	76.420
		2.625	8.160	8.247	2.750	84.667
		2.875	4.830	4.882	3.000	89.549
		3.125	2.920	2.951	3.250	92.501
		3.375	3.050	3.083	3.500	95.583
		3.625	2.920	2.951	3.750	98.534
		3.875	1.450	1.466	4.000	100.000

TOTAL WEIGHT (GRAMS) = 98.940

PERCENT FINER THAN 4.00 PHI = 2.22 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

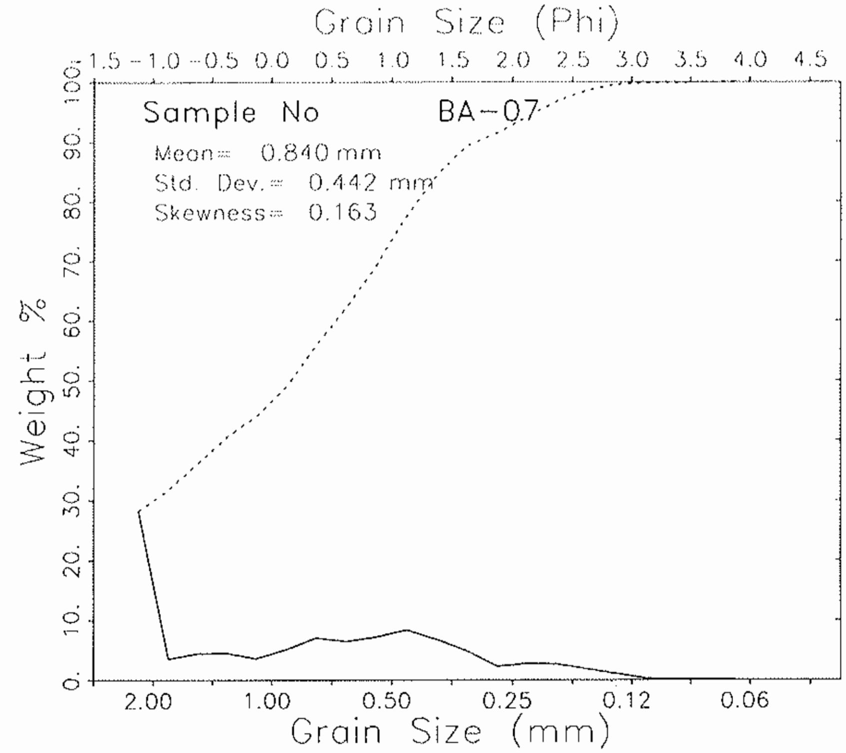
\+ MEAN = 1.228 STANDARD DEVIATION = 1.473 SKEWNESS = -.103 KURTOSIS = -1.092

0 DISPERSION = .659 STANDARD DEVIATION = 1.103 DEVIATION FROM NORMAL DISTR. = -25.15%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.232	-1.161	-.781	.059	1.375	2.456	2.730	3.453	3.829

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.974	1.108	MEDIUM SAND
STANDARD DEVIATION	1.756	1.577	POORLY SORTED
SKEWNESS(1)	-.228	-.164	COARSE-SKEWED
SKEWNESS(2)	-.130		
KURTOSIS	.314	.789	PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BA-07	140101					
Bogue Banks Borrow Area A						
		-1.125	28.260	28.125	-1.000	28.125
		-.875	3.510	3.493	-.750	31.618
		-.625	4.390	4.369	-.500	35.987
		-.375	4.520	4.498	-.250	40.486
		-.125	3.530	3.513	.000	43.999
		.125	5.080	5.056	.250	49.055
		.375	6.990	6.957	.500	56.011
		.625	6.390	6.359	.750	62.371
		.875	7.150	7.116	1.000	69.486
		1.125	8.320	8.280	1.250	77.767
		1.375	6.790	6.758	1.500	84.524
		1.625	4.830	4.807	1.750	89.331
		1.875	2.210	2.199	2.000	91.531
		2.125	2.730	2.717	2.250	94.248
		2.375	2.580	2.568	2.500	96.815
		2.625	1.770	1.762	2.750	98.577
		2.875	.970	.965	3.000	99.542
		3.125	.230	.229	3.250	99.771
		3.375	.080	.080	3.500	99.851
		3.625	.100	.100	3.750	99.950
		3.875	.050	.050	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.480

PERCENT FINER THAN 4.00 PHI = .09 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

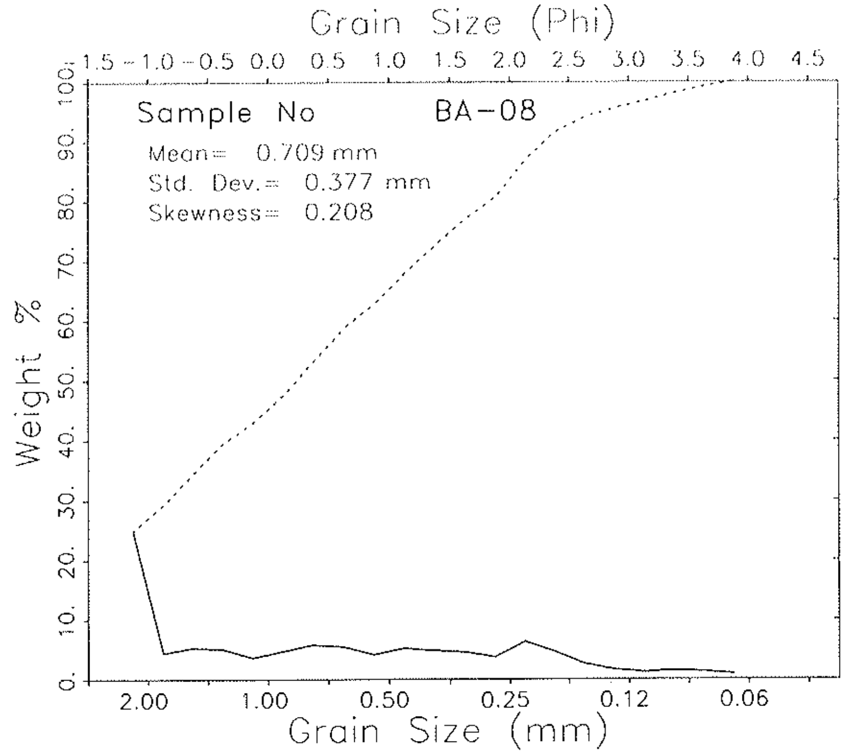
+ MEAN = .252 STANDARD DEVIATION = 1.179 SKEWNESS = .163 KURTOSIS = -.978

0 DISPERSION = .494 STANDARD DEVIATION = .755 DEVIATION FROM NORMAL DISTR. = -35.99%

0 PERCENTILES:

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.241	-1.206	-1.108	-1.028	.284	1.166	1.481	2.323	2.860

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	.186	.219	
+				COARSE SAND
0	STANDARD DEVIATION	1.294	1.182	
+				POORLY SORTED
0	SKEWNESS(1)	-.075	.040	
+				NEAR SYMMETRICAL
0	SKEWNESS(2)	.212		
0	KURTOSIS	.363	.659	
+				VERY PLATYKURTIC



1 SAMPLE NO. DATE

BA-08 140101

Bogue Banks Borrow Area A

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	25.670	24.840	-1.000	24.840
-.875	4.410	4.267	-.750	29.108
-.625	5.410	5.235	-.500	34.343
-.375	5.160	4.993	-.250	39.336
-.125	3.640	3.522	.000	42.859
.125	4.810	4.655	.250	47.513
.375	5.890	5.700	.500	53.213
.625	5.580	5.400	.750	58.612
.875	4.190	4.055	1.000	62.667
1.125	5.270	5.100	1.250	67.767
1.375	4.870	4.713	1.500	72.479
1.625	4.580	4.432	1.750	76.911
1.875	3.740	3.619	2.000	80.530
2.125	6.460	6.251	2.250	86.781
2.375	4.740	4.587	2.500	91.368
2.625	2.680	2.593	2.750	93.962
2.875	1.610	1.558	3.000	95.520
3.125	1.190	1.152	3.250	96.671
3.375	1.400	1.355	3.500	98.026
3.625	1.220	1.181	3.750	99.206
3.875	.820	.793	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.340

PERCENT FINER THAN 4.00 PHI = 1.30 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

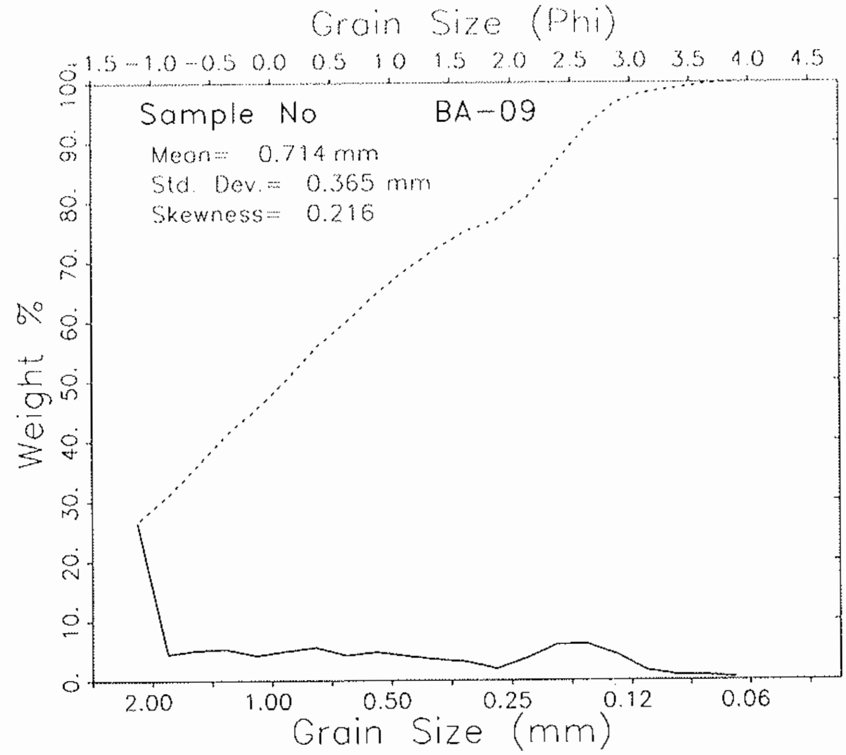
MEAN = .496 STANDARD DEVIATION = 1.406 SKEWNESS = .208 KURTOSIS = -.976

0 DISPERSION = .581 STANDARD DEVIATION = .923 DEVIATION FROM NORMAL DISTR. = -34.39%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.240	-1.200	-1.089	-.991	.359	1.642	2.139	2.917	3.706

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.525	.470	COARSE SAND
STANDARD DEVIATION	1.614	1.431	POORLY SORTED
SKEWNESS(1)	.103	.173	FINE-SKEWED
SKEWNESS(2)	.309		
KURTOSIS	.275	.641	VERY PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BA-09	140101					
Bogue Banks Borrow Area A						
		-1.125	26.580	26.395	-1.000	26.395
		-.875	4.450	4.419	-.750	30.814
		-.625	5.110	5.074	-.500	35.889
		-.375	5.270	5.233	-.250	41.122
		-.125	4.180	4.151	.000	45.273
		.125	4.950	4.916	.250	50.189
		.375	5.550	5.511	.500	55.700
		.625	4.170	4.141	.750	59.841
		.875	4.730	4.697	1.000	64.538
		1.125	4.050	4.022	1.250	68.560
		1.375	3.490	3.466	1.500	72.026
		1.625	3.040	3.019	1.750	75.045
		1.875	1.860	1.847	2.000	76.892
		2.125	3.680	3.654	2.250	80.546
		2.375	5.970	5.928	2.500	86.475
		2.625	5.990	5.948	2.750	92.423
		2.875	4.210	4.181	3.000	96.604
		3.125	1.580	1.569	3.250	98.173
		3.375	.800	.794	3.500	98.967
		3.625	.690	.685	3.750	99.652
		3.875	.350	.348	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.700

PERCENT FINER THAN 4.00 PHI = .58 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = .487 STANDARD DEVIATION = 1.456 SKEWNESS = .216 KURTOSIS = -1.166

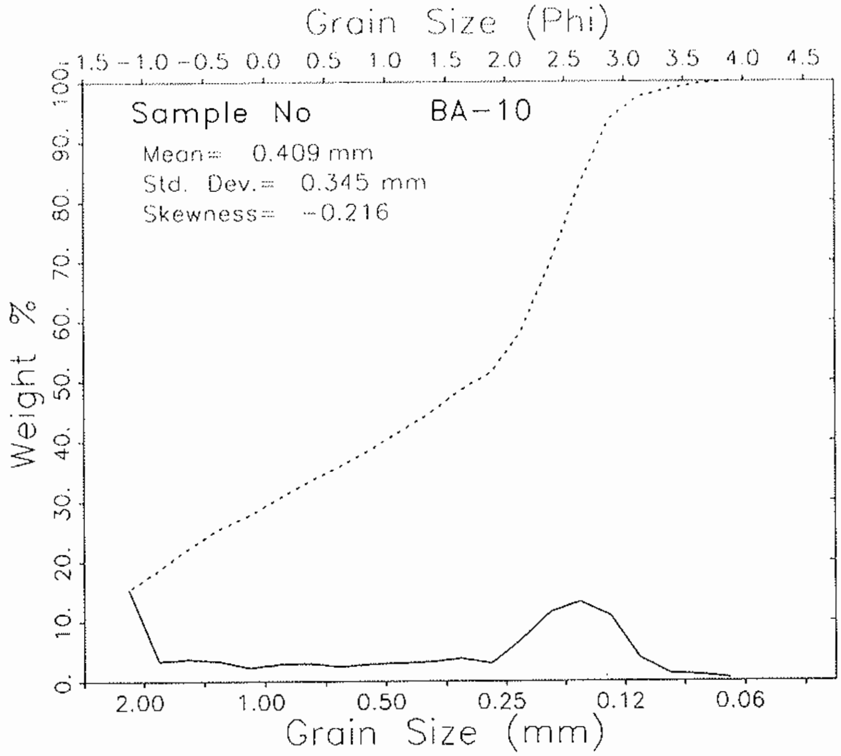
0 DISPERSION = .563 STANDARD DEVIATION = .884 DEVIATION FROM NORMAL DISTR. = -39.29%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.203	-1.098	-1.013	.240	1.746	2.396	2.904	3.512

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.649	.513	
			COARSE SAND
STANDARD DEVIATION	1.747	1.496	
			POORLY SORTED
SKEWNESS(1)	.234	.265	
			FINE-SKEWED
SKEWNESS(2)	.349		
KURTOSIS	.175	.610	
			VERY PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BA-10	140101					
Bogue Banks Borrow Area A						
		-1.125	16.440	15.273	-1.000	15.273
		-.875	3.540	3.289	-.750	18.562
		-.625	3.920	3.642	-.500	22.204
		-.375	3.520	3.270	-.250	25.474
		-.125	2.410	2.239	.000	27.713
		.125	3.040	2.824	.250	30.537
		.375	3.090	2.871	.500	33.408
		.625	2.590	2.406	.750	35.814
		.875	3.000	2.787	1.000	38.601
		1.125	3.220	2.991	1.250	41.592
		1.375	3.390	3.149	1.500	44.742
		1.625	4.040	3.753	1.750	48.495
		1.875	3.110	2.889	2.000	51.384
		2.125	7.310	6.791	2.250	58.175
		2.375	12.350	11.473	2.500	69.649
		2.625	14.160	13.155	2.750	82.804
		2.875	11.700	10.870	3.000	93.673
		3.125	4.050	3.763	3.250	97.436
		3.375	1.270	1.180	3.500	98.616
		3.625	1.000	.929	3.750	99.545
		3.875	.490	.455	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.640

PERCENT FINER THAN 4.00 PHI = .65 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.291 STANDARD DEVIATION = 1.535 SKEWNESS = -.216 KURTOSIS = -1.332

0 DISPERSION = .584 STANDARD DEVIATION = .929 DEVIATION FROM NORMAL DISTR. = -39.49%

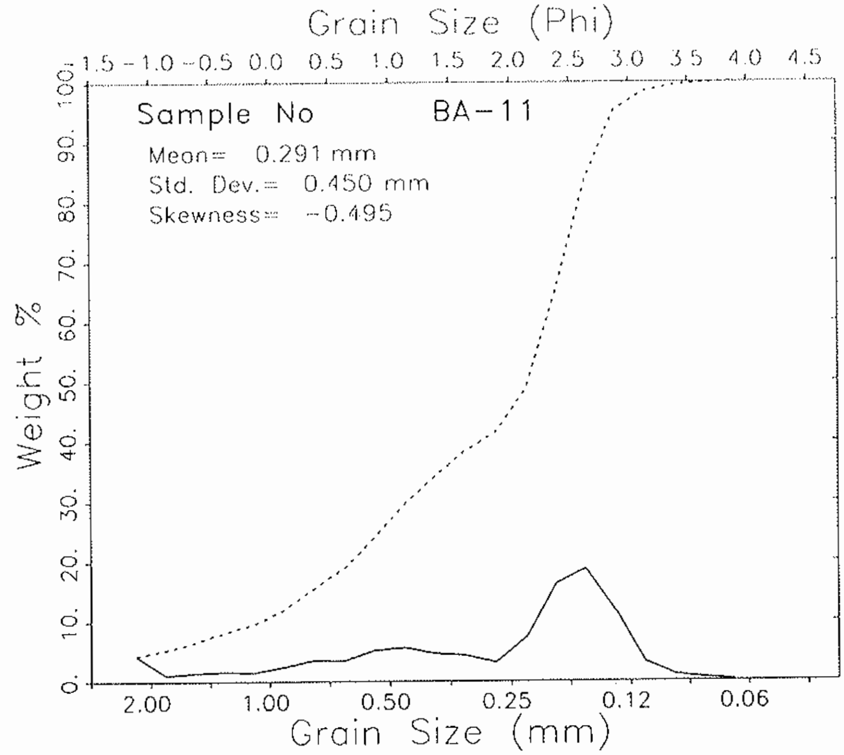
0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.234	-1.168	-.945	-.286	1.880	2.602	2.778	3.088	3.603

0

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.916	1.238	MEDIUM SAND
STANDARD DEVIATION	1.861	1.575	POORLY SORTED
SKEWNESS(1)	-.518	-.475	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.494		
KURTOSIS	.143	.604	VERY PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BA-11	140101					
Bogue Banks Borrow Area A						
		-1.125	4.260	4.223	-1.000	4.223
		-.875	.960	.952	-.750	5.175
		-.625	1.420	1.408	-.500	6.583
		-.375	1.580	1.566	-.250	8.149
		-.125	1.440	1.428	.000	9.577
		.125	2.440	2.419	.250	11.996
		.375	3.530	3.500	.500	15.495
		.625	3.450	3.420	.750	18.915
		.875	5.220	5.175	1.000	24.090
		1.125	5.590	5.542	1.250	29.632
		1.375	4.560	4.521	1.500	34.153
		1.625	4.290	4.253	1.750	38.406
		1.875	3.110	3.083	2.000	41.489
		2.125	7.270	7.207	2.250	48.696
		2.375	16.330	16.189	2.500	64.885
		2.625	18.820	18.658	2.750	83.543
		2.875	11.780	11.678	3.000	95.222
		3.125	3.170	3.143	3.250	98.364
		3.375	1.020	1.011	3.500	99.375
		3.625	.450	.446	3.750	99.822
		3.875	.180	.178	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.870

PERCENT FINER THAN 4.00 PHI = 3.18 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.781 STANDARD DEVIATION = 1.153 SKEWNESS = -.495 KURTOSIS = .077

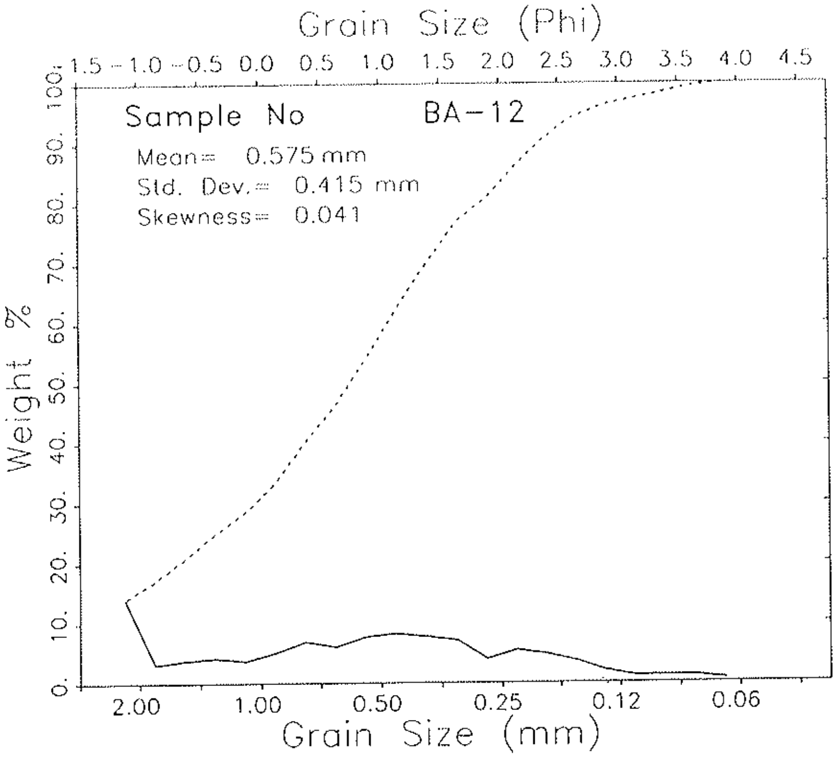
0 DISPERSION = .536 STANDARD DEVIATION = .831 DEVIATION FROM NORMAL DISTR. = -27.91%

0 PERCENTILES:

+

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.191	-.796	.537	1.041	2.270	2.636	2.760	2.995	3.407

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	1.648	1.856	
+				MEDIUM SAND
0	STANDARD DEVIATION	1.111	1.130	
+				POORLY SORTED
0	SKEWNESS(1)	-.559	-.588	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-1.053		
0	KURTOSIS	.706	.974	
+				MESOKURTIC



1 SAMPLE NO. DATE

BA-12 140101

Bogue Banks Borrow Area A

MIDPOINT (+PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	14.300	13.938	-1.000	13.938
-.875	3.160	3.080	-.750	17.018
-.625	3.800	3.704	-.500	20.721
-.375	4.210	4.103	-.250	24.825
-.125	3.740	3.645	.000	28.470
.125	5.150	5.019	.250	33.489
.375	6.960	6.784	.500	40.273
.625	6.150	5.994	.750	46.267
.875	7.830	7.632	1.000	53.899
1.125	8.350	8.138	1.250	62.037
1.375	7.860	7.661	1.500	69.698
1.625	7.230	7.047	1.750	76.745
1.875	3.980	3.879	2.000	80.624
2.125	5.490	5.351	2.250	85.975
2.375	4.810	4.688	2.500	90.663
2.625	3.690	3.596	2.750	94.259
2.875	2.060	2.008	3.000	96.267
3.125	1.070	1.043	3.250	97.310
3.375	1.100	1.072	3.500	98.382
3.625	1.070	1.043	3.750	99.425
3.875	.590	.575	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.600

PERCENT FINER THAN 4.00 PHI = .92 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

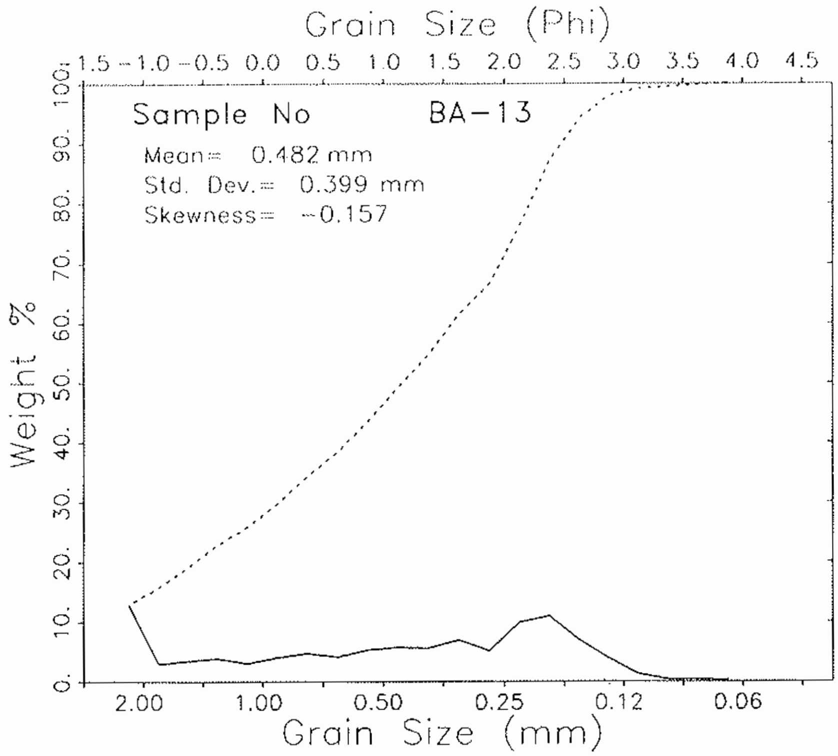
MEAN = .799 STANDARD DEVIATION = 1.269 SKEWNESS = .041 KURTOSIS = -.805

0 DISPERSION = .631 STANDARD DEVIATION = 1.034 DEVIATION FROM NORMAL DISTR. = -18.52%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.232	-1.160	-.833	-.238	.872	1.688	2.158	2.842	3.640

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.663	.732	COARSE SAND
STANDARD DEVIATION	1.495	1.354	POORLY SORTED
SKEWNESS(1)	-.140	-.078	NEAR SYMMETRICAL
SKEWNESS(2)	-.021		
KURTOSIS	.338	.852	PLATYKURTIC



1 SAMPLE NO. DATE

BA-13 140101

Bogue Banks Borrow Area A

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	12.940	12.814	-1.000	12.814
-.875	2.890	2.862	-.750	15.676
-.625	3.390	3.357	-.500	19.033
-.375	3.860	3.823	-.250	22.856
-.125	2.960	2.931	.000	25.787
.125	4.010	3.971	.250	29.758
.375	4.680	4.635	.500	34.393
.625	4.090	4.050	.750	38.443
.875	5.260	5.209	1.000	43.652
1.125	5.660	5.605	1.250	49.257
1.375	5.520	5.466	1.500	54.724
1.625	6.920	6.853	1.750	61.577
1.875	5.070	5.021	2.000	66.597
2.125	9.880	9.784	2.250	76.381
2.375	10.960	10.854	2.500	87.235
2.625	6.980	6.912	2.750	94.147
2.875	3.810	3.773	3.000	97.920
3.125	1.230	1.218	3.250	99.138
3.375	.320	.317	3.500	99.455
3.625	.310	.307	3.750	99.762
3.875	.240	.238	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.980

PERCENT FINER THAN 4.00 PHI = .44 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.053 STANDARD DEVIATION = 1.327 SKEWNESS = -.157 KURTOSIS = -1.151

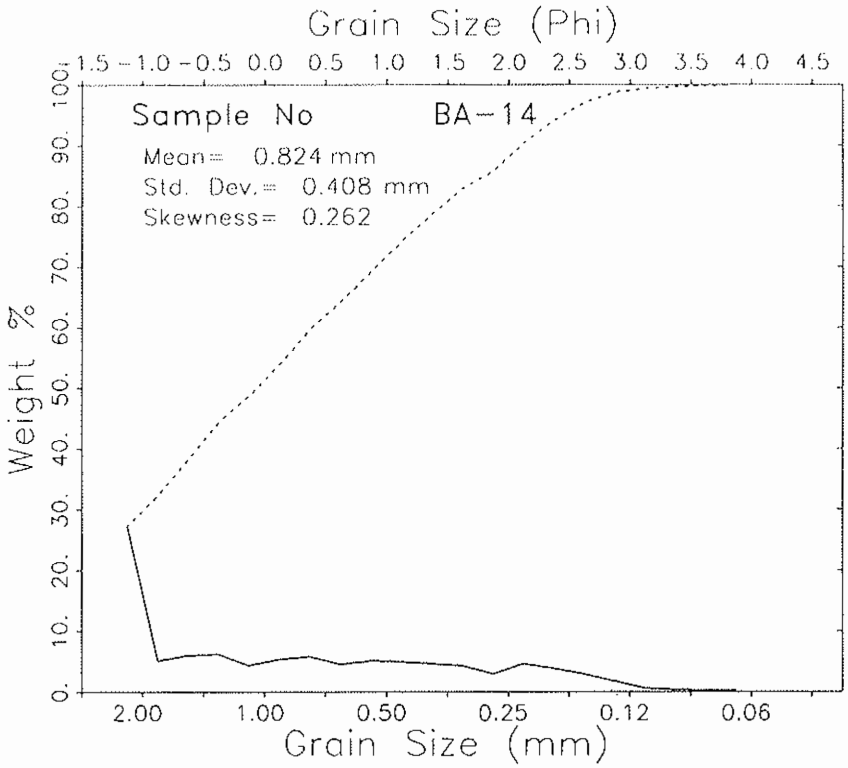
0 DISPERSION = .612 STANDARD DEVIATION = .991 DEVIATION FROM NORMAL DISTR. = -25.30%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.230	-1.152	-.726	-.067	1.284	2.215	2.425	2.806	3.222

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.850	.995	COARSE SAND
STANDARD DEVIATION	1.576	1.388	POORLY SORTED
SKEWNESS(1)	-.276	-.253	COARSE-SKEWED
SKEWNESS(2)	-.290		
KURTOSIS	.256	.711	PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
BA-14	160101					
Bogue Banks Borrow Area A						
		-1.125	28.460	27.224	-1.000	27.224
		-.875	5.250	5.022	-.750	32.246
		-.625	6.260	5.988	-.500	38.234
		-.375	6.460	6.179	-.250	44.414
		-.125	4.500	4.305	.000	48.718
		.125	5.550	5.309	.250	54.027
		.375	5.990	5.730	.500	59.757
		.625	4.710	4.505	.750	64.262
		.875	5.250	5.022	1.000	69.284
		1.125	5.150	4.926	1.250	74.211
		1.375	4.720	4.515	1.500	78.726
		1.625	4.390	4.199	1.750	82.925
		1.875	2.980	2.851	2.000	85.776
		2.125	4.730	4.525	2.250	90.300
		2.375	3.950	3.778	2.500	94.079
		2.625	3.040	2.908	2.750	96.987
		2.875	1.810	1.731	3.000	98.718
		3.125	.610	.584	3.250	99.302
		3.375	.290	.277	3.500	99.579
		3.625	.240	.230	3.750	99.809
		3.875	.200	.191	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.540

PERCENT FINER THAN 4.00 PHI = .49 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

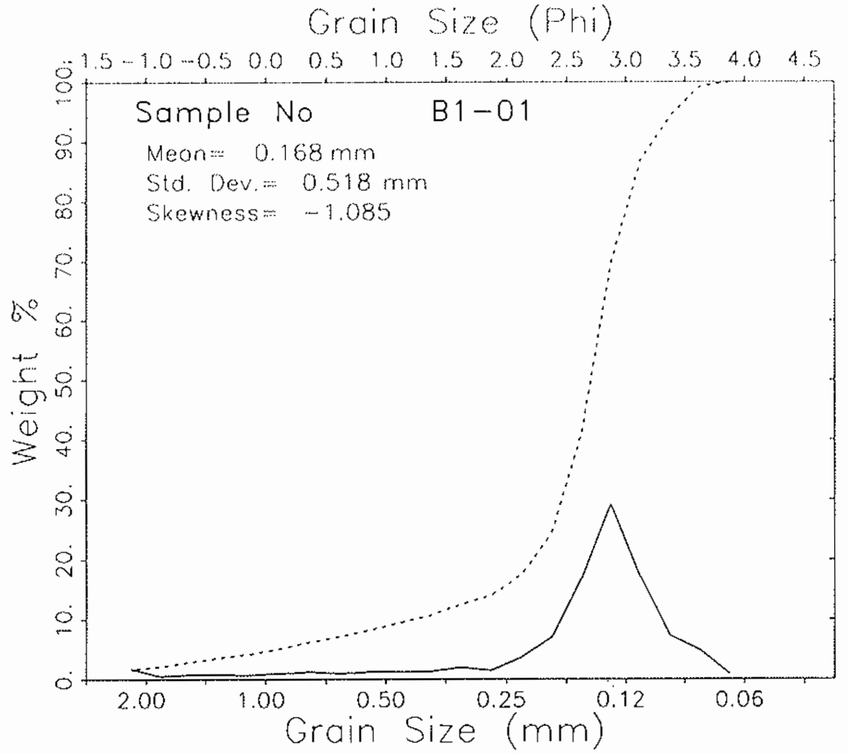
\+ MEAN = .279 STANDARD DEVIATION = 1.292 SKEWNESS = .262 KURTOSIS = -.925

0 DISPERSION = .537 STANDARD DEVIATION = .833 DEVIATION FROM NORMAL DISTR. = -35.58%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.241	-1.204	-1.103	-1.020	.060	1.294	1.844	2.579	3.121

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.371	.267	COARSE SAND
STANDARD DEVIATION	1.474	1.310	POORLY SORTED
SKEWNESS(1)	.211	.271	FINE-SKEWED
SKEWNESS(2)	.426		
KURTOSIS	.284	.670	PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-01	151100					
Bogue Banks Borrow Area B1						
		-1.125	1.770	1.614	-1.000	1.614
		-.875	.460	.420	-.750	2.034
		-.625	.820	.748	-.500	2.782
		-.375	.800	.730	-.250	3.511
		-.125	.710	.648	.000	4.159
		.125	.990	.903	.250	5.062
		.375	1.220	1.113	.500	6.175
		.625	1.000	.912	.750	7.087
		.875	1.270	1.158	1.000	8.245
		1.125	1.260	1.149	1.250	9.394
		1.375	1.300	1.186	1.500	10.580
		1.625	2.070	1.888	1.750	12.468
		1.875	1.540	1.405	2.000	13.873
		2.125	3.860	3.521	2.250	17.393
		2.375	7.590	6.923	2.500	24.316
		2.625	18.290	16.682	2.750	40.998
		2.875	31.860	29.059	3.000	70.057
		3.125	18.690	17.047	3.250	87.103
		3.375	7.900	7.205	3.500	94.309
		3.625	5.350	4.880	3.750	99.188
		3.875	.890	.812	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.640

PERCENT FINER THAN 4.00 PHI = 1.14 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.574 STANDARD DEVIATION = .949 SKEWNESS = -1.085 KURTOSIS = 4.799

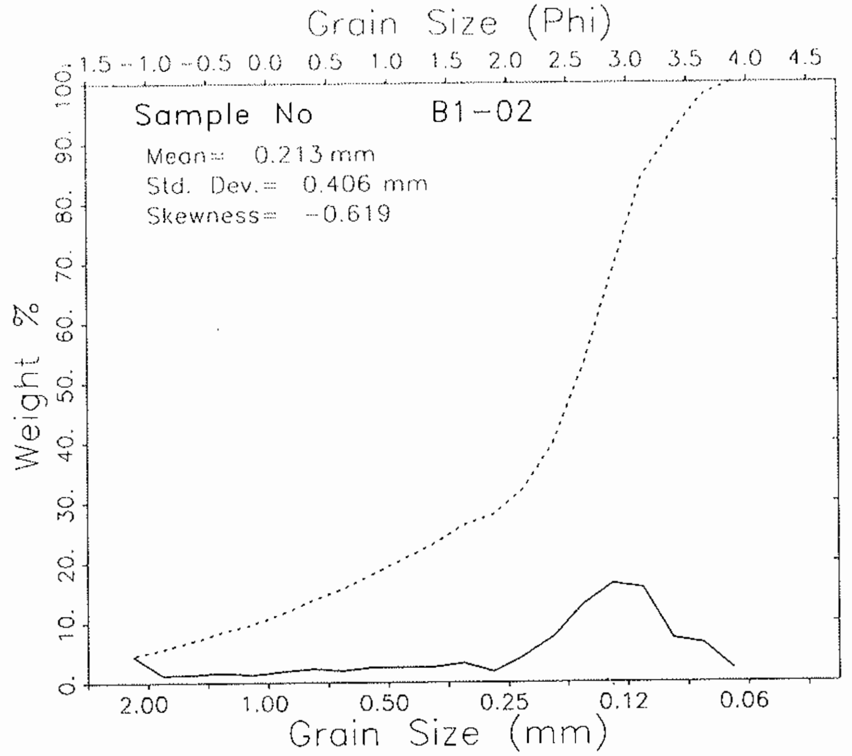
0 DISPERSION = .379 STANDARD DEVIATION = .579 DEVIATION FROM NORMAL DISTR. = -39.02%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.095	.233	2.151	2.510	2.827	3.072	3.204	3.535	3.740

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.678	2.728	FINE SAND
STANDARD DEVIATION	.527	.764	MODERATELY SORTED
SKEWNESS(1)	-.284	-.428	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.791		
KURTOSIS	2.135	2.407	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-02	151100					
Bogue Banks Borrow Area B1						
		-1.125	4.940	4.402	-1.000	4.402
		-.875	1.300	1.158	-.750	5.560
		-.625	1.490	1.328	-.500	6.888
		-.375	1.730	1.541	-.250	8.429
		-.125	1.410	1.256	.000	9.685
		.125	2.070	1.844	.250	11.530
		.375	2.480	2.210	.500	13.740
		.625	2.090	1.862	.750	15.602
		.875	2.730	2.433	1.000	18.034
		1.125	2.770	2.468	1.250	20.503
		1.375	2.790	2.486	1.500	22.989
		1.625	3.500	3.119	1.750	26.107
		1.875	1.940	1.729	2.000	27.836
		2.125	4.740	4.223	2.250	32.059
		2.375	8.400	7.485	2.500	39.544
		2.625	14.380	12.813	2.750	52.357
		2.875	18.300	16.306	3.000	68.663
		3.125	17.520	15.611	3.250	84.273
		3.375	8.080	7.200	3.500	91.473
		3.625	7.130	6.353	3.750	97.826
		3.875	2.440	2.174	4.000	100.000

TOTAL WEIGHT (GRAMS) = 112.230

PERCENT FINER THAN 4.00 PHI = 1.57 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

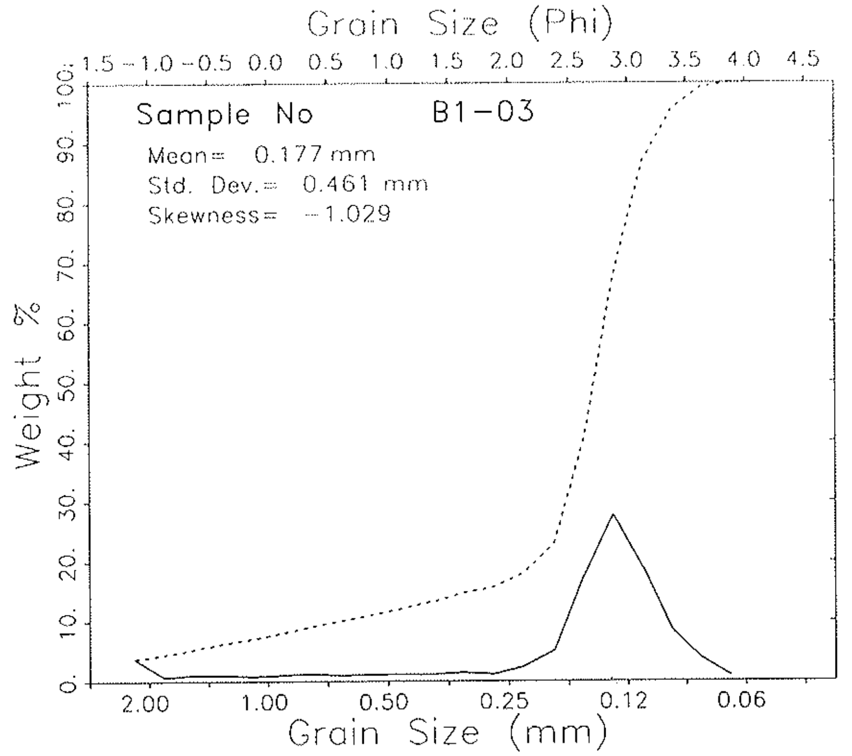
\+ MEAN = 2.231 STANDARD DEVIATION = 1.301 SKEWNESS = -.619 KURTOSIS = .550

0 DISPERSION = .559 STANDARD DEVIATION = .877 DEVIATION FROM NORMAL DISTR. = -32.60%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.193	-.871	.791	1.661	2.704	3.101	3.246	3.639	3.885

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.018	2.247	FINE SAND
STANDARD DEVIATION	1.227	1.297	POORLY SORTED
SKEWNESS(1)	-.559	-.572	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.076		
KURTOSIS	.837	1.283	LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-03	151100						
Bogue Banks Borrow Area B1							
		-1.125	3.950		3.695	-1.000	3.695
		-.875	.700		.655	-.750	4.350
		-.625	1.000		.936	-.500	5.286
		-.375	1.020		.954	-.250	6.240
		-.125	.800		.748	.000	6.988
		.125	1.070		1.001	.250	7.990
		.375	1.220		1.141	.500	9.131
		.625	.950		.889	.750	10.020
		.875	1.110		1.038	1.000	11.058
		1.125	1.170		1.095	1.250	12.153
		1.375	1.160		1.085	1.500	13.238
		1.625	1.470		1.375	1.750	14.613
		1.875	1.090		1.020	2.000	15.633
		2.125	2.450		2.292	2.250	17.925
		2.375	5.320		4.977	2.500	22.902
		2.625	18.550		17.354	2.750	40.256
		2.875	29.560		27.655	3.000	67.911
		3.125	20.240		18.935	3.250	86.846
		3.375	9.110		8.523	3.500	95.369
		3.625	4.050		3.789	3.750	99.158
		3.875	.900		.842	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.890

PERCENT FINER THAN 4.00 PHI = 1.18 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 2.498 STANDARD DEVIATION = 1.116 SKEWNESS = -1.029 KURTOSIS = 3.492

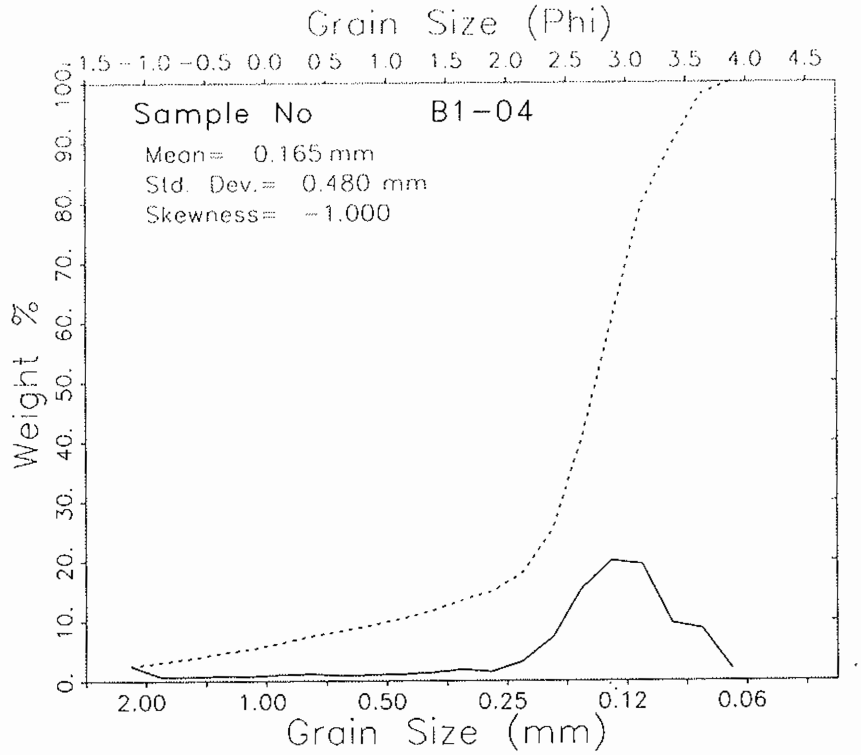
0 DISPERSION = .377 STANDARD DEVIATION = .577 DEVIATION FROM NORMAL DISTR. = -48.34%

0 PERCENTILES:

\+

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.182	-.576	2.040	2.530	2.838	3.094	3.212	3.489	3.740

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	2.626	2.697	
+				FINE SAND
0	STANDARD DEVIATION	.586	.909	
+				MODERATELY SORTED
0	SKEWNESS(1)	-.361	-.521	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-2.357		
0	KURTOSIS	2.468	2.958	
+				VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B1-04 151100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	2.560	2.433	-1.000	2.433
-.875	.670	.637	-.750	3.069
-.625	.710	.675	-.500	3.744
-.375	.880	.836	-.250	4.580
-.125	.790	.751	.000	5.331
.125	1.020	.969	.250	6.300
.375	1.230	1.169	.500	7.469
.625	.860	.817	.750	8.287
.875	1.020	.969	1.000	9.256
1.125	1.150	1.093	1.250	10.349
1.375	1.350	1.283	1.500	11.632
1.625	1.870	1.777	1.750	13.409
1.875	1.540	1.463	2.000	14.872
2.125	3.270	3.107	2.250	17.980
2.375	7.460	7.089	2.500	25.069
2.625	16.140	15.338	2.750	40.407
2.875	21.000	19.956	3.000	60.363
3.125	20.450	19.434	3.250	79.797
3.375	10.040	9.541	3.500	89.338
3.625	9.110	8.657	3.750	97.995
3.875	2.110	2.005	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.230

PERCENT FINER THAN 4.00 PHI = 4.71 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

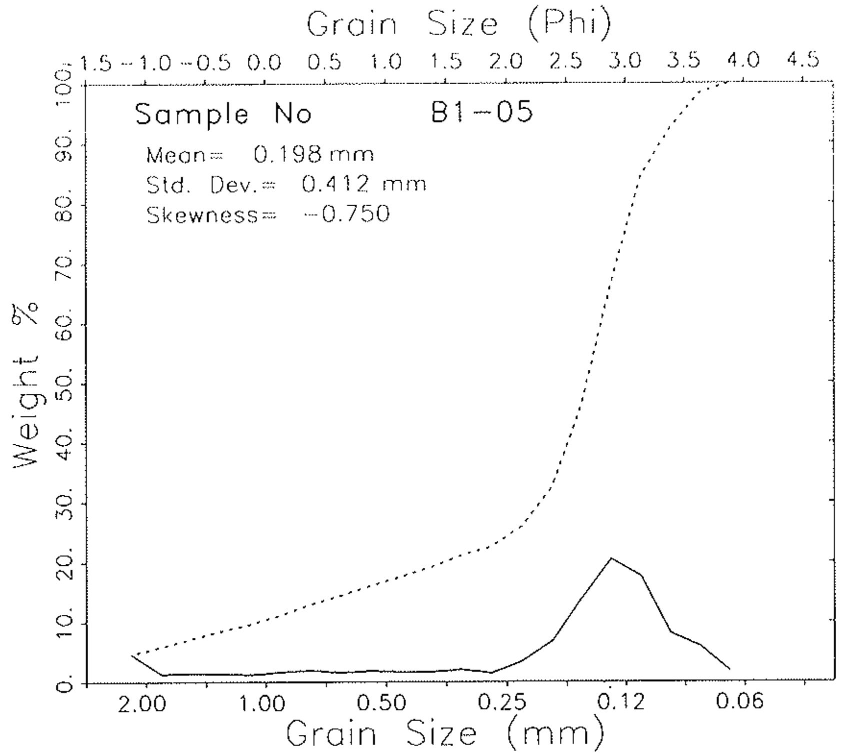
MEAN = 2.596 STANDARD DEVIATION = 1.058 SKEWNESS = -1.000 KURTOSIS = 3.801

0 DISPERSION = .436 STANDARD DEVIATION = .660 DEVIATION FROM NORMAL DISTR. = -37.60%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.147	-.110	2.091	2.498	2.870	3.188	3.360	3.664	3.875

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	2.725	2.774	FINE SAND
STANDARD DEVIATION	.635	.889	MODERATELY SORTED
SKEWNESS(1)	-.228	-.404	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.723		
KURTOSIS	1.973	2.239	VERY LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-05	151100					
Bogue Banks Borrow Area B1						
		-1.125	4.690	4.578	-1.000	4.578
		-.875	1.240	1.210	-.750	5.788
		-.625	1.390	1.357	-.500	7.145
		-.375	1.370	1.337	-.250	8.482
		-.125	1.130	1.103	.000	9.585
		.125	1.560	1.523	.250	11.108
		.375	1.840	1.796	.500	12.904
		.625	1.480	1.445	.750	14.348
		.875	1.730	1.689	1.000	16.037
		1.125	1.550	1.513	1.250	17.550
		1.375	1.600	1.562	1.500	19.112
		1.625	2.050	2.001	1.750	21.113
		1.875	1.430	1.396	2.000	22.509
		2.125	3.410	3.328	2.250	25.837
		2.375	6.770	6.608	2.500	32.445
		2.625	14.140	13.802	2.750	46.247
		2.875	20.910	20.410	3.000	66.657
		3.125	18.070	17.638	3.250	84.295
		3.375	8.230	8.033	3.500	92.328
		3.625	6.060	5.915	3.750	98.243
		3.875	1.800	1.757	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.450

PERCENT FINER THAN 4.00 PHI = .90 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.334 STANDARD DEVIATION = 1.280 SKEWNESS = -.750 KURTOSIS = 1.224

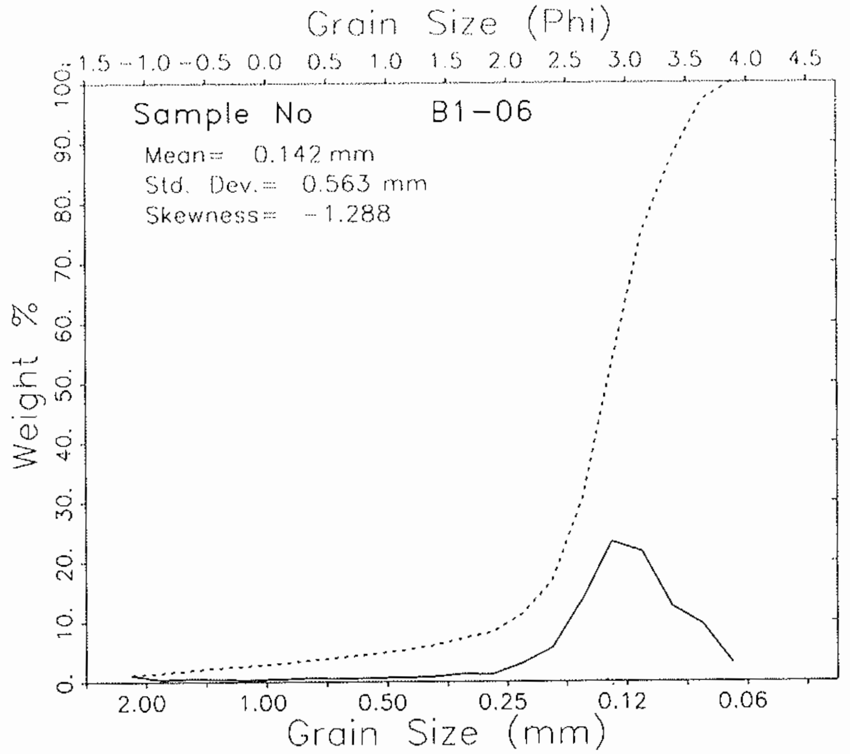
0 DISPERSION = .497 STANDARD DEVIATION = .759 DEVIATION FROM NORMAL DISTR. = -40.66%

0 PERCENTILES:

+

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.195	-.913	.995	2.187	2.796	3.118	3.246	3.613	3.858

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	2.120	2.345	
+				FINE SAND
0	STANDARD DEVIATION	1.126	1.249	
+				POORLY SORTED
0	SKEWNESS(1)	-.600	-.620	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-1.284		
0	KURTOSIS	1.010	1.992	
+				VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B1-06 151100
Bogue Banks Borrow Area B1

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	1.080	1.082	-1.000	1.082
-.875	.320	.321	-.750	1.403
-.625	.450	.451	-.500	1.854
-.375	.420	.421	-.250	2.275
-.125	.320	.321	.000	2.596
.125	.420	.421	.250	3.017
.375	.530	.531	.500	3.548
.625	.470	.471	.750	4.019
.875	.530	.531	1.000	4.550
1.125	.620	.621	1.250	5.172
1.375	.720	.722	1.500	5.894
1.625	1.210	1.213	1.750	7.106
1.875	1.120	1.123	2.000	8.229
2.125	2.980	2.987	2.250	11.216
2.375	5.500	5.513	2.500	16.728
2.625	13.320	13.351	2.750	30.079
2.875	23.180	23.233	3.000	53.313
3.125	21.630	21.680	3.250	74.992
3.375	12.430	12.459	3.500	87.451
3.625	9.500	9.522	3.750	96.973
3.875	3.020	3.027	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.770

PERCENT FINER THAN 4.00 PHI = 3.21   PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

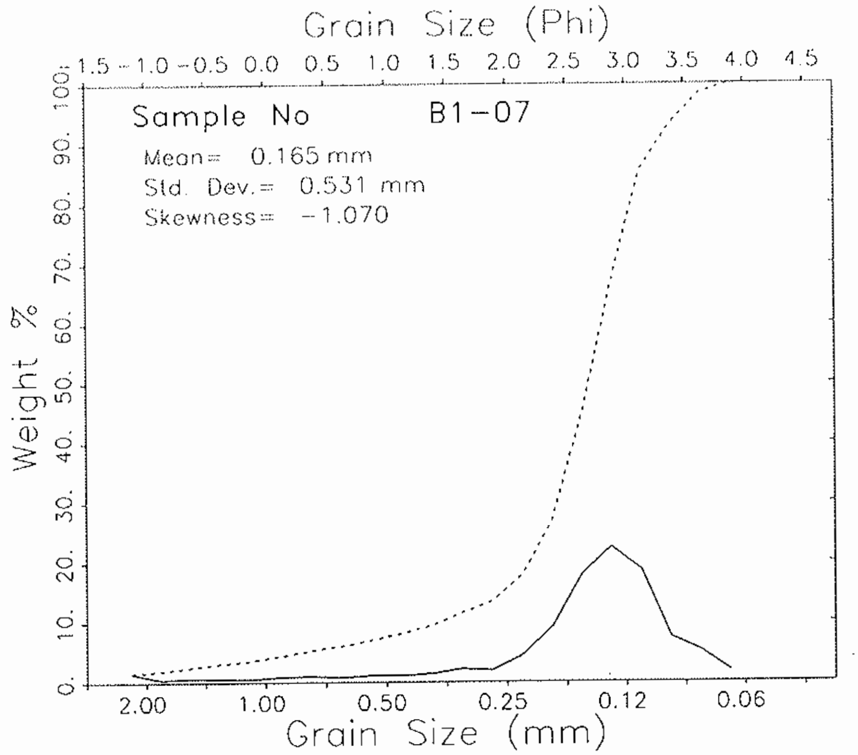
MEAN = 2.821 STANDARD DEVIATION = .829 SKEWNESS = -1.288 KURTOSIS = 8.348

0 DISPERSION = .354 STANDARD DEVIATION = .547 DEVIATION FROM NORMAL DISTR. = -34.04%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.019	1.181	2.467	2.655	2.964	3.250	3.431	3.698	3.917

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.949	2.954	FINE SAND
STANDARD DEVIATION	.482	.622	MODERATELY WELL SORTED
SKEWNESS(1)	-.032	-.225	COARSE-SKEWED
SKEWNESS(2)	-1.089		
KURTOSIS	1.612	1.733	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO. / DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-07 161100					
Bogue Banks Borrow Area B1					
	-1.125	1.740	1.483	-1.000	1.483
	-.875	.450	.383	-.750	1.866
	-.625	.700	.596	-.500	2.463
	-.375	.680	.579	-.250	3.042
	-.125	.540	.460	.000	3.502
	.125	.930	.792	.250	4.294
	.375	1.100	.937	.500	5.232
	.625	.800	.682	.750	5.913
	.875	1.190	1.014	1.000	6.927
	1.125	1.280	1.091	1.250	8.018
	1.375	1.540	1.312	1.500	9.330
	1.625	2.500	2.130	1.750	11.460
	1.875	2.220	1.892	2.000	13.352
	2.125	5.090	4.337	2.250	17.689
	2.375	10.660	9.083	2.500	26.772
	2.625	20.870	17.783	2.750	44.555
	2.875	26.290	22.401	3.000	66.956
	3.125	21.960	18.712	3.250	85.668
	3.375	8.630	7.353	3.500	93.021
	3.625	6.080	5.181	3.750	98.202
	3.875	2.110	1.798	4.000	100.000

TOTAL WEIGHT (GRAMS) = 117.360

PERCENT FINER THAN 4.00 PHI = 1.11 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

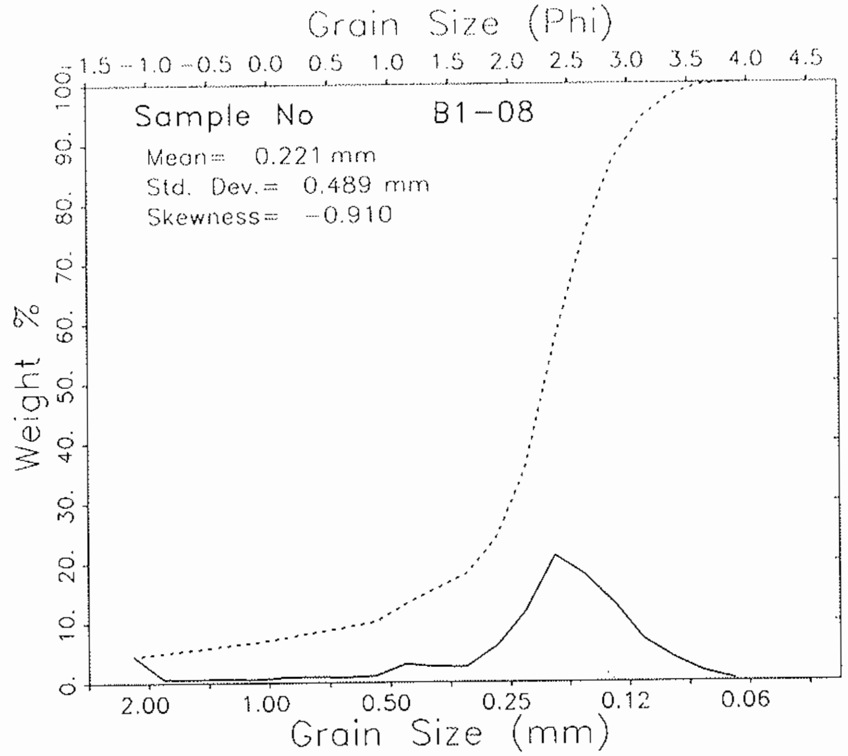
MEAN = 2.601 STANDARD DEVIATION = .914 SKEWNESS = -1.070 KURTOSIS = 5.228

0 DISPERSION = .406 STANDARD DEVIATION = .617 DEVIATION FROM NORMAL DISTR. = -32.52%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.081	.438	2.153	2.451	2.811	3.107	3.228	3.595	3.861

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.690	2.730	FINE SAND
STANDARD DEVIATION	.538	.747	MODERATELY SORTED
SKEWNESS(1)	-.224	-.364	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.477		
KURTOSIS	1.937	1.972	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B1-08 161100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	4.710	4.374	-1.000	4.374
-.875	.570	.529	-.750	4.904
-.625	.630	.585	-.500	5.489
-.375	.660	.613	-.250	6.102
-.125	.510	.474	.000	6.576
.125	.870	.808	.250	7.384
.375	.970	.901	.500	8.285
.625	.850	.789	.750	9.074
.875	1.030	.957	1.000	10.031
1.125	3.180	2.953	1.250	12.984
1.375	2.780	2.582	1.500	15.566
1.625	2.630	2.443	1.750	18.009
1.875	6.240	5.795	2.000	23.804
2.125	12.620	11.721	2.250	35.525
2.375	22.650	21.037	2.500	56.562
2.625	19.250	17.879	2.750	74.440
2.875	13.990	12.993	3.000	87.434
3.125	7.430	6.901	3.250	94.335
3.375	4.070	3.780	3.500	98.115
3.625	1.700	1.579	3.750	99.694
3.875	.330	.306	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.670

PERCENT FINER THAN 4.00 PHI = 1.22 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

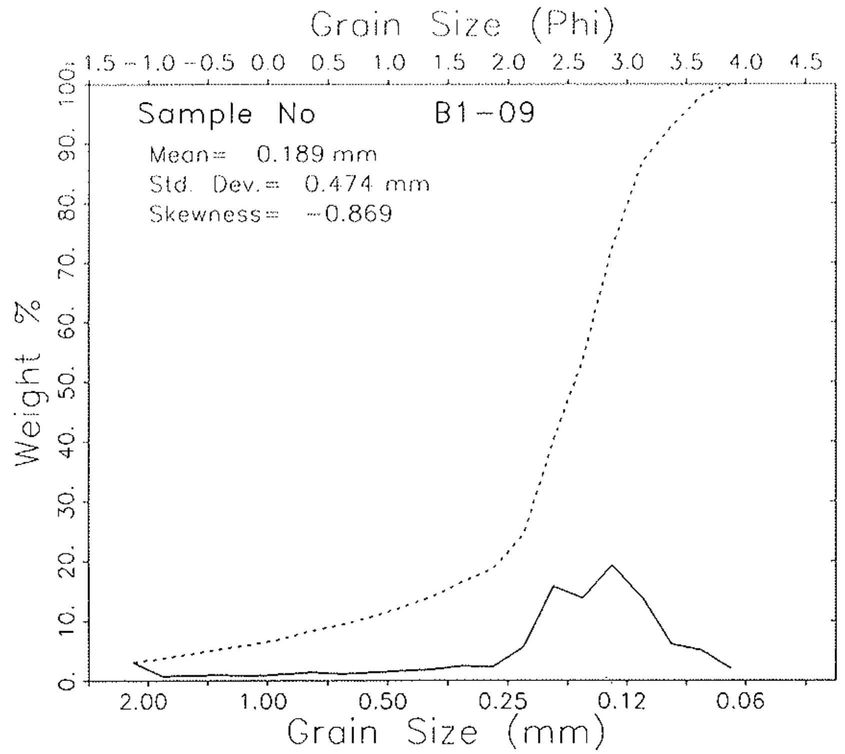
+ MEAN = 2.178 STANDARD DEVIATION = 1.031 SKEWNESS = -.910 KURTOSIS = 3.232

0 DISPERSION = .446 STANDARD DEVIATION = .676 DEVIATION FROM NORMAL DISTR. = -34.48%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.193	-.709	1.544	2.026	2.422	2.761	2.934	3.294	3.640

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.239	2.300	FINE SAND
STANDARD DEVIATION	.695	.954	MODERATELY SORTED
SKEWNESS(1)	-.263	-.414	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.626		
KURTOSIS	1.881	2.231	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B1-09 161100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	3.390	2.954	-1.000	2.954
-.875	.770	.671	-.750	3.625
-.625	.880	.767	-.500	4.392
-.375	.980	.854	-.250	5.246
-.125	.810	.706	.000	5.952
.125	1.130	.985	.250	6.936
.375	1.530	1.333	.500	8.269
.625	1.220	1.063	.750	9.333
.875	1.520	1.325	1.000	10.657
1.125	1.810	1.577	1.250	12.234
1.375	2.110	1.839	1.500	14.073
1.625	2.770	2.414	1.750	16.487
1.875	2.590	2.257	2.000	18.743
2.125	6.300	5.490	2.250	24.233
2.375	18.020	15.702	2.500	39.936
2.625	15.810	13.777	2.750	53.712
2.875	22.040	19.205	3.000	72.917
3.125	16.050	13.986	3.250	86.903
3.375	6.970	6.074	3.500	92.977
3.625	5.810	5.063	3.750	98.039
3.875	2.250	1.961	4.000	100.000

TOTAL WEIGHT (GRAMS) = 114.760

PERCENT FINER THAN 4.00 PHI = 1.34 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

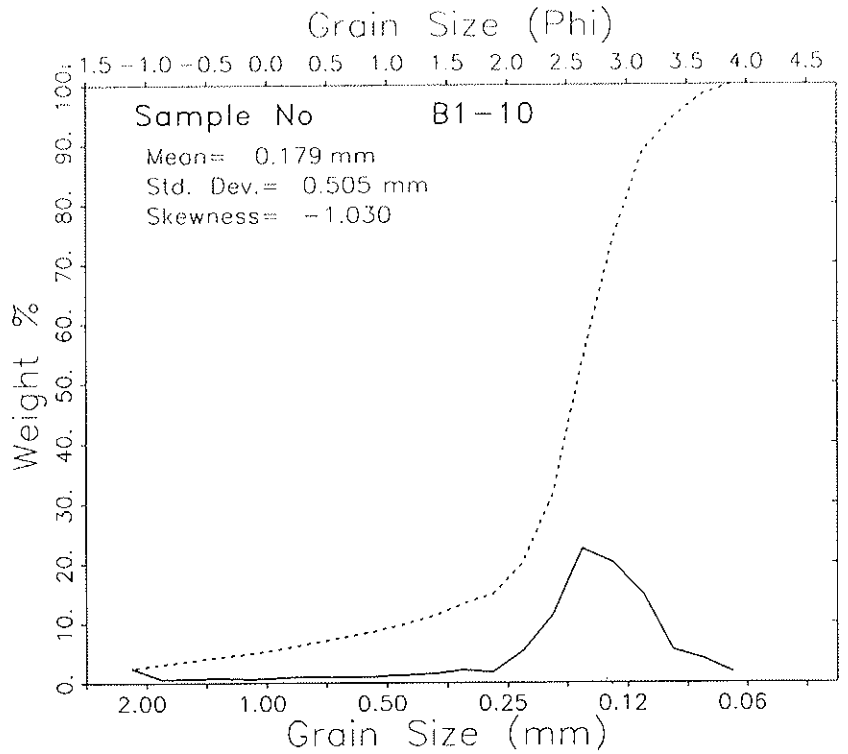
MEAN = 2.406 STANDARD DEVIATION = 1.077 SKEWNESS = -.869 KURTOSIS = 2.848

0 DISPERSION = .478 STANDARD DEVIATION = .727 DEVIATION FROM NORMAL DISTR. = -32.46%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.165	-.322	1.700	2.262	2.683	3.037	3.198	3.600	3.872

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.449	2.527	FINE SAND
STANDARD DEVIATION	.749	.969	MODERATELY SORTED
SKEWNESS(1)	-.312	-.422	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.393		
KURTOSIS	1.617	2.074	VERY LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-10	161100					
Bogue Banks Borrow Area B1						
		-1.125	2.720	2.401	-1.000	2.401
		-.875	.660	.583	-.750	2.984
		-.625	.720	.636	-.500	3.619
		-.375	.780	.689	-.250	4.308
		-.125	.620	.547	.000	4.855
		.125	.880	.777	.250	5.632
		.375	1.110	.980	.500	6.612
		.625	.980	.865	.750	7.477
		.875	1.120	.989	1.000	8.466
		1.125	1.370	1.209	1.250	9.675
		1.375	1.560	1.377	1.500	11.052
		1.625	2.360	2.083	1.750	13.136
		1.875	1.910	1.686	2.000	14.822
		2.125	5.940	5.244	2.250	20.065
		2.375	12.850	11.344	2.500	31.409
		2.625	25.360	22.387	2.750	53.796
		2.875	22.860	20.180	3.000	73.976
		3.125	16.880	14.901	3.250	88.877
		3.375	6.170	5.447	3.500	94.324
		3.625	4.470	3.946	3.750	98.270
		3.875	1.960	1.730	4.000	100.000

TOTAL WEIGHT (GRAMS) = 113.280

PERCENT FINER THAN 4.00 PHI = 1.10 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.486 STANDARD DEVIATION = .985 SKEWNESS = -1.030 KURTOSIS = 4.462

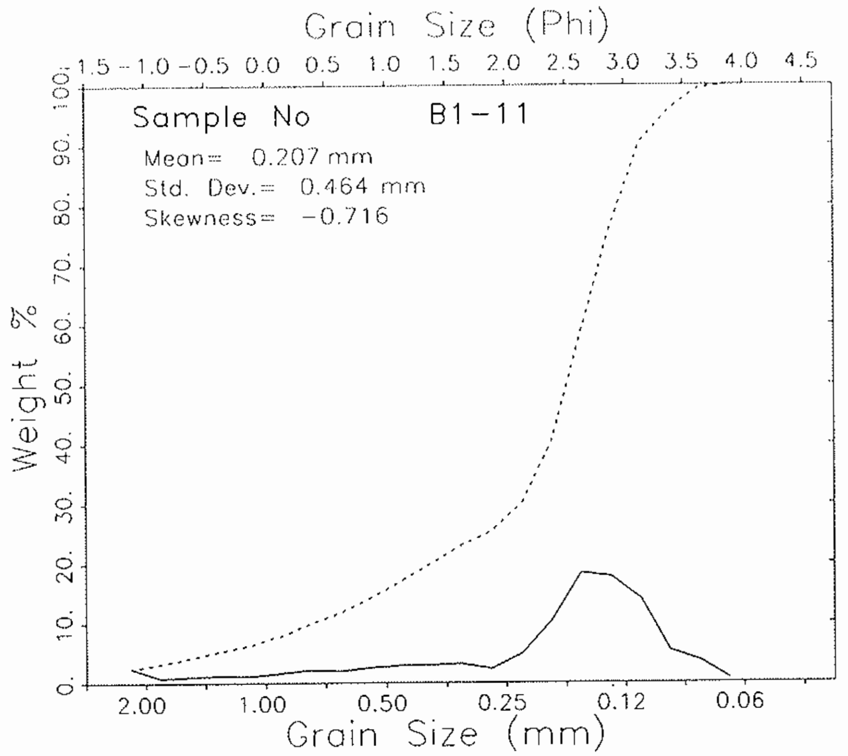
0 DISPERSION = .417 STANDARD DEVIATION = .632 DEVIATION FROM NORMAL DISTR. = -35.86%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.146	.047	2.056	2.359	2.708	3.017	3.168	3.543	3.856

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.612	2.644	FINE SAND
STANDARD DEVIATION	.556	.808	MODERATELY SORTED
SKEWNESS(1)	-.172	-.347	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.642		
KURTOSIS	2.144	2.176	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B1-11 151100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	2.410	2.351	-1.000	2.351
-.875	.770	.751	-.750	3.102
-.625	1.000	.976	-.500	4.078
-.375	1.180	1.151	-.250	5.229
-.125	1.050	1.024	.000	6.254
.125	1.600	1.561	.250	7.815
.375	2.070	2.020	.500	9.834
.625	1.950	1.902	.750	11.737
.875	2.520	2.459	1.000	14.195
1.125	2.900	2.829	1.250	17.024
1.375	2.970	2.898	1.500	19.922
1.625	3.150	3.073	1.750	22.995
1.875	2.250	2.195	2.000	25.190
2.125	4.850	4.732	2.250	29.922
2.375	10.530	10.273	2.500	40.195
2.625	18.800	18.341	2.750	58.537
2.875	18.190	17.746	3.000	76.283
3.125	14.400	14.049	3.250	90.332
3.375	5.470	5.337	3.500	95.668
3.625	3.760	3.668	3.750	99.337
3.875	.680	.663	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.500

PERCENT FINER THAN 4.00 PHI = 1.67 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.275 STANDARD DEVIATION = 1.109 SKEWNESS = -.716 KURTOSIS = 1.455

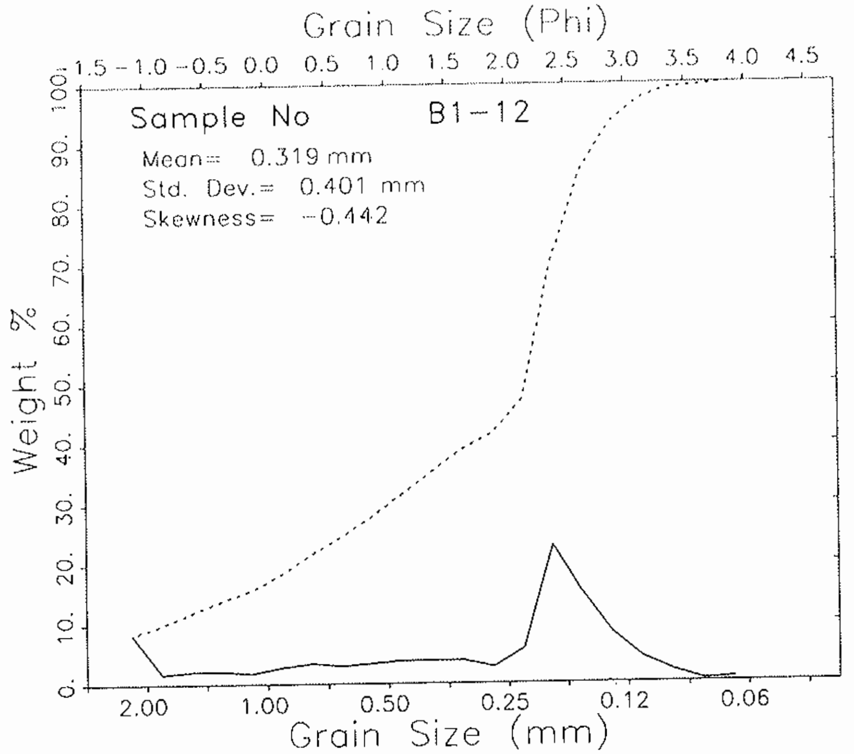
0 DISPERSION = .508 STANDARD DEVIATION = .779 DEVIATION FROM NORMAL DISTR. = -29.72%

0 PERCENTILES:

+

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.144	-.300	1.159	1.978	2.634	2.982	3.137	3.469	3.727

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	2.148	2.310	
+				FINE SAND
0	STANDARD DEVIATION	.989	1.065	
+				POORLY SORTED
0	SKEWNESS(1)	-.491	-.524	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-1.061		
0	KURTOSIS	.905	1.539	
+				VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B1-12 161100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	8.460	8.191	-1.000	8.191
-.875	1.670	1.617	-.750	9.808
-.625	2.130	2.062	-.500	11.871
-.375	2.120	2.053	-.250	13.923
-.125	1.790	1.733	.000	15.656
.125	2.770	2.682	.250	18.338
.375	3.440	3.331	.500	21.669
.625	3.020	2.924	.750	24.593
.875	3.390	3.282	1.000	27.876
1.125	3.820	3.699	1.250	31.574
1.375	3.860	3.737	1.500	35.312
1.625	3.830	3.708	1.750	39.020
1.875	2.700	2.614	2.000	41.634
2.125	5.820	5.635	2.250	47.270
2.375	23.640	22.889	2.500	70.159
2.625	15.400	14.911	2.750	85.070
2.875	8.410	8.143	3.000	93.213
3.125	4.200	4.067	3.250	97.279
3.375	1.880	1.820	3.500	99.100
3.625	.320	.310	3.750	99.409
3.875	.610	.591	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.280

PERCENT FINER THAN 4.00 PHI = .73 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.648 STANDARD DEVIATION = 1.320 SKEWNESS = -.442 KURTOSIS = -.437

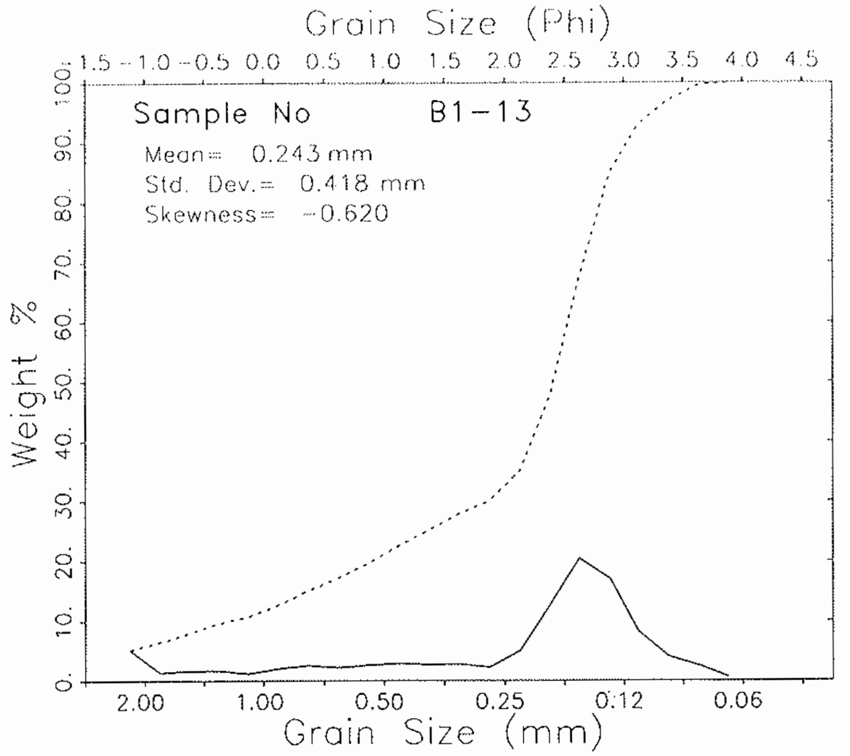
0 DISPERSION = .540 STANDARD DEVIATION = .838 DEVIATION FROM NORMAL DISTR. = -36.49%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.219	-1.097	.032	.781	2.280	2.581	2.732	3.110	3.486

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.382	1.681	MEDIUM SAND
STANDARD DEVIATION	1.350	1.312	POORLY SORTED
SKEWNESS(1)	-.665	-.635	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.943		
KURTOSIS	.558	.958	MESOKURTIC



1 SAMPLE NO. DATE

B1-13 161100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	5.360	5.092	-1.000	5.092
-.875	1.330	1.264	-.750	6.356
-.625	1.660	1.577	-.500	7.933
-.375	1.730	1.644	-.250	9.576
-.125	1.200	1.140	.000	10.716
.125	2.030	1.929	.250	12.645
.375	2.560	2.432	.500	15.077
.625	2.220	2.109	.750	17.186
.875	2.680	2.546	1.000	19.732
1.125	2.950	2.803	1.250	22.535
1.375	2.750	2.613	1.500	25.147
1.625	2.820	2.679	1.750	27.826
1.875	2.280	2.166	2.000	29.992
2.125	5.180	4.921	2.250	34.914
2.375	13.320	12.654	2.500	47.568
2.625	21.340	20.274	2.750	67.842
2.875	17.990	17.091	3.000	84.933
3.125	8.500	8.075	3.250	93.008
3.375	4.180	3.971	3.500	96.979
3.625	2.600	2.470	3.750	99.449
3.875	.580	.551	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.260

PERCENT FINER THAN 4.00 PHI = 1.10 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.039 STANDARD DEVIATION = 1.258 SKEWNESS = -.620 KURTOSIS = .503

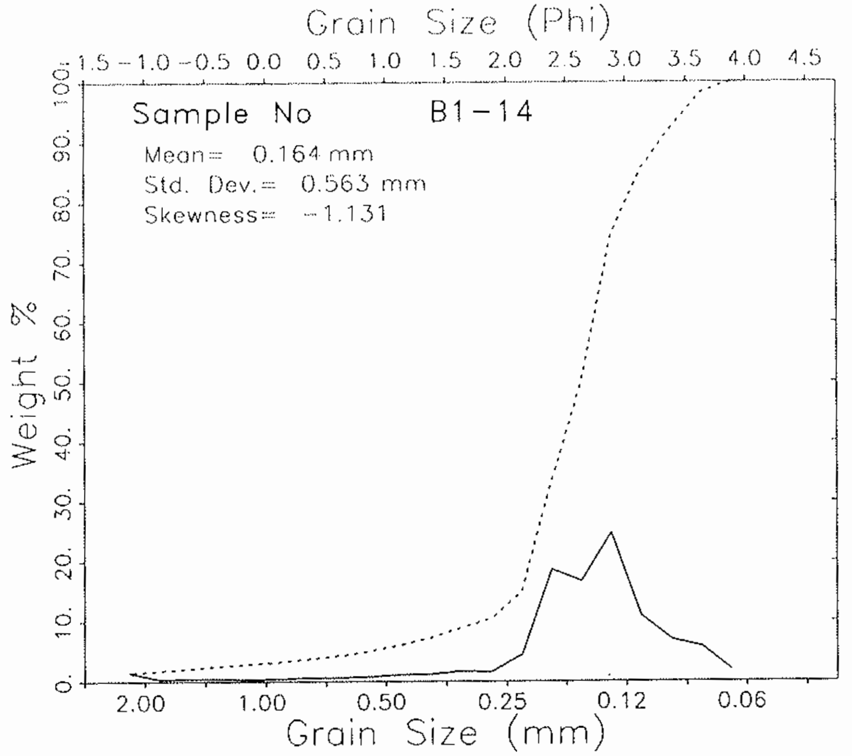
0 DISPERSION = .525 STANDARD DEVIATION = .810 DEVIATION FROM NORMAL DISTR. = -35.65%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.201	-1.005	.609	1.486	2.530	2.855	2.986	3.375	3.705

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.798	2.042	FINE SAND
STANDARD DEVIATION	1.188	1.258	POORLY SORTED
SKEWNESS(1)	-.616	-.615	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.131		
KURTOSIS	.843	1.311	LEPTOKURTIC



1 SAMPLE NO. DATE

B1-14 141100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	1.470	1.420	-1.000	1.420
-.875	.290	.280	-.750	1.700
-.625	.430	.415	-.500	2.115
-.375	.410	.396	-.250	2.511
-.125	.300	.290	.000	2.801
.125	.410	.396	.250	3.197
.375	.550	.531	.500	3.728
.625	.540	.521	.750	4.249
.875	.780	.753	1.000	5.002
1.125	1.060	1.024	1.250	6.026
1.375	1.210	1.169	1.500	7.195
1.625	1.720	1.661	1.750	8.856
1.875	1.650	1.593	2.000	10.449
2.125	4.530	4.375	2.250	14.824
2.375	19.210	18.551	2.500	33.375
2.625	17.240	16.649	2.750	50.024
2.875	25.550	24.674	3.000	74.698
3.125	11.200	10.816	3.250	85.514
3.375	7.150	6.905	3.500	92.419
3.625	5.940	5.736	3.750	98.155
3.875	1.910	1.845	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.550

PERCENT FINER THAN 4.00 PHI = .92 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.604 STANDARD DEVIATION = .829 SKEWNESS = -1.131 KURTOSIS = 7.056

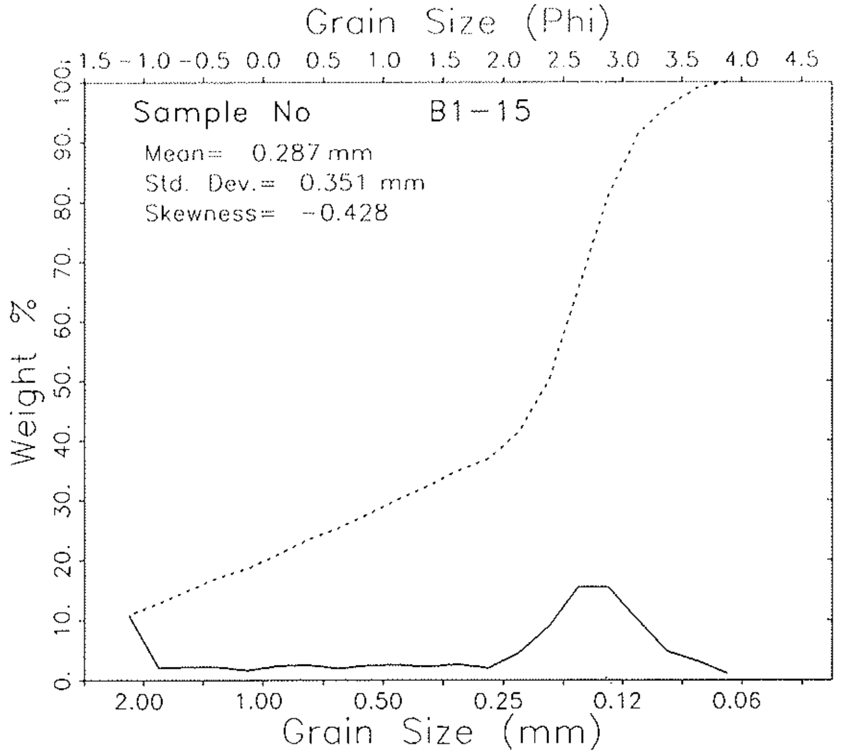
0 DISPERSION = .371 STANDARD DEVIATION = .569 DEVIATION FROM NORMAL DISTR. = -31.37%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.074	.999	2.266	2.387	2.750	3.007	3.215	3.612	3.864

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.740	2.743	FINE SAND
STANDARD DEVIATION	.475	.633	MODERATELY WELL SORTED
SKEWNESS(1)	-.019	-.180	COARSE-SKEWED
SKEWNESS(2)	-.935		
KURTOSIS	1.753	1.728	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-15	141100					
Bogue Banks Borrow Area B1						
		-1.125	11.710	10.792	-1.000	10.792
		-.875	2.130	1.963	-.750	12.755
		-.625	2.320	2.138	-.500	14.893
		-.375	2.340	2.156	-.250	17.049
		-.125	1.680	1.548	.000	18.597
		.125	2.520	2.322	.250	20.920
		.375	2.700	2.488	.500	23.408
		.625	2.080	1.917	.750	25.325
		.875	2.550	2.350	1.000	27.675
		1.125	2.650	2.442	1.250	30.117
		1.375	2.430	2.239	1.500	32.356
		1.625	2.740	2.525	1.750	34.882
		1.875	2.130	1.963	2.000	36.845
		2.125	4.790	4.414	2.250	41.259
		2.375	9.680	8.921	2.500	50.180
		2.625	16.750	15.436	2.750	65.616
		2.875	16.760	15.446	3.000	81.062
		3.125	10.930	10.073	3.250	91.134
		3.375	5.090	4.691	3.500	95.825
		3.625	3.380	3.115	3.750	98.940
		3.875	1.150	1.060	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.510

PERCENT FINER THAN 4.00 PHI = 1.23 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

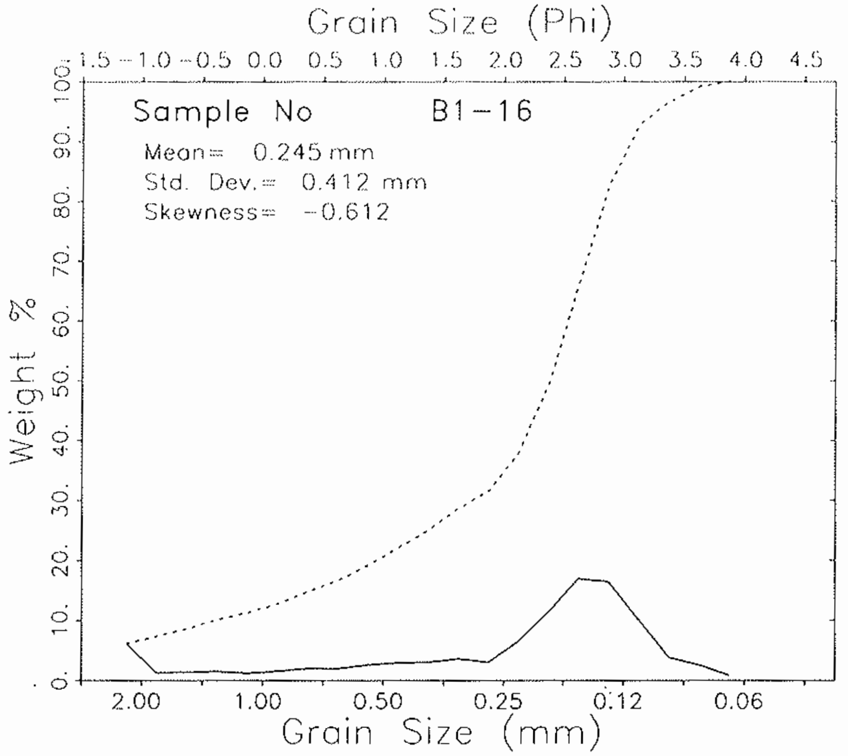
MEAN = 1.801 STANDARD DEVIATION = 1.512 SKEWNESS = -.428 KURTOSIS = -.683

0 DISPERSION = .569 STANDARD DEVIATION = .898 DEVIATION FROM NORMAL DISTR. = -40.66%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.134	-.372	.708	2.495	2.902	3.073	3.456	3.764

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.351	1.732	MEDIUM SAND
STANDARD DEVIATION	1.722	1.557	POORLY SORTED
SKEWNESS(1)	-.664	-.623	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.775		
KURTOSIS	.333	.857	PLATYKURTIC



1 SAMPLE NO. DATE

B1-16 141100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	6.680	6.106	-1.000	6.106
-.875	1.290	1.179	-.750	7.285
-.625	1.430	1.307	-.500	8.592
-.375	1.620	1.481	-.250	10.073
-.125	1.250	1.143	.000	11.216
.125	1.650	1.508	.250	12.724
.375	2.200	2.011	.500	14.735
.625	2.020	1.846	.750	16.581
.875	2.810	2.569	1.000	19.150
1.125	3.190	2.916	1.250	22.066
1.375	3.260	2.980	1.500	25.046
1.625	3.870	3.537	1.750	28.583
1.875	3.240	2.962	2.000	31.545
2.125	7.090	6.481	2.250	38.026
2.375	12.450	11.380	2.500	49.406
2.625	18.500	16.910	2.750	66.316
2.875	17.900	16.362	3.000	82.678
3.125	11.070	10.119	3.250	92.797
3.375	4.200	3.839	3.500	96.636
3.625	2.770	2.532	3.750	99.168
3.875	.910	.832	4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.400

PERCENT FINER THAN 4.00 PHI = .72 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

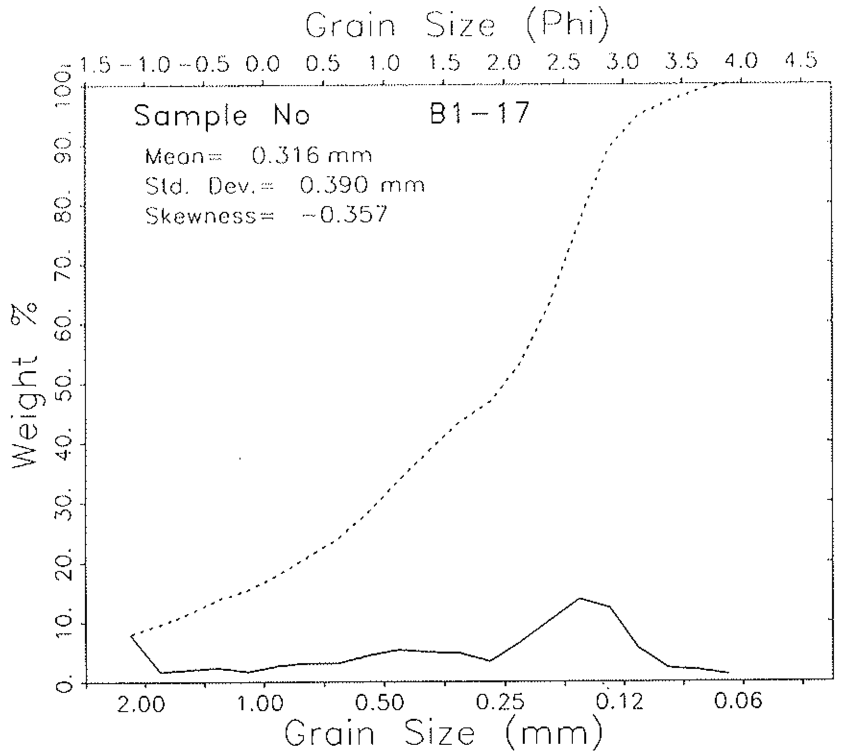
MEAN = 2.028 STANDARD DEVIATION = 1.279 SKEWNESS = -.612 KURTOSIS = .509

0 DISPERSION = .546 STANDARD DEVIATION = .851 DEVIATION FROM NORMAL DISTR. = -33.44%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.209	-1.045	.671	1.496	2.509	2.883	3.033	3.393	3.733

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.852	2.071	FINE SAND
STANDARD DEVIATION	1.181	1.263	POORLY SORTED
SKEWNESS(1)	-.556	-.579	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.130		
KURTOSIS	.880	1.312	LEPTOKURTIC



1 SAMPLE NO. DATE

	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-17 141100						
Bogue Banks Borrow Area B1						
	-1.125	8.590	7.851		-1.000	7.851
	-.875	1.810	1.654		-.750	9.506
	-.625	2.110	1.929		-.500	11.434
	-.375	2.510	2.294		-.250	13.728
	-.125	1.780	1.627		.000	15.355
	.125	2.840	2.596		.250	17.951
	.375	3.340	3.053		.500	21.004
	.625	3.320	3.034		.750	24.038
	.875	4.820	4.405		1.000	28.443
	1.125	5.800	5.301		1.250	33.745
	1.375	5.310	4.853		1.500	38.598
	1.625	5.130	4.689		1.750	43.287
	1.875	3.660	3.345		2.000	46.632
	2.125	7.060	6.453		2.250	53.085
	2.375	11.130	10.173		2.500	63.257
	2.625	15.010	13.719		2.750	76.977
	2.875	13.470	12.311		3.000	89.288
	3.125	5.980	5.466		3.250	94.754
	3.375	2.430	2.221		3.500	96.975
	3.625	2.090	1.910		3.750	98.885
	3.875	1.220	1.115		4.000	100.000

TOTAL WEIGHT (GRAMS) = 109.410

PERCENT FINER THAN 4.00 PHI = 1.54 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.663 STANDARD DEVIATION = 1.357 SKEWNESS = -.357 KURTOSIS = -.578

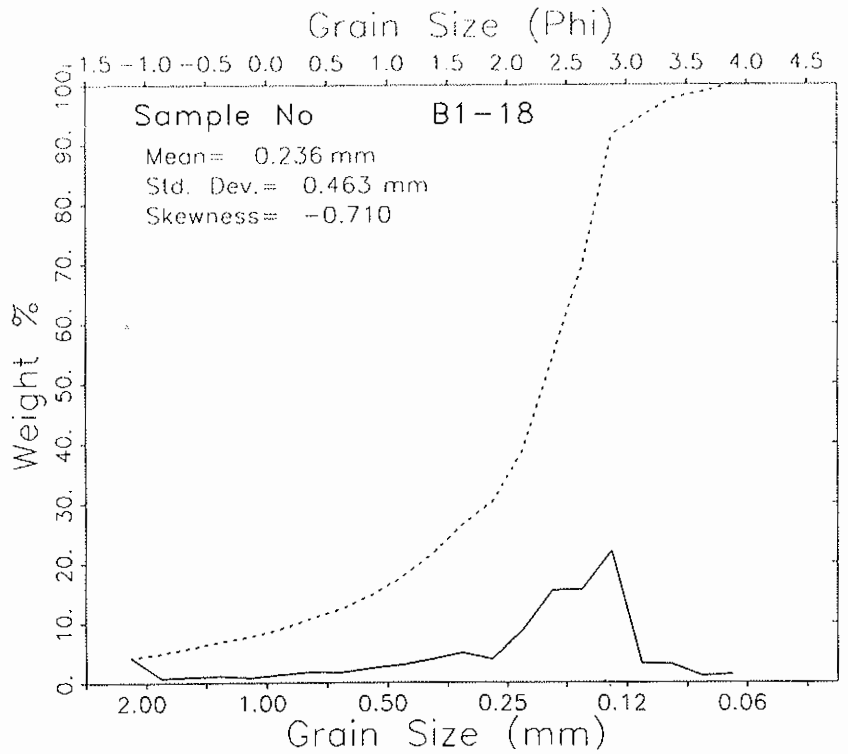
0 DISPERSION = .619 STANDARD DEVIATION = 1.006 DEVIATION FROM NORMAL DISTR. = -25.89%

0 PERCENTILES:

\+

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.218	-1.091	.062	.805	2.130	2.714	2.893	3.278	3.776

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	1.477	1.695	
+				MEDIUM SAND
0	STANDARD DEVIATION	1.415	1.370	
+				POORLY SORTED
0	SKEWNESS(1)	-.461	-.468	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-.733		
0	KURTOSIS	.543	.938	
+				MESOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO. / DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-18 141100					
Bogue Banks Borrow Area B1					
	-1.125	4.390	4.111	-1.000	4.111
	-.875	.770	.721	-.750	4.832
	-.625	.990	.927	-.500	5.759
	-.375	1.150	1.077	-.250	6.836
	-.125	.890	.833	.000	7.669
	.125	1.430	1.339	.250	9.008
	.375	1.830	1.714	.500	10.722
	.625	1.710	1.601	.750	12.323
	.875	2.590	2.425	1.000	14.749
	1.125	3.090	2.894	1.250	17.642
	1.375	4.090	3.830	1.500	21.472
	1.625	5.210	4.879	1.750	26.351
	1.875	4.040	3.783	2.000	30.134
	2.125	9.220	8.634	2.250	38.768
	2.375	16.370	15.329	2.500	54.097
	2.625	16.550	15.498	2.750	69.595
	2.875	23.380	21.893	3.000	91.488
	3.125	3.350	3.137	3.250	94.625
	3.375	3.210	3.006	3.500	97.631
	3.625	1.160	1.086	3.750	98.717
	3.875	1.370	1.283	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.790

PERCENT FINER THAN 4.00 PHI = .29 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

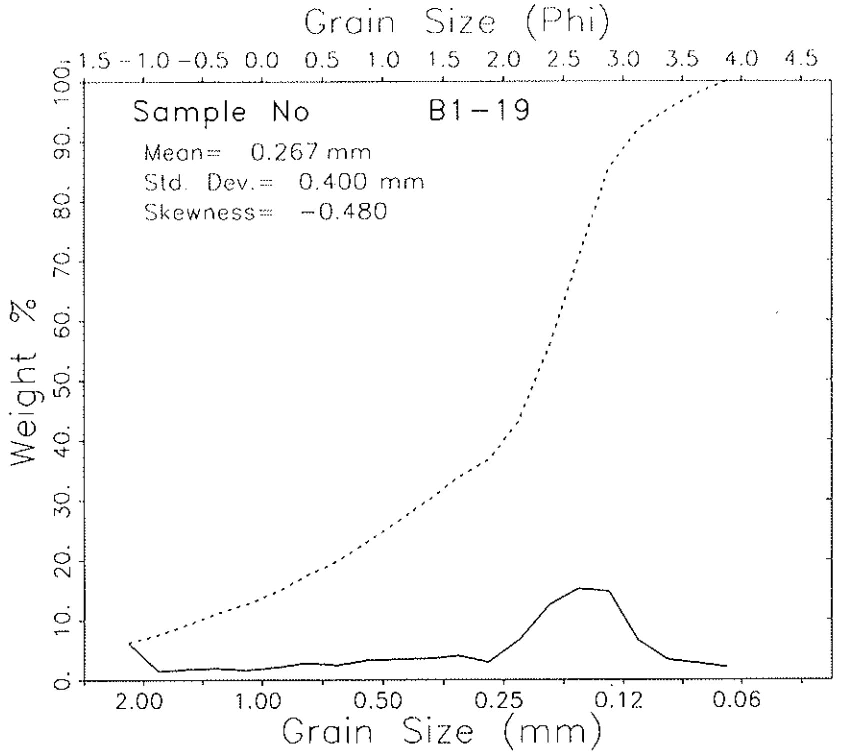
MEAN = 2.084 STANDARD DEVIATION = 1.112 SKEWNESS = -.710 KURTOSIS = 1.532

0 DISPERSION = .493 STANDARD DEVIATION = .752 DEVIATION FROM NORMAL DISTR. = -32.31%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.189	-.705	1.108	1.681	2.433	2.812	2.914	3.281	3.805

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.011	2.152	FINE SAND
STANDARD DEVIATION	.903	1.056	POORLY SORTED
SKEWNESS(1)	-.467	-.521	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.268		
KURTOSIS	1.207	1.444	LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-19	141100					
Bogue Banks Borrow Area B1						
		-1.125	6.840	6.125	-1.000	6.125
		-.875	1.550	1.388	-.750	7.513
		-.625	1.890	1.692	-.500	9.206
		-.375	2.100	1.881	-.250	11.086
		-.125	1.730	1.549	.000	12.635
		.125	2.280	2.042	.250	14.677
		.375	3.030	2.713	.500	17.391
		.625	2.690	2.409	.750	19.799
		.875	3.600	3.224	1.000	23.023
		1.125	3.750	3.358	1.250	26.381
		1.375	3.910	3.501	1.500	29.883
		1.625	4.390	3.931	1.750	33.814
		1.875	3.200	2.866	2.000	36.680
		2.125	7.320	6.555	2.250	43.235
		2.375	13.830	12.385	2.500	55.619
		2.625	16.900	15.134	2.750	70.753
		2.875	16.470	14.749	3.000	85.502
		3.125	7.240	6.483	3.250	91.985
		3.375	3.660	3.278	3.500	95.263
		3.625	3.010	2.695	3.750	97.958
		3.875	2.280	2.042	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.670

PERCENT FINER THAN 4.00 PHI = 2.52 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

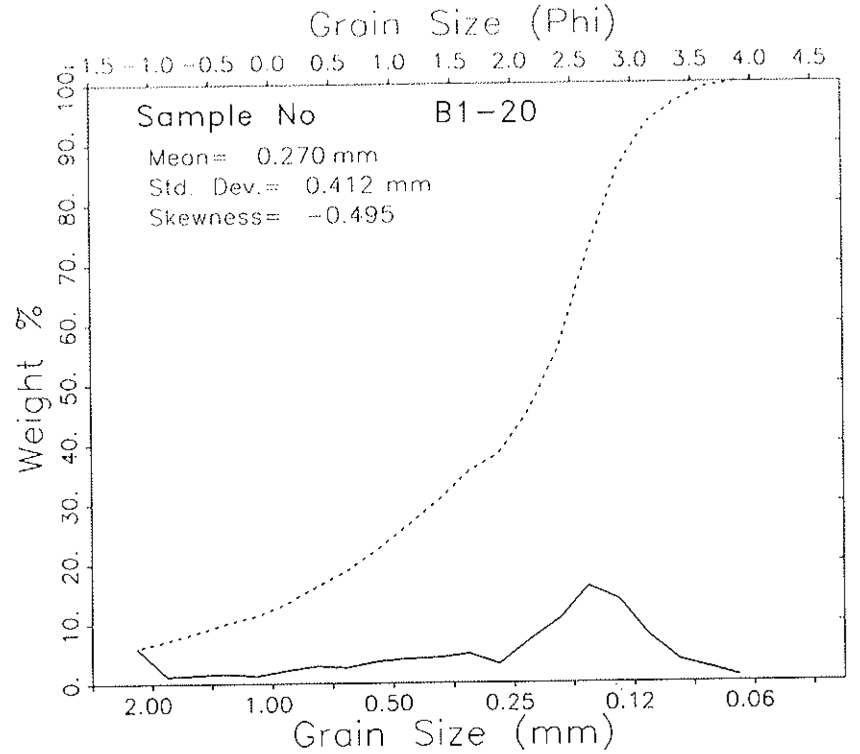
\+ MEAN = 1.904 STANDARD DEVIATION = 1.322 SKEWNESS = -.480 KURTOSIS = -.079

0 DISPERSION = .592 STANDARD DEVIATION = .945 DEVIATION FROM NORMAL DISTR. = -28.55%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.209	-1.046	.372	1.147	2.387	2.822	2.975	3.480	3.878

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.673	1.911	MEDIUM SAND
STANDARD DEVIATION	1.301	1.336	POORLY SORTED
SKEWNESS(1)	-.548	-.533	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.899		
KURTOSIS	.739	1.108	MESOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-20	141100						
Bogue Banks Borrow Area B1							
		-1.125	6.310		5.924	-1.000	5.924
		-.875	1.240		1.164	-.750	7.088
		-.625	1.470		1.380	-.500	8.468
		-.375	1.680		1.577	-.250	10.045
		-.125	1.320		1.239	.000	11.284
		.125	2.250		2.112	.250	13.397
		.375	2.990		2.807	.500	16.204
		.625	2.730		2.563	.750	18.766
		.875	3.750		3.520	1.000	22.287
		1.125	4.190		3.934	1.250	26.220
		1.375	4.370		4.103	1.500	30.323
		1.625	5.140		4.825	1.750	35.148
		1.875	3.280		3.079	2.000	38.228
		2.125	7.430		6.975	2.250	45.203
		2.375	11.170		10.486	2.500	55.689
		2.625	16.990		15.950	2.750	71.639
		2.875	14.740		13.838	3.000	85.477
		3.125	8.240		7.736	3.250	93.213
		3.375	3.870		3.633	3.500	96.846
		3.625	2.450		2.300	3.750	99.146
		3.875	.910		.854	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.520

PERCENT FINER THAN 4.00 PHI = .78 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

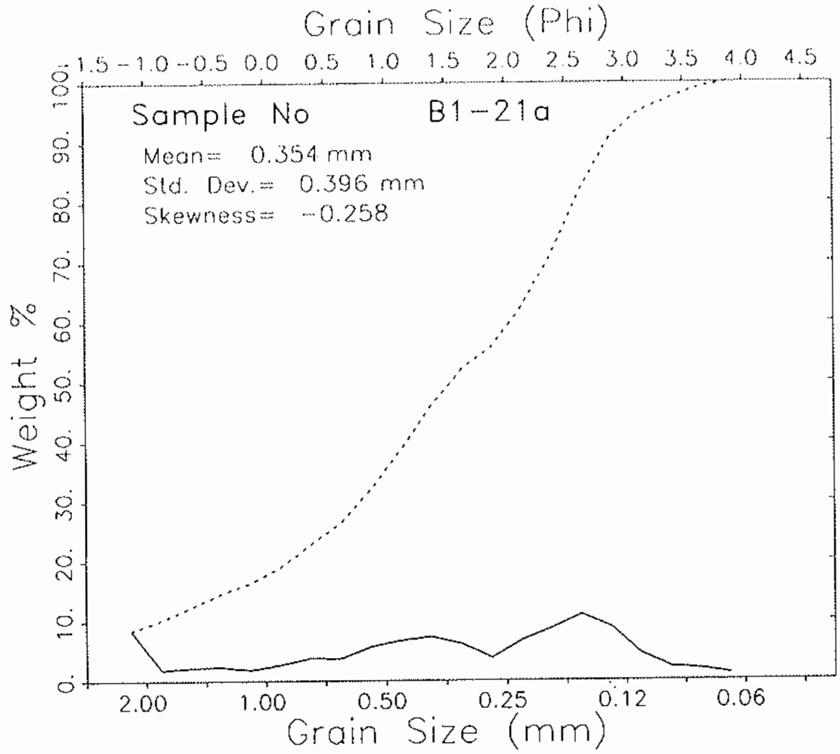
+ MEAN = 1.899 STANDARD DEVIATION = 1.281 SKEWNESS = -.495 KURTOSIS = .035

0 DISPERSION = .587 STANDARD DEVIATION = .935 DEVIATION FROM NORMAL DISTR. = -27.00%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.208	-1.039	.482	1.172	2.364	2.811	2.973	3.373	3.734

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.728	1.940	MEDIUM SAND
STANDARD DEVIATION	1.246	1.291	POORLY SORTED
SKEWNESS(1)	-.511	-.527	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.961		
KURTOSIS	.771	1.104	MESOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-21a	141100					
Bogue Banks Borrow Area B1						
		-1.125	9.290	8.370	-1.000	8.370
		-.875	1.970	1.775	-.750	10.145
		-.625	2.390	2.153	-.500	12.298
		-.375	2.520	2.270	-.250	14.569
		-.125	1.980	1.784	.000	16.353
		.125	2.920	2.631	.250	18.984
		.375	4.100	3.694	.500	22.678
		.625	4.080	3.676	.750	26.354
		.875	6.300	5.676	1.000	32.030
		1.125	7.370	6.640	1.250	38.670
		1.375	8.020	7.226	1.500	45.896
		1.625	6.730	6.064	1.750	51.960
		1.875	4.150	3.739	2.000	55.699
		2.125	7.330	6.604	2.250	62.303
		2.375	9.630	8.676	2.500	70.979
		2.625	12.130	10.929	2.750	81.908
		2.875	9.750	8.785	3.000	90.693
		3.125	4.830	4.352	3.250	95.045
		3.375	2.360	2.126	3.500	97.171
		3.625	1.980	1.784	3.750	98.955
		3.875	1.160	1.045	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.990

PERCENT FINER THAN 4.00 PHI = 1.20 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

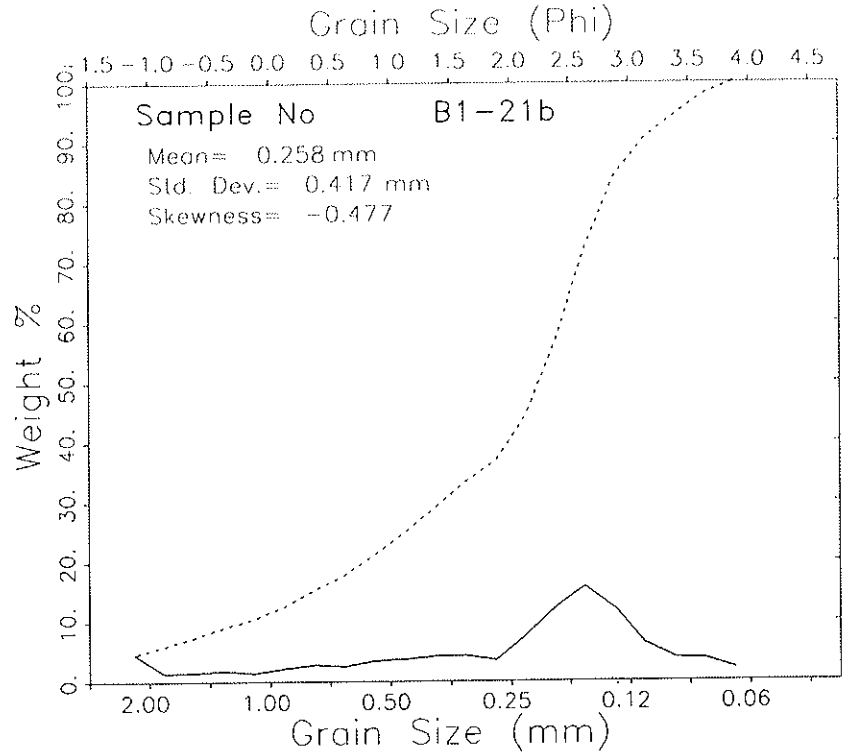
+ MEAN = 1.497 STANDARD DEVIATION = 1.338 SKEWNESS = -.258 KURTOSIS = -.701

0 DISPERSION = .644 STANDARD DEVIATION = 1.066 DEVIATION FROM NORMAL DISTR. = -20.33%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.220	-1.101	-.049	.658	1.669	2.592	2.810	3.247	3.761

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.380	1.476	MEDIUM SAND
STANDARD DEVIATION	1.429	1.374	POORLY SORTED
SKEWNESS(1)	-.202	-.238	COARSE-SKEWED
SKEWNESS(2)	-.417		
KURTOSIS	.521	.921	MESOKURTIC



1 SAMPLE NO. DATE

B1-21b 141100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	4.830	4.564	-1.000	4.564
-.875	1.420	1.342	-.750	5.906
-.625	1.550	1.465	-.500	7.371
-.375	1.860	1.758	-.250	9.129
-.125	1.480	1.399	.000	10.527
.125	2.220	2.098	.250	12.625
.375	2.890	2.731	.500	15.356
.625	2.640	2.495	.750	17.851
.875	3.560	3.364	1.000	21.215
1.125	3.890	3.676	1.250	24.891
1.375	4.410	4.167	1.500	29.059
1.625	4.500	4.253	1.750	33.311
1.875	3.710	3.506	2.000	36.817
2.125	7.970	7.532	2.250	44.349
2.375	12.920	12.209	2.500	56.558
2.625	16.610	15.696	2.750	72.255
2.875	12.740	12.039	3.000	84.294
3.125	6.600	6.237	3.250	90.531
3.375	4.020	3.799	3.500	94.330
3.625	3.830	3.619	3.750	97.949
3.875	2.170	2.051	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.820

PERCENT FINER THAN 4.00 PHI = 2.70 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

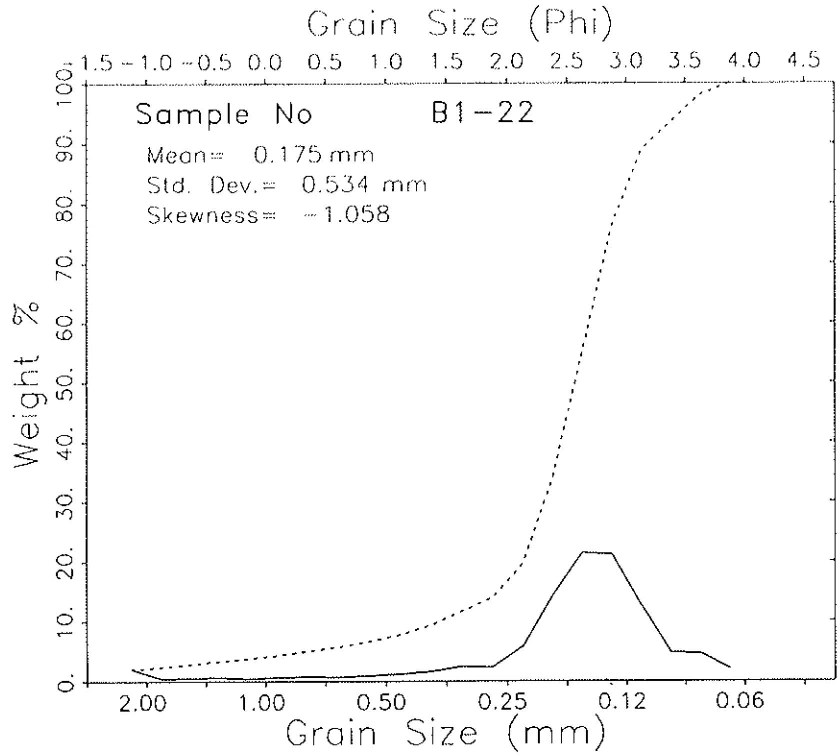
\+ MEAN = 1.953 STANDARD DEVIATION = 1.263 SKEWNESS = -.477 KURTOSIS = .101

0 DISPERSION = .604 STANDARD DEVIATION = .972 DEVIATION FROM NORMAL DISTR. = -23.03%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.195	-.919	.565	1.257	2.366	2.807	2.994	3.546	3.878

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.779	1.975	MEDIUM SAND
STANDARD DEVIATION	1.215	1.284	POORLY SORTED
SKEWNESS(1)	-.483	-.477	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.866		
KURTOSIS	.830	1.180	LEPTOKURTIC



1 SAMPLE NO. DATE

B1-22 141100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
-1.125	2.150	1.934	-1.000	1.934
-.875	.400	.360	-.750	2.294
-.625	.550	.495	-.500	2.788
-.375	.580	.522	-.250	3.310
-.125	.450	.405	.000	3.715
.125	.660	.594	.250	4.308
.375	.820	.738	.500	5.046
.625	.730	.657	.750	5.702
.875	1.030	.926	1.000	6.629
1.125	1.230	1.106	1.250	7.735
1.375	1.730	1.556	1.500	9.291
1.625	2.630	2.366	1.750	11.657
1.875	2.480	2.231	2.000	13.887
2.125	6.280	5.648	2.250	19.536
2.375	15.830	14.238	2.500	33.774
2.625	23.760	21.371	2.750	55.145
2.875	23.510	21.146	3.000	76.291
3.125	13.920	12.520	3.250	88.811
3.375	5.170	4.650	3.500	93.461
3.625	5.050	4.542	3.750	98.003
3.875	2.220	1.997	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.180

PERCENT FINER THAN 4.00 PHI = 1.62 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

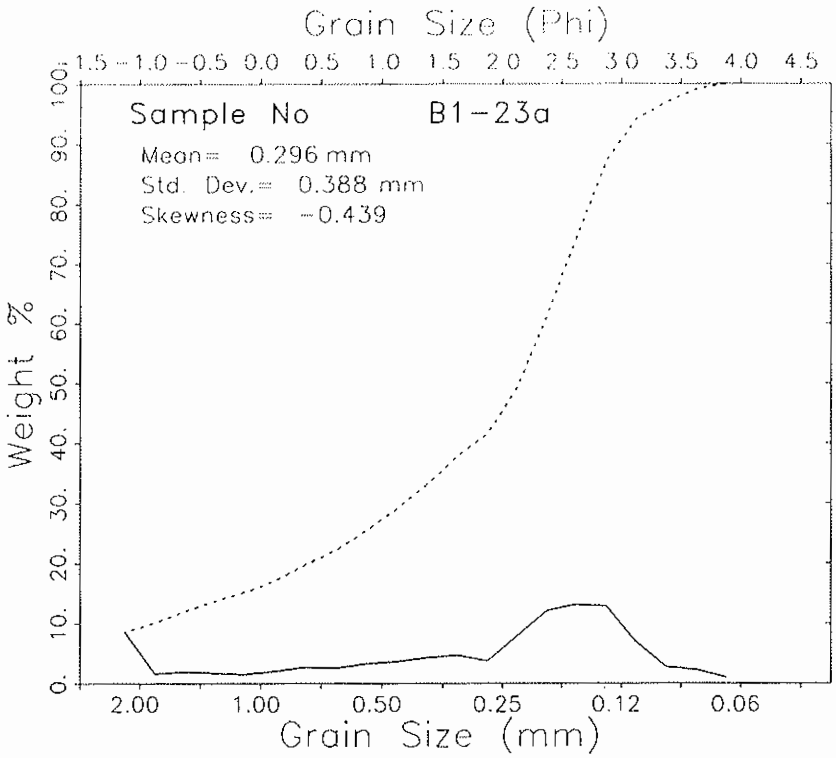
\+ MEAN = 2.517 STANDARD DEVIATION = .905 SKEWNESS = -1.058 KURTOSIS = 5.489

0 DISPERSION = .407 STANDARD DEVIATION = .617 DEVIATION FROM NORMAL DISTR. = -31.76%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.121	.484	2.094	2.346	2.690	2.985	3.154	3.585	3.875

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.624	2.646	FINE SAND
STANDARD DEVIATION	.530	.735	MODERATELY SORTED
SKEWNESS(1)	-.125	-.274	COARSE-SKEWED
SKEWNESS(2)	-1.236		
KURTOSIS	1.924	1.989	VERY LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-23a	141100					
Bogue Banks Borrow Area B1						
		-1.125	8.920	8.524	-1.000	8.524
		-.875	1.620	1.548	-.750	10.073
		-.625	2.000	1.911	-.500	11.984
		-.375	1.740	1.663	-.250	13.647
		-.125	1.570	1.500	.000	15.147
		.125	2.040	1.950	.250	17.097
		.375	2.770	2.647	.500	19.744
		.625	2.560	2.446	.750	22.190
		.875	3.370	3.221	1.000	25.411
		1.125	3.710	3.545	1.250	28.956
		1.375	4.380	4.186	1.500	33.142
		1.625	4.880	4.664	1.750	37.806
		1.875	3.850	3.679	2.000	41.485
		2.125	8.220	7.856	2.250	49.341
		2.375	12.600	12.041	2.500	61.382
		2.625	13.700	13.093	2.750	74.474
		2.875	13.410	12.815	3.000	87.290
		3.125	7.200	6.881	3.250	94.171
		3.375	2.820	2.695	3.500	96.865
		3.625	2.280	2.179	3.750	99.044
		3.875	1.000	.956	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.640

PERCENT FINER THAN 4.00 PHI = .96 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.756 STANDARD DEVIATION = 1.366 SKEWNESS = -.439 KURTOSIS = -.349

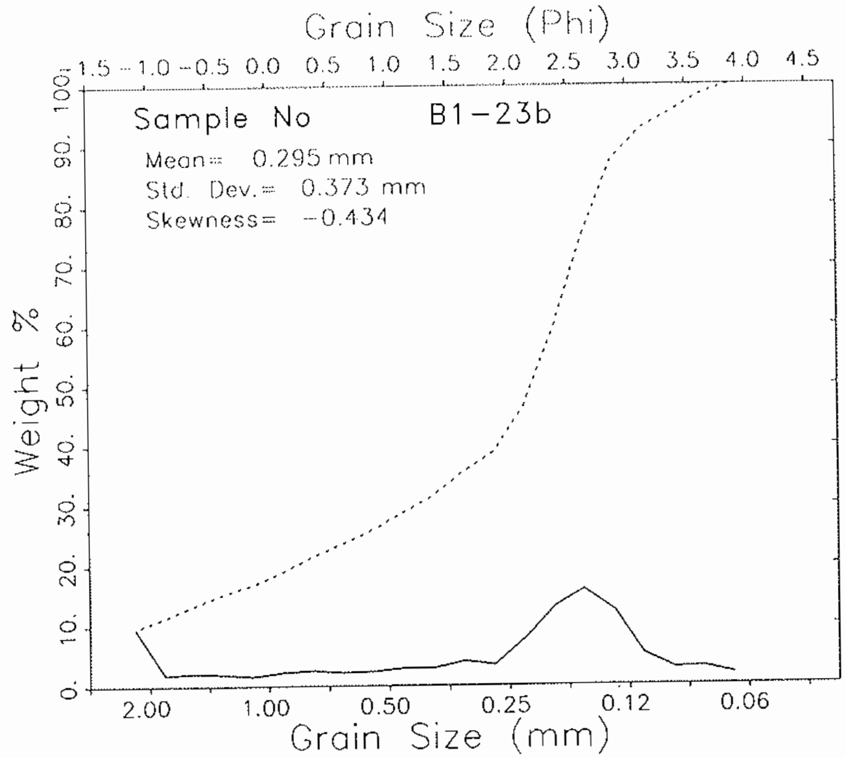
0 DISPERSION = .599 STANDARD DEVIATION = .960 DEVIATION FROM NORMAL DISTR. = -29.71%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.221	-1.103	.109	.968	2.264	2.760	2.936	3.327	3.745

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.523	1.770	MEDIUM SAND
STANDARD DEVIATION	1.413	1.378	POORLY SORTED
SKEWNESS(1)	-.524	-.522	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.815		
KURTOSIS	.567	1.013	MESOKURTIC



1 SAMPLE NO. DATE

B1-23b 131100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	10.000	9.506	-1.000	9.506
-.875	1.930	1.835	-.750	11.340
-.625	2.180	2.072	-.500	13.413
-.375	1.970	1.873	-.250	15.285
-.125	1.660	1.578	.000	16.863
.125	2.340	2.224	.250	19.087
.375	2.630	2.500	.500	21.587
.625	2.220	2.110	.750	23.698
.875	2.390	2.272	1.000	25.970
1.125	2.980	2.833	1.250	28.802
1.375	2.910	2.766	1.500	31.568
1.625	4.150	3.945	1.750	35.513
1.875	3.480	3.308	2.000	38.821
2.125	8.000	7.605	2.250	46.426
2.375	13.610	12.937	2.500	59.363
2.625	16.590	15.770	2.750	75.133
2.875	13.060	12.414	3.000	87.548
3.125	5.320	5.057	3.250	92.605
3.375	2.880	2.738	3.500	95.342
3.625	3.050	2.899	3.750	98.241
3.875	1.850	1.759	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.200

PERCENT FINER THAN 4.00 PHI = 2.62 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

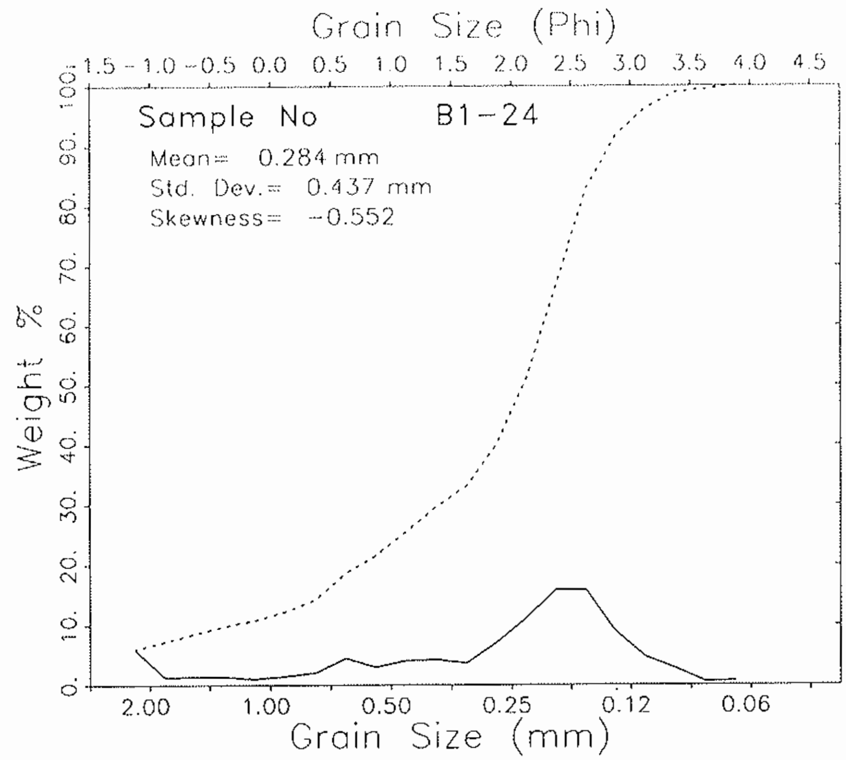
+ MEAN = 1.760 STANDARD DEVIATION = 1.422 SKEWNESS = -.434 KURTOSIS = -.461

0 DISPERSION = .586 STANDARD DEVIATION = .933 DEVIATION FROM NORMAL DISTR. = -34.40%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.118	-.137	.893	2.319	2.748	2.929	3.469	3.850

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.396	1.704	MEDIUM SAND
STANDARD DEVIATION	1.533	1.461	POORLY SORTED
SKEWNESS(1)	-.602	-.551	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.746		
KURTOSIS	.497	1.014	MESOKURTIC



1 SAMPLE NO. DATE

B1-24 141100

Bogue Banks Borrow Area B1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	6.130	5.918	-1.000	5.918
-.875	1.260	1.216	-.750	7.134
-.625	1.380	1.332	-.500	8.466
-.375	1.310	1.265	-.250	9.731
-.125	1.040	1.004	.000	10.735
.125	1.470	1.419	.250	12.154
.375	2.080	2.008	.500	14.162
.625	4.550	4.392	.750	18.554
.875	3.020	2.915	1.000	21.469
1.125	4.110	3.968	1.250	25.437
1.375	4.290	4.141	1.500	29.578
1.625	3.640	3.514	1.750	33.092
1.875	7.260	7.008	2.000	40.100
2.125	11.560	11.159	2.250	51.260
2.375	16.340	15.774	2.500	67.033
2.625	16.300	15.735	2.750	82.769
2.875	9.160	8.843	3.000	91.611
3.125	4.760	4.595	3.250	96.206
3.375	2.770	2.674	3.500	98.880
3.625	.520	.502	3.750	99.382
3.875	.640	.618	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.590

PERCENT FINER THAN 4.00 PHI = 2.81 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

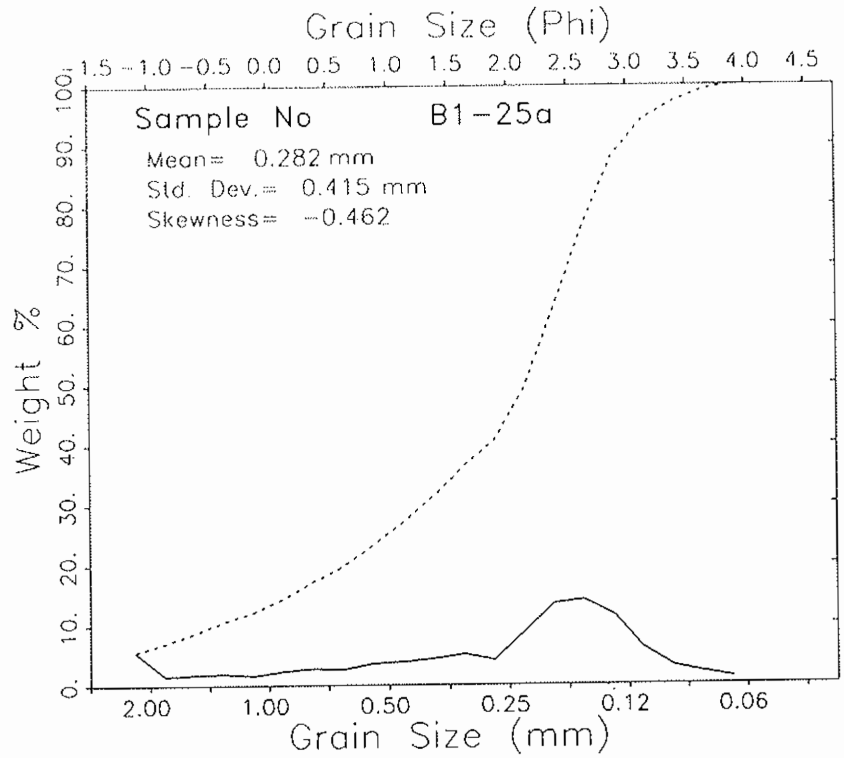
+ MEAN = 1.816 STANDARD DEVIATION = 1.194 SKEWNESS = -.552 KURTOSIS = .421

0 DISPERSION = .554 STANDARD DEVIATION = .866 DEVIATION FROM NORMAL DISTR. = -27.50%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.208	-1.039	.605	1.222	2.222	2.627	2.785	3.184	3.560

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.695	1.870	MEDIUM SAND
STANDARD DEVIATION	1.090	1.185	POORLY SORTED
SKEWNESS(1)	-.483	-.514	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.054		
KURTOSIS	.937	1.233	LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-25a	131100					
Bogue Banks Borrow Area B1						
		-1.125	6.360	5.503	-1.000	5.503
		-.875	1.700	1.471	-.750	6.974
		-.625	1.970	1.704	-.500	8.678
		-.375	2.190	1.895	-.250	10.573
		-.125	1.820	1.575	.000	12.147
		.125	2.690	2.327	.250	14.475
		.375	3.170	2.743	.500	17.218
		.625	2.910	2.518	.750	19.735
		.875	4.100	3.547	1.000	23.283
		1.125	4.370	3.781	1.250	27.064
		1.375	4.950	4.283	1.500	31.346
		1.625	5.820	5.035	1.750	36.382
		1.875	4.680	4.049	2.000	40.431
		2.125	10.080	8.721	2.250	49.152
		2.375	15.500	13.411	2.500	62.563
		2.625	16.190	14.008	2.750	76.570
		2.875	13.300	11.507	3.000	88.078
		3.125	6.870	5.944	3.250	94.021
		3.375	3.400	2.942	3.500	96.963
		3.625	2.300	1.990	3.750	98.953
		3.875	1.210	1.047	4.000	100.000

TOTAL WEIGHT (GRAMS) = 115.580

PERCENT FINER THAN 4.00 PHI = 1.21 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

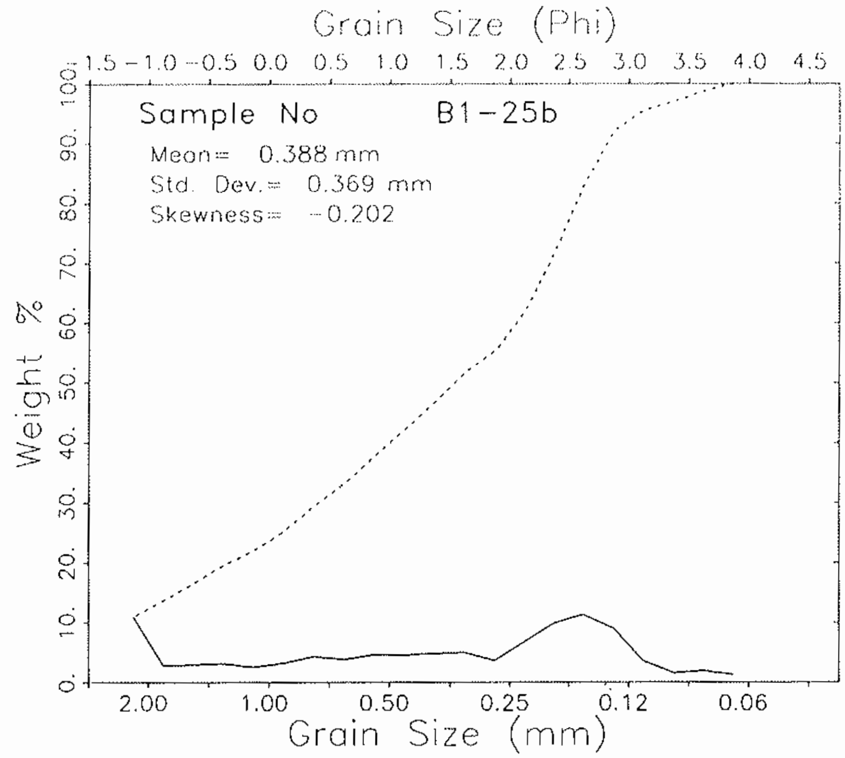
\+ MEAN = 1.825 STANDARD DEVIATION = 1.268 SKEWNESS = -.462 KURTOSIS = -.063

0 DISPERSION = .602 STANDARD DEVIATION = .967 DEVIATION FROM NORMAL DISTR. = -23.74%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.205	-1.023	.389	1.114	2.266	2.722	2.911	3.333	3.761

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.650	1.855	MEDIUM SAND
STANDARD DEVIATION	1.261	1.291	POORLY SORTED
SKEWNESS(1)	-.488	-.499	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.881		
KURTOSIS	.727	1.110	MESOKURTIC



1 SAMPLE NO. DATE

B1-25b 131100
Bogue Banks Borrow Area B1

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	11.600	10.879	-1.000	10.879
-.875	2.900	2.720	-.750	13.598
-.625	3.080	2.888	-.500	16.487
-.375	3.250	3.048	-.250	19.535
-.125	2.630	2.466	.000	22.001
.125	3.380	3.170	.250	25.171
.375	4.480	4.201	.500	29.373
.625	3.990	3.742	.750	33.115
.875	4.830	4.530	1.000	37.644
1.125	4.730	4.436	1.250	42.080
1.375	5.000	4.689	1.500	46.769
1.625	5.220	4.895	1.750	51.665
1.875	3.830	3.592	2.000	55.257
2.125	7.140	6.696	2.250	61.953
2.375	10.480	9.828	2.500	71.781
2.625	12.010	11.263	2.750	83.044
2.875	9.600	9.003	3.000	92.047
3.125	3.720	3.489	3.250	95.536
3.375	1.540	1.444	3.500	96.980
3.625	1.930	1.810	3.750	98.790
3.875	1.290	1.210	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.630

PERCENT FINER THAN 4.00 PHI = 2.54 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.366 STANDARD DEVIATION = 1.438 SKEWNESS = -.202 KURTOSIS = -1.068

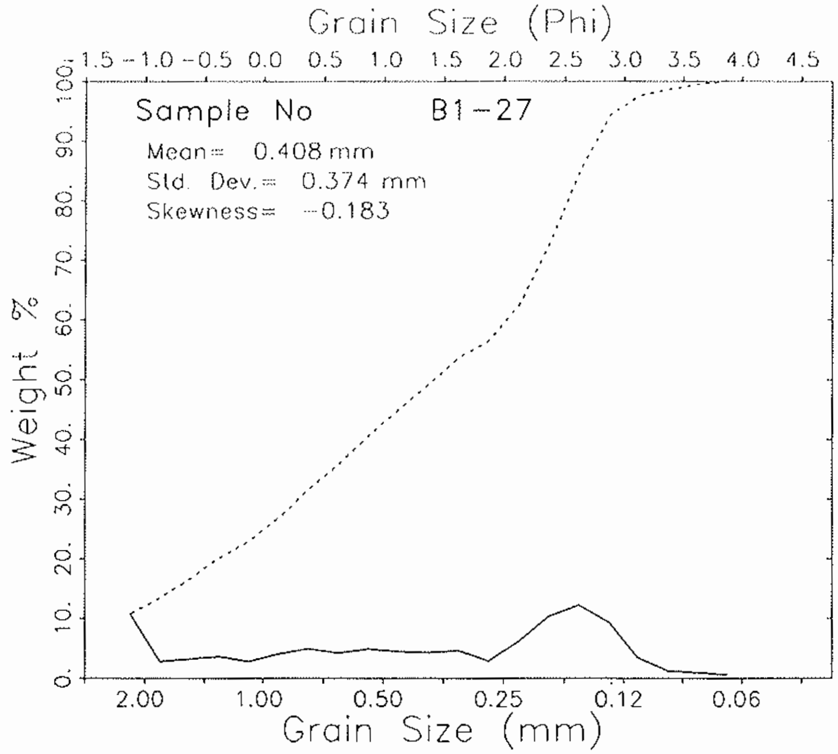
0 DISPERSION = .644 STANDARD DEVIATION = 1.067 DEVIATION FROM NORMAL DISTR. = -25.79%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.135	-.542	.237	1.665	2.571	2.777	3.212	3.793

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.117	1.300	MEDIUM SAND
STANDARD DEVIATION	1.659	1.488	POORLY SORTED
SKEWNESS(1)	-.330	-.309	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.378		
KURTOSIS	.310	.763	PLATYKURTIC



1 SAMPLE NO. DATE

B1-27 270301
Borrow B1 - Station 27

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	11.280	10.698	-1.000	10.698
-.875	2.830	2.684	-.750	13.382
-.625	3.320	3.149	-.500	16.531
-.375	3.750	3.557	-.250	20.087
-.125	2.880	2.731	.000	22.819
.125	4.170	3.955	.250	26.774
.375	5.110	4.846	.500	31.620
.625	4.340	4.116	.750	35.736
.875	5.100	4.837	1.000	40.573
1.125	4.610	4.372	1.250	44.945
1.375	4.440	4.211	1.500	49.156
1.625	4.760	4.514	1.750	53.670
1.875	2.980	2.826	2.000	56.497
2.125	6.350	6.022	2.250	62.519
2.375	10.830	10.271	2.500	72.790
2.625	12.820	12.159	2.750	84.949
2.875	9.780	9.275	3.000	94.224
3.125	3.460	3.281	3.250	97.506
3.375	1.160	1.100	3.500	98.606
3.625	.910	.863	3.750	99.469
3.875	.560	.531	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.440

PERCENT FINER THAN 4.00 PHI = 1.09 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

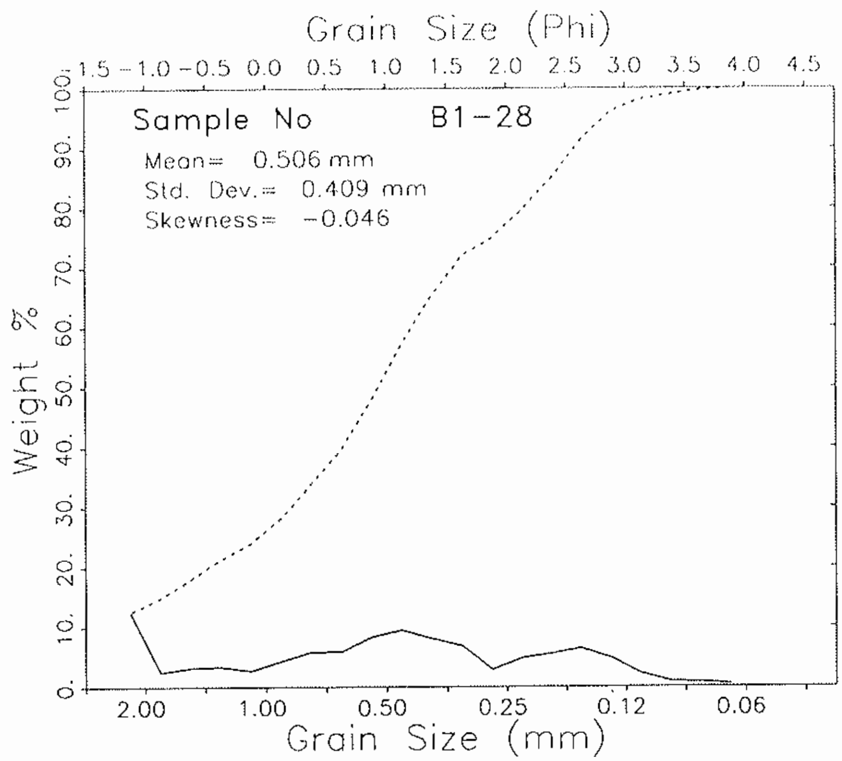
+ MEAN = 1.294 STANDARD DEVIATION = 1.417 SKEWNESS = -.183 KURTOSIS = -1.170

0 DISPERSION = .629 STANDARD DEVIATION = 1.031 DEVIATION FROM NORMAL DISTR. = -27.28%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.133	-.542	.138	1.547	2.545	2.730	3.059	3.614

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.094	1.245	MEDIUM SAND
STANDARD DEVIATION	1.636	1.453	POORLY SORTED
SKEWNESS(1)	-.277	-.278	COARSE-SKEWED
SKEWNESS(2)	-.357		
KURTOSIS	.281	.714	PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-28	270301					
Borrow B1 - Station 28						
		-1.125	12.520	12.428	-1.000	12.428
		-.875	2.380	2.363	-.750	14.791
		-.625	3.170	3.147	-.500	17.937
		-.375	3.340	3.315	-.250	21.253
		-.125	2.680	2.660	.000	23.913
		.125	4.240	4.209	.250	28.122
		.375	5.780	5.738	.500	33.859
		.625	5.810	5.767	.750	39.627
		.875	8.260	8.199	1.000	47.826
		1.125	9.460	9.391	1.250	57.217
		1.375	8.070	8.011	1.500	65.227
		1.625	6.780	6.730	1.750	71.958
		1.875	2.830	2.809	2.000	74.767
		2.125	4.790	4.755	2.250	79.522
		2.375	5.470	5.430	2.500	84.951
		2.625	6.310	6.264	2.750	91.215
		2.875	4.780	4.745	3.000	95.960
		3.125	2.150	2.134	3.250	98.094
		3.375	.780	.774	3.500	98.868
		3.625	.740	.735	3.750	99.603
		3.875	.400	.397	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.740

PERCENT FINER THAN 4.00 PHI = .78 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = .982 STANDARD DEVIATION = 1.291 SKEWNESS = -.046 KURTOSIS = -.894

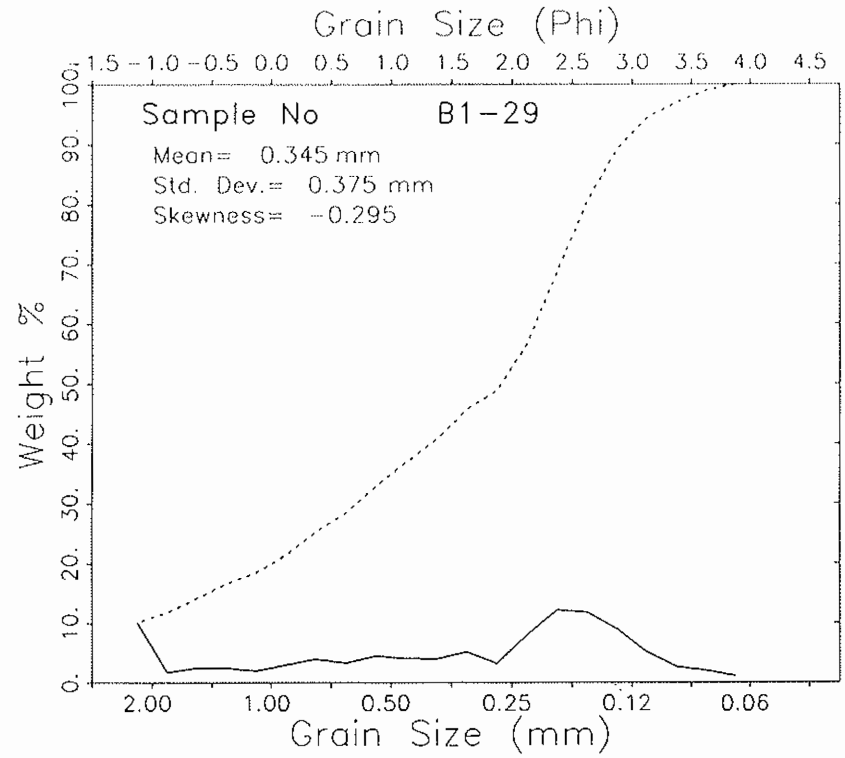
0 DISPERSION = .631 STANDARD DEVIATION = 1.033 DEVIATION FROM NORMAL DISTR. = -19.95%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.230	-1.149	-.654	.065	1.058	2.012	2.456	2.949	3.545

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.901	.953	
			COARSE SAND
STANDARD DEVIATION	1.555	1.399	
			POORLY SORTED
SKEWNESS(1)	-.101	-.089	
			NEAR SYMMETRICAL
SKEWNESS(2)	-.102		
KURTOSIS	.318	.862	
			PLATYKURTIC



1 SAMPLE NO. DATE

B1-29 270301
Borrow B1 - Station 29

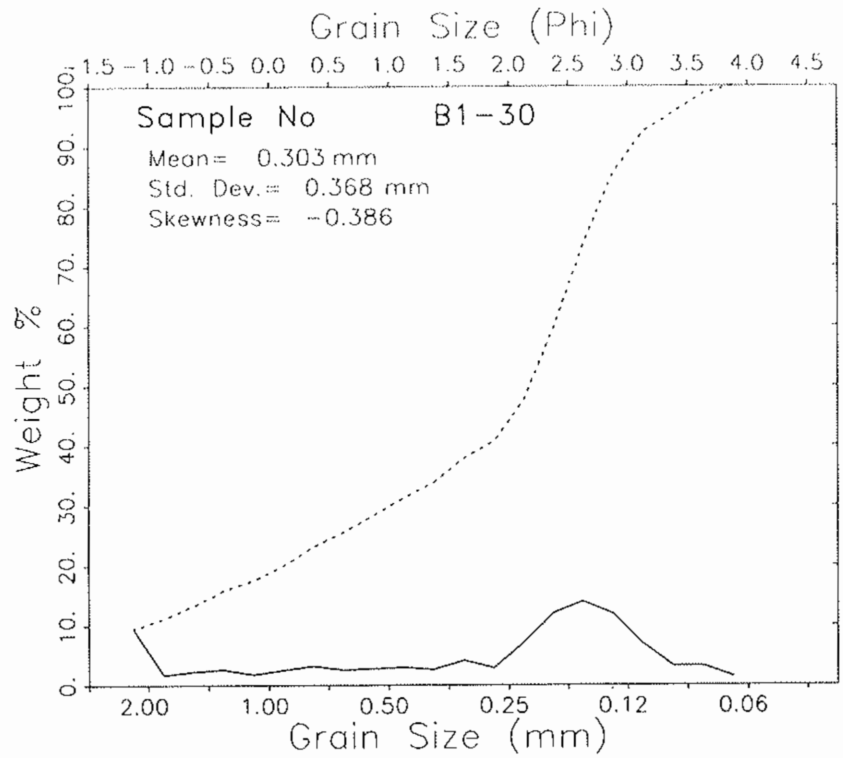
MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
-1.125	9.890	10.048	-1.000	10.048
-.875	1.630	1.656	-.750	11.704
-.625	2.370	2.408	-.500	14.112
-.375	2.390	2.428	-.250	16.540
-.125	1.890	1.920	.000	18.460
.125	2.850	2.895	.250	21.355
.375	3.800	3.861	.500	25.216
.625	3.150	3.200	.750	28.416
.875	4.350	4.419	1.000	32.836
1.125	3.940	4.003	1.250	36.838
1.375	3.790	3.850	1.500	40.689
1.625	4.950	5.029	1.750	45.718
1.875	3.080	3.129	2.000	48.847
2.125	7.740	7.863	2.250	56.710
2.375	11.880	12.069	2.500	68.780
2.625	11.510	11.694	2.750	80.473
2.875	8.720	8.859	3.000	89.333
3.125	4.970	5.049	3.250	94.382
3.375	2.530	2.570	3.500	96.952
3.625	1.940	1.971	3.750	98.923
3.875	1.060	1.077	4.000	100.000

TOTAL WEIGHT (GRAMS) = 98.430

PERCENT FINER THAN 4.00 PHI = 1.86 PERCENT COARSER THAN -1.00 PHI = .00
0 MOMENT MEASURES:
+
MEAN = 1.534 STANDARD DEVIATION = 1.414 SKEWNESS = -.295 KURTOSIS = -.839
0 DISPERSION = .630 STANDARD DEVIATION = 1.031 DEVIATION FROM NORMAL DISTR. = -27.06%
0 PERCENTILES:
+

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.225	-1.126	-.306	.486	2.037	2.633	2.850	3.310	3.768

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	1.272	1.527	
+				MEDIUM SAND
0	STANDARD DEVIATION	1.578	1.461	
+				POORLY SORTED
0	SKEWNESS(1)	-.485	-.455	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-.599		
0	KURTOSIS	.406	.847	
+				PLATYKURTIC



1 SAMPLE NO. DATE

B1-30 270301
Borrow 1 - Station 30

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	9.960	9.394	-1.000	9.394
-.875	1.730	1.632	-.750	11.025
-.625	2.390	2.254	-.500	13.279
-.375	2.700	2.546	-.250	15.826
-.125	1.800	1.698	.000	17.523
.125	2.640	2.490	.250	20.013
.375	3.310	3.122	.500	23.135
.625	2.610	2.462	.750	25.597
.875	2.900	2.735	1.000	28.332
1.125	3.080	2.905	1.250	31.236
1.375	2.730	2.575	1.500	33.811
1.625	4.310	4.065	1.750	37.876
1.875	2.980	2.811	2.000	40.687
2.125	7.450	7.026	2.250	47.713
2.375	12.680	11.959	2.500	59.672
2.625	14.710	13.873	2.750	73.545
2.875	12.610	11.893	3.000	85.438
3.125	7.260	6.847	3.250	92.285
3.375	3.320	3.131	3.500	95.416
3.625	3.370	3.178	3.750	98.595
3.875	1.490	1.405	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.030

PERCENT FINER THAN 4.00 PHI = 2.39 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

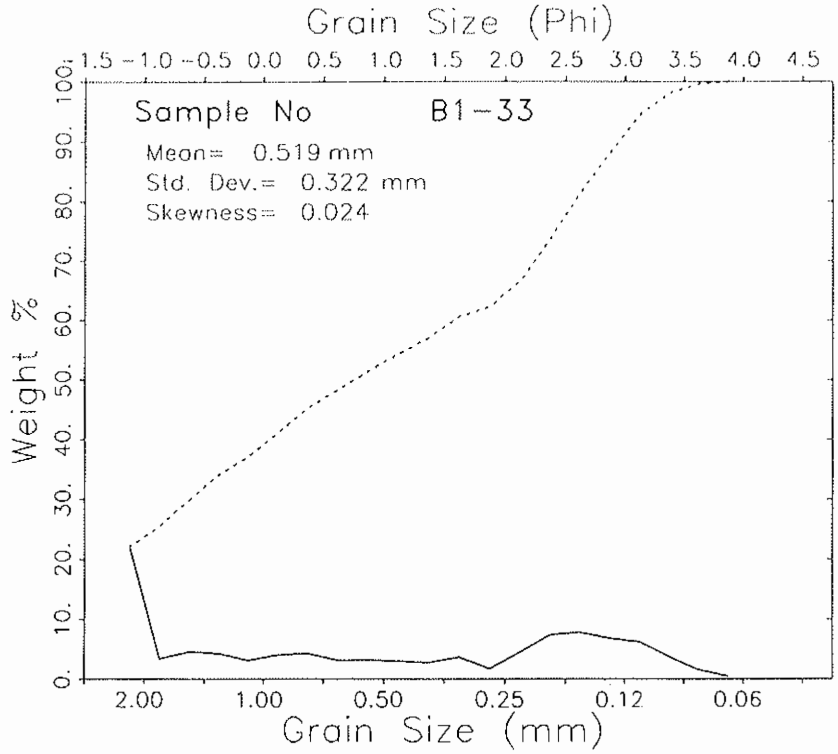
\+ MEAN = 1.724 STANDARD DEVIATION = 1.443 SKEWNESS = -.386 KURTOSIS = -.658

0 DISPERSION = .607 STANDARD DEVIATION = .979 DEVIATION FROM NORMAL DISTR. = -32.16%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.223	-1.117	-.224	.689	2.298	2.781	2.970	3.467	3.822

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.373	1.681	MEDIUM SAND
STANDARD DEVIATION	1.597	1.493	POORLY SORTED
SKEWNESS(1)	-.579	-.535	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.703		
KURTOSIS	.435	.898	PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-33	280301					
Borrow B1 - Station 33						
		-1.125	24.000	22.093	-1.000	22.093
		-.875	3.560	3.277	-.750	25.371
		-.625	4.840	4.455	-.500	29.826
		-.375	4.570	4.207	-.250	34.033
		-.125	3.360	3.093	.000	37.126
		.125	4.350	4.004	.250	41.130
		.375	4.550	4.189	.500	45.319
		.625	3.320	3.056	.750	48.375
		.875	3.410	3.139	1.000	51.514
		1.125	3.120	2.872	1.250	54.386
		1.375	2.910	2.679	1.500	57.065
		1.625	3.870	3.563	1.750	60.628
		1.875	1.780	1.639	2.000	62.266
		2.125	4.780	4.400	2.250	66.667
		2.375	7.900	7.272	2.500	73.939
		2.625	8.350	7.687	2.750	81.626
		2.875	7.320	6.738	3.000	88.364
		3.125	6.640	6.112	3.250	94.477
		3.375	3.940	3.627	3.500	98.104
		3.625	1.620	1.491	3.750	99.595
		3.875	.440	.405	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.630

PERCENT FINER THAN 4.00 PHI = .36 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

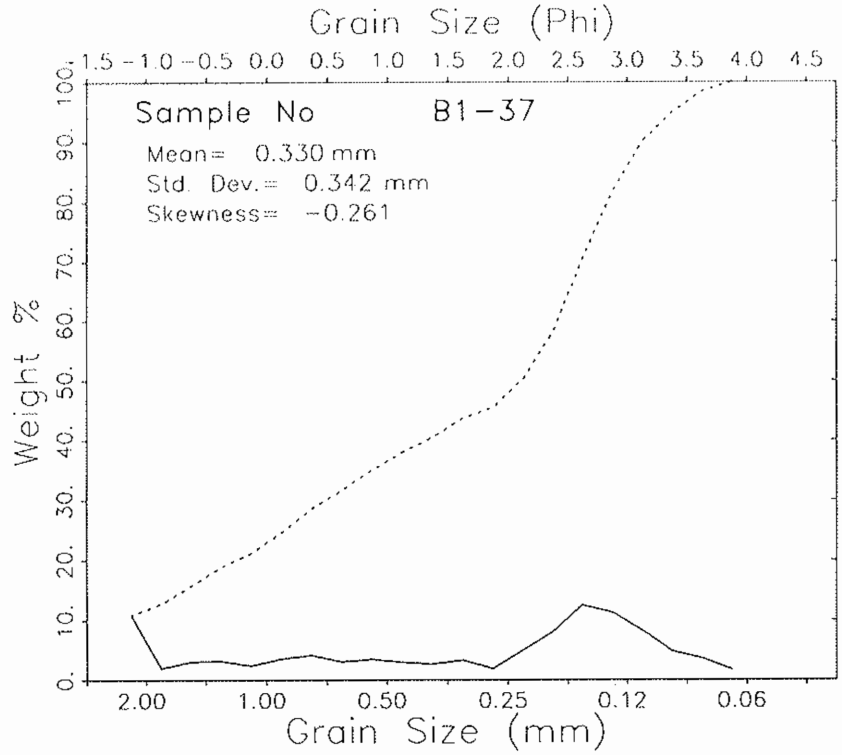
MEAN = .945 STANDARD DEVIATION = 1.637 SKEWNESS = .024 KURTOSIS = -1.530

0 DISPERSION = .601 STANDARD DEVIATION = .966 DEVIATION FROM NORMAL DISTR. = -41.00%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.239	-1.193	-1.069	-.778	.879	2.535	2.838	3.286	3.650

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.885	.883	COARSE SAND
STANDARD DEVIATION	1.954	1.655	POORLY SORTED
SKEWNESS(1)	.003	.039	NEAR SYMMETRICAL
SKEWNESS(2)	.085		
KURTOSIS	.147	.554	VERY PLATYKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-37	280301					
Borrow B1 - Station 37						
		-1.125	10.900	10.791	-1.000	10.791
		-.875	1.930	1.911	-.750	12.702
		-.625	2.960	2.930	-.500	15.632
		-.375	3.160	3.128	-.250	18.761
		-.125	2.360	2.336	.000	21.097
		.125	3.470	3.435	.250	24.532
		.375	4.090	4.049	.500	28.581
		.625	3.040	3.010	.750	31.591
		.875	3.420	3.386	1.000	34.977
		1.125	2.920	2.891	1.250	37.868
		1.375	2.570	2.544	1.500	40.412
		1.625	3.240	3.208	1.750	43.619
		1.875	1.790	1.772	2.000	45.392
		2.125	4.930	4.881	2.250	50.272
		2.375	8.080	7.999	2.500	58.271
		2.625	12.510	12.385	2.750	70.656
		2.875	11.310	11.197	3.000	81.853
		3.125	8.330	8.247	3.250	90.100
		3.375	4.800	4.752	3.500	94.852
		3.625	3.550	3.515	3.750	98.366
		3.875	1.650	1.634	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.010

PERCENT FINER THAN 4.00 PHI = 2.38 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.599 STANDARD DEVIATION = 1.546 SKEWNESS = -.261 KURTOSIS = -1.115

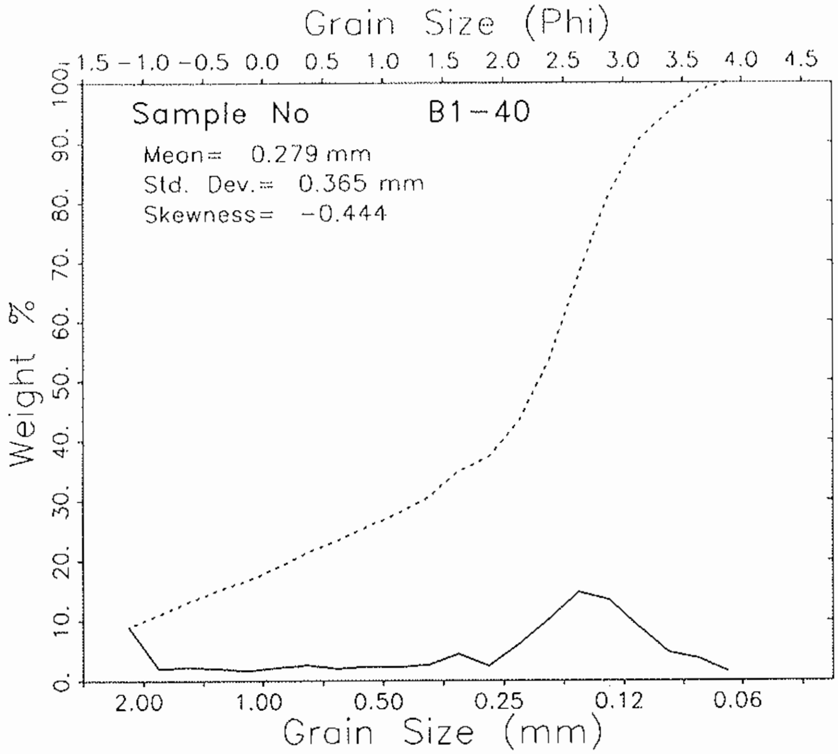
0 DISPERSION = .635 STANDARD DEVIATION = 1.043 DEVIATION FROM NORMAL DISTR. = -32.52%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.227	-1.134	-.471	.279	2.236	2.847	3.065	3.511	3.847

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.297	1.610	MEDIUM SAND
STANDARD DEVIATION	1.768	1.588	POORLY SORTED
SKEWNESS(1)	-.531	-.491	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.593		
KURTOSIS	.314	.741	PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B1-40	280301					
Borrow B1 - Station 40						
		-1.125	9.520	8.937	-1.000	8.937
		-.875	2.100	1.971	-.750	10.909
		-.625	2.340	2.197	-.500	13.106
		-.375	2.060	1.934	-.250	15.039
		-.125	1.740	1.633	.000	16.673
		.125	2.310	2.169	.250	18.842
		.375	2.700	2.535	.500	21.376
		.625	2.080	1.953	.750	23.329
		.875	2.460	2.309	1.000	25.638
		1.125	2.370	2.225	1.250	27.863
		1.375	2.730	2.563	1.500	30.426
		1.625	4.650	4.365	1.750	34.792
		1.875	2.560	2.403	2.000	37.195
		2.125	6.360	5.971	2.250	43.166
		2.375	10.830	10.167	2.500	53.333
		2.625	15.590	14.636	2.750	67.968
		2.875	14.260	13.387	3.000	81.356
		3.125	9.440	8.862	3.250	90.218
		3.375	4.950	4.647	3.500	94.865
		3.625	3.890	3.652	3.750	98.517
		3.875	1.580	1.483	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.520

PERCENT FINER THAN 4.00 PHI = 1.01 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.841 STANDARD DEVIATION = 1.453 SKEWNESS = -.444 KURTOSIS = -.481

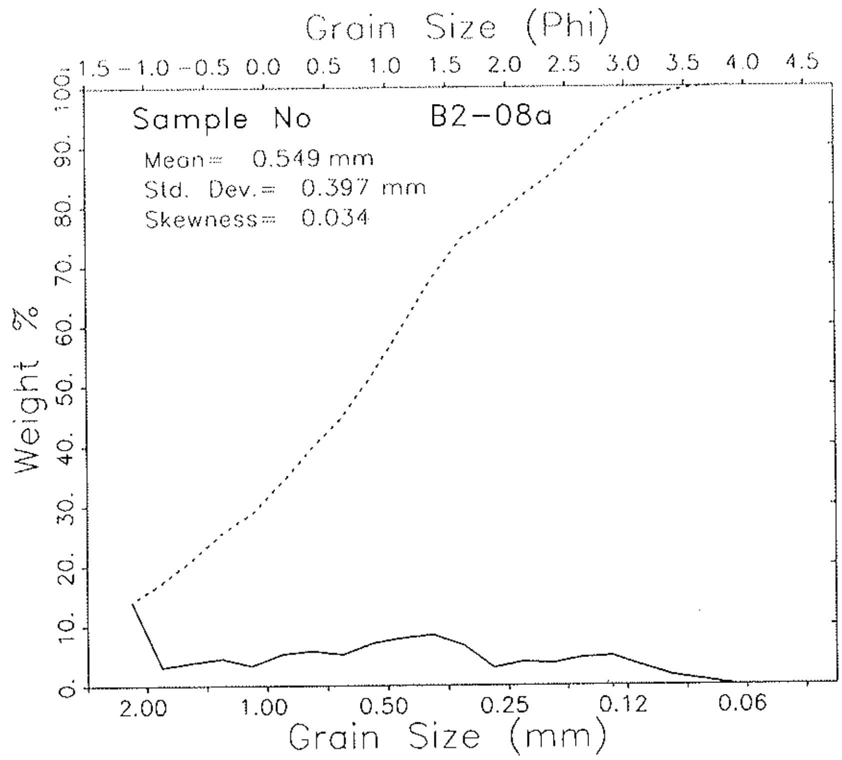
0 DISPERSION = .595 STANDARD DEVIATION = .953 DEVIATION FROM NORMAL DISTR. = -34.38%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.222	-1.110	-.103	.931	2.418	2.881	3.075	3.509	3.831

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.486	1.797	MEDIUM SAND
STANDARD DEVIATION	1.589	1.494	POORLY SORTED
SKEWNESS(1)	-.587	-.557	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.767		
KURTOSIS	.454	.971	MESOKURTIC



1 SAMPLE NO. DATE

	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-08a 100101					
Bogue Banks Borrow Area B2					
	-1.125	14.930	14.056	-1.000	14.056
	-.875	3.240	3.050	-.750	17.106
	-.625	4.070	3.832	-.500	20.938
	-.375	4.710	4.434	-.250	25.372
	-.125	3.530	3.323	.000	28.695
	.125	5.540	5.216	.250	33.911
	.375	6.090	5.733	.500	39.644
	.625	5.470	5.150	.750	44.794
	.875	7.460	7.023	1.000	51.817
	1.125	8.380	7.889	1.250	59.706
	1.375	8.880	8.360	1.500	68.066
	1.625	7.030	6.618	1.750	74.685
	1.875	3.110	2.928	2.000	77.613
	2.125	4.130	3.888	2.250	81.501
	2.375	3.830	3.606	2.500	85.106
	2.625	4.850	4.566	2.750	89.672
	2.875	5.120	4.820	3.000	94.493
	3.125	3.290	3.097	3.250	97.590
	3.375	1.630	1.535	3.500	99.124
	3.625	.870	.819	3.750	99.944
	3.875	.060	.056	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.220

PERCENT FINER THAN 4.00 PHI = .94   PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = .865   STANDARD DEVIATION = 1.333   SKEWNESS = .034   KURTOSIS = -.995

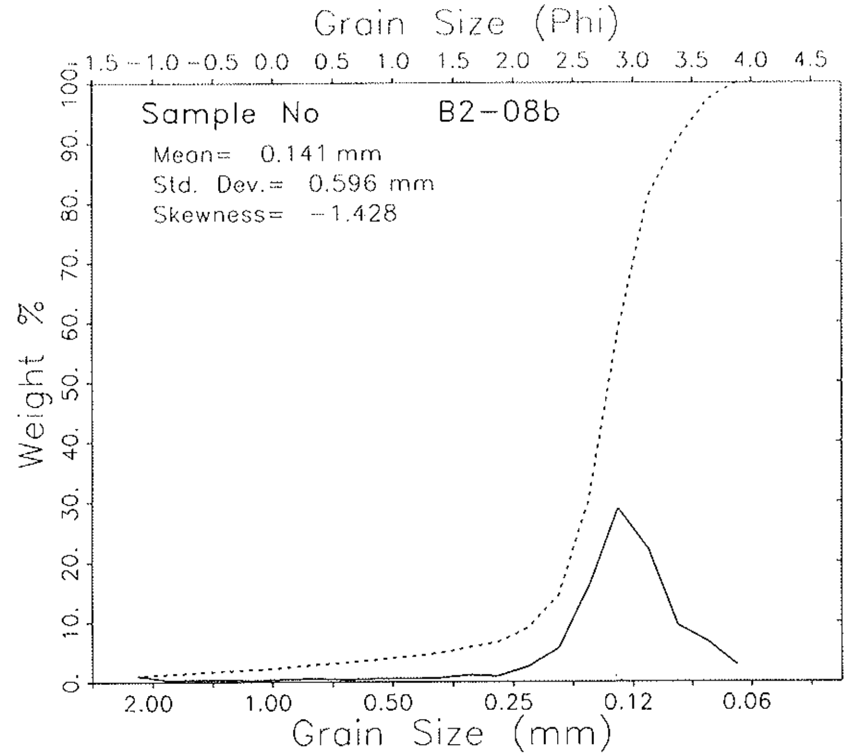
0 DISPERSION = .638   STANDARD DEVIATION = 1.051   DEVIATION FROM NORMAL DISTR. = -21.16%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.232	-1.161	-.841	-.271	.935	1.777	2.423	3.041	3.480

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.791	.839	COARSE SAND
STANDARD DEVIATION	1.632	1.453	POORLY SORTED
SKEWNESS(1)	-.088	-.043	NEAR SYMMETRICAL
SKEWNESS(2)	.003		
KURTOSIS	.287	.841	PLATYKURTIC



1 SAMPLE NO. DATE

B2-08b 100101

Bogue Banks Borrow Area B2

MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.990	.996	-1.000	.996
-.875	.200	.201	-.750	1.198
-.625	.280	.282	-.500	1.480
-.375	.320	.322	-.250	1.802
-.125	.190	.191	.000	1.993
.125	.360	.362	.250	2.355
.375	.490	.493	.500	2.849
.625	.330	.332	.750	3.181
.875	.460	.463	1.000	3.644
1.125	.470	.473	1.250	4.117
1.375	.550	.554	1.500	4.670
1.625	1.010	1.017	1.750	5.687
1.875	.850	.856	2.000	6.543
2.125	2.420	2.436	2.250	8.978
2.375	5.400	5.435	2.500	14.414
2.625	15.520	15.622	2.750	30.035
2.875	28.620	28.807	3.000	58.842
3.125	22.060	22.204	3.250	81.047
3.375	9.300	9.361	3.500	90.408
3.625	6.710	6.754	3.750	97.162
3.875	2.820	2.838	4.000	100.000

(Column heading "WEIGHT" printed above the WEIGHT PERCENT / GRAM columns.)

TOTAL WEIGHT (GRAMS) = 99.350

PERCENT FINER THAN 4.00 PHI = 1.92   PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

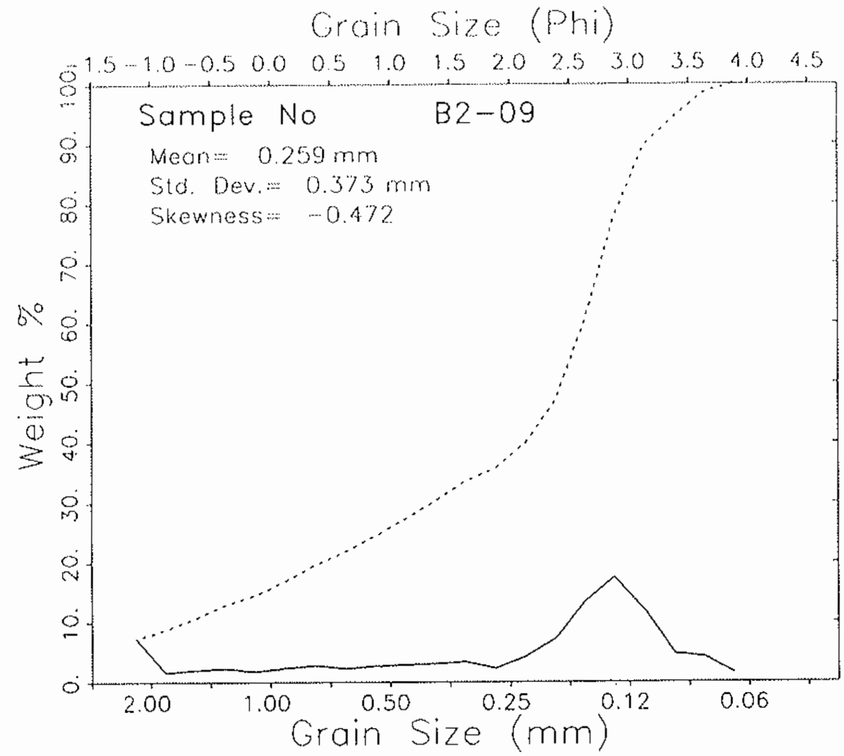
MEAN = 2.822 STANDARD DEVIATION = .746 SKEWNESS = -1.428 KURTOSIS = 11.076

0 DISPERSION = .299 STANDARD DEVIATION = .481 DEVIATION FROM NORMAL DISTR. = -35.49%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.996	1.581	2.525	2.669	2.923	3.182	3.329	3.670	3.912

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.927	2.926	FINE SAND
STANDARD DEVIATION	.402	.517	MODERATELY WELL SORTED
SKEWNESS(1)	.010	-.138	COARSE-SKEWED
SKEWNESS(2)	-.741		
KURTOSIS	1.600	1.670	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B2-09 100101

Bogue Banks Borrow Area B2

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	7.190	7.187	-1.000	7.187
-.875	1.520	1.519	-.750	8.707
-.625	1.990	1.989	-.500	10.696
-.375	2.200	2.199	-.250	12.895
-.125	1.680	1.679	.000	14.574
.125	2.340	2.339	.250	16.913
.375	2.720	2.719	.500	19.632
.625	2.180	2.179	.750	21.811
.875	2.670	2.669	1.000	24.480
1.125	2.780	2.779	1.250	27.259
1.375	2.970	2.969	1.500	30.228
1.625	3.290	3.289	1.750	33.517
1.875	2.180	2.179	2.000	35.696
2.125	4.180	4.178	2.250	39.874
2.375	7.120	7.117	2.500	46.991
2.625	13.350	13.345	2.750	60.336
2.875	17.440	17.433	3.000	77.769
3.125	11.940	11.935	3.250	89.704
3.375	4.660	4.658	3.500	94.362
3.625	4.170	4.168	3.750	98.531
3.875	1.470	1.469	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.040

PERCENT FINER THAN 4.00 PHI = 1.80 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.947 STANDARD DEVIATION = 1.423 SKEWNESS = -.472 KURTOSIS = -.357

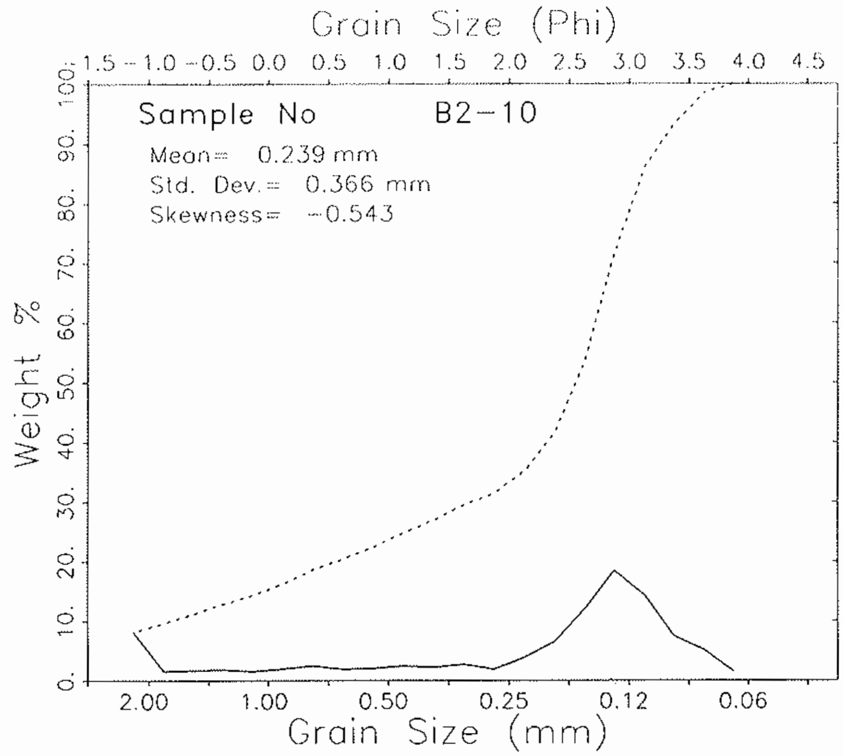
0 DISPERSION = .585 STANDARD DEVIATION = .931 DEVIATION FROM NORMAL DISTR. = -34.57%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.215	-1.076	.152	1.047	2.556	2.960	3.131	3.538	3.830

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.641	1.946	MEDIUM SAND
STANDARD DEVIATION	1.489	1.444	POORLY SORTED
SKEWNESS(1)	-.614	-.594	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.890		
KURTOSIS	.549	.988	MESOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-10	100101					
Bogue Banks Borrow Area B2						
		-1.125	8.020	8.069	-1.000	8.069
		-.875	1.450	1.459	-.750	9.528
		-.625	1.590	1.600	-.500	11.128
		-.375	1.690	1.700	-.250	12.828
		-.125	1.450	1.459	.000	14.287
		.125	1.900	1.912	.250	16.199
		.375	2.400	2.415	.500	18.614
		.625	1.790	1.801	.750	20.415
		.875	1.990	2.002	1.000	22.417
		1.125	2.340	2.354	1.250	24.771
		1.375	2.110	2.123	1.500	26.894
		1.625	2.600	2.616	1.750	29.510
		1.875	1.830	1.841	2.000	31.351
		2.125	3.710	3.733	2.250	35.084
		2.375	6.330	6.369	2.500	41.453
		2.625	11.750	11.822	2.750	53.275
		2.875	18.260	18.372	3.000	71.647
		3.125	14.280	14.368	3.250	86.015
		3.375	7.330	7.375	3.500	93.390
		3.625	5.070	5.101	3.750	98.491
		3.875	1.500	1.509	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.390

PERCENT FINER THAN 4.00 PHI = 1.68 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

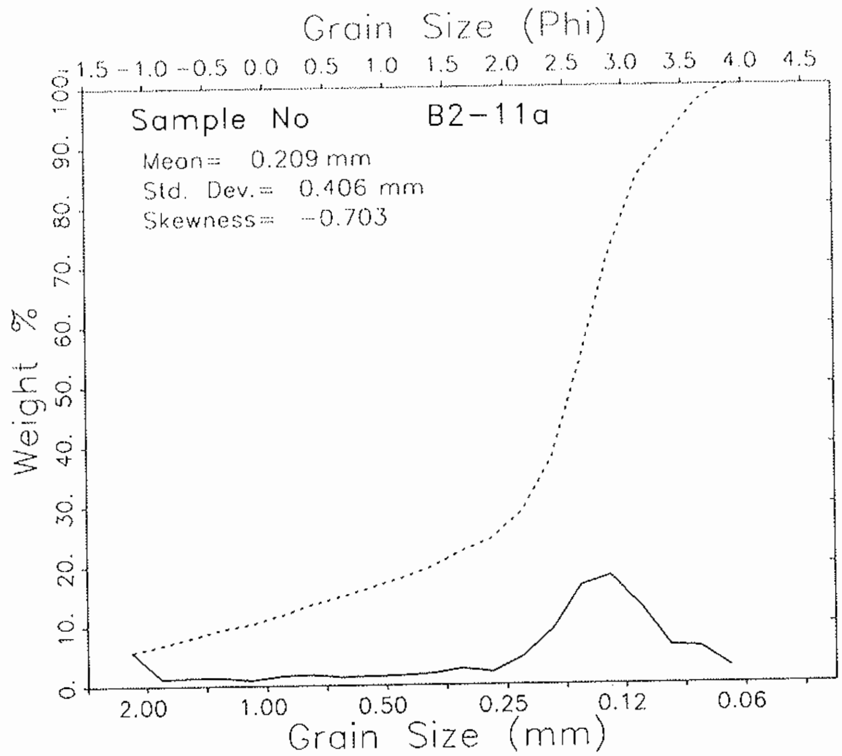
MEAN = 2.062 STANDARD DEVIATION = 1.450 SKEWNESS = -.543 KURTOSIS = -.119

0 DISPERSION = .555 STANDARD DEVIATION = .869 DEVIATION FROM NORMAL DISTR. = -40.07%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.219	-1.095	.224	1.277	2.681	3.058	3.215	3.579	3.834

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.719	2.040	FINE SAND
STANDARD DEVIATION	1.495	1.456	POORLY SORTED
SKEWNESS(1)	-.643	-.629	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.962		
KURTOSIS	.563	1.075	MESOKURTIC



1 SAMPLE NO. DATE

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-11a 100101				
Bogue Banks Borrow Area B2				
-1.125	5.450	5.608	-1.000	5.608
-.875	1.080	1.111	-.750	6.719
-.625	1.240	1.276	-.500	7.995
-.375	1.300	1.338	-.250	9.332
-.125	.840	.864	.000	10.197
.125	1.500	1.543	.250	11.740
.375	1.670	1.718	.500	13.458
.625	1.300	1.338	.750	14.796
.875	1.440	1.482	1.000	16.277
1.125	1.530	1.574	1.250	17.852
1.375	1.760	1.811	1.500	19.663
1.625	2.540	2.613	1.750	22.276
1.875	2.000	2.058	2.000	24.334
2.125	4.320	4.445	2.250	28.779
2.375	8.700	8.952	2.500	37.730
2.625	15.960	16.421	2.750	54.152
2.875	17.440	17.944	3.000	72.096
3.125	12.610	12.975	3.250	85.070
3.375	6.040	6.215	3.500	91.285
3.625	5.820	5.988	3.750	97.273
3.875	2.650	2.727	4.000	100.000

TOTAL WEIGHT (GRAMS) = 97.190

PERCENT FINER THAN 4.00 PHI = 4.05 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.258 STANDARD DEVIATION = 1.301 SKEWNESS = -.703 KURTOSIS = 1.031

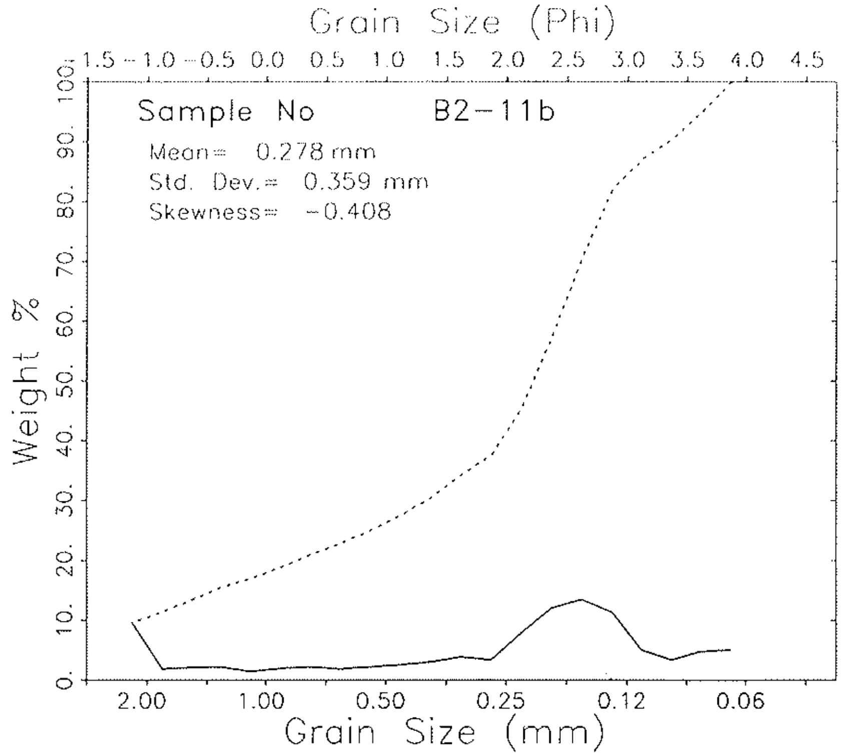
0 DISPERSION = .526 STANDARD DEVIATION = .812 DEVIATION FROM NORMAL DISTR. = -37.57%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.205	-1.027	.953	2.037	2.687	3.056	3.229	3.655	3.908

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	2.091	2.290	
+				FINE SAND
0	STANDARD DEVIATION	1.138	1.278	
+				POORLY SORTED
0	SKEWNESS(1)	-.523	-.555	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-1.206		
0	KURTOSIS	1.057	1.884	
+				VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B2-11b 100101

Bogue Banks Borrow Area B2

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	8.500	9.537	-1.000	9.537
-.875	1.580	1.773	-.750	11.309
-.625	1.850	2.076	-.500	13.385
-.375	1.890	2.120	-.250	15.505
-.125	1.270	1.425	.000	16.930
.125	1.670	1.874	.250	18.804
.375	1.930	2.165	.500	20.969
.625	1.640	1.840	.750	22.809
.875	1.940	2.177	1.000	24.986
1.125	2.210	2.480	1.250	27.466
1.375	2.620	2.940	1.500	30.405
1.625	3.370	3.781	1.750	34.186
1.875	2.980	3.343	2.000	37.529
2.125	6.980	7.831	2.250	45.361
2.375	10.660	11.960	2.500	57.321
2.625	11.900	13.351	2.750	70.672
2.875	10.100	11.332	3.000	82.004
3.125	4.430	4.970	3.250	86.974
3.375	2.950	3.310	3.500	90.284
3.625	4.200	4.712	3.750	94.996
3.875	4.460	5.004	4.000	100.000

TOTAL WEIGHT (GRAMS) = 89.130

PERCENT FINER THAN 4.00 PHI = 11.45 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

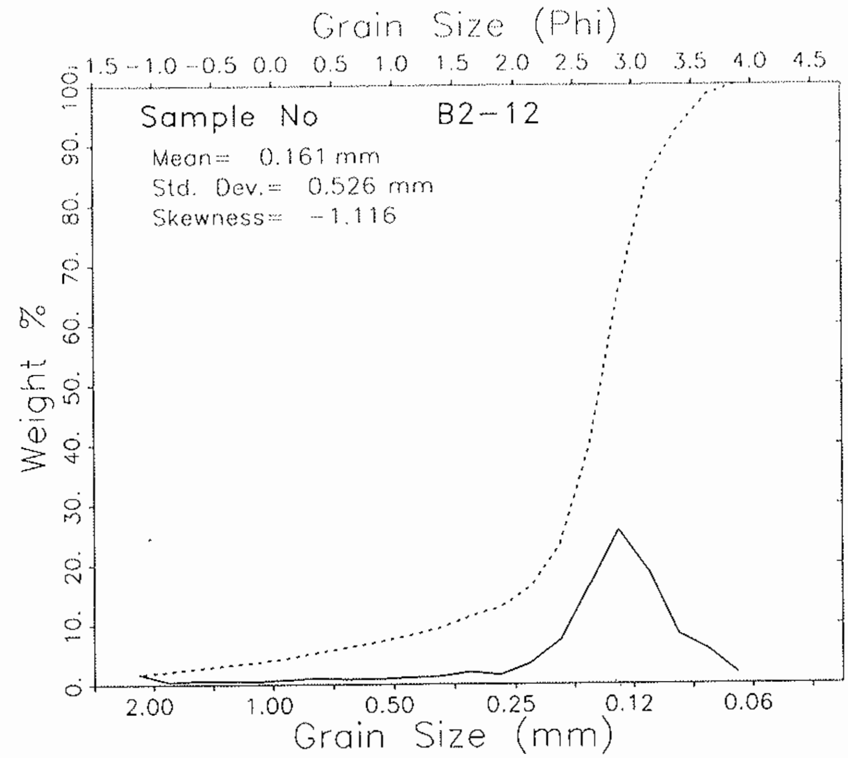
MEAN = 1.846 STANDARD DEVIATION = 1.478 SKEWNESS = -.408 KURTOSIS = -.474

0 DISPERSION = .610 STANDARD DEVIATION = .985 DEVIATION FROM NORMAL DISTR. = -33.36%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.119	-.163	1.001	2.347	2.845	3.100	3.750	3.950

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.469	1.761	MEDIUM SAND
STANDARD DEVIATION	1.632	1.554	POORLY SORTED
SKEWNESS(1)	-.538	-.481	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.632		
KURTOSIS	.492	1.082	MESOKURTIC



1 SAMPLE NO. DATE

B2-12 10D101
Bogue Banks Borrow Area B2

MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	1.650	1.682	-1.000	1.682
-.875	.380	.387	-.750	2.069
-.625	.530	.540	-.500	2.609
-.375	.560	.571	-.250	3.180
-.125	.460	.469	.000	3.649
.125	.710	.724	.250	4.373
.375	.930	.948	.500	5.321
.625	.810	.826	.750	6.146
.875	.900	.917	1.000	7.063
1.125	1.040	1.060	1.250	8.124
1.375	1.200	1.223	1.500	9.347
1.625	1.930	1.967	1.750	11.314
1.875	1.410	1.437	2.000	12.751
2.125	3.290	3.353	2.250	16.104
2.375	7.080	7.216	2.500	23.321
2.625	16.050	16.359	2.750	39.680
2.875	25.150	25.634	3.000	65.314
3.125	18.500	18.856	3.250	84.171
3.375	8.160	8.317	3.500	92.488
3.625	5.650	5.759	3.750	98.247
3.875	1.720	1.753	4.000	100.000

TOTAL WEIGHT (GRAMS) = 98.110

PERCENT FINER THAN 4.00 PHI = 1.73 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.633 STANDARD DEVIATION = .928 SKEWNESS = -1.116 KURTOSIS = 5.488

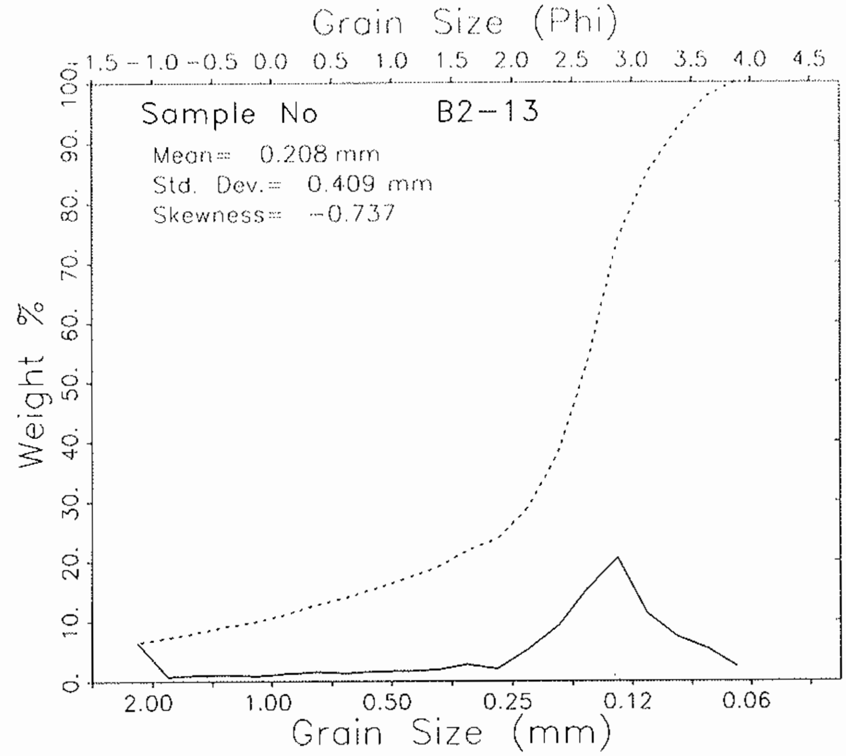
0 DISPERSION = .389 STANDARD DEVIATION = .592 DEVIATION FROM NORMAL DISTR. = -36.17%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.101	.415	2.242	2.526	2.851	3.128	3.248	3.609	3.857

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.745	2.780	FINE SAND
STANDARD DEVIATION	.503	.735	MODERATELY SORTED
SKEWNESS(1)	-.210	-.368	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.668		
KURTOSIS	2.176	2.171	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B2-13 100101

Bogue Banks Borrow Area B2

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	6.200	6.381	-1.000	6.381
-.875	.730	.751	-.750	7.133
-.625	.940	.967	-.500	8.100
-.375	1.010	1.040	-.250	9.140
-.125	.740	.762	.000	9.901
.125	1.220	1.256	.250	11.157
.375	1.460	1.503	.500	12.660
.625	1.250	1.287	.750	13.946
.875	1.500	1.544	1.000	15.490
1.125	1.600	1.647	1.250	17.137
1.375	1.770	1.822	1.500	18.958
1.625	2.670	2.748	1.750	21.706
1.875	1.910	1.966	2.000	23.672
2.125	4.980	5.126	2.250	28.798
2.375	8.830	9.088	2.500	37.886
2.625	14.960	15.397	2.750	53.283
2.875	19.930	20.513	3.000	73.796
3.125	10.830	11.147	3.250	84.942
3.375	7.080	7.287	3.500	92.229
3.625	5.260	5.414	3.750	97.643
3.875	2.290	2.357	4.000	100.000

TOTAL WEIGHT (GRAMS) = 97.160

PERCENT FINER THAN 4.00 PHI = 3.19 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.265 STANDARD DEVIATION = 1.289 SKEWNESS = -.737 KURTOSIS = 1.268

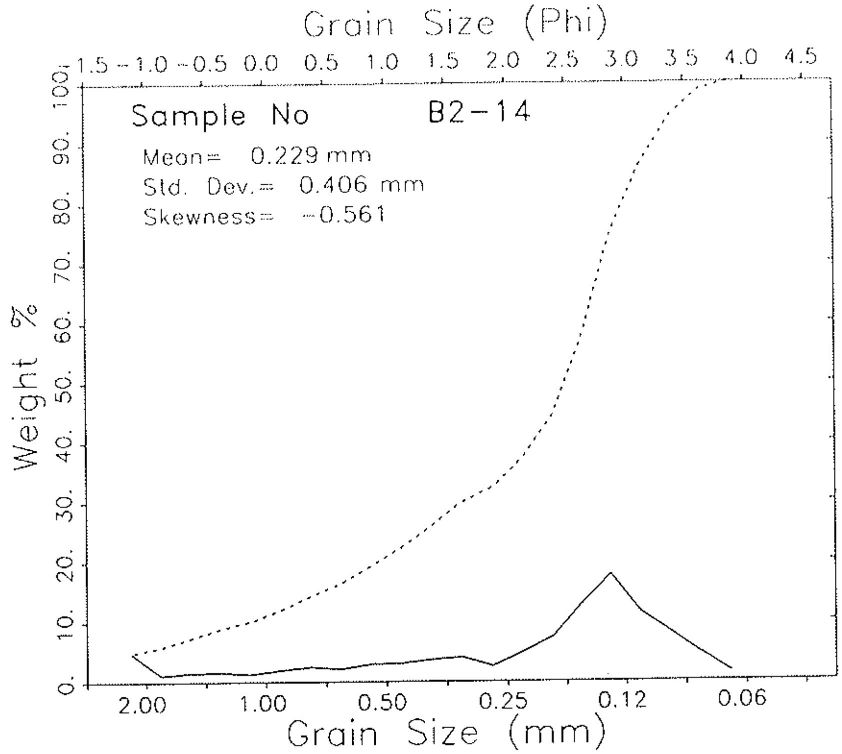
0 DISPERSION = .511 STANDARD DEVIATION = .784 DEVIATION FROM NORMAL DISTR. = -39.19%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.211	-1.054	1.077	2.065	2.697	3.027	3.229	3.628	3.894

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.153	2.334	FINE SAND
STANDARD DEVIATION	1.076	1.247	POORLY SORTED
SKEWNESS(1)	-.505	-.554	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.311		
KURTOSIS	1.176	1.994	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B2-14 120101

Bogue Banks Borrow Area B2

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	5.090	4.712	-1.000	4.712
-.875	1.130	1.046	-.750	5.758
-.625	1.630	1.509	-.500	7.266
-.375	1.720	1.592	-.250	8.859
-.125	1.280	1.185	.000	10.044
.125	2.060	1.907	.250	11.950
.375	2.540	2.351	.500	14.302
.625	2.230	2.064	.750	16.366
.875	3.140	2.907	1.000	19.272
1.125	3.230	2.990	1.250	22.262
1.375	3.840	3.555	1.500	25.817
1.625	4.320	3.999	1.750	29.816
1.875	2.630	2.435	2.000	32.250
2.125	5.110	4.730	2.250	36.980
2.375	7.860	7.276	2.500	44.256
2.625	13.760	12.737	2.750	56.993
2.875	19.070	17.653	3.000	74.646
3.125	12.330	11.413	3.250	86.059
3.375	8.640	7.998	3.500	94.057
3.625	4.920	4.554	3.750	98.612
3.875	1.500	1.389	4.000	100.000

TOTAL WEIGHT (GRAMS) = 108.030

PERCENT FINER THAN 4.00 PHI = 1.42 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.124 STANDARD DEVIATION = 1.299 SKEWNESS = -.561 KURTOSIS = .292

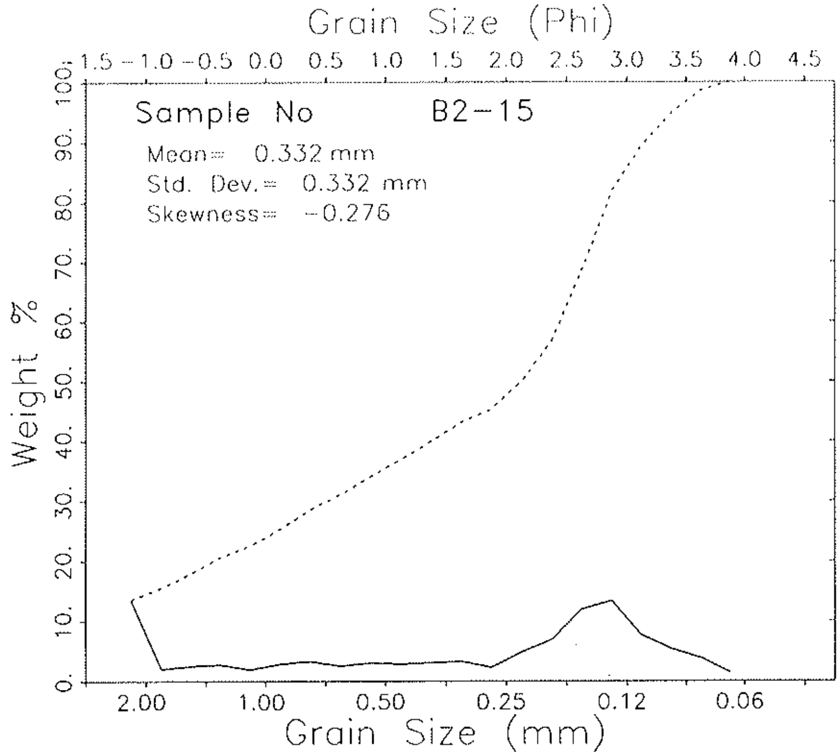
0 DISPERSION = .578 STANDARD DEVIATION = .915 DEVIATION FROM NORMAL DISTR. = -29.56%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.197	-.931	.706	1.443	2.613	3.008	3.205	3.552	3.820

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.955	2.174	FINE SAND
STANDARD DEVIATION	1.250	1.304	POORLY SORTED
SKEWNESS(1)	-.526	-.554	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.042		
KURTOSIS	.794	1.174	LEPTOKURTIC



+1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT (PHI)	CLASS LIMITS	CUM PERCENT
B2-15	120101						
Bogue Banks Borrow Area B2							
		-1.125	13.650	13.505	-1.000	13.505	
		-.875	1.990	1.969	-.750	15.474	
		-.625	2.470	2.444	-.500	17.918	
		-.375	2.740	2.711	-.250	20.629	
		-.125	1.930	1.910	.000	22.539	
		.125	2.820	2.790	.250	25.329	
		.375	3.270	3.235	.500	28.564	
		.625	2.520	2.493	.750	31.058	
		.875	2.980	2.948	1.000	34.006	
		1.125	2.870	2.840	1.250	36.846	
		1.375	3.040	3.008	1.500	39.854	
		1.625	3.220	3.186	1.750	43.039	
		1.875	2.220	2.196	2.000	45.236	
		2.125	4.730	4.680	2.250	49.916	
		2.375	6.870	6.797	2.500	56.713	
		2.625	12.030	11.903	2.750	68.616	
		2.875	13.430	13.288	3.000	81.904	
		3.125	7.610	7.529	3.250	89.433	
		3.375	5.370	5.313	3.500	94.746	
		3.625	3.880	3.839	3.750	98.585	
		3.875	1.430	1.415	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 101.070

PERCENT FINER THAN 4.00 PHI = .99 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.590 STANDARD DEVIATION = 1.592 SKEWNESS = -.276 KURTOSIS = -1.132

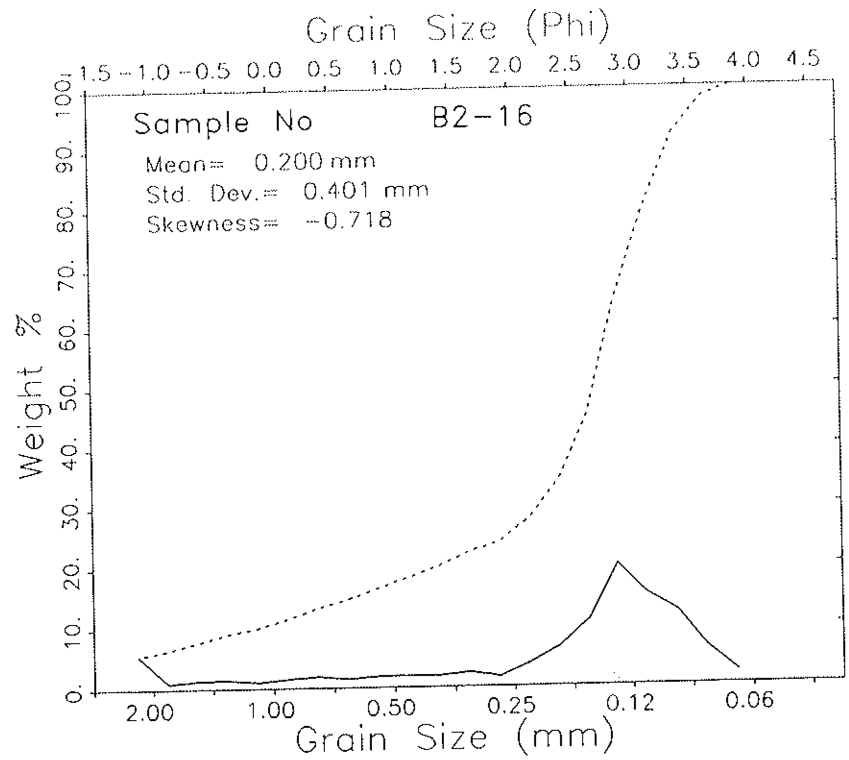
0 DISPERSION = .615 STANDARD DEVIATION = .997 DEVIATION FROM NORMAL DISTR. = -37.34%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.231	-1.157	-.696	.221	2.253	2.870	3.070	3.517	3.823

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	1.187	1.542	
+				MEDIUM SAND
0	STANDARD DEVIATION	1.883	1.650	
+				POORLY SORTED
0	SKEWNESS(1)	-.566	-.513	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-.570		
0	KURTOSIS	.241	.723	
+				PLATYKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-16	120101					
Bogue Banks Borrow Area B2						
		-1.125	5.430	5.468	-1.000	5.468
		-.875	.880	.886	-.750	6.354
		-.625	1.290	1.299	-.500	7.653
		-.375	1.360	1.369	-.250	9.022
		-.125	.970	.977	.000	9.999
		.125	1.500	1.510	.250	11.509
		.375	1.770	1.782	.500	13.292
		.625	1.400	1.410	.750	14.701
		.875	1.760	1.772	1.000	16.474
		1.125	1.770	1.782	1.250	18.256
		1.375	1.800	1.813	1.500	20.068
		1.625	2.260	2.276	1.750	22.344
		1.875	1.530	1.541	2.000	23.885
		2.125	3.700	3.726	2.250	27.611
		2.375	6.350	6.394	2.500	34.005
		2.625	10.690	10.764	2.750	44.769
		2.875	19.900	20.038	3.000	64.807
		3.125	14.950	15.054	3.250	79.861
		3.375	12.040	12.124	3.500	91.985
		3.625	6.020	6.062	3.750	98.047
		3.875	1.940	1.953	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.310

PERCENT FINER THAN 4.00 PHI = 1.63 PERCENT COARSER THAN -1.00 PHI = .00

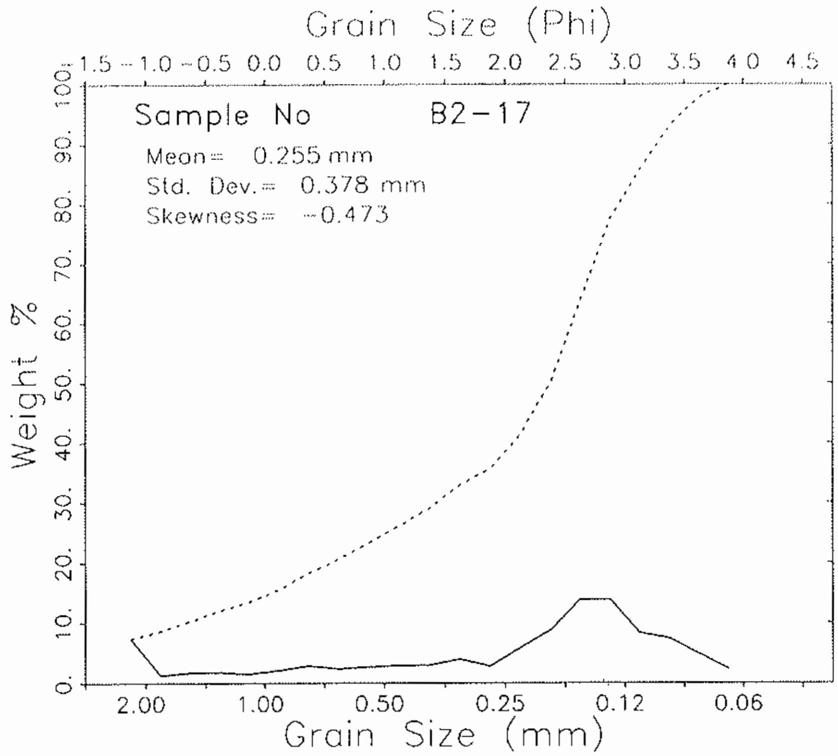
0 MOMENT MEASURES:

MEAN = 2.325	STANDARD DEVIATION = 1.319	SKEWNESS = -.718	KURTOSIS = 1.004
DISPERSION = .514	STANDARD DEVIATION = .791	DEVIATION FROM NORMAL DISTR. = -40.03%	

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.204	-1.021	.933	2.075	2.815	3.169	3.335	3.624	3.872

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.134	2.361	FINE SAND
STANDARD DEVIATION	1.201	1.304	POORLY SORTED
SKEWNESS(1)	-.567	-.609	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.260		
KURTOSIS	.934	1.740	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-17	120101					
Bogue Banks Borrow Area B2						
		-1.125	8.180	7.311	-1.000	7.311
		+ -.875	1.380	1.233	-.750	8.545
		-.625	1.940	1.734	-.500	10.279
		-.375	1.940	1.734	-.250	12.013
		-.125	1.610	1.439	.000	13.452
		.125	2.290	2.047	.250	15.499
		.375	3.110	2.780	.500	18.279
		.625	2.600	2.324	.750	20.602
		.875	2.970	2.655	1.000	23.257
		1.125	3.170	2.833	1.250	26.090
		1.375	3.250	2.905	1.500	28.995
		1.625	4.340	3.879	1.750	32.875
		1.875	3.050	2.726	2.000	35.601
		2.125	6.410	5.729	2.250	41.330
		2.375	9.630	8.607	2.500	49.937
		2.625	15.470	13.827	2.750	63.765
		2.875	15.450	13.809	3.000	77.574
		3.125	9.230	8.250	3.250	85.824
		3.375	8.140	7.276	3.500	93.100
		3.625	5.280	4.719	3.750	97.819
		3.875	2.440	2.181	4.000	100.000

TOTAL WEIGHT (GRAMS) = 111.880

PERCENT FINER THAN 4.00 PHI = 1.75 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.970 STANDARD DEVIATION = 1.405 SKEWNESS = -.473 KURTOSIS = -.221

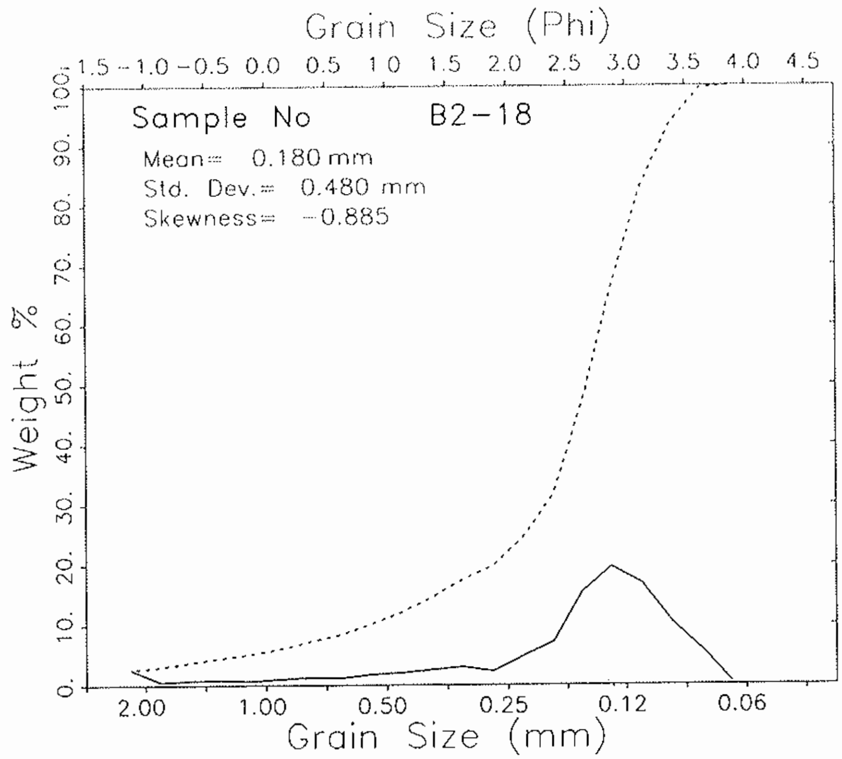
0 DISPERSION = .607 STANDARD DEVIATION = .979 DEVIATION FROM NORMAL DISTR. = -30.34%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.216	-1.079	.295	1.154	2.501	2.953	3.195	3.601	3.885

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	1.745	1.997	
+				MEDIUM SAND
0	STANDARD DEVIATION	1.450	1.434	
+				POORLY SORTED
0	SKEWNESS(1)	-.522	-.526	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-.855		
0	KURTOSIS	.614	1.066	
+				MESOKURTIC



1 SAMPLE NO. DATE

B2-18 120101

Bogue Banks Borrow Area B2

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	2.560	2.516	-1.000	2.516
-.875	.490	.482	-.750	2.998
-.625	.710	.698	-.500	3.696
-.375	.780	.767	-.250	4.463
-.125	.630	.619	.000	5.082
.125	.960	.944	.250	6.026
.375	1.240	1.219	.500	7.245
.625	1.160	1.140	.750	8.385
.875	1.780	1.750	1.000	10.135
1.125	1.980	1.946	1.250	12.081
1.375	2.530	2.487	1.500	14.568
1.625	2.990	2.939	1.750	17.507
1.875	2.270	2.231	2.000	19.739
2.125	4.790	4.709	2.250	24.447
2.375	7.170	7.048	2.500	31.495
2.625	15.660	15.394	2.750	46.889
2.875	19.860	19.522	3.000	66.411
3.125	17.160	16.868	3.250	83.279
3.375	10.580	10.400	3.500	93.679
3.625	5.960	5.859	3.750	99.538
3.875	.470	.462	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.730

PERCENT FINER THAN 4.00 PHI = 2.44 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.475 STANDARD DEVIATION = 1.058 SKEWNESS = -.885 KURTOSIS = 2.892

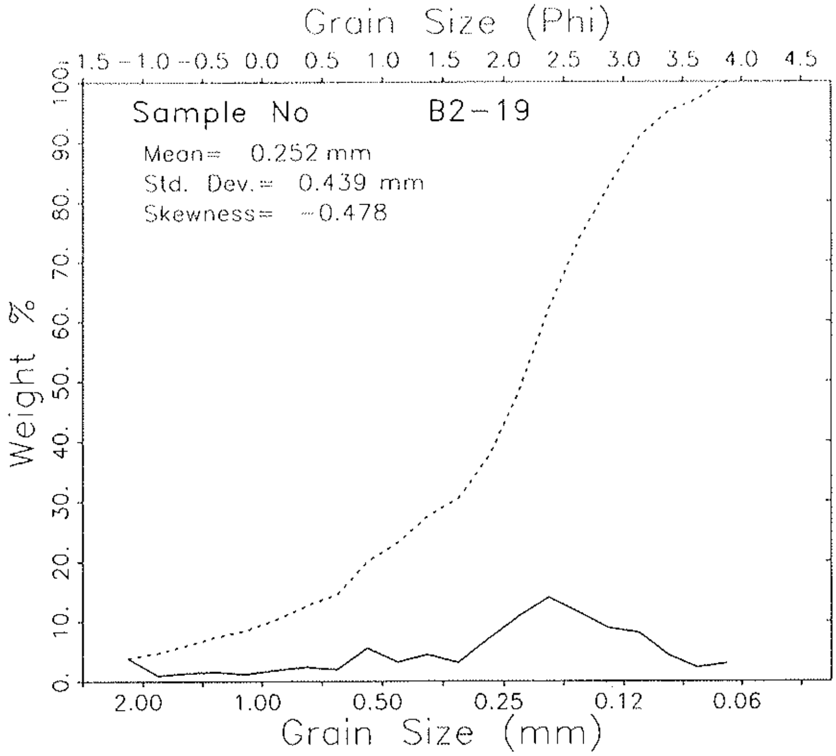
0 DISPERSION = .468 STANDARD DEVIATION = .710 DEVIATION FROM NORMAL DISTR. = -32.88%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.151	-.033	1.622	2.270	2.790	3.127	3.267	3.556	3.727

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.445	2.560	FINE SAND
STANDARD DEVIATION	.823	.955	MODERATELY SORTED
SKEWNESS(1)	-.420	-.496	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.250		
KURTOSIS	1.181	1.715	VERY LEPTOKURTIC



1 SAMPLE NO. DATE

B2-19 120101

Bogue Banks Borrow Area B2

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	3.900	3.802	-1.000	3.802
-.875	.900	.877	-.750	4.679
-.625	1.300	1.267	-.500	5.947
-.375	1.470	1.433	-.250	7.380
-.125	1.130	1.102	.000	8.481
.125	1.870	1.823	.250	10.304
.375	2.400	2.340	.500	12.644
.625	1.900	1.852	.750	14.496
.875	5.580	5.440	1.000	19.936
1.125	3.220	3.139	1.250	23.075
1.375	4.480	4.367	1.500	27.442
1.625	3.110	3.032	1.750	30.474
1.875	7.200	7.019	2.000	37.493
2.125	11.100	10.821	2.250	48.314
2.375	14.310	13.950	2.500	62.264
2.625	11.760	11.464	2.750	73.728
2.875	9.030	8.803	3.000	82.531
3.125	8.290	8.081	3.250	90.612
3.375	4.410	4.299	3.500	94.911
3.625	2.240	2.184	3.750	97.095
3.875	2.980	2.905	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.580

PERCENT FINER THAN 4.00 PHI = 2.41 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.986 STANDARD DEVIATION = 1.189 SKEWNESS = -.478 KURTOSIS = .423

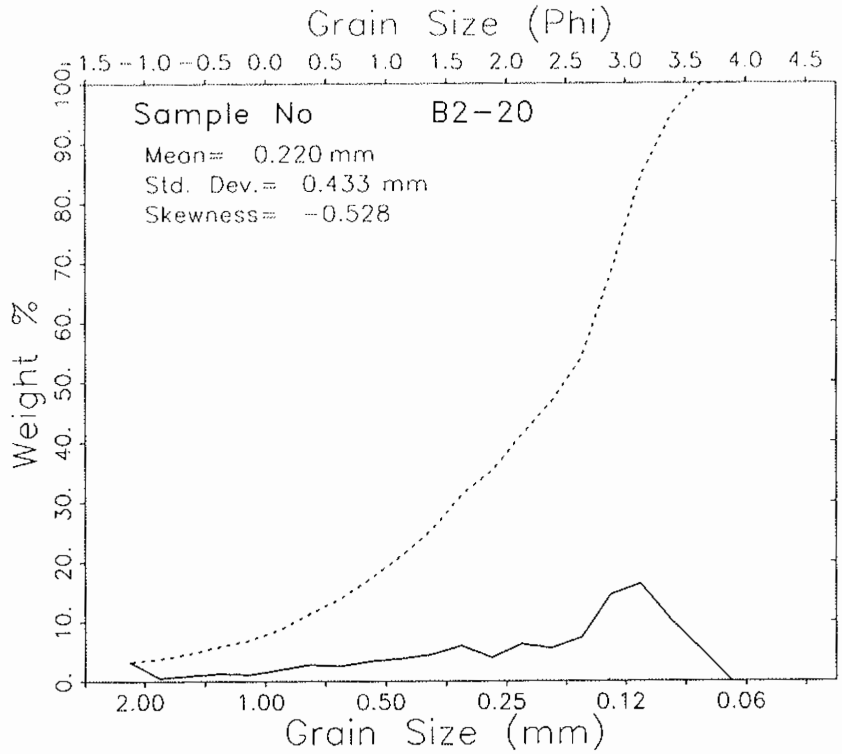
D DISPERSION = .599 STANDARD DEVIATION = .961 DEVIATION FROM NORMAL DISTR. = -19.22%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.184	-.687	.819	1.360	2.280	2.786	3.045	3.510	3.914

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.932	2.048	FINE SAND
STANDARD DEVIATION	1.113	1.192	POORLY SORTED
SKEWNESS(1)	-.313	-.363	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.780		
KURTOSIS	.885	1.206	LEPTOKURTIC



1 SAMPLE NO. DATE

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT

B2-20 120101
Bogue Banks Borrow Area B2

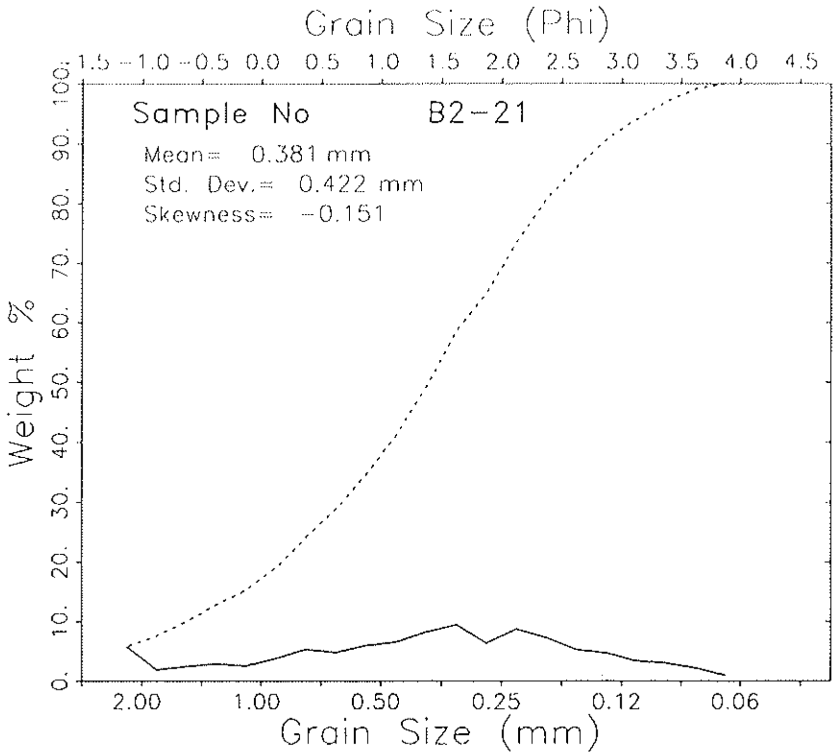
MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	3.240	3.193	-1.000	3.193
-.875	.470	.463	-.750	3.656
-.625	.940	.926	-.500	4.583
-.375	1.220	1.202	-.250	5.785
-.125	1.040	1.025	.000	6.810
.125	1.890	1.863	.250	8.673
.375	2.740	2.700	.500	11.373
.625	2.520	2.483	.750	13.856
.875	3.360	3.311	1.000	17.168
1.125	3.790	3.735	1.250	20.903
1.375	4.460	4.395	1.500	25.298
1.625	5.990	5.903	1.750	31.201
1.875	3.970	3.912	2.000	35.114
2.125	6.210	6.120	2.250	41.234
2.375	5.590	5.509	2.500	46.743
2.625	7.240	7.135	2.750	53.878
2.875	14.570	14.359	3.000	68.237
3.125	16.430	16.192	3.250	84.429
3.375	10.350	10.200	3.500	94.629
3.625	5.370	5.292	3.750	99.921
3.875	.080	.079	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.470

PERCENT FINER THAN 4.00 PHI = 2.79 PERCENT COARSER THAN -1.00 PHI = .00
0 MOMENT MEASURES:
+
MEAN = 2.183 STANDARD DEVIATION = 1.209 SKEWNESS = -.528 KURTOSIS = .349
0 DISPERSION = .568 STANDARD DEVIATION = .896 DEVIATION FROM NORMAL DISTR. = -25.90%
0 PERCENTILES:
+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.172	-.413	.912	1.483	2.614	3.104	3.243	3.518	3.706

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.078	2.256	FINE SAND
STANDARD DEVIATION	1.166	1.178	POORLY SORTED
SKEWNESS(1)	-.460	-.500	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.911		
KURTOSIS	.686	.994	MESOKURTIC



1 SAMPLE NO. DATE MIDPOINT (PHI) WEIGHT (GRAM) WEIGHT PERCENT CLASS LIMITS (PHI) CUM PERCENT

B2-21 130101

Bogue Banks Borrow Area B2

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	5.890	5.718	-1.000	5.718
-.875	1.840	1.786	-.750	7.504
-.625	2.500	2.427	-.500	9.931
-.375	2.910	2.825	-.250	12.756
-.125	2.540	2.466	.000	15.222
.125	3.820	3.708	.250	18.930
.375	5.360	5.203	.500	24.134
.625	4.860	4.718	.750	28.852
.875	6.040	5.864	1.000	34.715
1.125	6.670	6.475	1.250	41.190
1.375	8.370	8.125	1.500	49.316
1.625	9.690	9.407	1.750	58.722
1.875	6.480	6.291	2.000	65.013
2.125	8.900	8.640	2.250	73.653
2.375	7.480	7.261	2.500	80.914
2.625	5.340	5.184	2.750	86.098
2.875	4.750	4.611	3.000	90.710
3.125	3.420	3.320	3.250	94.030
3.375	3.040	2.951	3.500	96.981
3.625	2.200	2.136	3.750	99.117
3.875	.910	.883	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.010

PERCENT FINER THAN 4.00 PHI = .84 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.391 STANDARD DEVIATION = 1.246 SKEWNESS = -.151 KURTOSIS = -.591

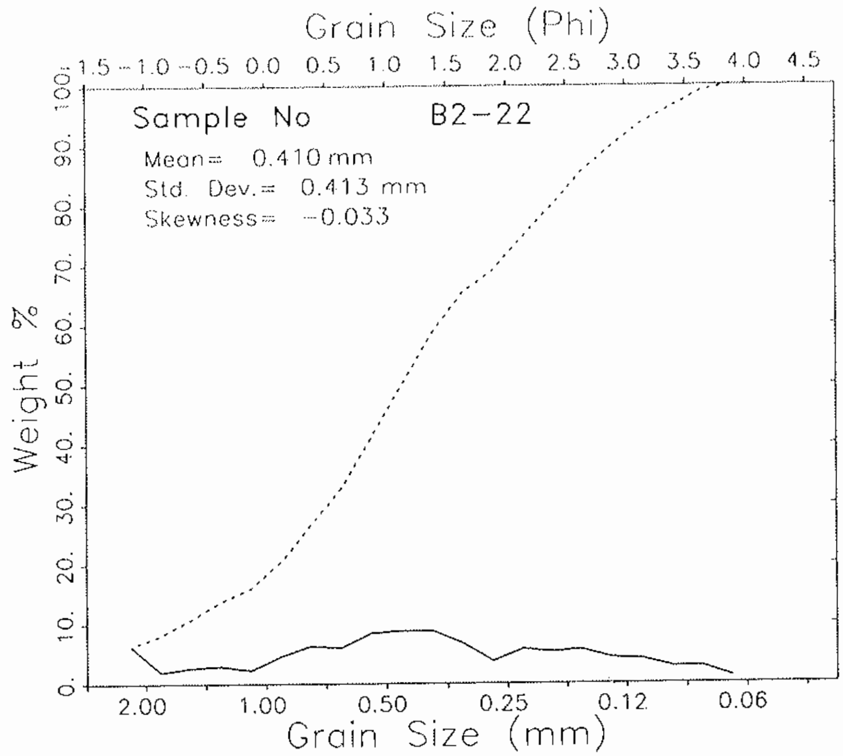
0 DISPERSION = .666 STANDARD DEVIATION = 1.122 DEVIATION FROM NORMAL DISTR. = -9.98%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.206	-1.031	.052	.546	1.518	2.296	2.649	3.332	3.736

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.351	1.406	MEDIUM SAND
STANDARD DEVIATION	1.298	1.310	POORLY SORTED
SKEWNESS(1)	-.129	-.149	COARSE-SKEWED
SKEWNESS(2)	-.283		
KURTOSIS	.681	1.022	MESOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-22	140101					
Bogue Banks Borrow Area B2						
		-1.125	6.520	6.214	-1.000	6.214
		-.875	1.950	1.858	-.750	8.072
		-.625	2.810	2.678	-.500	10.750
		-.375	3.060	2.916	-.250	13.666
		-.125	2.350	2.240	.000	15.906
		.125	4.820	4.594	.250	20.499
		.375	6.490	6.185	.500	26.684
		.625	6.300	6.004	.750	32.688
		.875	8.840	8.425	1.000	41.113
		1.125	9.180	8.749	1.250	49.862
		1.375	9.160	8.730	1.500	58.591
		1.625	6.990	6.662	1.750	65.253
		1.875	3.800	3.621	2.000	68.874
		2.125	5.950	5.670	2.250	74.545
		2.375	5.470	5.213	2.500	79.758
		2.625	5.810	5.537	2.750	85.295
		2.875	4.450	4.241	3.000	89.536
		3.125	4.130	3.936	3.250	93.472
		3.375	2.860	2.726	3.500	96.197
		3.625	2.860	2.726	3.750	98.923
		3.875	1.130	1.077	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.930

PERCENT FINER THAN 4.00 PHI = .99 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.285 STANDARD DEVIATION = 1.276 SKEWNESS = -.033 KURTOSIS = -.688

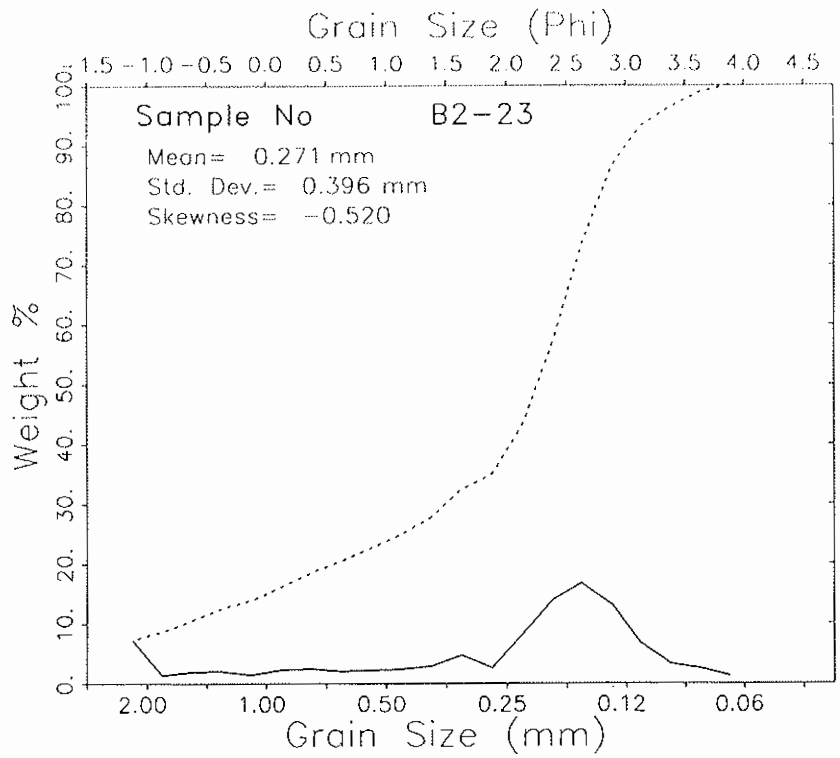
0 DISPERSION = .672 STANDARD DEVIATION = 1.136 DEVIATION FROM NORMAL DISTR. = -10.99%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.210	-1.049	.005	.432	1.254	2.272	2.692	3.390	3.768

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.348	1.317	MEDIUM SAND
STANDARD DEVIATION	1.343	1.344	POORLY SORTED
SKEWNESS(1)	.070	.016	NEAR SYMMETRICAL
SKEWNESS(2)	-.062		
KURTOSIS	.652	.989	MESOKURTIC



1 SAMPLE NO. DATE

B2-23 280301

Borrow B2 - Station 23

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	7.370	7.263	-1.000	7.263
-.875	1.320	1.301	-.750	8.564
-.625	1.930	1.902	-.500	10.466
-.375	1.980	1.951	-.250	12.417
-.125	1.430	1.409	.000	13.827
.125	2.290	2.257	.250	16.084
.375	2.420	2.385	.500	18.469
.625	1.970	1.941	.750	20.410
.875	2.170	2.139	1.000	22.549
1.125	2.360	2.326	1.250	24.874
1.375	2.880	2.838	1.500	27.713
1.625	4.710	4.642	1.750	32.354
1.875	2.560	2.523	2.000	34.877
2.125	8.180	8.061	2.250	42.939
2.375	14.000	13.797	2.500	56.736
2.625	16.880	16.635	2.750	73.371
2.875	13.310	13.117	3.000	86.489
3.125	6.730	6.633	3.250	93.121
3.375	3.280	3.232	3.500	96.354
3.625	2.500	2.464	3.750	98.817
3.875	1.200	1.183	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.470

PERCENT FINER THAN 4.00 PHI = 1.57 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

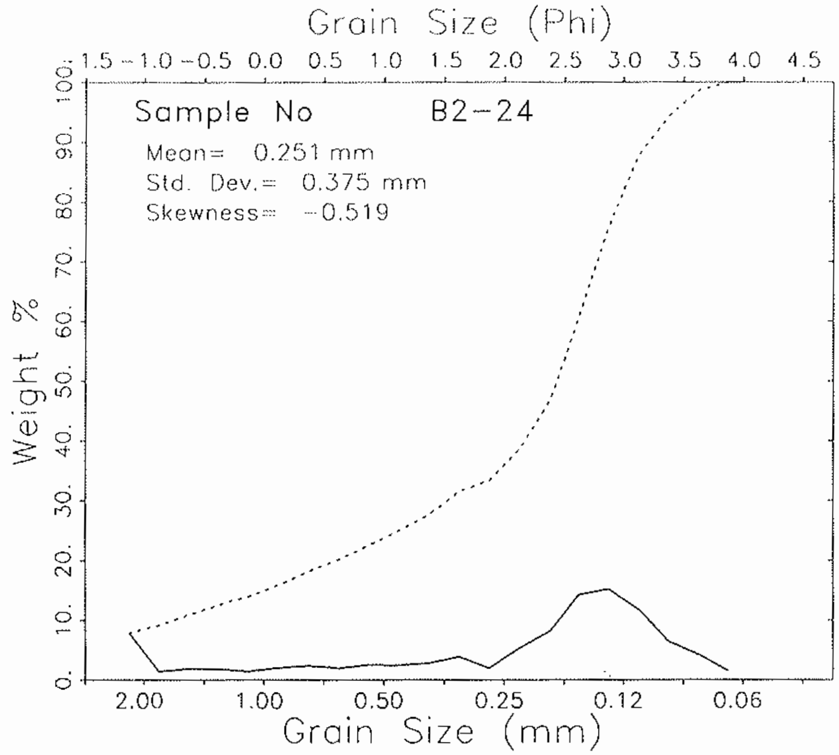
MEAN = 1.881 STANDARD DEVIATION = 1.337 SKEWNESS = -.520 KURTOSIS = -.025

0 DISPERSION = .567 STANDARD DEVIATION = .893 DEVIATION FROM NORMAL DISTR. = -33.19%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.216	-1.078	.241	1.261	2.378	2.781	2.953	3.395	3.789

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.597	1.857	MEDIUM SAND
STANDARD DEVIATION	1.356	1.356	POORLY SORTED
SKEWNESS(1)	-.576	-.561	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.899		
KURTOSIS	.650	1.206	LEPTOKURTIC



1 SAMPLE NO. DATE

B2-24 280301
Borrow B2 - Station 24

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	7.850	7.800	-1.000	7.800
-.875	1.280	1.272	-.750	9.072
-.625	1.810	1.798	-.500	10.870
-.375	1.690	1.679	-.250	12.550
-.125	1.430	1.421	.000	13.971
.125	1.960	1.948	.250	15.918
.375	2.300	2.285	.500	18.203
.625	1.930	1.918	.750	20.121
.875	2.460	2.444	1.000	22.566
1.125	2.400	2.305	1.250	24.950
1.375	2.700	2.683	1.500	27.633
1.625	3.830	3.806	1.750	31.439
1.875	1.920	1.908	2.000	33.347
2.125	5.280	5.246	2.250	38.593
2.375	8.100	8.048	2.500	46.641
2.625	14.340	14.249	2.750	60.890
2.875	15.280	15.183	3.000	76.073
3.125	11.900	11.824	3.250	87.897
3.375	6.440	6.399	3.500	94.297
3.625	4.250	4.223	3.750	98.519
3.875	1.490	1.481	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.640

PERCENT FINER THAN 4.00 PHI = .99 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.997 STANDARD DEVIATION = 1.414 SKEWNESS = -.519 KURTOSIS = -.125

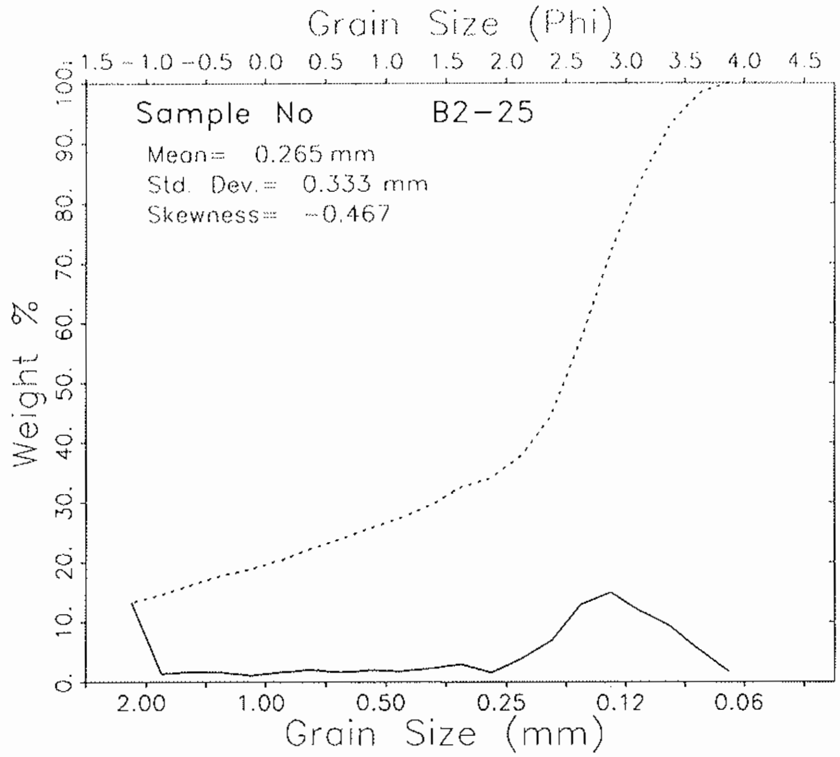
0 DISPERSION = .578 STANDARD DEVIATION = .916 DEVIATION FROM NORMAL DISTR. = -35.22%

D PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.090	.259	1.255	2.559	2.982	3.168	3.542	3.831

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.713	1.995	MEDIUM SAND
STANDARD DEVIATION	1.454	1.429	POORLY SORTED
SKEWNESS(1)	-.581	-.579	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.917		
KURTOSIS	.592	1.099	MESOKURTIC



1 SAMPLE NO. DATE

B2-25 280301
Borrow B2 - Station 25

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	13.860	13.185	-1.000	13.185
-.875	1.370	1.303	-.750	14.488
-.625	1.750	1.665	-.500	16.153
-.375	1.630	1.551	-.250	17.704
-.125	1.130	1.075	.000	18.779
.125	1.590	1.513	.250	20.291
.375	2.040	1.941	.500	22.232
.625	1.630	1.551	.750	23.782
.875	1.980	1.884	1.000	25.666
1.125	1.780	1.693	1.250	27.359
1.375	2.290	2.178	1.500	29.538
1.625	3.070	2.920	1.750	32.458
1.875	1.580	1.503	2.000	33.961
2.125	3.990	3.796	2.250	37.757
2.375	7.120	6.773	2.500	44.530
2.625	13.470	12.814	2.750	57.344
2.875	15.610	14.850	3.000	72.194
3.125	12.320	11.720	3.250	83.914
3.375	9.700	9.228	3.500	93.141
3.625	5.510	5.242	3.750	98.383
3.875	1.700	1.617	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.120

PERCENT FINER THAN 4.00 PHI = 1.55 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

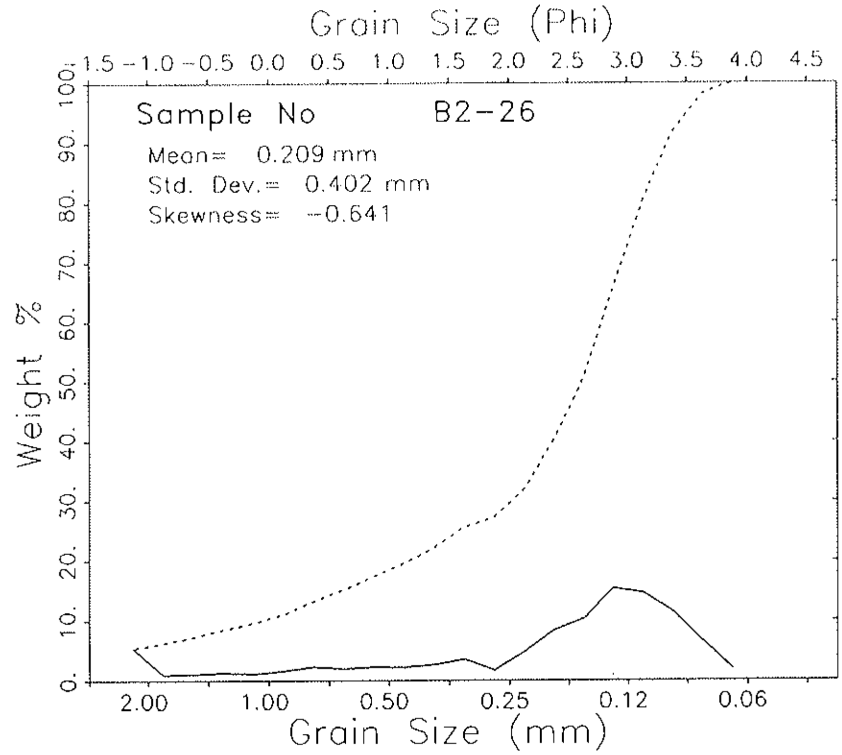
MEAN = 1.918 STANDARD DEVIATION = 1.586 SKEWNESS = -.467 KURTOSIS = -.587

0 DISPERSION = .548 STANDARD DEVIATION = .855 DEVIATION FROM NORMAL DISTR. = -46.08%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.231	-1.155	-.523	.912	2.607	3.060	3.252	3.589	3.845

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.365	1.779	MEDIUM SAND
STANDARD DEVIATION	1.888	1.663	POORLY SORTED
SKEWNESS(1)	-.658	-.622	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.736		
KURTOSIS	.257	.905	MESOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-26	280301					
Borrow B2 - Station 26						
		-1.125	5.410	5.305	-1.000	5.305
		-.875	.890	.873	-.750	6.178
		-.625	1.070	1.049	-.500	7.228
		-.375	1.260	1.236	-.250	8.463
		-.125	1.080	1.059	.000	9.522
		.125	1.570	1.540	.250	11.062
		.375	2.230	2.187	.500	13.249
		.625	1.910	1.873	.750	15.122
		.875	2.300	2.256	1.000	17.378
		1.125	2.150	2.108	1.250	19.486
		1.375	2.600	2.550	1.500	22.036
		1.625	3.570	3.501	1.750	25.537
		1.875	1.690	1.657	2.000	27.194
		2.125	4.780	4.688	2.250	31.882
		2.375	8.500	8.336	2.500	40.218
		2.625	10.340	10.140	2.750	50.358
		2.875	15.610	15.308	3.000	65.666
		3.125	14.820	14.534	3.250	80.200
		3.375	11.650	11.425	3.500	91.625
		3.625	6.610	6.482	3.750	98.107
		3.875	1.930	1.893	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.970

PERCENT FINER THAN 4.00 PHI = 1.49 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.260 STANDARD DEVIATION = 1.314 SKEWNESS = -.641 KURTOSIS = .686

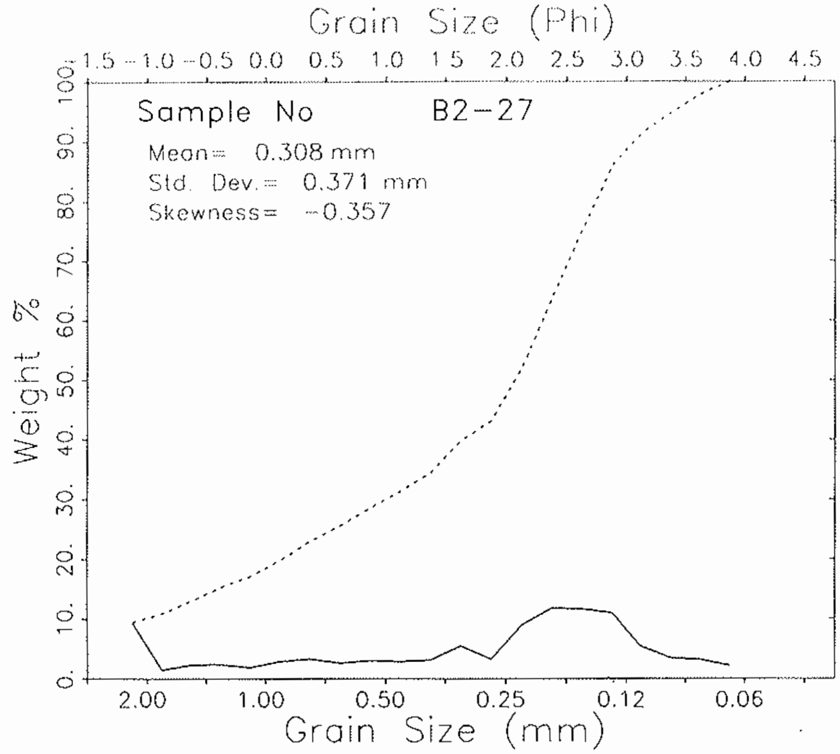
0 DISPERSION = .556 STANDARD DEVIATION = .870 DEVIATION FROM NORMAL DISTR. = -33.77%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.203	-1.014	.847	1.712	2.741	3.161	3.333	3.630	3.868

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.090	2.307	FINE SAND
STANDARD DEVIATION	1.243	1.325	POORLY SORTED
SKEWNESS(1)	-.524	-.570	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.153		
KURTOSIS	.868	1.314	LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-27	290301					
Borrow B2 - Station 27						
		-1.125	9.810	9.319	-1.000	9.319
		-.875	1.500	1.425	-.750	10.744
		-.625	2.330	2.213	-.500	12.957
		-.375	2.410	2.289	-.250	15.247
		-.125	1.870	1.776	.000	17.023
		.125	2.930	2.783	.250	19.806
		.375	3.390	3.220	.500	23.027
		.625	2.670	2.536	.750	25.563
		.875	3.160	3.002	1.000	28.565
		1.125	2.910	2.764	1.250	31.329
		1.375	3.250	3.087	1.500	34.416
		1.625	5.630	5.348	1.750	39.764
		1.875	3.410	3.239	2.000	43.004
		2.125	9.240	8.777	2.250	51.781
		2.375	12.290	11.675	2.500	63.456
		2.625	12.190	11.580	2.750	75.036
		2.875	11.460	10.886	3.000	85.922
		3.125	5.620	5.339	3.250	91.261
		3.375	3.600	3.420	3.500	94.680
		3.625	3.340	3.173	3.750	97.853
		3.875	2.260	2.147	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.270

PERCENT FINER THAN 4.00 PHI = 2.46 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

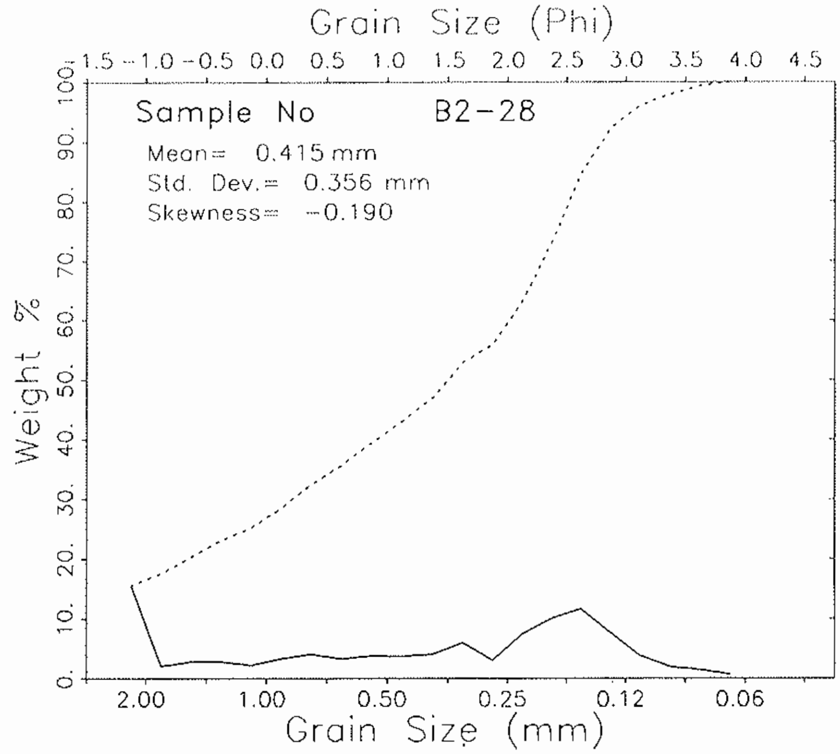
+ MEAN = 1.698 STANDARD DEVIATION = 1.431 SKEWNESS = -.357 KURTOSIS = -.646

0 DISPERSION = .625 STANDARD DEVIATION = 1.021 DEVIATION FROM NORMAL DISTR. = -28.60%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.223	-1.116	-.144	.695	2.199	2.749	2.956	3.525	3.884

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.406	1.670	MEDIUM SAND
STANDARD DEVIATION	1.550	1.478	POORLY SORTED
SKEWNESS(1)	-.512	-.470	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.642		
KURTOSIS	.497	.926	MESOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-28	290301					
B2-28						
		-1.125	15.250	15.489	-1.000	15.489
		-.875	1.980	2.011	-.750	17.499
		-.625	2.700	2.742	-.500	20.242
		-.375	2.690	2.732	-.250	22.974
		-.125	2.120	2.153	.000	25.127
		.125	3.210	3.260	.250	28.387
		.375	3.940	4.002	.500	32.389
		.625	3.210	3.260	.750	35.649
		.875	3.660	3.717	1.000	39.366
		1.125	3.580	3.636	1.250	43.002
		1.375	3.920	3.981	1.500	46.984
		1.625	5.830	5.921	1.750	52.905
		1.875	2.950	2.996	2.000	55.901
		2.125	7.270	7.384	2.250	63.285
		2.375	9.810	9.963	2.500	73.248
		2.625	11.350	11.528	2.750	84.776
		2.875	7.430	7.546	3.000	92.322
		3.125	3.670	3.727	3.250	96.049
		3.375	1.860	1.889	3.500	97.938
		3.625	1.370	1.391	3.750	99.330
		3.875	.660	.670	4.000	100.000

TOTAL WEIGHT (GRAMS) = 98.460

PERCENT FINER THAN 4.00 PHI = 1.15 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

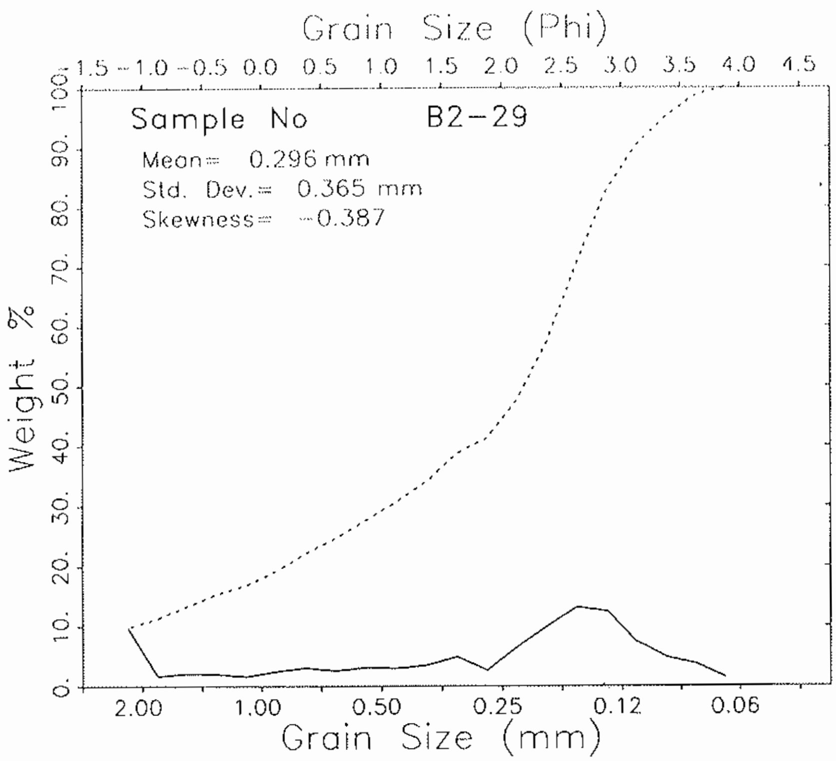
+ MEAN = 1.268 STANDARD DEVIATION = 1.492 SKEWNESS = -.190 KURTOSIS = -1.210

0 DISPERSION = .614 STANDARD DEVIATION = .994 DEVIATION FROM NORMAL DISTR. = -33.34%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.234	-1.169	-.936	-.015	1.627	2.538	2.733	3.180	3.691

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.898	1.141	MEDIUM SAND
STANDARD DEVIATION	1.835	1.576	POORLY SORTED
SKEWNESS(1)	-.397	-.342	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.339		
KURTOSIS	.185	.698	PLATYKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-29	290301					
Borrow B2 - Station 29						
		-1.125	10.360	9.689	-1.000	9.689
		-.875	1.720	1.609	-.750	11.298
		-.625	2.190	2.048	-.500	13.346
		-.375	2.100	1.964	-.250	15.311
		-.125	1.620	1.515	.000	16.826
		.125	2.530	2.366	.250	19.192
		.375	3.160	2.955	.500	22.147
		.625	2.660	2.488	.750	24.635
		.875	3.260	3.049	1.000	27.684
		1.125	3.110	2.909	1.250	30.593
		1.375	3.580	3.348	1.500	33.941
		1.625	5.100	4.770	1.750	38.711
		1.875	2.730	2.553	2.000	41.264
		2.125	6.920	6.472	2.250	47.737
		2.375	10.540	9.858	2.500	57.594
		2.625	13.940	13.038	2.750	70.632
		2.875	13.230	12.374	3.000	83.006
		3.125	7.770	7.267	3.250	90.273
		3.375	5.010	4.686	3.500	94.959
		3.625	3.900	3.648	3.750	98.606
		3.875	1.490	1.394	4.000	100.000

1

TOTAL WEIGHT (GRAMS) = 106.920

PERCENT FINER THAN 4.00 PHI = 1.20 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

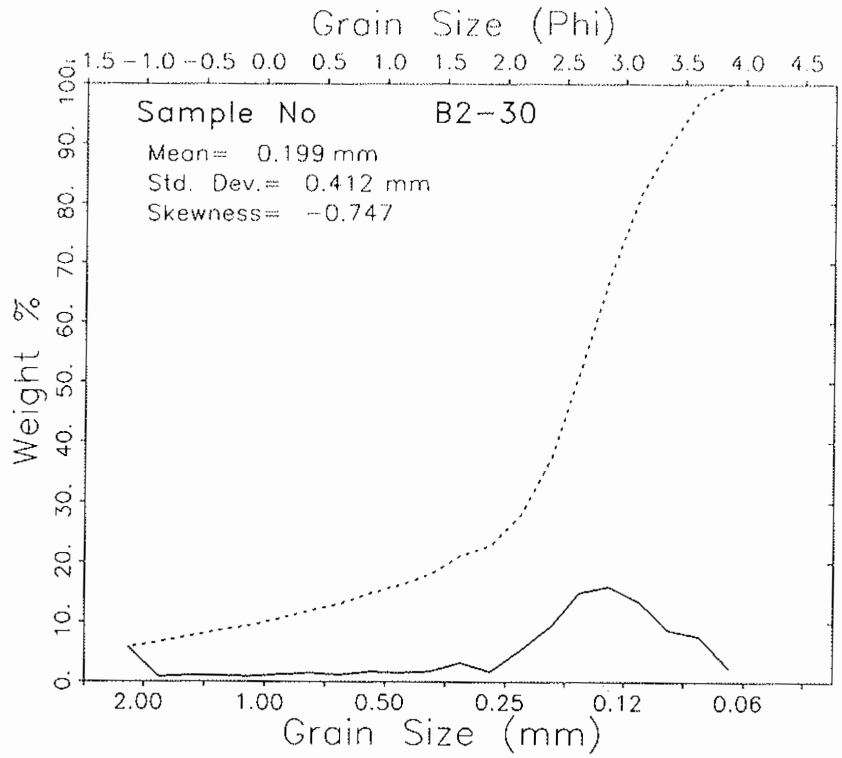
\+ MEAN = 1.756 STANDARD DEVIATION = 1.455 SKEWNESS = -.387 KURTOSIS = -.626

0 DISPERSION = .615 STANDARD DEVIATION = .998 DEVIATION FROM NORMAL DISTR. = -31.38%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.224	-1.121	-.136	.780	2.307	2.838	3.034	3.503	3.821

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.449	1.735	MEDIUM SAND
STANDARD DEVIATION	1.585	1.493	POORLY SORTED
SKEWNESS(1)	-.542	-.512	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.704		
KURTOSIS	.458	.921	MESOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-30	290301					
Borrow B2 - Station 30						
		-1.125	5.690	5.750	-1.000	5.750
		-.875	.830	.839	-.750	6.589
		-.625	.940	.950	-.500	7.539
		-.375	.980	.990	-.250	8.530
		-.125	.810	.819	.000	9.348
		.125	1.110	1.122	.250	10.470
		.375	1.370	1.385	.500	11.854
		.625	1.160	1.172	.750	13.027
		.875	1.650	1.668	1.000	14.694
		1.125	1.450	1.465	1.250	16.160
		1.375	1.730	1.748	1.500	17.908
		1.625	3.080	3.113	1.750	21.021
		1.875	1.650	1.668	2.000	22.688
		2.125	5.140	5.195	2.250	27.883
		2.375	9.070	9.166	2.500	37.049
		2.625	14.740	14.896	2.750	51.945
		2.875	15.720	15.887	3.000	67.832
		3.125	13.330	13.471	3.250	81.304
		3.375	8.580	8.671	3.500	89.975
		3.625	7.550	7.630	3.750	97.605
		3.875	2.370	2.395	4.000	100.000

TOTAL WEIGHT (GRAMS) = 98.950

PERCENT FINER THAN 4.00 PHI = 1.71 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.327 STANDARD DEVIATION = 1.280 SKEWNESS = -.747 KURTOSIS = 1.404

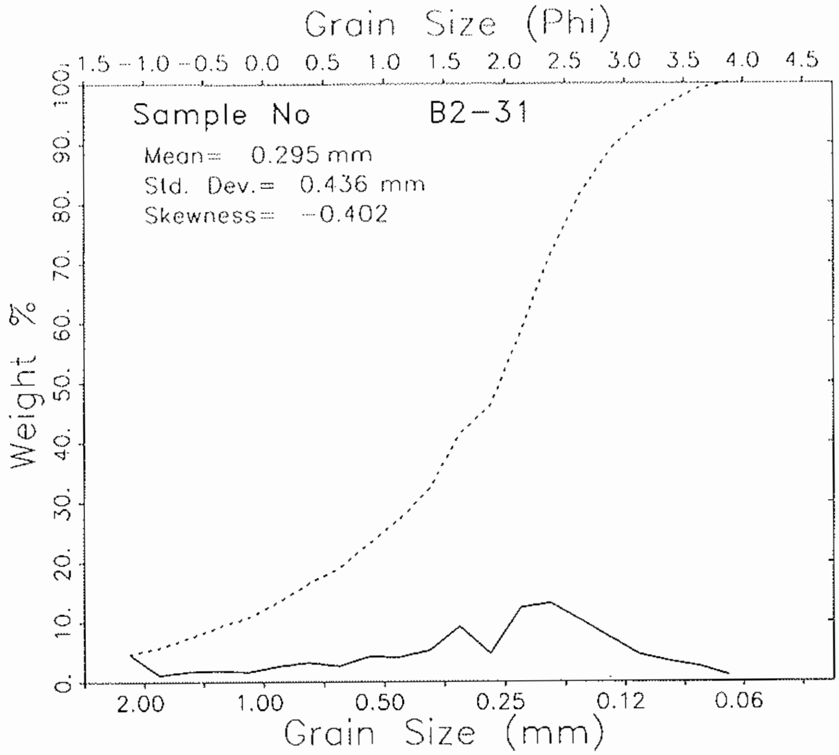
0 DISPERSION = .522 STANDARD DEVIATION = .805 DEVIATION FROM NORMAL DISTR. = -37.06%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.207	-1.033	1.223	2.111	2.717	3.133	3.328	3.665	3.896

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.275	2.423	FINE SAND
STANDARD DEVIATION	1.052	1.238	POORLY SORTED
SKEWNESS(1)	-.420	-.508	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.331		
KURTOSIS	1.232	1.884	VERY LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B2-31	290301					
Borrow B2 - Station 31						
		-1.125	4.600	4.581	-1.000	4.581
		-.875	1.090	1.086	-.750	5.667
		-.625	1.640	1.633	-.500	7.300
		-.375	1.840	1.832	-.250	9.133
		-.125	1.590	1.584	.000	10.716
		.125	2.590	2.579	.250	13.295
		.375	3.170	3.157	.500	16.453
		.625	2.530	2.520	.750	18.972
		.875	4.120	4.103	1.000	23.075
		1.125	4.080	4.063	1.250	27.139
		1.375	5.140	5.119	1.500	32.258
		1.625	9.170	9.133	1.750	41.390
		1.875	4.650	4.631	2.000	46.021
		2.125	12.360	12.310	2.250	58.331
		2.375	13.140	13.086	2.500	71.417
		2.625	10.260	10.218	2.750	81.635
		2.875	7.280	7.250	3.000	88.886
		3.125	4.410	4.392	3.250	93.278
		3.375	3.340	3.326	3.500	96.604
		3.625	2.460	2.450	3.750	99.054
		3.875	.950	.946	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.410

PERCENT FINER THAN 4.00 PHI = .82 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

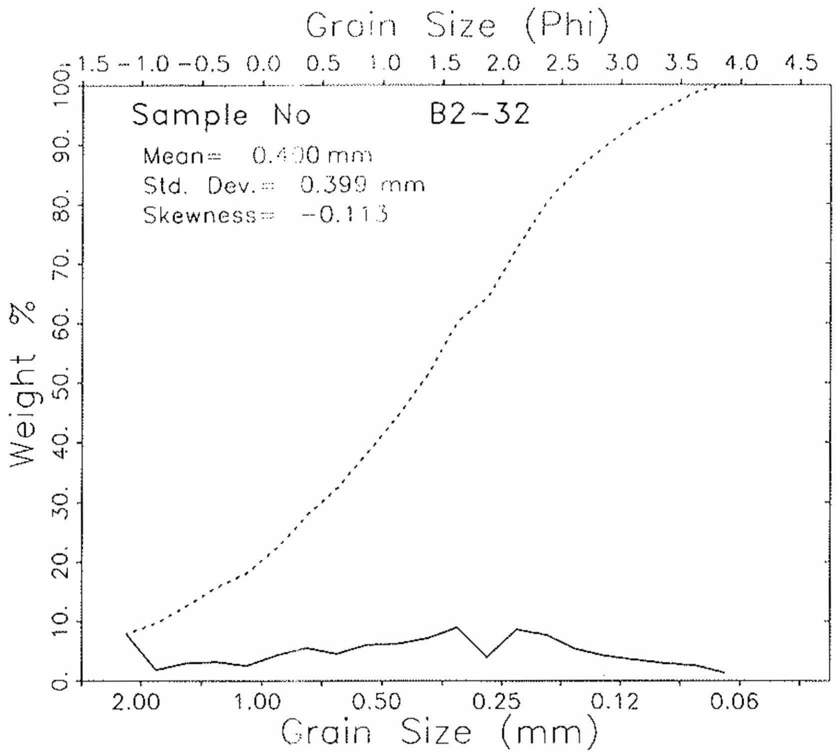
MEAN = 1.762 STANDARD DEVIATION = 1.199 SKEWNESS = -.402 KURTOSIS = .020

0 DISPERSION = .614 STANDARD DEVIATION = .994 DEVIATION FROM NORMAL DISTR. = -17.09%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.195	-.904	.464	1.118	2.081	2.588	2.832	3.379	3.745

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.648	1.792	
			MEDIUM SAND
STANDARD DEVIATION	1.184	1.241	
			POORLY SORTED
SKEWNESS(1)	-.366	-.380	
			STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.712		
KURTOSIS	.809	1.195	
			LEPTOKURTIC



1 SAMPLE NO. DATE

B2-32 290301
Borrow B2 - Station 32

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	8.140	7.855	-1.000	7.855
-.875	1.840	1.776	-.750	9.630
-.625	2.980	2.876	-.500	12.506
-.375	3.210	3.098	-.250	15.604
-.125	2.580	2.490	.000	18.093
.125	4.370	4.217	.250	22.310
.375	5.670	5.471	.500	27.782
.625	4.640	4.477	.750	32.259
.875	6.170	5.954	1.000	38.213
1.125	6.350	6.128	1.250	44.340
1.375	7.340	7.083	1.500	51.423
1.625	9.190	8.868	1.750	60.291
1.875	4.020	3.879	2.000	64.171
2.125	8.830	8.521	2.250	72.691
2.375	7.940	7.662	2.500	80.353
2.625	5.470	5.278	2.750	85.632
2.875	4.320	4.169	3.000	89.800
3.125	3.620	3.493	3.250	93.293
3.375	2.950	2.847	3.500	96.140
3.625	2.670	2.576	3.750	98.717
3.875	1.330	1.283	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.630

PERCENT FINER THAN 4.00 PHI = 1.91 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.322 STANDARD DEVIATION = 1.325 SKEWNESS = -.113 KURTOSIS = -.786

0 DISPERSION = .673 STANDARD DEVIATION = 1.139 DEVIATION FROM NORMAL DISTR. = -14.07%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.218	-1.091	-.210	.373	1.450	2.325	2.673	3.400	3.805

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.231	1.304	MEDIUM SAND
STANDARD DEVIATION	1.441	1.401	POORLY SORTED
SKEWNESS(1)	-.152	-.142	COARSE-SKEWED
SKEWNESS(2)	-.205		
KURTOSIS	.558	.943	MESOKURTIC

ANNEX E-4
Part 4

Supplementary Beach Sediment Samples
May 2001

CSE COASTAL SCIENCE & ENGINEERING LLC
PO BOX 8056 COLUMBIA SC 29202 • TEL 803-799-8949 • FAX 803-799-9481 • EMAIL cse@coastalscience.com

May 24, 2001

Mr. Garland Pardue
US Fish & Wildlife Service
551-F Pylon Drive
Raleigh NC 27606

Tel: 919-856-4520
Fax: 919-856-4556

RE: Carteret County – Bogue Banks Beach Restoration Project – Federal Action ID# 200000362]
Supplementary Information Requested by USFWS on 11 May 2001 (interagency meeting)

Dear Mr. Pardue:

I am writing on behalf of Carteret County and the Towns of Pine Knoll Shores, Indian Beach, and Emerald Isle in regard to the permit application for the above-referenced project. Representatives from your agency, Ms. Tracy Rice and Mr. John Ellis, attended an interagency meeting in Morehead City on 11 May 2001 and provided comments and requests for additional information. This letter and its attachments provide the information requested. These data are intended to supplement the information contained in the permit application and final EIS approved under the SEPA review process.

Work Accomplished

At the request of your agency, the Towns of Pine Knoll Shores and Indian Beach funded additional beach sediment collection and analyses as follows:

- 64 surficial sediment samples from Bogue Banks transect 48 (Emerald Isle) through transect 78 (Atlantic Beach). Sixteen, even-numbered transects were sampled along the dune face, top of berm, beach face, and low-tide terrace at low tide on 15 May 2001.

- 32 samples were analyzed in the laboratory by combining physical pairs from adjacent transects (eg, dune samples from transects 48 and 50 were combined physically, mixed completely, and a representative ~100-gram sample was tested for sediment properties). Samples were labeled B4850a for dune samples at transects 48 and 50, B4850b for berm samples, etc.

- Laboratory analysis of each sample consisted of:
  - Mechanical sieving at 0.25ϕ intervals.
  - Computation of grain-size distribution (GSD) parameters (mean, standard deviation, skewness, percent coarser than 2 mm, etc.).
  - Chemical analysis of the calcium carbonate fraction via acid reduction (dilute HCl) using a representative 20-gram sample.
  - Physical separation of the mud fraction (sizes passing the 230 ASTM sieve; ie, <0.0625 mm diameter) to determine the mud percent.
  - Size parameters were calculated by the Method of Moments and via graphic techniques of Inman (1952) and Folk and Ward (1957).

- Groups of samples were combined statistically using the raw weight percentages of each size fraction to calculate "composite" GSDs. Composites included:
  - CDUNE8 – composite of the eight dune tests (representing 16 physical samples).
  - CDUNE4 – composite of four of the dune tests (representing transects less altered by scraping).
  - CBERM8 – composite of the eight berm tests (representing 16 berm samples).
  - CBF8 – composite of the eight beach face tests, etc.
  - CLTT8 – composite of the eight low-tide terrace tests, etc.

- Overall beach composites were computed for all 32 tests ("COMP32") and 28 tests ("Comp28" which omits four of the dune samples).

- The composites from the 15 May 2001 sampling were compared with the June 1999 results. All new beach sediment data have been added to Table E3-Revised (EIS) and are attached to this letter. The 1999 "Native Beach" composite is compared with the 2001 composites at the bottom of Table E3.

- The "Native Beach" GSD was revised by averaging the results from the June 1999 and the May 2001 survey as follows (see Table E3 for additional details):
  - 1999 beach composite (20 samples) – mean = 0.302 mm
  - 2001 beach composite (28 samples) – mean = 0.298 mm
  - Revised native composite – mean = 0.300 mm

CSE

- Overfill ratios (RAs) for individual samples in three offshore borrow areas were recomputed using the revised native composite GSDs. These are given in Table E5-Revised. The typical change in RAs after this revision was ~0.01, or about 1 percent.

- Sediment characteristic maps of various textural parameters were updated for the three borrow areas. These include data from additional borings obtained between November 2000 and March 2001, which were in processing at the time of the interagency meeting.
    - Area A – ~76 cores
    - Area B1 – ~46 cores
    - Area B2 – ~42 cores

  Additional core data are given in Annex E1-Table E1-F (Appendix E to EIS).

- Results of the supplementary individual and composite GSDs (sample split weights, frequency, cumulative frequency, and statistics) are enclosed with this letter.

Borrow Area Delineation

As part of the final design for the Pine Knoll Shores and Indian Beach projects, we will optimize borrow areas A, B1, and B2 to effect a close match between the borrow sediments and the revised native beach sediments. This is an iterative process because of the number of variables involved and the natural variability of Bogue Banks' beach and offshore area. However, final decisions regarding exactly which portions of the borrow areas will be used cannot be made until all variables are known. These include the capabilities of each dredge of the winning construction bidder and the unit-volume bid price. (For example, if bid prices are lower than expected, more sand may be dredged, up to the maximum permitted volume.)

The final design will identify the optimal areas for excavations and will provide statistical composites for applicable groups of samples from borrow areas A, B1, and B2.

We anticipate collecting additional borings prior to any nourishment along Emerald Isle. The present data are focused in anticipation of construction along Pine Knoll Shores and Indian Beach reaches between November 2001 and April 2002. We request that your agency review these data in the context of the Pine Knoll Shores and Indian Beach reaches.

CSE

Supplement to the Biological Assessment

Also enclosed herein is a supplement to the biological assessment given in the EIS. Additional site visits and surveys have been performed since the EIS was prepared. The most recent survey was 14-15 May. The majority of Pine Knoll Shores and Indian Beach lacks any dry beach. Property owners are continuing to scrape the beach and rebuild the foredune. There are escarpments up to 8 feet high in some newly scraped dunes (see photo 1.4) and continued undercutting and mass wasting of vegetated dunes. In addition to the reduction of viable turtle nesting and seabeach amaranth habitat (see photos), even more habitable structures are imminently threatened than was reported in the EIS. We encourage you and your staff to visit the site and see the continued loss of dune and dry beach habitat. This is particularly noticeable upon leaving Pine Knoll Shores and traveling east along the beach into the Town of Atlantic Beach (which was nourished in 1986 and 1994 prior to five landfall hurricanes, see photo 1.6).

We appreciate the comments from your agency and hope you find the enclosed information responsive. Time is of the essence, and it is critical that we obtain your review of the project at the earliest time. Our project team and representatives of the county and towns would like to meet with you any time in the next two weeks and discuss these results in detail. Thank you for your consideration.

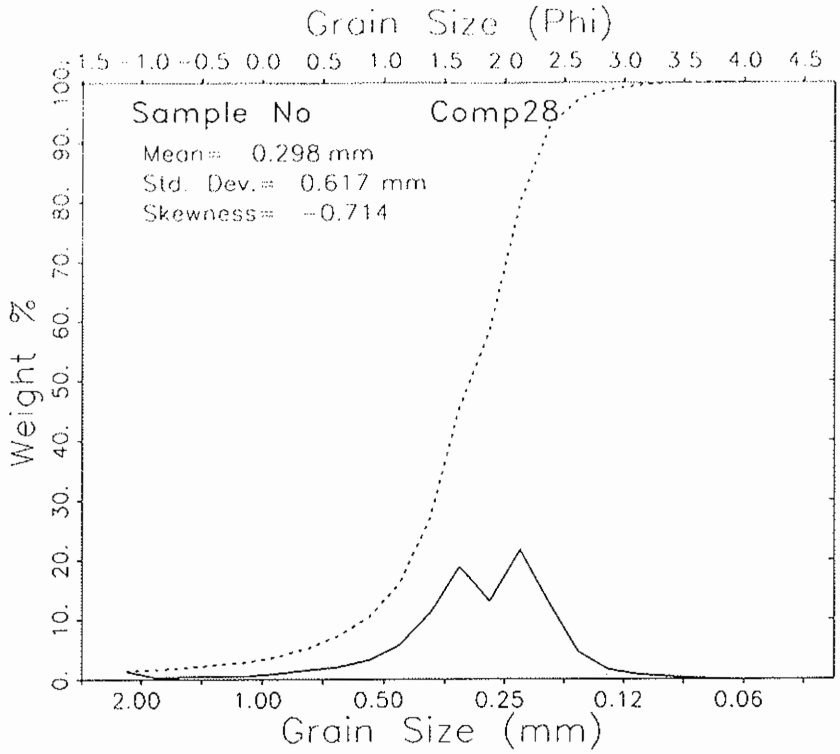
Yours truly,

Tim Kana

Timothy W Kana PhD
Project Director

cc: USACE, c/o Mickey Sugg
NMFS, Morehead City, Ron Sechler
NC CAMA, Doug Huggett
Carteret County, Pete Allen
Town of Pine Knoll Shores, Mayor Reese Musgrave
Town of Indian Beach, Mayor Buck Fugate
Town of Emerald Isle, Mayor Barbara Harris
CSE, Bill Forman

Attachments



1 SAMPLE NO. DATE

Comp28 150501
PKS-IB Dune(4)-Berm-BF-LTT Composite

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	1.360	1.319	-1.000	1.319
-.875	.230	.223	-.750	1.543
-.625	.380	.369	-.500	1.911
-.375	.480	.466	-.250	2.377
-.125	.470	.456	.000	2.833
.125	.900	.873	.250	3.706
.375	1.480	1.436	.500	5.142
.625	2.070	2.008	.750	7.150
.875	3.230	3.134	1.000	10.284
1.125	5.790	5.618	1.250	15.902
1.375	11.120	10.789	1.500	26.691
1.625	19.420	18.842	1.750	45.532
1.875	13.380	12.981	2.000	58.514
2.125	22.350	21.684	2.250	80.198
2.375	12.980	12.593	2.500	92.791
2.625	4.580	4.444	2.750	97.235
2.875	1.600	1.552	3.000	98.787
3.125	.780	.757	3.250	99.544
3.375	.370	.359	3.500	99.903
3.625	.100	.097	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.070

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

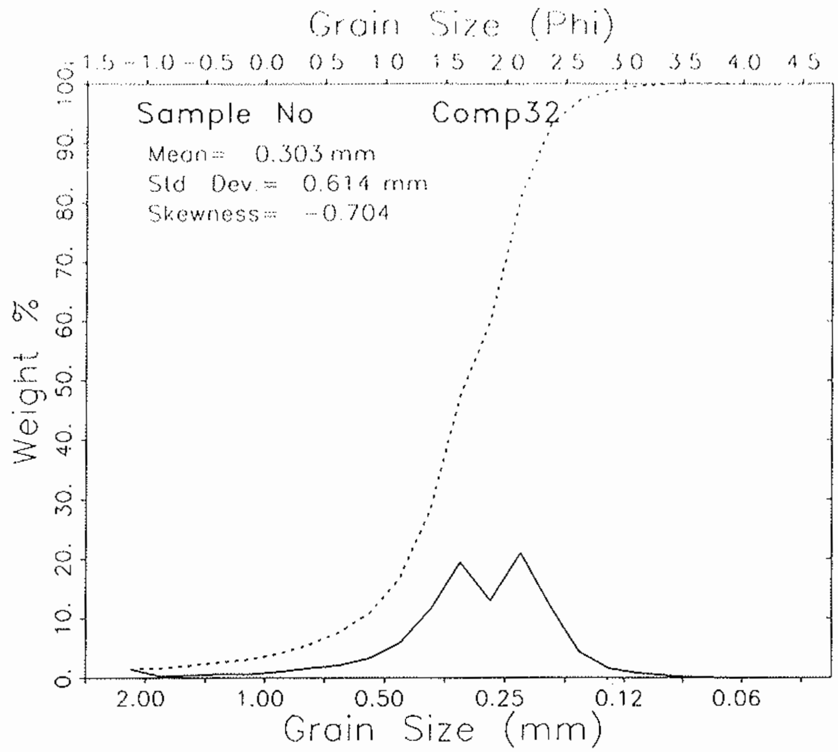
MEAN = 1.747 STANDARD DEVIATION = .696 SKEWNESS = -.714 KURTOSIS = 3.736

0 DISPERSION = .384 STANDARD DEVIATION = .586 DEVIATION FROM NORMAL DISTR. = -15.79%

0 PERCENTILES:

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.061	.475	1.252	1.461	1.836	2.190	2.325	2.624	3.070

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
0	MEAN	1.789	1.805	MEDIUM SAND
0	STANDARD DEVIATION	.537	.594	MODERATELY WELL SORTED
0	SKEWNESS(1)	-.088	-.177	COARSE-SKEWED
0	SKEWNESS(2)	-.534		
0	KURTOSIS	1.002	1.208	LEPTOKURTIC



1 SAMPLE NO. DATE

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
Comp32 150501				
PKS-IB Dune-Berm-BF-LTT Composite				
-1.125	1.400	1.361	-1.000	1.361
-.875	.240	.233	-.750	1.594
-.625	.420	.408	-.500	2.002
-.375	.550	.535	-.250	2.537
-.125	.530	.515	.000	3.052
.125	1.000	.972	.250	4.024
.375	1.580	1.536	.500	5.560
.625	2.120	2.061	.750	7.621
.875	3.340	3.247	1.000	10.867
1.125	6.010	5.842	1.250	16.709
1.375	11.610	11.285	1.500	27.994
1.625	19.930	19.372	1.750	47.366
1.875	13.280	12.908	2.000	60.274
2.125	21.620	21.015	2.250	81.289
2.375	12.290	11.946	2.500	93.235
2.625	4.300	4.180	2.750	97.414
2.875	1.500	1.458	3.000	98.872
3.125	.730	.710	3.250	99.582
3.375	.340	.330	3.500	99.913
3.625	.090	.087	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.880

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

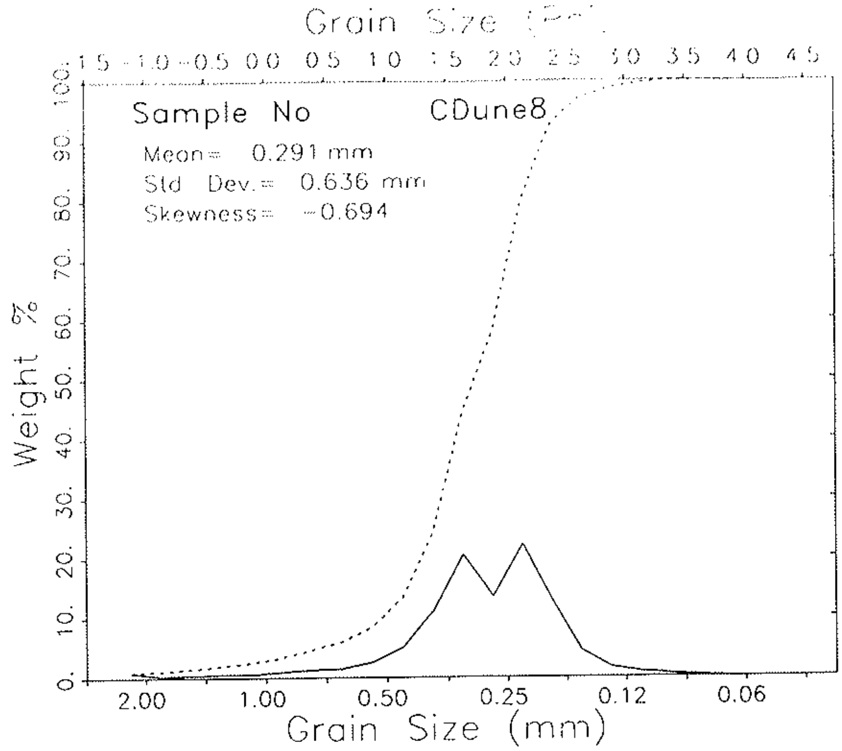
+ MEAN = 1.722 STANDARD DEVIATION = .703 SKEWNESS = -.704 KURTOSIS = 3.552

0 DISPERSION = .389 STANDARD DEVIATION = .592 DEVIATION FROM NORMAL DISTR. = -15.79%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.066	.409	1.220	1.434	1.801	2.175	2.307	2.606	3.045

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.763	1.776	MEDIUM SAND
STANDARD DEVIATION	.544	.605	MODERATELY WELL SORTED
SKEWNESS(1)	-.070	-.169	COARSE-SKEWED
SKEWNESS(2)	-.541		
KURTOSIS	1.021	1.214	LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
CDune8	150501					
PKS-IB Dune (8) Composite						
		-1.125	.850	.832	-1.000	.832
		-.875	.200	.196	-.750	1.028
		-.625	.370	.362	-.500	1.390
		-.375	.510	.499	-.250	1.890
		-.125	.510	.499	.000	2.389
		.125	.900	.881	.250	3.270
		.375	1.260	1.234	.500	4.504
		.625	1.380	1.351	.750	5.855
		.875	2.490	2.438	1.000	8.293
		1.125	4.970	4.866	1.250	13.158
		1.375	11.110	10.877	1.500	24.036
		1.625	20.950	20.511	1.750	44.547
		1.875	13.660	13.374	2.000	57.920
		2.125	22.700	22.224	2.250	80.145
		2.375	12.920	12.649	2.500	92.794
		2.625	4.400	4.308	2.750	97.102
		2.875	1.620	1.586	3.000	98.688
		3.125	.820	.803	3.250	99.491
		3.375	.410	.401	3.500	99.892
		3.625	.110	.108	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.140

PERCENT FINER THAN 4.00 PHI = .01 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.782 STANDARD DEVIATION = .653 SKEWNESS = -.694 KURTOSIS = 4.034

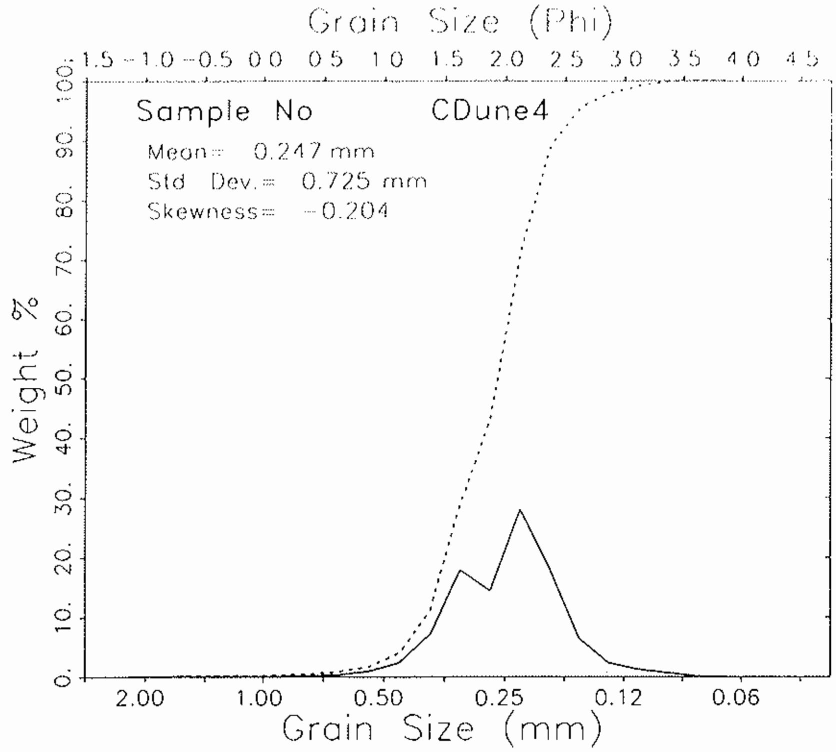
0 DISPERSION = .361 STANDARD DEVIATION = .556 DEVIATION FROM NORMAL DISTR. = -14.97%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.786	.592	1.315	1.512	1.852	2.192	2.326	2.628	3.097

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.821	1.831	MEDIUM SAND
STANDARD DEVIATION	.505	.561	MODERATELY WELL SORTED
SKEWNESS(1)	-.062	-.150	COARSE-SKEWED
SKEWNESS(2)	-.479		
KURTOSIS	1.014	1.227	LEPTOKURTIC



1 SAMPLE NO. DATE

CDune4 150501

PKS-IB Dune (4) Composite

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.040	.039	-1.000	.039
-.875	.030	.029	-.750	.068
-.625	.040	.039	-.500	.107
-.375	.050	.049	-.250	.156
-.125	.050	.049	.000	.204
.125	.080	.078	.250	.282
.375	.200	.195	.500	.477
.625	.330	.321	.750	.798
.875	.900	.875	1.000	1.673
1.125	2.390	2.325	1.250	3.998
1.375	7.130	6.935	1.500	10.933
1.625	18.420	17.917	1.750	28.849
1.875	14.770	14.366	2.000	43.216
2.125	28.890	28.100	2.250	71.316
2.375	18.440	17.936	2.500	89.252
2.625	6.570	6.390	2.750	95.642
2.875	2.410	2.344	3.000	97.987
3.125	1.230	1.196	3.250	99.183
3.375	.660	.642	3.500	99.825
3.625	.180	.175	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.810

PERCENT FINER THAN 4.00 PHI = .02 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.015 STANDARD DEVIATION = .464 SKEWNESS = -.204 KURTOSIS = 2.625

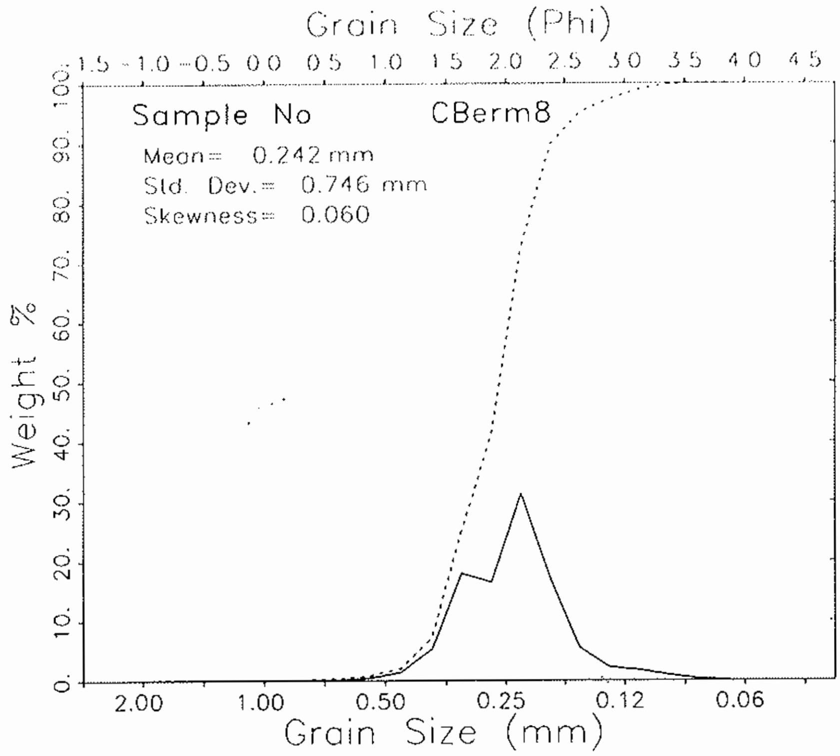
0 DISPERSION = .257 STANDARD DEVIATION = .437 DEVIATION FROM NORMAL DISTR. = -5.78%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
.808	1.286	1.571	1.696	2.060	2.301	2.427	2.725	3.212

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	1.999	2.019	
+				FINE SAND
0	STANDARD DEVIATION	.428	.432	
+				WELL SORTED
0	SKEWNESS(1)	-.144	-.110	
+				COARSE-SKEWED
0	SKEWNESS(2)	-.128		
0	KURTOSIS	.681	.975	
+				MESOKURTIC



1

SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
CBerm8 150501					
PKS-IB Berm (8) Composite					
	-1.125	.000	.000	-1.000	.000
	-.875	.010	.010	-.750	.010
	-.625	.020	.019	-.500	.029
	-.375	.020	.019	-.250	.049
	-.125	.020	.019	.000	.068
	.125	.040	.039	.250	.107
	.375	.080	.078	.500	.185
	.625	.140	.136	.750	.321
	.875	.410	.399	1.000	.720
	1.125	1.320	1.284	1.250	2.004
	1.375	5.200	5.058	1.500	7.062
	1.625	18.430	17.928	1.750	24.990
	1.875	16.840	16.381	2.000	41.372
	2.125	32.220	31.342	2.250	72.714
	2.375	17.530	17.053	2.500	89.767
	2.625	5.550	5.399	2.750	95.165
	2.875	2.230	2.169	3.000	97.335
	3.125	1.660	1.615	3.250	98.949
	3.375	.860	.837	3.500	99.786
	3.625	.220	.214	3.750	100.000
	3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.800

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.048 STANDARD DEVIATION = .423 SKEWNESS = .060 KURTOSIS = 1.924

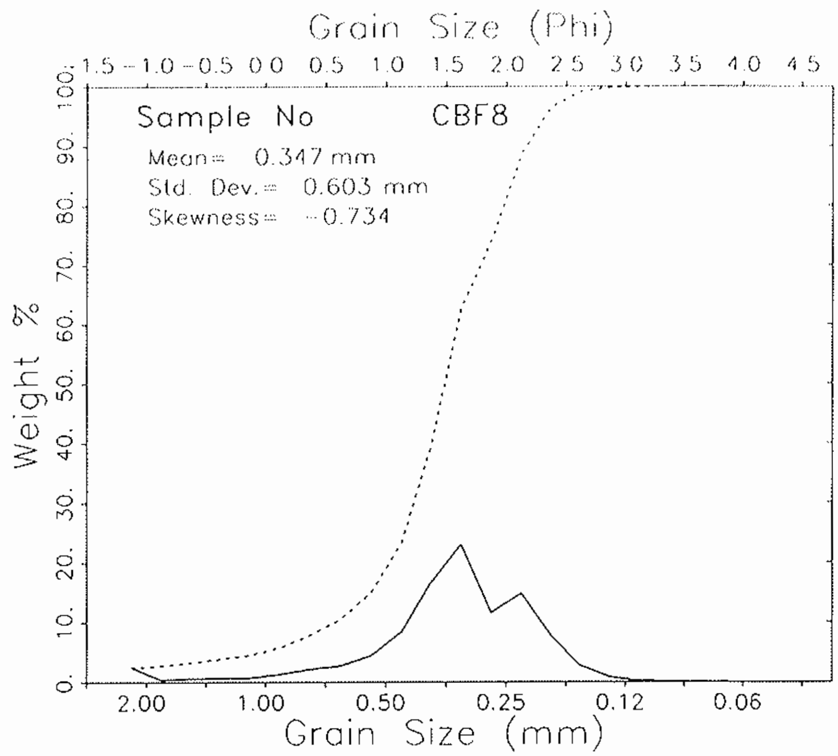
0 DISPERSION = .216 STANDARD DEVIATION = .397 DEVIATION FROM NORMAL DISTR. = -5.96%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.055	1.398	1.625	1.750	2.069	2.284	2.415	2.742	3.265

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.020	2.036	FINE SAND
STANDARD DEVIATION	.395	.401	WELL SORTED
SKEWNESS(1)	-.123	-.061	NEAR SYMMETRICAL
SKEWNESS(2)	.004		
KURTOSIS	.700	1.033	MESOKURTIC



1 SAMPLE NO. DATE

MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
CBF8 150501					
PKS-IB Beach Face (8) Composite					
-1.125	2.430	2.357	-1.000	2.357	
-.875	.320	.310	-.750	2.667	
-.625	.540	.524	-.500	3.191	
-.375	.660	.640	-.250	3.831	
-.125	.640	.621	.000	4.452	
.125	1.300	1.261	.250	5.712	
.375	2.160	2.095	.500	7.807	
.625	2.700	2.619	.750	10.426	
.875	4.480	4.345	1.000	14.771	
1.125	8.470	8.215	1.250	22.985	
1.375	17.190	16.672	1.500	39.657	
1.625	23.670	22.956	1.750	62.613	
1.875	11.840	11.483	2.000	74.096	
2.125	15.220	14.761	2.250	88.857	
2.375	7.870	7.633	2.500	96.489	
2.625	2.690	2.609	2.750	99.098	
2.875	.720	.698	3.000	99.796	
3.125	.160	.155	3.250	99.951	
3.375	.040	.039	3.500	99.990	
3.625	.010	.010	3.750	100.000	
3.875	.000	.000	4.000	100.000	

TOTAL WEIGHT (GRAMS) = 103.110

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

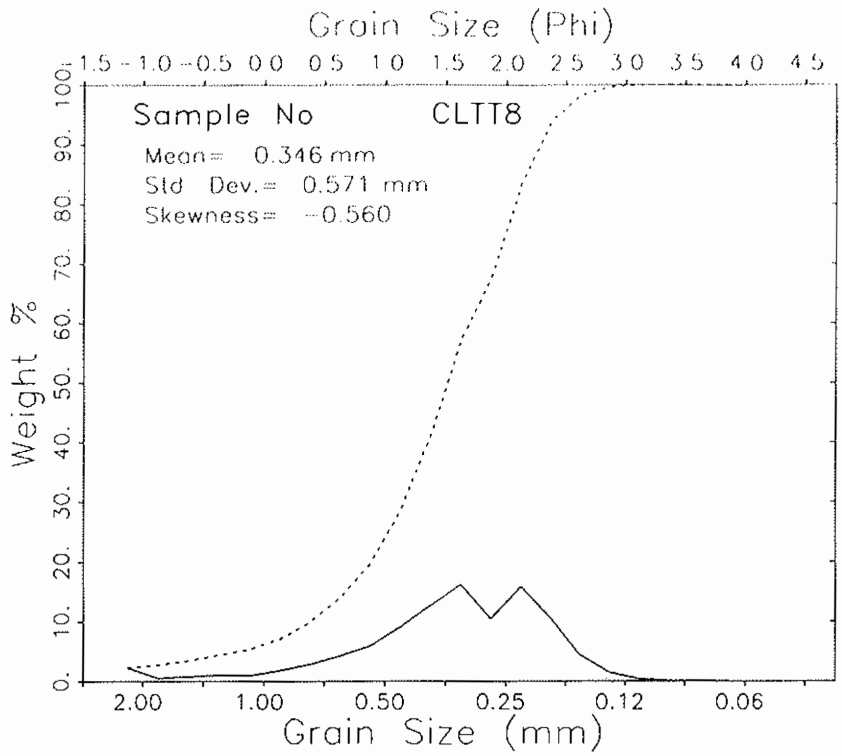
MEAN = 1.528 STANDARD DEVIATION = .729 SKEWNESS = -.734 KURTOSIS = 3.255

0 DISPERSION = .387 STANDARD DEVIATION = .590 DEVIATION FROM NORMAL DISTR. = -18.99%

0 PERCENTILES:

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.144	.109	1.037	1.280	1.613	2.015	2.168	2.451	2.741

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.603	1.606	MEDIUM SAND
STANDARD DEVIATION	.565	.638	MODERATELY WELL SORTED
SKEWNESS(1)	-.018	-.151	COARSE-SKEWED
SKEWNESS(2)	-.589		
KURTOSIS	1.072	1.306	LEPTOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
CLTT8	150501					
PKS-IB LowTide Terrace (8) Composite						
		-1.125	2.300	2.223	-1.000	2.223
		-.875	.450	.435	-.750	2.658
		-.625	.740	.715	-.500	3.373
		-.375	.990	.957	-.250	4.330
		-.125	.950	.918	.000	5.248
		.125	1.770	1.711	.250	6.959
		.375	2.840	2.745	.500	9.703
		.625	4.240	4.098	.750	13.801
		.875	5.980	5.779	1.000	19.581
		1.125	9.290	8.978	1.250	28.559
		1.375	12.950	12.516	1.500	41.075
		1.625	16.660	16.101	1.750	57.176
		1.875	10.780	10.418	2.000	67.594
		2.125	16.360	15.811	2.250	83.406
		2.375	10.830	10.467	2.500	93.873
		2.625	4.510	4.359	2.750	98.231
		2.875	1.440	1.392	3.000	99.623
		3.125	.300	.290	3.250	99.913
		3.375	.070	.068	3.500	99.981
		3.625	.020	.019	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.470

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

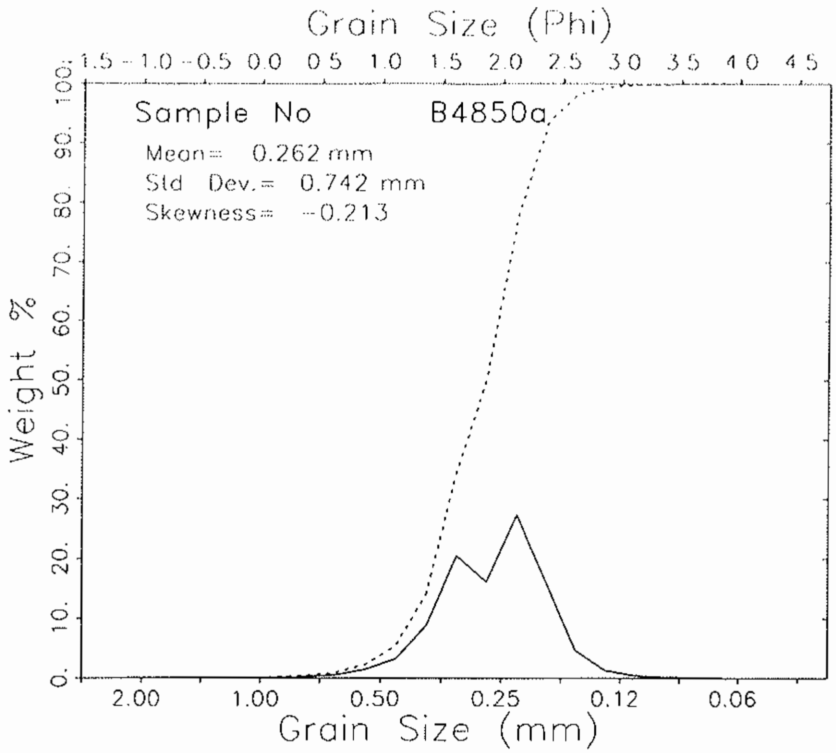
MEAN = 1.532 STANDARD DEVIATION = .809 SKEWNESS = -.560 KURTOSIS = 1.613

0 DISPERSION = .461 STANDARD DEVIATION = .700 DEVIATION FROM NORMAL DISTR. = -13.42%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.138	-.067	.845	1.151	1.639	2.117	2.264	2.565	2.888

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.555	1.503	
			MEDIUM SAND
STANDARD DEVIATION	.710	.754	
			MODERATELY SORTED
SKEWNESS(1)	-.118	-.207	
			COARSE-SKEWED
SKEWNESS(2)	-.550		
KURTOSIS	.855	1.117	
			LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
b4850a	140501					
Station 48-50 Dune						
		-1.125	.000	.000	-1.000	.000
		-.875	.010	.010	-.750	.010
		-.625	.020	.020	-.500	.029
		-.375	.040	.039	-.250	.068
		-.125	.030	.029	.000	.098
		.125	.060	.059	.250	.156
		.375	.210	.205	.500	.361
		.625	.470	.459	.750	.820
		.875	1.380	1.347	1.000	2.166
		1.125	3.210	3.132	1.250	5.299
		1.375	8.860	8.646	1.500	13.944
		1.625	20.980	20.472	1.750	34.416
		1.875	16.430	16.032	2.000	50.449
		2.125	27.960	27.283	2.250	77.732
		2.375	16.280	15.886	2.500	93.618
		2.625	4.680	4.567	2.750	98.185
		2.875	1.260	1.230	3.000	99.415
		3.125	.430	.420	3.250	99.834
		3.375	.130	.127	3.500	99.961
		3.625	.040	.039	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.480

PERCENT FINER THAN 4.00 PHI = .03 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

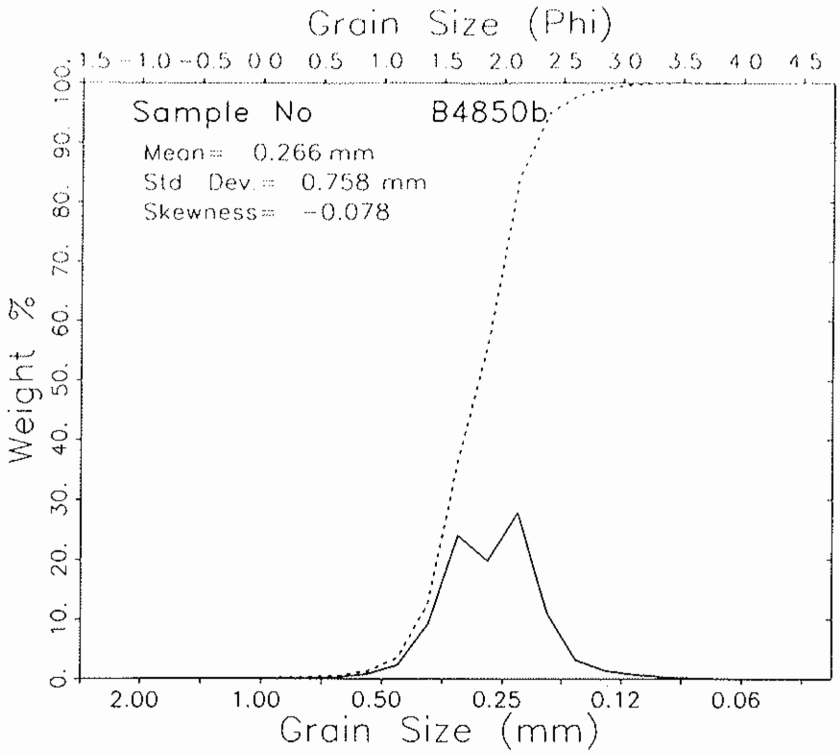
MEAN = 1.934 STANDARD DEVIATION = .431 SKEWNESS = -.213 KURTOSIS = 1.239

0 DISPERSION = .233 STANDARD DEVIATION = .414 DEVIATION FROM NORMAL DISTR. = -4.13%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	04.	95.	99.
.783	1.226	1.525	1.635	1.993	2.225	2.349	2.576	2.916

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.937	1.956	MEDIUM SAND
STANDARD DEVIATION	.412	.410	WELL SORTED
SKEWNESS(1)	-.136	-.136	COARSE-SKEWED
SKEWNESS(2)	-.224		
KURTOSIS	.639	.937	MESOKURTIC



1

SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B4850b 140501					
Station 48-50 Berm					
	-1.125	.000	.000	-1.000	.000
	-.875	.030	.030	-.750	.030
	-.625	.020	.020	-.500	.050
	-.375	.040	.040	-.250	.090
	-.125	.040	.040	.000	.129
	.125	.040	.040	.250	.169
	.375	.090	.090	.500	.259
	.625	.220	.219	.750	.478
	.875	.690	.687	1.000	1.165
	1.125	2.270	2.260	1.250	3.424
	1.375	9.030	8.989	1.500	12.413
	1.625	24.060	23.950	1.750	36.363
	1.875	19.780	19.689	2.000	56.052
	2.125	27.960	27.832	2.250	83.884
	2.375	10.970	10.920	2.500	94.804
	2.625	3.050	3.036	2.750	97.840
	2.875	1.290	1.284	3.000	99.124
	3.125	.660	.657	3.250	99.781
	3.375	.180	.179	3.500	99.960
	3.625	.040	.040	3.750	100.000
	3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.460

PERCENT FINER THAN 4.00 PHI = .01 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.910 STANDARD DEVIATION = .400 SKEWNESS = -.078 KURTOSIS = 2.296

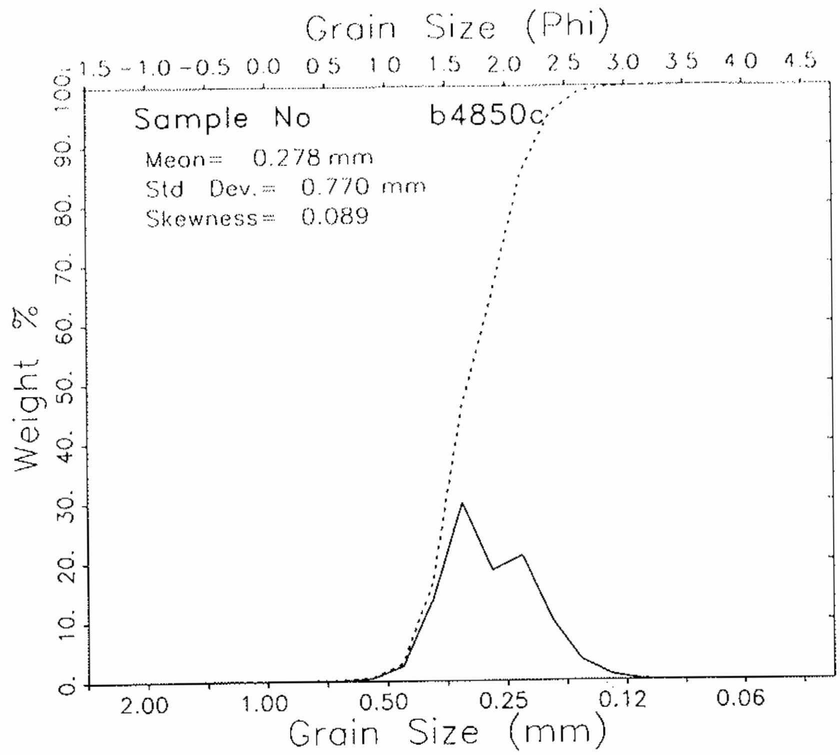
0 DISPERSION = .197 STANDARD DEVIATION = .381 DEVIATION FROM NORMAL DISTR. = -4.77%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
.940	1.294	1.537	1.631	1.923	2.170	2.253	2.516	2.976

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	1.895	1.904	
+				MEDIUM SAND
0	STANDARD DEVIATION	.358	.364	
+				WELL SORTED
0	SKEWNESS(1)	-.079	-.054	
+				NEAR SYMMETRICAL
0	SKEWNESS(2)	-.051		
0	KURTOSIS	.709	.930	
+				MESOKURTIC



1 SAMPLE NO. DATE

b4850c 140501
Station 48-50 Beach Face

MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.000		.000	-1.000	.000
-.875	.000		.000	-.750	.000
-.625	.020		.020	-.500	.020
-.375	.020		.020	-.250	.039
-.125	.000		.000	.000	.039
.125	.020		.020	.250	.059
.375	.040		.039	.500	.099
.625	.080		.079	.750	.178
.875	.370		.365	1.000	.543
1.125	2.390		2.358	1.250	2.901
1.375	13.590		13.408	1.500	16.308
1.625	30.210		29.805	1.750	46.113
1.875	18.750		18.498	2.000	64.611
2.125	21.150		20.866	2.250	85.478
2.375	10.170		10.034	2.500	95.511
2.625	3.470		3.423	2.750	98.934
2.875	.920		.908	3.000	99.842
3.125	.160		.158	3.250	100.000
3.375	.000		.000	3.500	100.000
3.625	.000		.000	3.750	100.000
3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.360

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

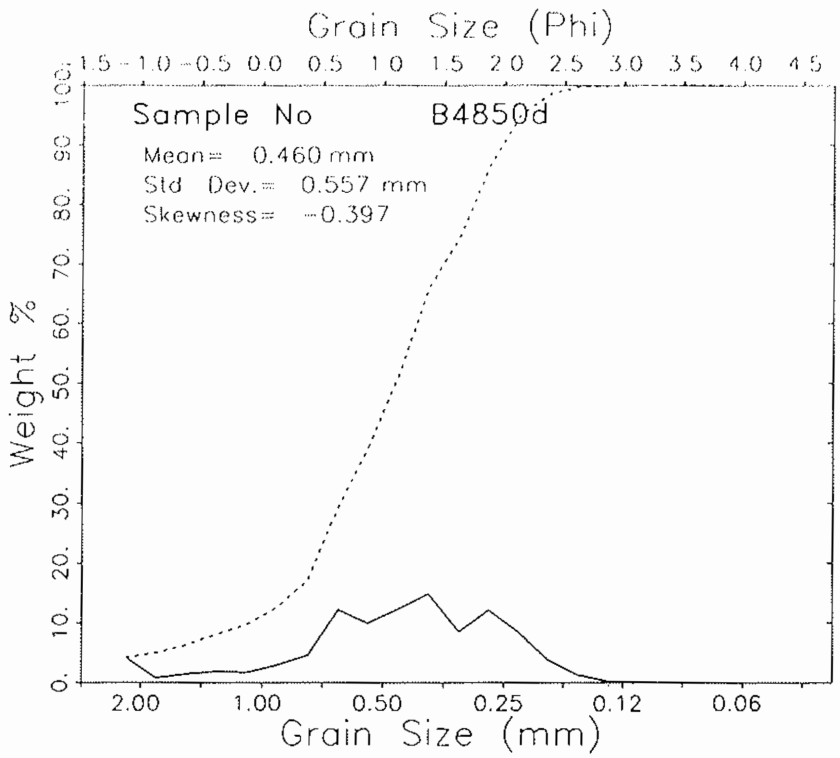
MEAN = 1.848 STANDARD DEVIATION = .377 SKEWNESS = .089 KURTOSIS = .483

0 DISPERSION = .176 STANDARD DEVIATION = .363 DEVIATION FROM NORMAL DISTR. = -3.83%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.048	1.289	1.494	1.573	1.003	2.124	2.232	2.487	2.768

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.863	1.843	MEDIUM SAND
STANDARD DEVIATION	.369	.366	WELL SORTED
SKEWNESS(1)	.165	.154	FINE-SKEWED
SKEWNESS(2)	.232		
KURTOSIS	.623	.890	PLATYKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B4850d	140501						
Station 48-50 LTT							
		-1.125	4.350		4.190	-1.000	4.190
		-.875	.740		.713	-.750	4.903
		-.625	1.400		1.349	-.500	6.252
		-.375	1.830		1.763	-.250	8.015
		-.125	1.740		1.676	.000	9.691
		.125	2.970		2.861	.250	12.552
		.375	4.640		4.470	.500	17.021
		.625	12.640		12.176	.750	29.198
		.875	10.290		9.912	1.000	39.110
		1.125	12.650		12.186	1.250	51.296
		1.375	15.290		14.729	1.500	66.024
		1.625	8.810		8.487	1.750	74.511
		1.875	12.490		12.032	2.000	86.543
		2.125	8.660		8.342	2.250	94.885
		2.375	3.780		3.641	2.500	98.526
		2.625	1.290		1.243	2.750	99.769
		2.875	.200		.193	3.000	99.961
		3.125	.040		.039	3.250	100.000
		3.375	.000		.000	3.500	100.000
		3.625	.000		.000	3.750	100.000
		3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.810

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

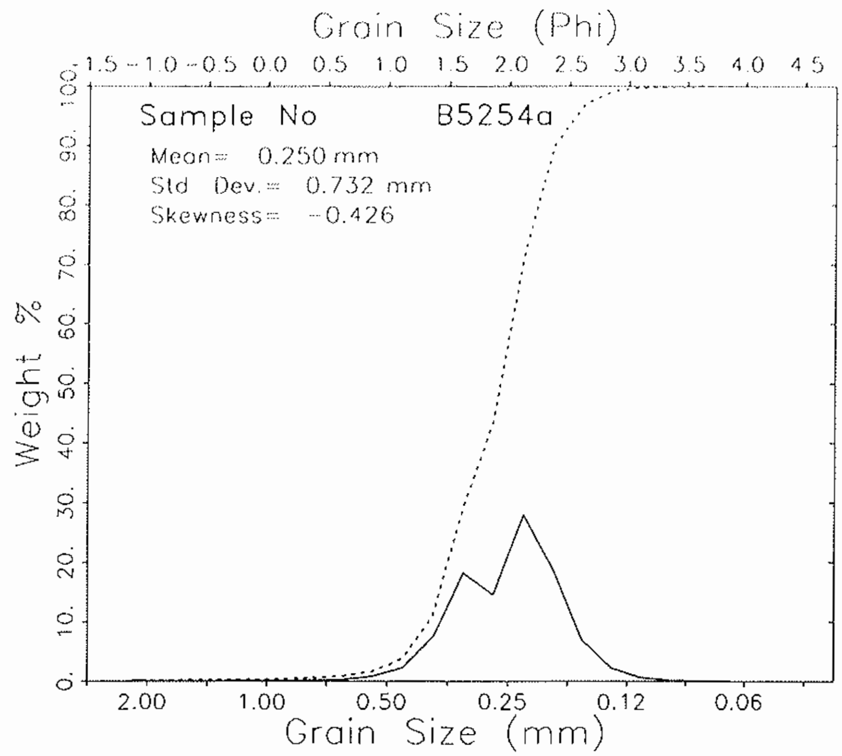
\+ MEAN = 1.119 STANDARD DEVIATION = .844 SKEWNESS = -.397 KURTOSIS = .525

0 DISPERSION = .480 STANDARD DEVIATION = .731 DEVIATION FROM NORMAL DISTR. = -13.34%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.190	-.732	.443	.664	1.223	1.760	1.947	2.258	2.595

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.195	1.204	MEDIUM SAND
STANDARD DEVIATION	.752	.829	MODERATELY SORTED
SKEWNESS(1)	-.038	-.173	COARSE-SKEWED
SKEWNESS(2)	-.612		
KURTOSIS	.988	1.118	LEPTOKURTIC



1 SAMPLE NO. DATE

B5254a 150501
Station 52-54 Dune

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.110	.109	-1.000	.109
-.875	.040	.040	-.750	.148
-.625	.050	.049	-.500	.198
-.375	.050	.049	-.250	.247
-.125	.050	.049	.000	.297
.125	.080	.079	.250	.376
.375	.170	.168	.500	.544
.625	.250	.247	.750	.792
.875	.730	.723	1.000	1.514
1.125	2.180	2.158	1.250	3.672
1.375	7.400	7.325	1.500	10.997
1.625	18.370	18.183	1.750	29.179
1.875	14.620	14.471	2.000	43.650
2.125	28.220	27.932	2.250	71.583
2.375	18.800	18.608	2.500	90.191
2.625	6.900	6.830	2.750	97.021
2.875	2.190	2.168	3.000	99.188
3.125	.590	.584	3.250	99.772
3.375	.140	.139	3.500	99.911
3.625	.080	.079	3.750	99.990
3.875	.010	.010	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.030

PERCENT FINER THAN 4.00 PHI = .03 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

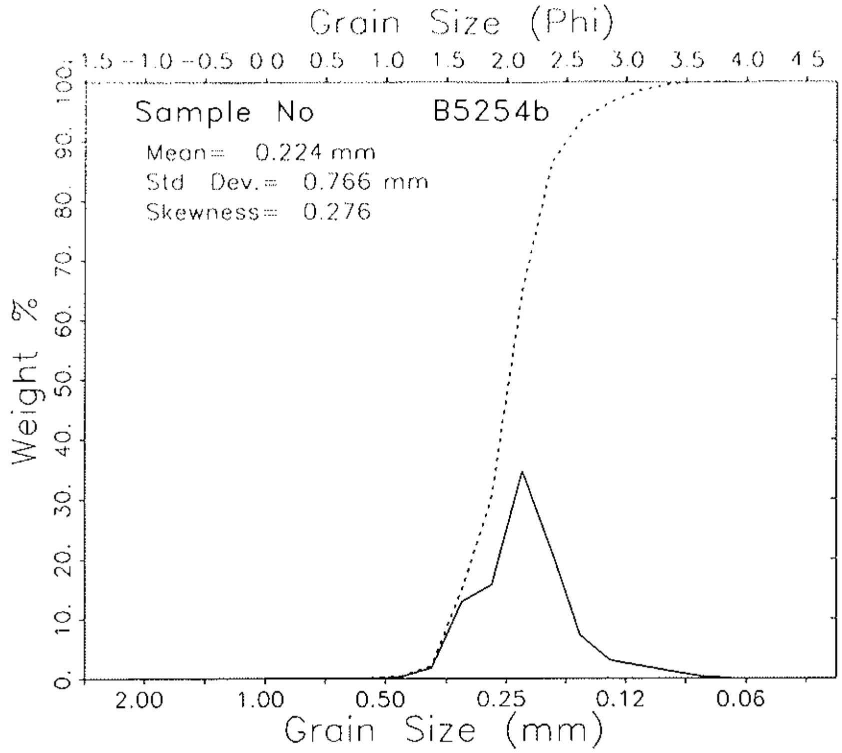
MEAN = 2.002 STANDARD DEVIATION = .450 SKEWNESS = -.426 KURTOSIS = 4.260

0 DISPERSION = .238 STANDARD DEVIATION = .418 DEVIATION FROM NORMAL DISTR. = -7.05%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.822	1.295	1.569	1.693	2.057	2.296	2.417	2.676	2.978

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.993	2.014	FINE SAND
STANDARD DEVIATION	.424	.421	WELL SORTED
SKEWNESS(1)	-.151	-.127	COARSE-SKEWED
SKEWNESS(2)	-.168		
KURTOSIS	.628	.930	MESOKURTIC



1 SAMPLE NO. DATE

B5254b 150501
Station 52-54 Berm

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.000	.000	-1.000	.000
-.875	.000	.000	-.750	.000
-.625	.000	.000	-.500	.000
-.375	.000	.000	-.250	.000
-.125	.000	.000	.000	.000
.125	.020	.019	.250	.019
.375	.020	.019	.500	.039
.625	.020	.019	.750	.058
.875	.050	.048	1.000	.106
1.125	.240	.232	1.250	.338
1.375	1.720	1.660	1.500	1.998
1.625	13.240	12.781	1.750	14.779
1.875	16.200	15.639	2.000	30.418
2.125	35.860	34.617	2.250	65.035
2.375	22.200	21.431	2.500	86.466
2.625	7.370	7.115	2.750	93.580
2.875	3.040	2.935	3.000	96.515
3.125	2.150	2.075	3.250	98.591
3.375	1.180	1.139	3.500	99.730
3.625	.280	.270	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.590

PERCENT FINER THAN 4.00 PHI = .02 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

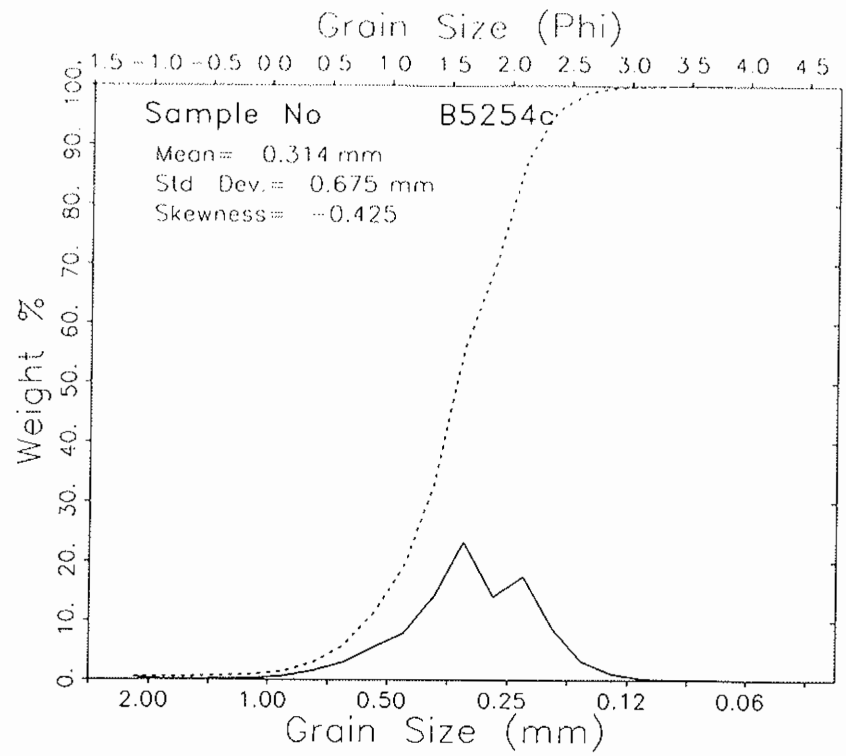
MEAN = 2.156 STANDARD DEVIATION = .384 SKEWNESS = .276 KURTOSIS = 1.394

0 DISPERSION = .171 STANDARD DEVIATION = .359 DEVIATION FROM NORMAL DISTR. = -6.53%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.350	1.559	1.770	1.913	2.141	2.366	2.471	2.871	3.340

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.120	2.127	FINE SAND
STANDARD DEVIATION	.351	.374	WELL SORTED
SKEWNESS(1)	-.060	.026	NEAR SYMMETRICAL
SKEWNESS(2)	.209		
KURTOSIS	.870	1.188	LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B5254c	150501					
Station 52-54 Beach Face						
		-1.125	.450	.426	-1.000	.426
		-.875	.020	.019	-.750	.445
		-.625	.070	.066	-.500	.512
		-.375	.140	.133	-.250	.644
		-.125	.220	.208	.000	.853
		.125	.560	.531	.250	1.384
		.375	1.530	1.450	.500	2.834
		.625	3.010	2.853	.750	5.686
		.875	5.660	5.364	1.000	11.050
		1.125	8.120	7.695	1.250	18.745
		1.375	14.610	13.846	1.500	32.591
		1.625	24.470	23.190	1.750	55.781
		1.875	14.730	13.959	2.000	69.740
		2.125	18.380	17.418	2.250	87.159
		2.375	9.040	8.567	2.500	95.726
		2.625	3.250	3.080	2.750	98.806
		2.875	1.000	.948	3.000	99.754
		3.125	.200	.190	3.250	99.943
		3.375	.040	.038	3.500	99.981
		3.625	.020	.019	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.520

PERCENT FINER THAN 4.00 PHI = .01 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.670 STANDARD DEVIATION = .566 SKEWNESS = -.425 KURTOSIS = 2.419

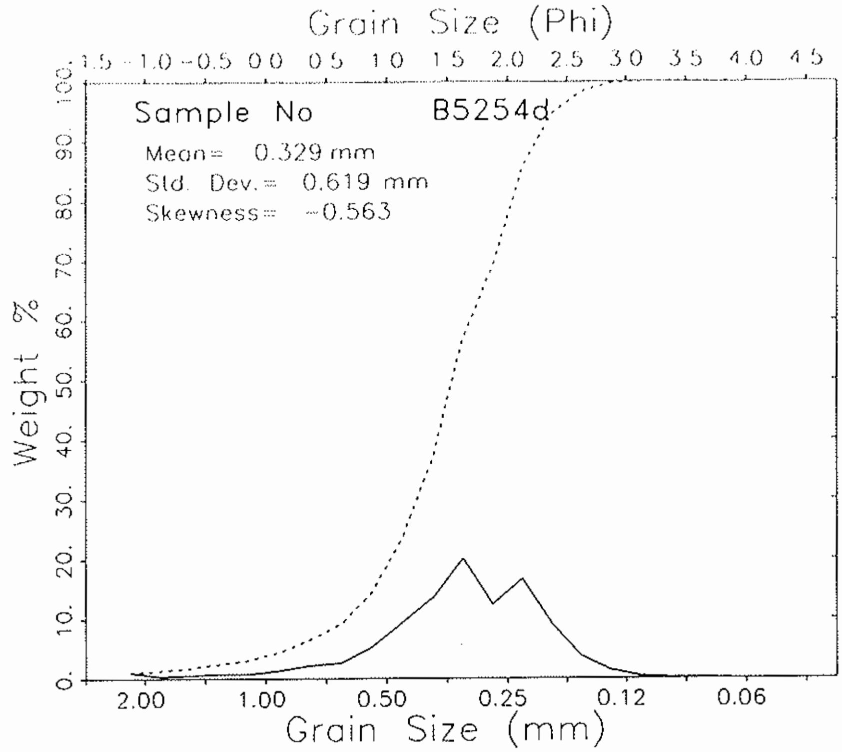
0 DISPERSION = .339 STANDARD DEVIATION = .528 DEVIATION FROM NORMAL DISTR. = -6.64%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
.069	.690	1.161	1.363	1.688	2.075	2.205	2.479	2.801

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.683	1.684	MEDIUM SAND
STANDARD DEVIATION	.522	.532	MODERATELY WELL SORTED
SKEWNESS(1)	-.009	-.062	NEAR SYMMETRICAL
SKEWNESS(2)	-.198		
KURTOSIS	.714	1.029	MESOKURTIC



1 SAMPLE NO. DATE

B5254d 150501
Station 52-54 LTT

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.970	.953	-1.000	.953
-.875	.290	.285	-.750	1.238
-.625	.490	.481	-.500	1.720
-.375	.700	.688	-.250	2.407
-.125	.710	.698	.000	3.105
.125	1.340	1.317	.250	4.422
.375	2.170	2.132	.500	6.554
.625	2.630	2.584	.750	9.138
.875	5.230	5.139	1.000	14.277
1.125	9.360	9.197	1.250	23.475
1.375	13.580	13.344	1.500	36.818
1.625	20.410	20.055	1.750	56.873
1.875	12.540	12.322	2.000	69.195
2.125	16.820	16.527	2.250	85.723
2.375	9.120	8.961	2.500	94.684
2.625	3.740	3.675	2.750	98.359
2.875	1.320	1.297	3.000	99.656
3.125	.270	.265	3.250	99.921
3.375	.050	.049	3.500	99.971
3.625	.030	.029	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.770

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

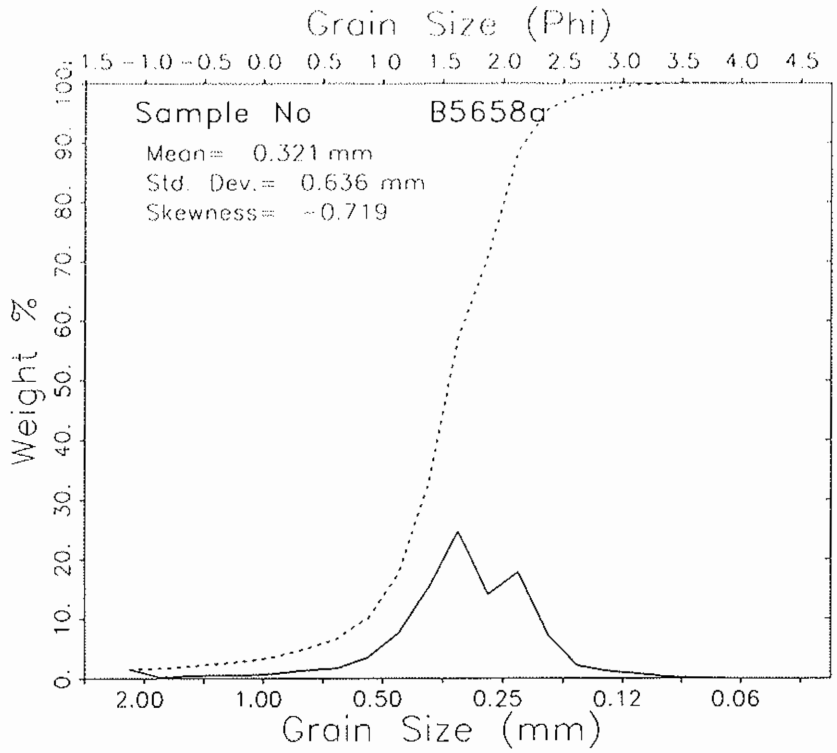
\+ MEAN = 1.604 STANDARD DEVIATION = .691 SKEWNESS = -.563 KURTOSIS = 2.366

0 DISPERSION = .407 STANDARD DEVIATION = .618 DEVIATION FROM NORMAL DISTR. = -10.54%

D PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.959	.318	1.047	1.279	1.664	2.088	2.224	2.521	2.874

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.635	1.645	MEDIUM SAND
STANDARD DEVIATION	.589	.628	MODERATELY WELL SORTED
SKEWNESS(1)	-.049	-.136	COARSE-SKEWED
SKEWNESS(2)	-.416		
KURTOSIS	.872	1.116	LEPTOKURTIC



SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B5658a 150501 Station 56-58 Dune						
	-1.125	1.460		1.444	-1.000	1.444
	-.875	.180		.178	-.750	1.622
	-.625	.350		.346	-.500	1.968
	-.375	.450		.445	-.250	2.412
	-.125	.440		.435	.000	2.848
	.125	.840		.831	.250	3.678
	.375	1.300		1.285	.500	4.963
	.625	1.670		1.651	.750	6.615
	.875	3.420		3.381	1.000	9.996
	1.125	7.450		7.366	1.250	17.362
	1.375	15.150		14.979	1.500	32.341
	1.625	24.950		24.669	1.750	57.010
	1.875	14.140		13.981	2.000	70.991
	2.125	17.940		17.738	2.250	88.728
	2.375	7.180		7.099	2.500	95.828
	2.625	2.080		2.057	2.750	97.884
	2.875	1.110		1.097	3.000	98.982
	3.125	.720		.712	3.250	99.693
	3.375	.260		.257	3.500	99.951
	3.625	.050		.049	3.750	100.000
	3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.140

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

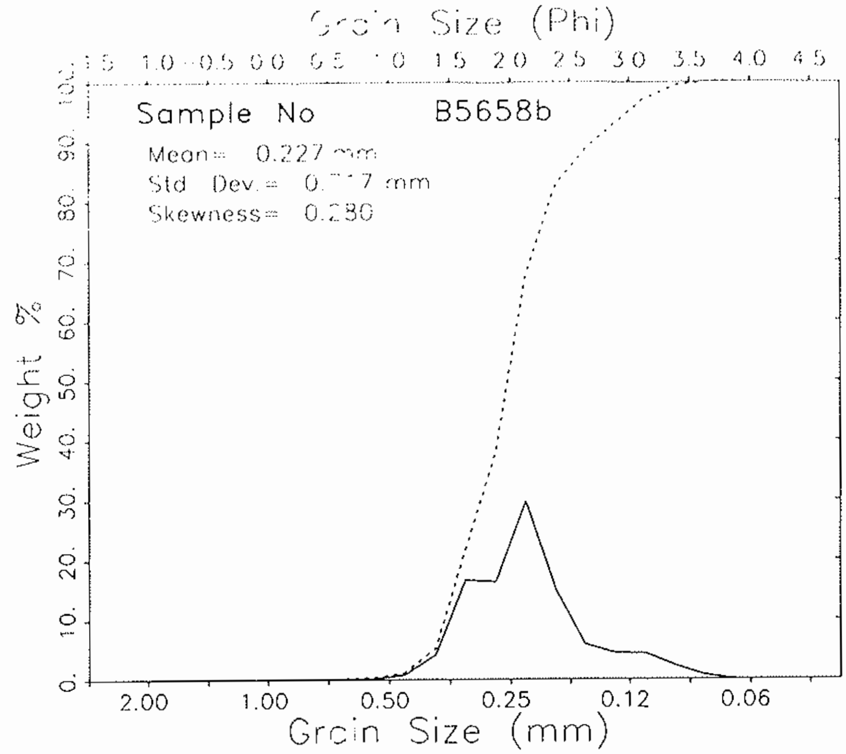
MEAN = 1.639 STANDARD DEVIATION = .654 SKEWNESS = -.719 KURTOSIS = 4.519

DISPERSION = .350 STANDARD DEVIATION = .542 DEVIATION FROM NORMAL DISTR. = -17.08%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.077	.506	1.204	1.377	1.679	2.057	2.183	2.471	3.006

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.694	1.689	MEDIUM SAND
STANDARD DEVIATION	.490	.543	MODERATELY WELL SORTED
SKEWNESS(1)	.030	-.082	NEAR SYMMETRICAL
SKEWNESS(2)	-.389		
KURTOSIS	1.006	1.186	LEPTOKURTIC



1 SAMPLE NO. DATE

B5658b 150501
Station 56-58 Berm

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.000	.000	-1.000	.000
-.875	.000	.000	-.750	.000
-.625	.020	.020	-.500	.020
-.375	.020	.020	-.250	.040
-.125	.010	.010	.000	.050
.125	.020	.020	.250	.070
.375	.040	.040	.500	.110
.625	.050	.050	.750	.160
.875	.160	.160	1.000	.320
1.125	.740	.740	1.250	1.059
1.375	3.990	3.988	1.500	5.047
1.625	16.630	16.622	1.750	21.669
1.875	16.320	16.312	2.000	37.981
2.125	29.820	29.805	2.250	67.786
2.375	14.940	14.933	2.500	82.719
2.625	5.820	5.817	2.750	88.536
2.875	4.350	4.348	3.000	92.884
3.125	4.290	4.288	3.250	97.171
3.375	2.200	2.199	3.500	99.370
3.625	.630	.630	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.050

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

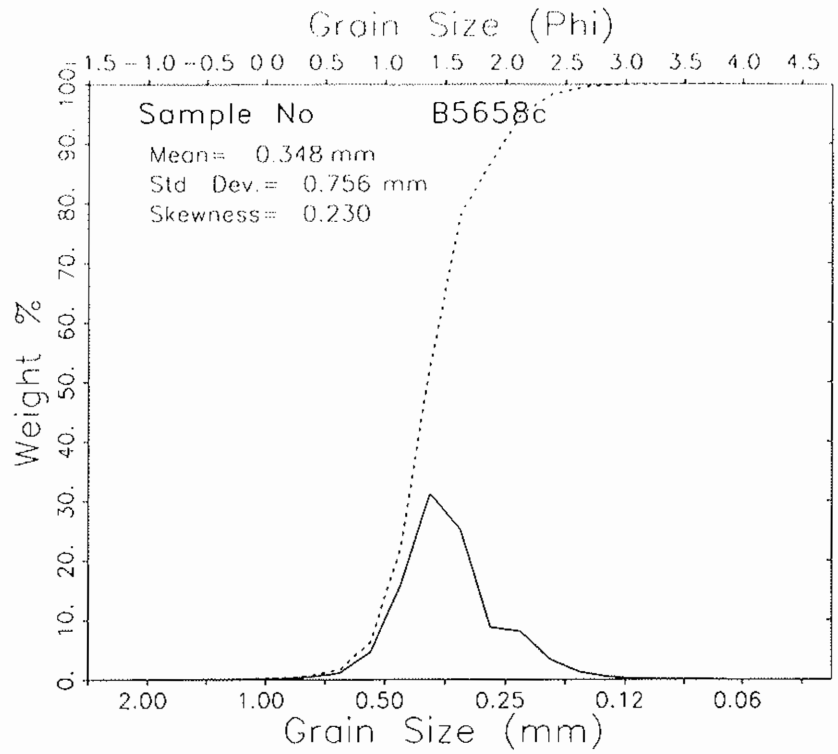
MEAN = 2.138 STANDARD DEVIATION = .480 SKEWNESS = .280 KURTOSIS = .955

0 DISPERSION = .258 STANDARD DEVIATION = .438 DEVIATION FROM NORMAL DISTR. = -8.70%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.230	1.497	1.665	1.801	2.101	2.371	2.555	3.123	3.458

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.110	2.107	FINE SAND
STANDARD DEVIATION	.445	.469	WELL SORTED
SKEWNESS(1)	.020	.139	FINE-SKEWED
SKEWNESS(2)	.470		
KURTOSIS	.827	1.170	LEPTOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B5658c	150501					
Station 56-58 Beach Face						
		-1.125	.000	.000	-1.000	.000
		-.875	.010	.010	-.750	.010
		-.625	.020	.020	-.500	.030
		-.375	.030	.030	-.250	.060
		-.125	.050	.050	.000	.110
		.125	.120	.120	.250	.230
		.375	.350	.350	.500	.579
		.625	1.040	1.039	.750	1.618
		.875	4.450	4.444	1.000	6.062
		1.125	15.760	15.738	1.250	21.799
		1.375	31.190	31.146	1.500	52.946
		1.625	25.260	25.225	1.750	78.171
		1.875	8.740	8.728	2.000	86.898
		2.125	8.070	8.059	2.250	94.957
		2.375	3.290	3.285	2.500	98.242
		2.625	1.200	1.198	2.750	99.441
		2.875	.370	.369	3.000	99.810
		3.125	.130	.130	3.250	99.940
		3.375	.040	.040	3.500	99.980
		3.625	.020	.020	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.140

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

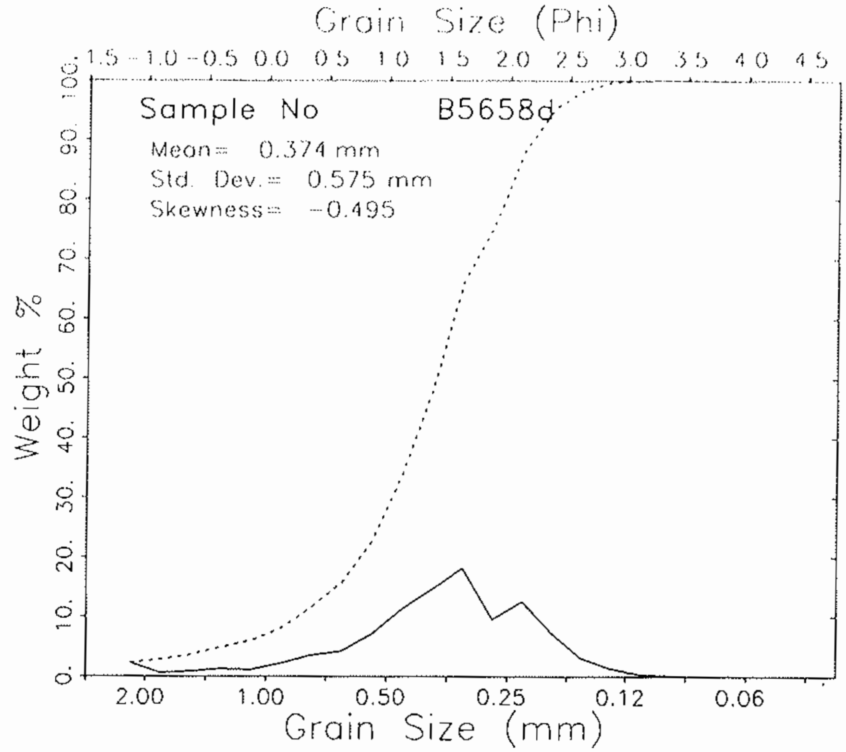
MEAN = 1.523 STANDARD DEVIATION = .404 SKEWNESS = .230 KURTOSIS = 1.548

0 DISPERSION = .197 STANDARD DEVIATION = .381 DEVIATION FROM NORMAL DISTR. = -5.73%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.601	.940	1.158	1.276	1.476	1.719	1.917	2.253	2.658

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.537	1.517	MEDIUM SAND
STANDARD DEVIATION	.380	.389	WELL SORTED
SKEWNESS(1)	.161	.172	FINE-SKEWED
SKEWNESS(2)	.317		
KURTOSIS	.730	1.215	LEPTOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B5658d 150501					
Station 56-58 LTT					
	-1.125	2.320	2.206	-1.000	2.206
	-.875	.560	.533	-.750	2.739
	-.625	.880	.837	-.500	3.576
	-.375	1.290	1.227	-.250	4.802
	-.125	1.150	1.094	.000	5.896
	.125	2.230	2.121	.250	8.016
	.375	3.690	3.509	.500	11.525
	.625	4.310	4.099	.750	15.624
	.875	7.290	6.932	1.000	22.556
	1.125	11.740	11.164	1.250	33.720
	1.375	15.180	14.435	1.500	48.155
	1.625	19.000	18.068	1.750	66.223
	1.875	10.000	9.509	2.000	75.732
	2.125	13.150	12.505	2.250	88.237
	2.375	7.510	7.141	2.500	95.378
	2.625	3.170	3.014	2.750	98.393
	2.875	1.360	1.293	3.000	99.686
	3.125	.280	.266	3.250	99.952
	3.375	.050	.048	3.500	100.000
	3.625	.000	.000	3.750	100.000
	3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.160

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

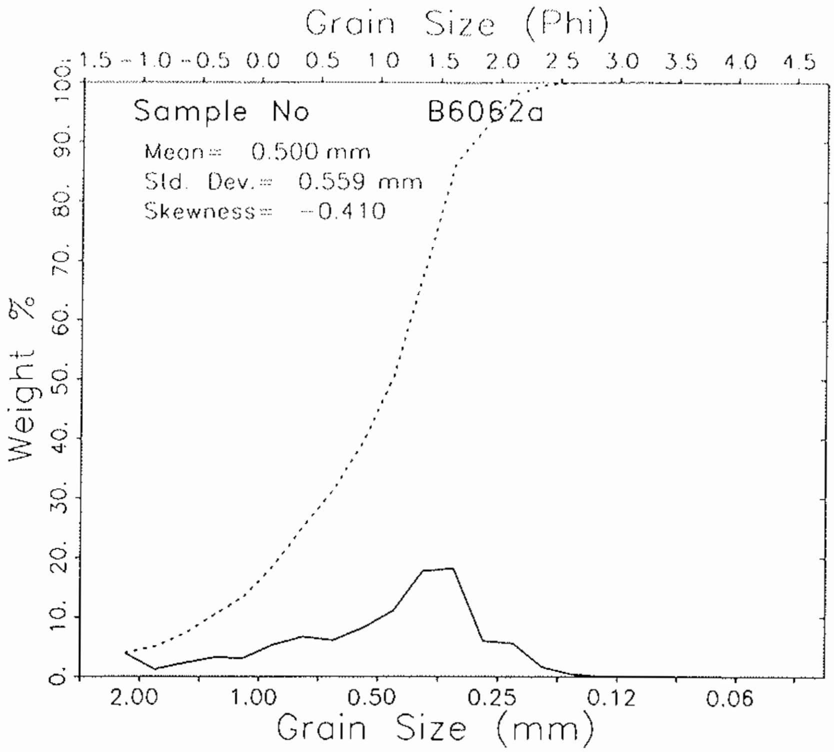
MEAN = 1.419 STANDARD DEVIATION = .798 SKEWNESS = -.495 KURTOSIS = 1.378

D DISPERSION = .465 STANDARD DEVIATION = .706 DEVIATION FROM NORMAL DISTR. = -11.53%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.137	-.205	.764	1.055	1.526	1.981	2.165	2.487	2.867

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.464	1.485	MEDIUM SAND
STANDARD DEVIATION	.701	.758	MODERATELY SORTED
SKEWNESS(1)	-.087	-.186	COARSE-SKEWED
SKEWNESS(2)	-.549		
KURTOSIS	.920	1.191	LEPTOKURTIC



1 SAMPLE NO. DATE

B6062a 150501
Station 60-62 Dune

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	3.860	3.851	-1.000	3.851
-.875	1.110	1.107	-.750	4.958
-.625	2.240	2.235	-.500	7.193
-.375	3.140	3.132	-.250	10.325
-.125	3.080	3.073	.000	13.398
.125	5.300	5.287	.250	18.685
.375	6.630	6.614	.500	25.299
.625	6.110	6.095	.750	31.395
.875	8.180	8.160	1.000	39.555
1.125	11.020	10.994	1.250	50.549
1.375	17.760	17.717	1.500	68.266
1.625	18.210	18.166	1.750	86.433
1.875	6.020	6.006	2.000	92.438
2.125	5.540	5.527	2.250	97.965
2.375	1.560	1.556	2.500	99.521
2.625	.380	.379	2.750	99.900
2.875	.080	.080	3.000	99.980
3.125	.020	.020	3.250	100.000
3.375	.000	.000	3.500	100.000
3.625	.000	.000	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.240

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

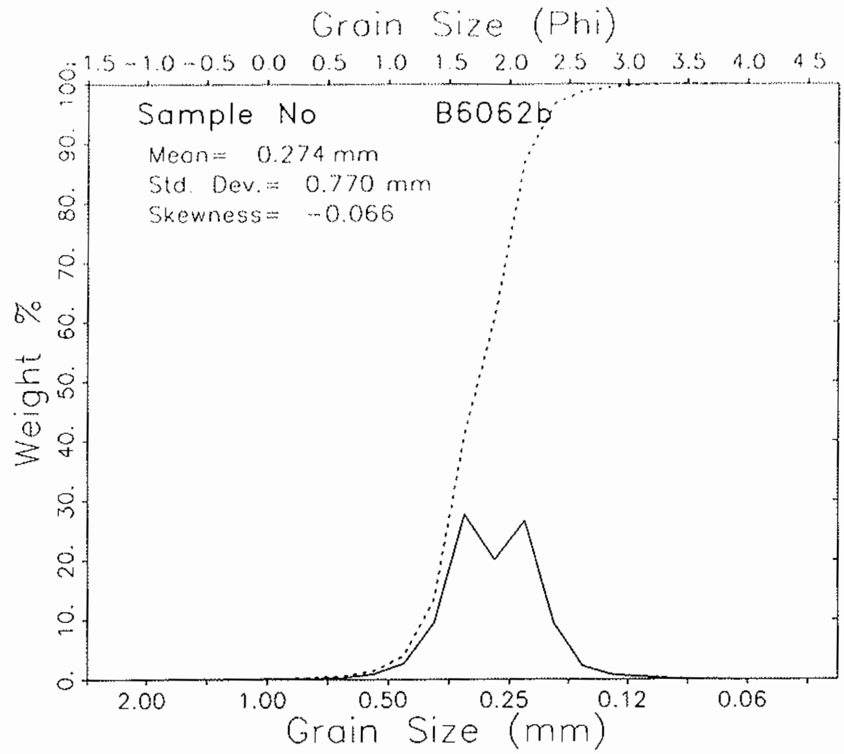
+ MEAN = 1.001 STANDARD DEVIATION = .838 SKEWNESS = -.410 KURTOSIS = .106

0 DISPERSION = .469 STANDARD DEVIATION = .713 DEVIATION FROM NORMAL DISTR. = -14.92%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.185	-.745	.123	.489	1.238	1.593	1.717	2.116	2.416

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	.920	1.026	MEDIUM SAND
STANDARD DEVIATION	.797	.832	MODERATELY SORTED
SKEWNESS(1)	-.399	-.392	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.693		
KURTOSIS	.796	1.062	MESOKURTIC



1 SAMPLE NO. DATE

B6062b 150501
Station 60-62 Berm

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.000	.000	-1.000	.000
-.875	.000	.000	-.750	.000
-.625	.030	.029	-.500	.029
-.375	.020	.019	-.250	.048
-.125	.030	.029	.000	.077
.125	.050	.048	.250	.125
.375	.130	.125	.500	.250
.625	.260	.250	.750	.500
.875	.810	.780	1.000	1.280
1.125	2.660	2.560	1.250	3.840
1.375	9.710	9.346	1.500	13.186
1.625	28.750	27.671	1.750	40.857
1.875	20.730	19.952	2.000	60.808
2.125	27.590	26.554	2.250	87.363
2.375	9.640	9.278	2.500	96.641
2.625	2.230	2.146	2.750	98.787
2.875	.730	.703	3.000	99.490
3.125	.360	.346	3.250	99.836
3.375	.130	.125	3.500	99.961
3.625	.040	.038	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.900

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

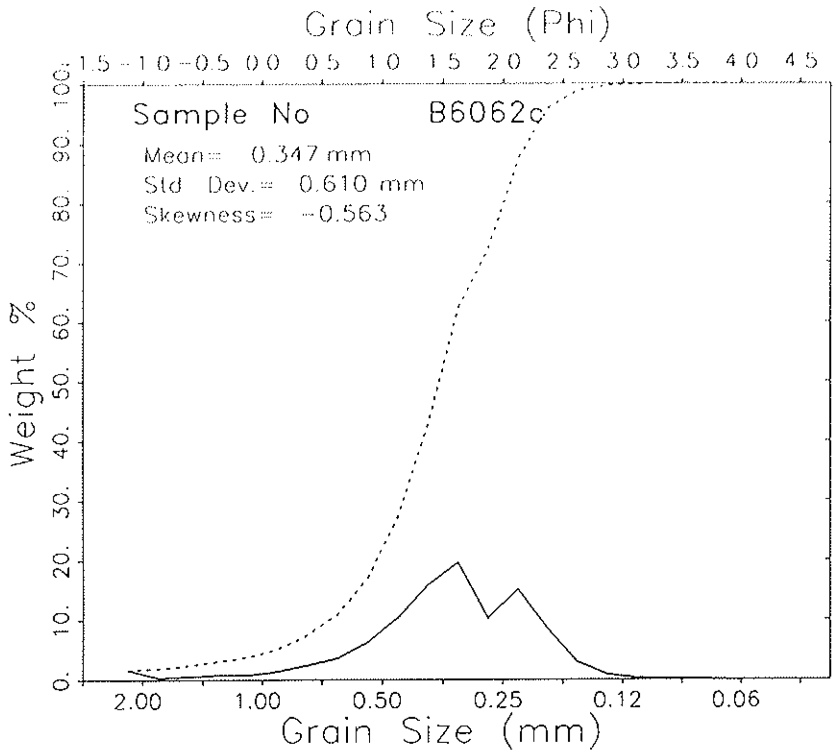
\+ MEAN = 1.867 STANDARD DEVIATION = .378 SKEWNESS = -.066 KURTOSIS = 1.845

0 DISPERSION = .173 STANDARD DEVIATION = .360 DEVIATION FROM NORMAL DISTR. = -4.77%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.910	1.281	1.525	1.607	1.865	2.134	2.218	2.456	2.826

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.872	1.869	MEDIUM SAND
STANDARD DEVIATION	.346	.351	WELL SORTED
SKEWNESS(1)	.021	.014	NEAR SYMMETRICAL
SKEWNESS(2)	.011		
KURTOSIS	.695	.914	MESOKURTIC



1 SAMPLE NO. DATE

B6062c 150501
Station 60-62 Beach Face

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	1.700	1.543	-1.000	1.543
-.875	.290	.263	-.750	1.807
-.625	.550	.499	-.500	2.306
-.375	.760	.690	-.250	2.996
-.125	.750	.681	.000	3.677
.125	1.440	1.307	.250	4.984
.375	2.570	2.333	.500	7.317
.625	3.800	3.450	.750	10.767
.875	6.740	6.119	1.000	16.886
1.125	11.220	10.186	1.250	27.072
1.375	17.340	15.742	1.500	42.814
1.625	21.550	19.564	1.750	62.379
1.875	11.170	10.141	2.000	72.519
2.125	16.570	15.043	2.250	87.562
2.375	9.240	8.389	2.500	95.951
2.625	3.180	2.887	2.750	98.838
2.875	.890	.808	3.000	99.646
3.125	.240	.218	3.250	99.864
3.375	.100	.091	3.500	99.955
3.625	.050	.045	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 110.150

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

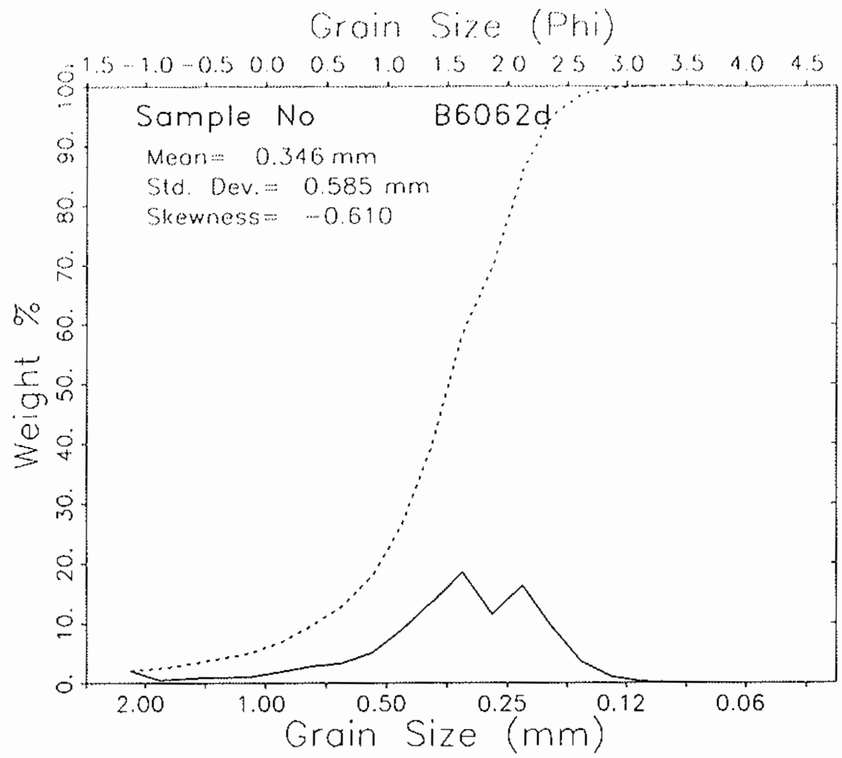
MEAN = 1.528 STANDARD DEVIATION = .714 SKEWNESS = -.563 KURTOSIS = 2.370

0 DISPERSION = .414 STANDARD DEVIATION = .627 DEVIATION FROM NORMAL DISTR. = -12.16%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.008	.252	.964	1.199	1.592	2.041	2.191	2.472	2.800

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.577	1.582	MEDIUM SAND
STANDARD DEVIATION	.613	.643	MODERATELY WELL SORTED
SKEWNESS(1)	-.024	-.116	COARSE-SKEWED
SKEWNESS(2)	-.375		
KURTOSIS	.809	1.080	MESOKURTIC



1 SAMPLE NO. DATE

B6062d 150501
Station 60-62 LTT

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	1.990	1.975	-1.000	1.975
-.875	.400	.397	-.750	2.372
-.625	.750	.744	-.500	3.117
-.375	.900	.893	-.250	4.010
-.125	.950	.943	.000	4.953
.125	1.810	1.797	.250	6.749
.375	2.780	2.759	.500	9.509
.625	3.270	3.246	.750	12.754
.875	4.970	4.933	1.000	17.687
1.125	8.880	8.814	1.250	26.501
1.375	13.550	13.449	1.500	39.950
1.625	18.610	18.471	1.750	58.422
1.875	11.460	11.375	2.000	69.797
2.125	16.350	16.228	2.250	86.025
2.375	9.260	9.191	2.500	95.216
2.625	3.530	3.504	2.750	98.720
2.875	.990	.983	3.000	99.702
3.125	.240	.238	3.250	99.940
3.375	.060	.060	3.500	100.000
3.625	.000	.000	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.750

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

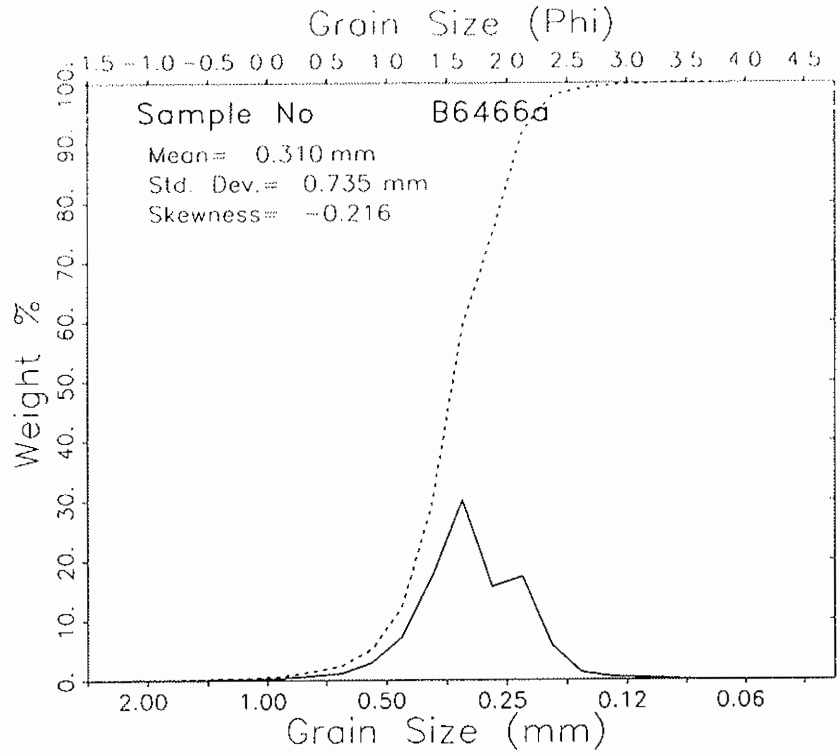
MEAN = 1.532 STANDARD DEVIATION = .774 SKEWNESS = -.610 KURTOSIS = 1.998

0 DISPERSION = .437 STANDARD DEVIATION = .662 DEVIATION FROM NORMAL DISTR. = -14.49%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.123	.007	.914	1.207	1.636	2.080	2.219	2.494	2.821

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.567	1.590	MEDIUM SAND
STANDARD DEVIATION	.652	.703	MODERATELY WELL SORTED
SKEWNESS(1)	-.106	-.200	COARSE-SKEWED
SKEWNESS(2)	-.591		
KURTOSIS	.907	1.168	LEPTOKURTIC



1

SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B6466a 150501					
Station 64-66 Dune					
	-1.125	.040	.039	-1.000	.039
	-.875	.030	.029	-.750	.068
	-.625	.040	.039	-.500	.107
	-.375	.110	.107	-.250	.215
	-.125	.130	.127	.000	.342
	.125	.270	.264	.250	.605
	.375	.690	.673	.500	1.279
	.625	1.060	1.035	.750	2.313
	.875	2.840	2.772	1.000	5.085
	1.125	7.190	7.018	1.250	12.103
	1.375	17.520	17.101	1.500	29.204
	1.625	30.770	30.034	1.750	59.239
	1.875	15.960	15.578	2.000	74.817
	2.125	17.680	17.257	2.250	92.074
	2.375	5.890	5.749	2.500	97.823
	2.625	1.230	1.201	2.750	99.024
	2.875	.500	.488	3.000	99.512
	3.125	.340	.332	3.250	99.844
	3.375	.160	.156	3.500	100.000
	3.625	.000	.000	3.750	100.000
	3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.450

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.691 STANDARD DEVIATION = .445 SKEWNESS = -.216 KURTOSIS = 2.507

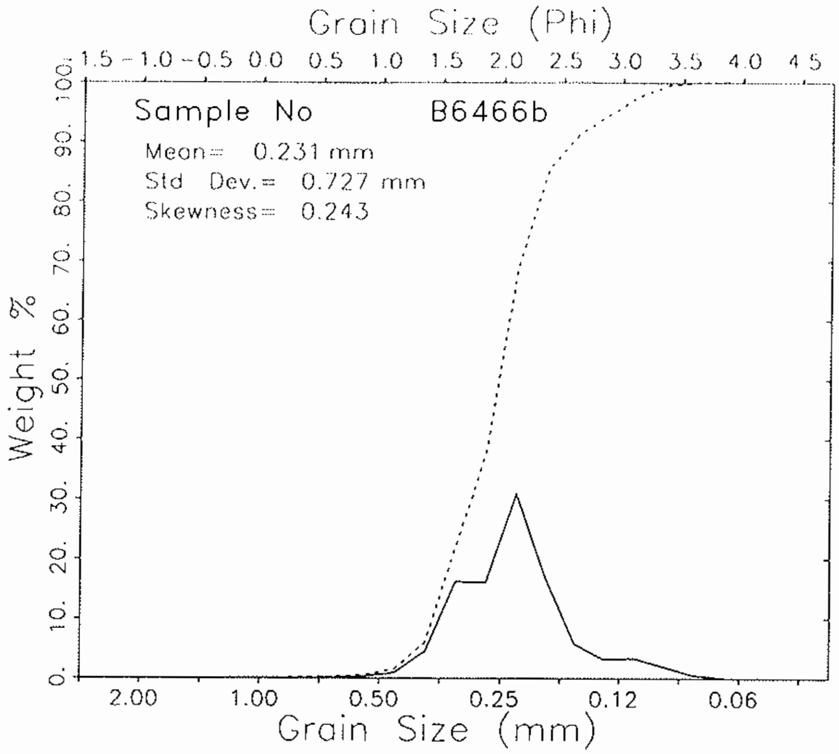
0 DISPERSION = .230 STANDARD DEVIATION = .419 DEVIATION FROM NORMAL DISTR. = -5.93%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
.397	.992	1.307	1.439	1.673	2.003	2.133	2.377	2.745

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.720	1.704	
			MEDIUM SAND
STANDARD DEVIATION	.413	.416	
			WELL SORTED
SKEWNESS(1)	.114	.065	
			NEAR SYMMETRICAL
SKEWNESS(2)	.028		
KURTOSIS	.677	1.006	
			MESOKURTIC



SAMPLE NO.	DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B6466b	150501					
Station 64-66 Berm						
		-1.125	.000	.000	-1.000	.000
		-.875	.000	.000	-.750	.000
		-.625	.000	.000	-.500	.000
		-.375	.000	.000	-.250	.000
		-.125	.030	.028	.000	.028
		.125	.030	.028	.250	.057
		.375	.090	.085	.500	.142
		.625	.130	.123	.750	.265
		.875	.300	.284	1.000	.549
		1.125	.970	.919	1.250	1.468
		1.375	4.580	4.339	1.500	5.807
		1.625	17.000	16.105	1.750	21.912
		1.875	16.900	16.010	2.000	37.922
		2.125	32.610	30.892	2.250	68.814
		2.375	17.610	16.682	2.500	85.496
		2.625	6.020	5.703	2.750	91.199
		2.875	3.340	3.164	3.000	94.363
		3.125	3.470	3.287	3.250	97.651
		3.375	1.990	1.885	3.500	99.536
		3.625	.460	.436	3.750	99.972
		3.875	.030	.028	4.000	100.000

TOTAL WEIGHT (GRAMS) = 105.560

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

MOMENT MEASURES:

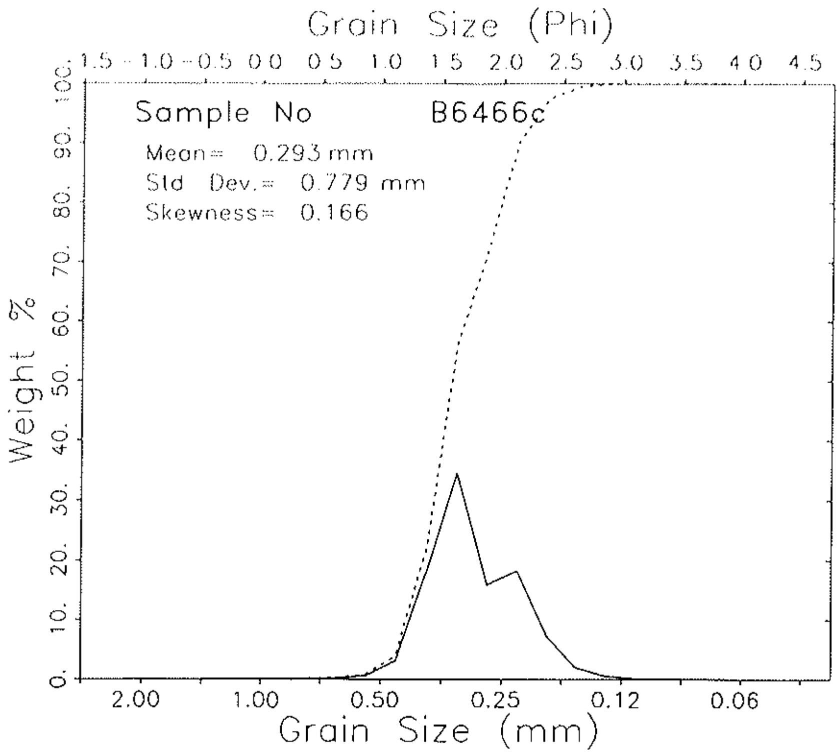
MEAN = 2.112 STANDARD DEVIATION = .460 SKEWNESS = .243 KURTOSIS = 1.171

DISPERSION = .245 STANDARD DEVIATION = .425 DEVIATION FROM NORMAL DISTR. = -7.60%

PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.123	1.453	1.658	1.798	2.098	2.343	2.478	3.048	3.429

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.068	2.078	FINE SAND
STANDARD DEVIATION	.410	.446	WELL SORTED
SKEWNESS(1)	-.073	.060	NEAR SYMMETRICAL
SKEWNESS(2)	.374		
KURTOSIS	.947	1.201	LEPTOKURTIC



1 SAMPLE NO. DATE

B6466c 150501

Station 64-66 Beach Face

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.000	.000	-1.000	.000
-.875	.000	.000	-.750	.000
-.625	.000	.000	-.500	.000
-.375	.020	.019	-.250	.019
-.125	.020	.019	.000	.039
.125	.020	.019	.250	.058
.375	.040	.039	.500	.097
.625	.100	.097	.750	.194
.875	.580	.561	1.000	.755
1.125	3.180	3.078	1.250	3.833
1.375	18.370	17.780	1.500	21.612
1.625	35.750	34.601	1.750	56.214
1.875	16.370	15.844	2.000	72.058
2.125	18.760	18.157	2.250	90.215
2.375	7.460	7.220	2.500	97.435
2.625	1.990	1.926	2.750	99.361
2.875	.520	.503	3.000	99.864
3.125	.120	.116	3.250	99.981
3.375	.020	.019	3.500	100.000
3.625	.000	.000	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.320

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

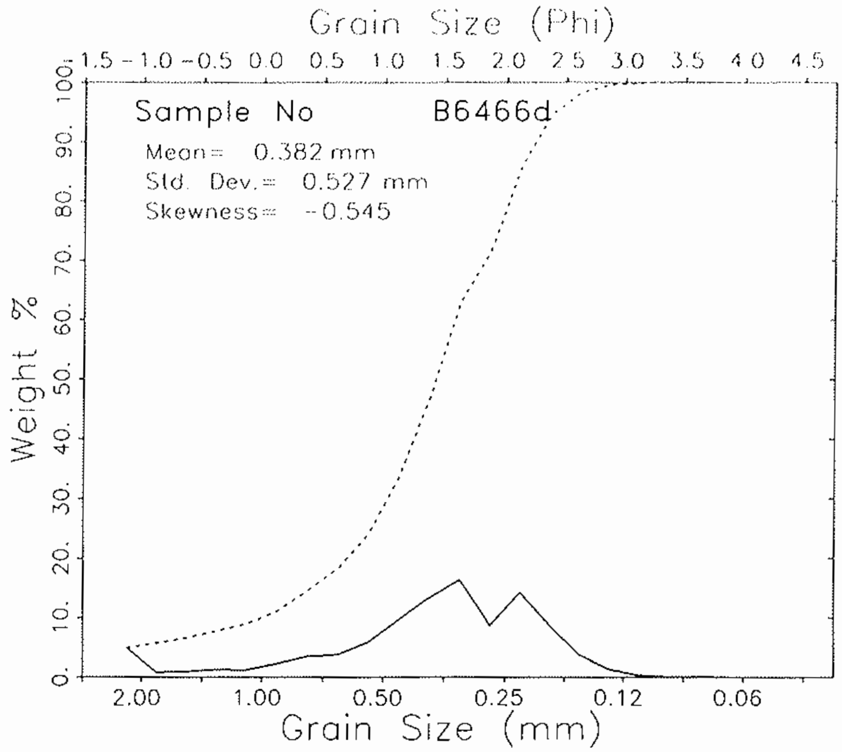
MEAN = 1.771 STANDARD DEVIATION = .361 SKEWNESS = .166 KURTOSIS = .536

0 DISPERSION = .149 STANDARD DEVIATION = .341 DEVIATION FROM NORMAL DISTR. = -5.60%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.020	1.266	1.421	1.524	1.705	2.041	2.164	2.416	2.703

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.793	1.764	MEDIUM SAND
STANDARD DEVIATION	.372	.360	WELL SORTED
SKEWNESS(1)	.236	.236	FINE-SKEWED
SKEWNESS(2)	.366		
KURTOSIS	.546	.913	MESOKURTIC



1 SAMPLE NO. DATE

B6466d 150501
Station 64-66 LTT

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	4.930	4.908	-1.000	4.908
-.875	.730	.727	-.750	5.635
-.625	.910	.906	-.500	6.541
-.375	1.190	1.185	-.250	7.725
-.125	1.150	1.145	.000	8.870
.125	2.190	2.180	.250	11.050
.375	3.450	3.435	.500	14.485
.625	3.750	3.733	.750	18.218
.875	5.810	5.784	1.000	24.002
1.125	9.570	9.527	1.250	33.529
1.375	13.260	13.201	1.500	46.730
1.625	16.390	16.317	1.750	63.046
1.875	8.660	8.621	2.000	71.667
2.125	14.300	14.236	2.250	85.903
2.375	8.650	8.611	2.500	94.515
2.625	3.790	3.773	2.750	98.288
2.875	1.310	1.304	3.000	99.592
3.125	.290	.289	3.250	99.881
3.375	.080	.080	3.500	99.960
3.625	.040	.040	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.450

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.389 STANDARD DEVIATION = .923 SKEWNESS = -.545 KURTOSIS = 1.014

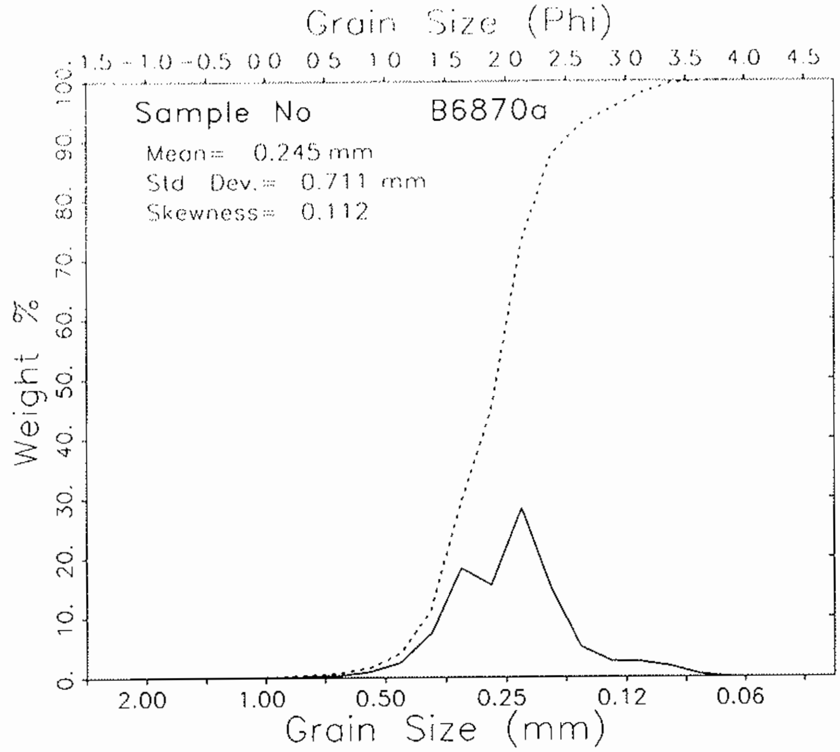
0 DISPERSION = .488 STANDARD DEVIATION = .744 DEVIATION FROM NORMAL DISTR. = -19.36%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.199	-.968	.601	1.026	1.550	2.059	2.217	2.532	2.887

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
MEAN	1.409	1.456	MEDIUM SAND
STANDARD DEVIATION	.808	.934	MODERATELY SORTED
SKEWNESS(1)	-.175	-.307	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.951		
KURTOSIS	1.167	1.390	LEPTOKURTIC



1

SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B6870a 150501						
Station 68-70 Dune						
	-1.125	.000		.000	-1.000	.000
	-.875	.000		.000	-.750	.000
	-.625	.010		.009	-.500	.009
	-.375	.030		.028	-.250	.037
	-.125	.040		.037	.000	.074
	.125	.090		.083	.250	.157
	.375	.230		.213	.500	.371
	.625	.360		.333	.750	.704
	.875	.920		.852	1.000	1.556
	1.125	2.590		2.399	1.250	3.956
	1.375	7.720		7.151	1.500	11.107
	1.625	19.720		18.268	1.750	29.375
	1.875	16.640		15.415	2.000	44.789
	2.125	30.530		28.282	2.250	73.071
	2.375	15.780		14.618	2.500	87.689
	2.625	5.410		5.012	2.750	92.700
	2.875	2.870		2.659	3.000	95.359
	3.125	2.710		2.510	3.250	97.869
	3.375	1.890		1.751	3.500	99.620
	3.625	.410		.380	3.750	100.000
	3.875	.000		.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.950

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.029 STANDARD DEVIATION = .493 SKEWNESS = .112 KURTOSIS = 1.259

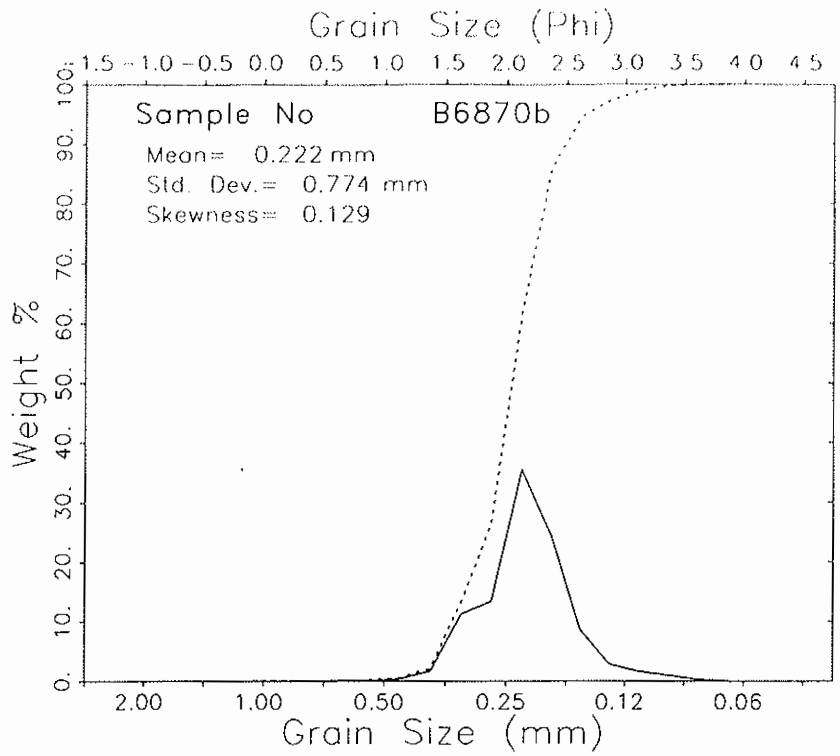
0 DISPERSION = .280 STANDARD DEVIATION = .461 DEVIATION FROM NORMAL DISTR. = -6.46%

0 PERCENTILES:

+

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	.837	1.287	1.567	1.690	2.046	2.283	2.437	2.966	3.411

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	2.002	2.017	FINE SAND
0	STANDARD DEVIATION	.435	.472	WELL SORTED
0	SKEWNESS(1)	-.101	-.003	NEAR SYMMETRICAL
0	SKEWNESS(2)	.185		
0	KURTOSIS	.931	1.161	LEPTOKURTIC



1 SAMPLE NO. DATE

B6870b 150501
Station 68-70 Berm

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.000	.000	-1.000	.000
-.875	.000	.000	-.750	.000
-.625	.010	.010	-.500	.010
-.375	.000	.000	-.250	.010
-.125	.000	.000	.000	.010
.125	.010	.010	.250	.020
.375	.040	.040	.500	.060
.625	.040	.040	.750	.099
.875	.090	.089	1.000	.189
1.125	.290	.288	1.250	.477
1.375	1.530	1.521	1.500	1.999
1.625	11.170	11.107	1.750	13.105
1.875	13.380	13.304	2.000	26.409
2.125	35.600	35.398	2.250	61.808
2.375	24.420	24.282	2.500	86.089
2.625	8.510	8.462	2.750	94.551
2.875	2.810	2.794	3.000	97.345
3.125	1.600	1.591	3.250	98.936
3.375	.860	.855	3.500	99.791
3.625	.210	.209	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.570

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

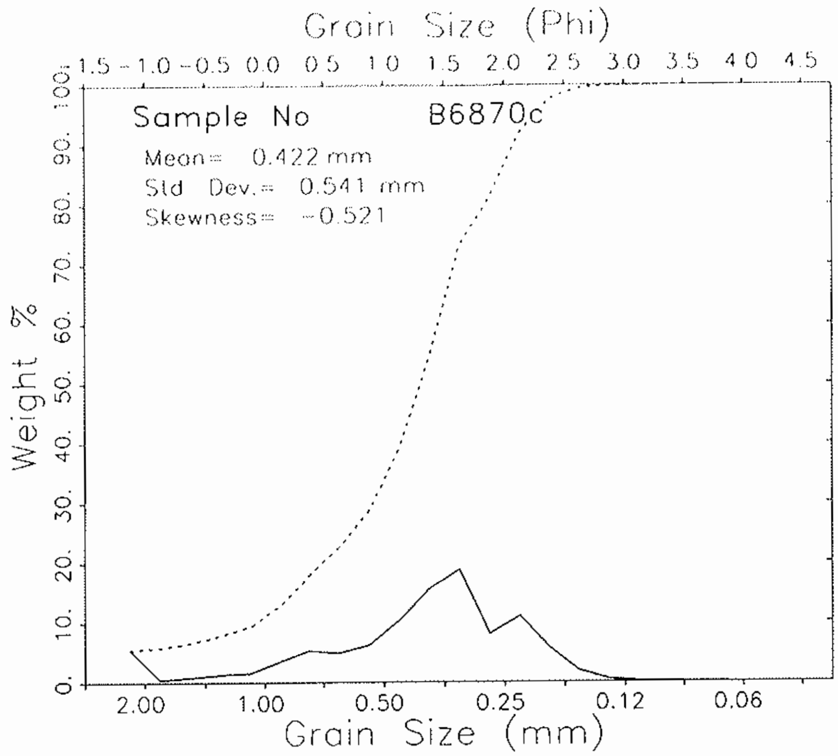
MEAN = 2.173 STANDARD DEVIATION = .369 SKEWNESS = .129 KURTOSIS = 1.709

0 DISPERSION = .157 STANDARD DEVIATION = .347 DEVIATION FROM NORMAL DISTR. = -5.86%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.336	1.568	1.804	1.974	2.167	2.386	2.478	2.790	3.269

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.141	2.150	FINE SAND
STANDARD DEVIATION	.337	.354	WELL SORTED
SKEWNESS(1)	-.075	-.027	NEAR SYMMETRICAL
SKEWNESS(2)	.036		
KURTOSIS	.814	1.215	LEPTOKURTIC



1 SAMPLE NO. DATE

B6870c 150501

Station 68-70 Beach Face

MIDPOINT (PHI)	(GRAM) WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	5.470	5.366	-1.000	5.366
-.875	.400	.392	-.750	5.758
-.625	.800	.785	-.500	6.543
-.375	1.220	1.197	-.250	7.740
-.125	1.490	1.462	.000	9.201
.125	3.480	3.414	.250	12.615
.375	5.280	5.180	.500	17.795
.625	4.860	4.768	.750	22.562
.875	6.280	6.160	1.000	28.723
1.125	10.400	10.202	1.250	38.925
1.375	15.820	15.519	1.500	54.444
1.625	19.050	18.687	1.750	73.131
1.875	8.090	7.936	2.000	81.067
2.125	11.170	10.957	2.250	92.025
2.375	5.770	5.660	2.500	97.685
2.625	1.800	1.766	2.750	99.451
2.875	.420	.412	3.000	99.863
3.125	.110	.108	3.250	99.971
3.375	.030	.029	3.500	100.000
3.625	.000	.000	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.940

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.243 STANDARD DEVIATION = .885 SKEWNESS = -.521 KURTOSIS = .868

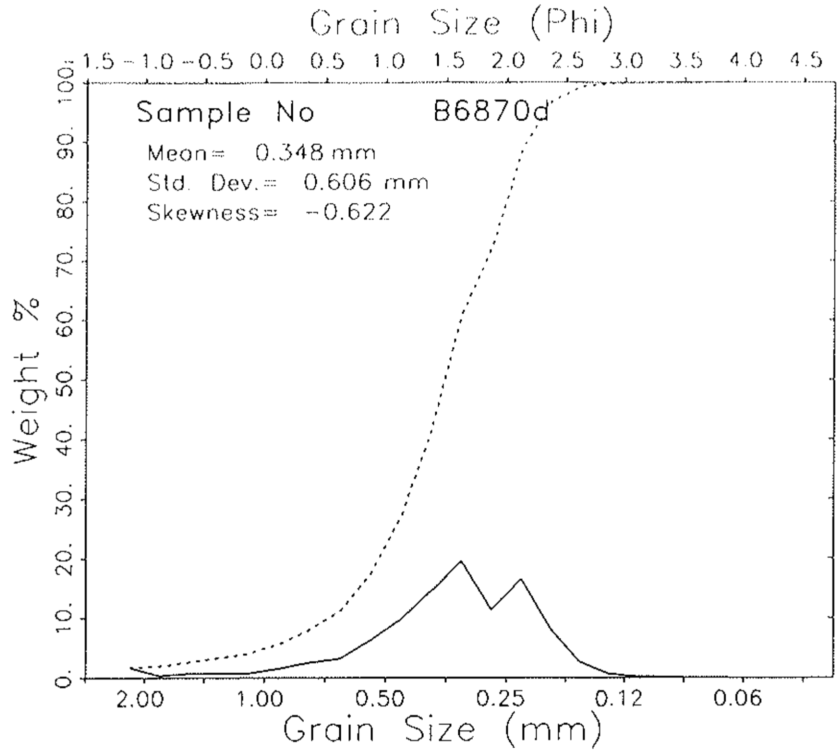
0 DISPERSION = .467 STANDARD DEVIATION = .709 DEVIATION FROM NORMAL DISTR. = -19.86%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.203	-1.017	.413	.849	1.428	1.809	2.067	2.381	2.686

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.240	1.303	MEDIUM SAND
STANDARD DEVIATION	.827	.928	MODERATELY SORTED
SKEWNESS(1)	-.228	-.333	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.903		
KURTOSIS	1.055	1.451	LEPTOKURTIC



1 SAMPLE NO. DATE

B6870d 150501
Station 68-70 LTT

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	1.740	1.612	-1.000	1.612
-.875	.340	.315	-.750	1.927
-.625	.650	.602	-.500	2.529
-.375	.810	.750	-.250	3.280
-.125	.820	.760	.000	4.039
.125	1.630	1.510	.250	5.549
.375	2.650	2.455	.500	8.004
.625	3.390	3.141	.750	11.145
.875	6.640	6.152	1.000	17.297
1.125	10.370	9.607	1.250	26.904
1.375	15.570	14.425	1.500	41.329
1.625	21.060	19.511	1.750	60.839
1.875	12.210	11.312	2.000	72.151
2.125	17.800	16.491	2.250	88.642
2.375	8.720	8.079	2.500	96.720
2.625	2.750	2.548	2.750	99.268
2.875	.600	.556	3.000	99.824
3.125	.140	.130	3.250	99.954
3.375	.050	.046	3.500	100.000
3.625	.000	.000	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 107.940

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.522 STANDARD DEVIATION = .720 SKEWNESS = -.622 KURTOSIS = 2.385

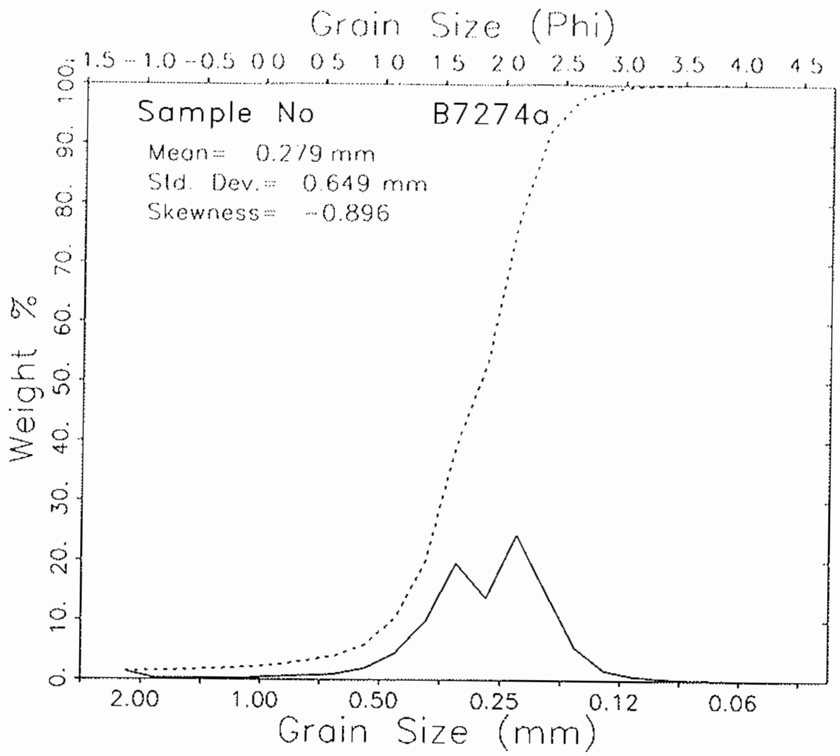
0 DISPERSION = .409 STANDARD DEVIATION = .621 DEVIATION FROM NORMAL DISTR. = -13.78%

0 PERCENTILES:

\+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.095	.159	.947	1.200	1.611	2.043	2.180	2.447	2.724

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.563	1.579	MEDIUM SAND
STANDARD DEVIATION	.616	.655	MODERATELY WELL SORTED
SKEWNESS(1)	-.077	-.173	COARSE-SKEWED
SKEWNESS(2)	-.500		
KURTOSIS	.856	1.113	LEPTOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B7274a	150501					
Station 72-74 Dune						
		-1.125	1.290	1.261	-1.000	1.261
		-.875	.140	.137	-.750	1.398
		-.625	.180	.176	-.500	1.573
		-.375	.210	.205	-.250	1.779
		-.125	.230	.225	.000	2.004
		.125	.440	.430	.250	2.434
		.375	.680	.665	.500	3.098
		.625	.900	.880	.750	3.978
		.875	1.890	1.847	1.000	5.825
		1.125	4.500	4.398	1.250	10.223
		1.375	9.920	9.695	1.500	19.918
		1.625	20.010	19.556	1.750	39.474
		1.875	14.060	13.741	2.000	53.215
		2.125	24.860	24.296	2.250	77.512
		2.375	14.990	14.650	2.500	92.162
		2.625	5.530	5.405	2.750	97.566
		2.875	1.630	1.593	3.000	99.160
		3.125	.570	.557	3.250	99.717
		3.375	.220	.215	3.500	99.932
		3.625	.070	.068	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.320

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

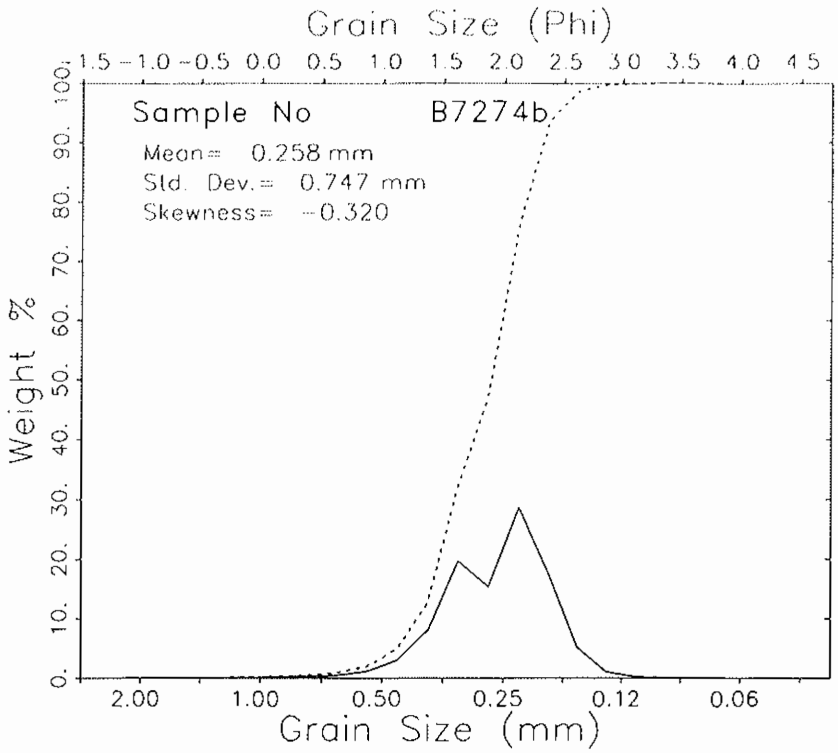
\+ MEAN = 1.844 STANDARD DEVIATION = .623 SKEWNESS = -.896 KURTOSIS = 6.340

0 DISPERSION = .321 STANDARD DEVIATION = .507 DEVIATION FROM NORMAL DISTR. = -18.73%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.052	.888	1.399	1.565	1.942	2.224	2.361	2.631	2.975

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.880	1.900	MEDIUM SAND
STANDARD DEVIATION	.481	.505	MODERATELY WELL SORTED
SKEWNESS(1)	-.128	-.168	COARSE-SKEWED
SKEWNESS(2)	-.378		
KURTOSIS	.812	1.084	MESOKURTIC



1 SAMPLE NO. DATE

B7274b 150501
Station 72-74 Berm

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.000	.000	-1.000	.000
-.875	.000	.000	-.750	.000
-.625	.050	.049	-.500	.049
-.375	.030	.030	-.250	.079
-.125	.040	.039	.000	.118
.125	.100	.099	.250	.217
.375	.210	.207	.500	.424
.625	.390	.385	.750	.809
.875	1.100	1.085	1.000	1.894
1.125	2.930	2.890	1.250	4.784
1.375	7.900	7.793	1.500	12.578
1.625	19.950	19.680	1.750	32.258
1.875	15.540	15.330	2.000	47.588
2.125	29.060	28.667	2.250	76.255
2.375	17.710	17.471	2.500	93.726
2.625	5.090	5.021	2.750	98.747
2.875	.980	.967	3.000	99.714
3.125	.230	.227	3.250	99.941
3.375	.060	.059	3.500	100.000
3.625	.000	.000	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 101.370

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

\+

MEAN = 1.952 STANDARD DEVIATION = .421 SKEWNESS = -.320 KURTOSIS = 1.536

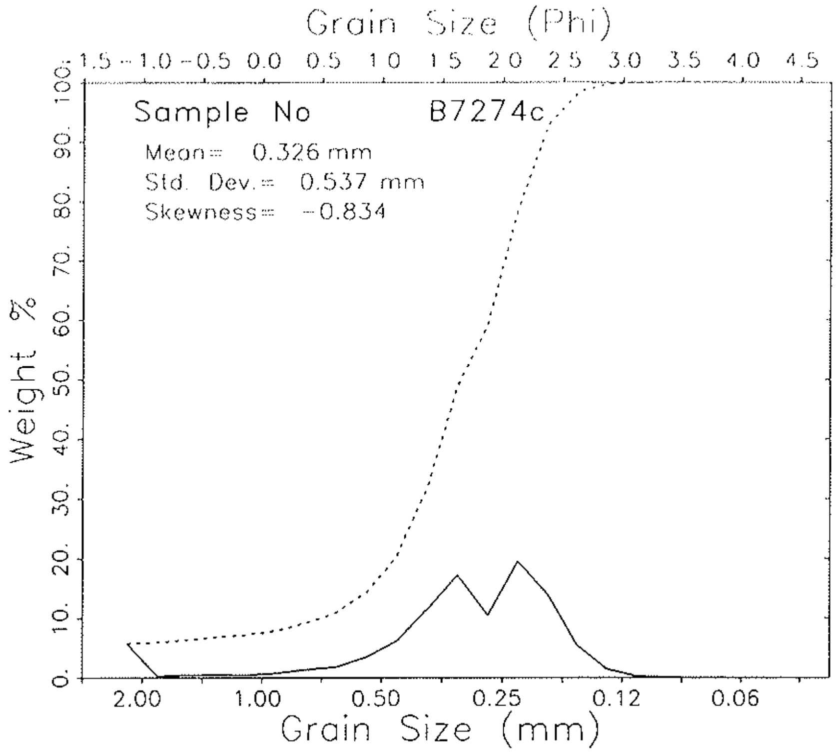
0 DISPERSION = .216 STANDARD DEVIATION = .398 DEVIATION FROM NORMAL DISTR. = -5.41%

0 PERCENTILES:

\+

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	.794	1.257	1.543	1.658	2.021	2.239	2.361	2.563	2.815

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND HARD (1957)	
0	MEAN	1.952	1.975	
+				MEDIUM SAND
0	STANDARD DEVIATION	.409	.402	
+				WELL SORTED
0	SKEWNESS(1)	-.169	-.169	
+				COARSE-SKEWED
0	SKEWNESS(2)	-.271		
0	KURTOSIS	.598	.921	
+				MESOKURTIC



1 SAMPLE NO. DATE

B7274c 150501
Station 72-74 Beach Face

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	5.680	5.670	-1.000	5.670
-.875	.230	.230	-.750	5.900
-.625	.400	.399	-.500	6.299
-.375	.480	.479	-.250	6.778
-.125	.380	.379	.000	7.158
.125	.740	.739	.250	7.897
.375	1.280	1.278	.500	9.174
.625	1.720	1.717	.750	10.891
.875	3.410	3.404	1.000	14.296
1.125	6.040	6.030	1.250	20.325
1.375	11.400	11.381	1.500	31.706
1.625	17.240	17.211	1.750	48.917
1.875	10.460	10.442	2.000	59.359
2.125	19.560	19.527	2.250	78.886
2.375	14.040	14.016	2.500	92.902
2.625	5.430	5.421	2.750	98.323
2.875	1.360	1.358	3.000	99.681
3.125	.260	.260	3.250	99.940
3.375	.060	.060	3.500	100.000
3.625	.000	.000	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 100.170

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

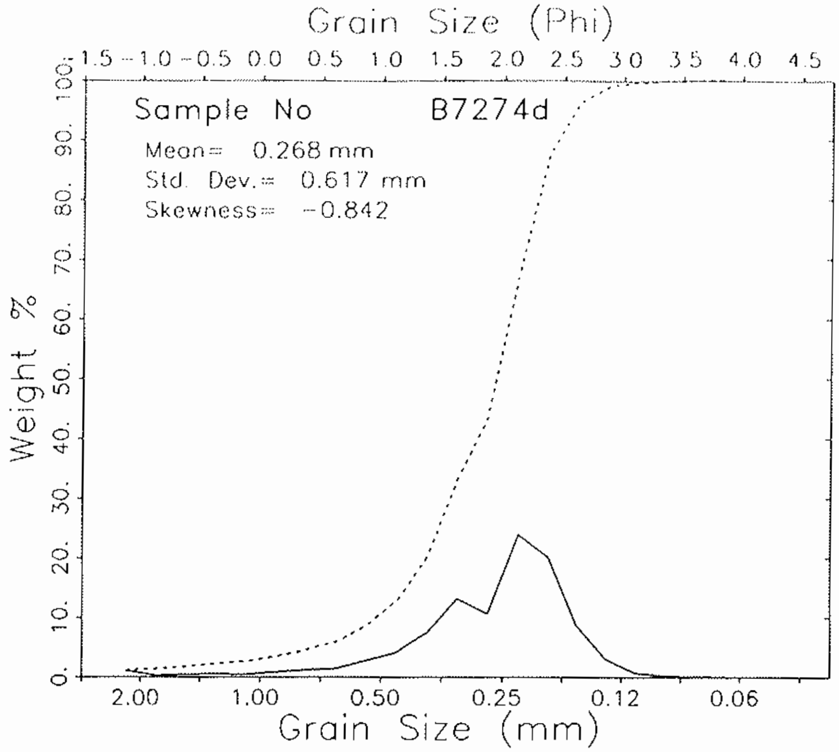
MEAN = 1.615 STANDARD DEVIATION = .898 SKEWNESS = -.834 KURTOSIS = 2.783

0 DISPERSION = .400 STANDARD DEVIATION = .608 DEVIATION FROM NORMAL DISTR. = -32.25%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.206	-1.030	1.071	1.353	1.776	2.200	2.341	2.597	2.875

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.706	1.729	MEDIUM SAND
STANDARD DEVIATION	.635	.867	MODERATELY SORTED
SKEWNESS(1)	-.110	-.329	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-1.562		
KURTOSIS	1.854	1.753	VERY LEPTOKURTIC



1

SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B7274d 150501						
Station 72-74 LTT						
	-1.125	1.120	1.082		-1.000	1.082
	-.875	.260	.251		-.750	1.333
	-.625	.390	.377		-.500	1.709
	-.375	.510	.493		-.250	2.202
	-.125	.400	.386		.000	2.588
	.125	.800	.773		.250	3.361
	.375	1.160	1.120		.500	4.481
	.625	1.420	1.371		.750	5.853
	.875	2.780	2.685		1.000	8.538
	1.125	4.240	4.095		1.250	12.633
	1.375	7.590	7.330		1.500	19.963
	1.625	13.640	13.174		1.750	33.137
	1.875	10.910	10.537		2.000	43.674
	2.125	24.750	23.904		2.250	67.578
	2.375	20.850	20.137		2.500	87.715
	2.625	8.800	8.499		2.750	96.214
	2.875	2.980	2.878		3.000	99.092
	3.125	.680	.657		3.250	99.749
	3.375	.180	.174		3.500	99.923
	3.625	.080	.077		3.750	100.000
	3.875	.000	.000		4.000	100.000

TOTAL WEIGHT (GRAMS) = 103.540

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.898 STANDARD DEVIATION = .696 SKEWNESS = -.842 KURTOSIS = 4.291

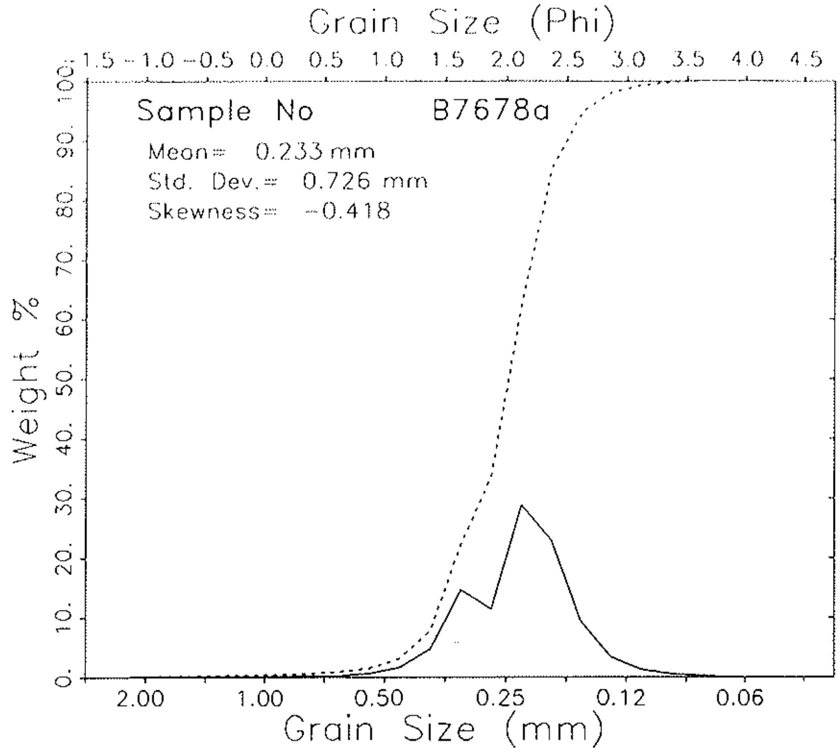
0 DISPERSION = .366 STANDARD DEVIATION = .562 DEVIATION FROM NORMAL DISTR. = -19.28%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
-1.019	.595	1.365	1.596	2.066	2.342	2.454	2.714	2.992

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.909	1.962	MEDIUM SAND
STANDARD DEVIATION	.545	.593	MODERATELY WELL SORTED
SKEWNESS(1)	-.288	-.338	STRONGLY COARSE-SKEWED
SKEWNESS(2)	-.756		
KURTOSIS	.946	1.164	LEPTOKURTIC



1 SAMPLE NO. DATE

B7678a 150501
Station 76-78 Dune

MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
-1.125	.040	.040	-1.000	.040
-.875	.060	.060	-.750	.100
-.625	.060	.060	-.500	.160
-.375	.080	.080	-.250	.241
-.125	.070	.070	.000	.311
.125	.100	.100	.250	.411
.375	.190	.190	.500	.601
.625	.250	.251	.750	.852
.875	.580	.581	1.000	1.433
1.125	1.580	1.583	1.250	3.017
1.375	4.540	4.550	1.500	7.567
1.625	14.590	14.622	1.750	22.189
1.875	11.400	11.425	2.000	33.614
2.125	28.830	28.894	2.250	62.508
2.375	22.900	22.950	2.500	85.458
2.625	9.300	9.321	2.750	94.779
2.875	3.330	3.337	3.000	98.116
3.125	1.190	1.193	3.250	99.308
3.375	.490	.491	3.500	99.800
3.625	.200	.200	3.750	100.000
3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 99.780

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

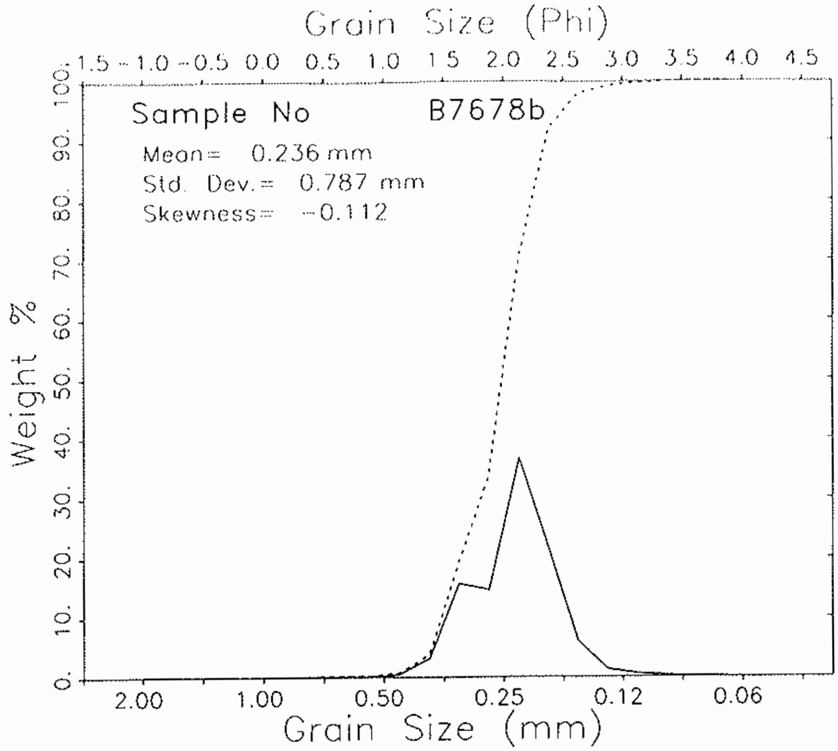
\+ MEAN = 2.099 STANDARD DEVIATION = .461 SKEWNESS = -.418 KURTOSIS = 4.092

0 DISPERSION = .242 STANDARD DEVIATION = .423 DEVIATION FROM NORMAL DISTR. = -8.23%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
.814	1.359	1.644	1.812	2.142	2.386	2.484	2.767	3.185

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.064	2.090	FINE SAND
STANDARD DEVIATION	.420	.423	WELL SORTED
SKEWNESS(1)	-.185	-.149	COARSE-SKEWED
SKEWNESS(2)	-.188		
KURTOSIS	.676	1.004	MESOKURTIC



1 SAMPLE NO. DATE

SAMPLE NO. DATE	MIDPOINT (PHI)	WEIGHT (GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B7678b 150501					
Station 76-78 Borm					
	-1.125	.000	.000	-1.000	.000
	-.875	.020	.019	-.750	.019
	-.625	.000	.000	-.500	.019
	-.375	.020	.019	-.250	.038
	-.125	.000	.000	.000	.038
	.125	.020	.019	.250	.056
	.375	.030	.028	.500	.085
	.625	.030	.028	.750	.113
	.875	.100	.094	1.000	.207
	1.125	.440	.414	1.250	.621
	1.375	3.170	2.983	1.500	3.604
	1.625	16.650	15.666	1.750	19.270
	1.875	15.550	14.631	2.000	33.901
	2.125	39.120	36.808	2.250	70.709
	2.375	22.710	21.368	2.500	92.078
	2.625	6.300	5.928	2.750	98.005
	2.875	1.290	1.214	3.000	99.219
	3.125	.510	.480	3.250	99.699
	3.375	.250	.235	3.500	99.934
	3.625	.070	.066	3.750	100.000
	3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 106.280

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 2.081 STANDARD DEVIATION = .345 SKEWNESS = -.112 KURTOSIS = 2.322

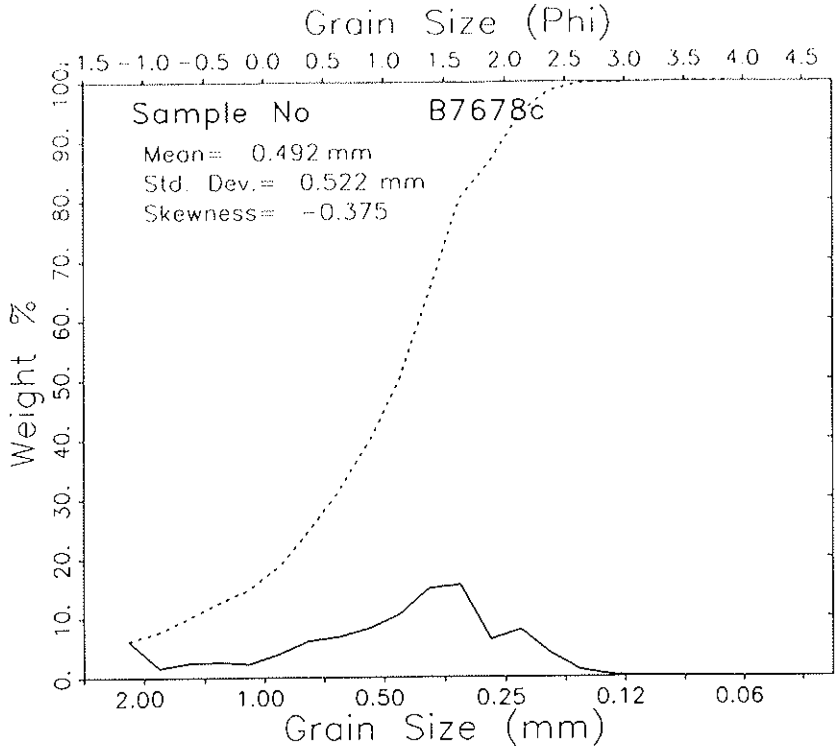
0 DISPERSION = .127 STANDARD DEVIATION = .324 DEVIATION FROM NORMAL DISTR. = -5.99%

0 PERCENTILES:

+

1.	5.	16.	25.	50.	75.	84.	95.	99.
1.282	1.522	1.698	1.848	2.109	2.300	2.405	2.623	2.955

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	2.052	2.071	FINE SAND
STANDARD DEVIATION	.354	.344	VERY WELL SORTED
SKEWNESS(1)	-.163	-.115	COARSE-SKEWED
SKEWNESS(2)	-.103		
KURTOSIS	.556	.990	MESOKURTIC



1

SAMPLE NO.	DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT	WEIGHT PERCENT CLASS LIMITS (PHI)	CUM PERCENT
B7678c	150501					
Station 76-78 Beach Face						
		-1.125	6.170	6.043	-1.000	6.043
		-.875	1.600	1.567	-.750	7.609
		-.625	2.440	2.390	-.500	9.999
		-.375	2.640	2.585	-.250	12.584
		-.125	2.230	2.184	.000	14.768
		.125	3.980	3.898	.250	18.666
		.375	6.190	6.062	.500	24.728
		.625	6.860	6.718	.750	31.446
		.875	8.350	8.177	1.000	39.624
		1.125	10.670	10.450	1.250	50.073
		1.375	15.220	14.905	1.500	64.979
		1.625	15.820	15.493	1.750	80.472
		1.875	6.390	6.258	2.000	86.730
		2.125	8.090	7.923	2.250	94.653
		2.375	3.930	3.849	2.500	98.502
		2.625	1.200	1.175	2.750	99.677
		2.875	.270	.264	3.000	99.941
		3.125	.060	.059	3.250	100.000
		3.375	.000	.000	3.500	100.000
		3.625	.000	.000	3.750	100.000
		3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 102.110

PERCENT FINER THAN 4.00 PHI = .00   PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

+

MEAN = 1.024   STANDARD DEVIATION = .937   SKEWNESS = -.375   KURTOSIS = -.066

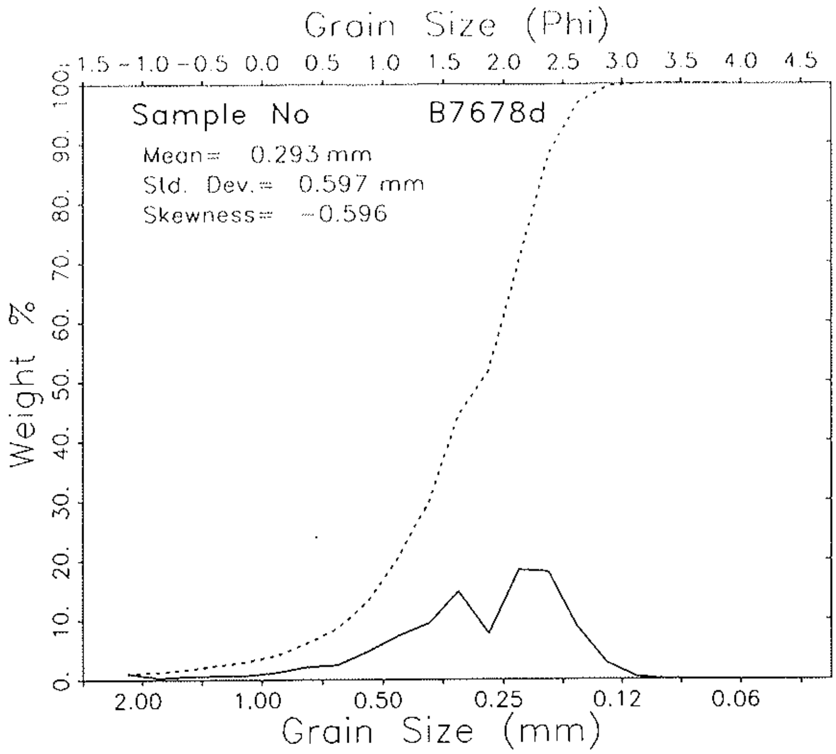
0 DISPERSION = .512   STANDARD DEVIATION = .787   DEVIATION FROM NORMAL DISTR. = -16.07%

0 PERCENTILES:

+

	1.	5.	16.	25.	50.	75.	84.	95.	99.
0	-1.209	-1.043	.079	.510	1.248	1.662	1.891	2.273	2.606

	GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
0	MEAN	.985	1.073	
+				MEDIUM SAND
0	STANDARD DEVIATION	.906	.955	
+				MODERATELY SORTED
0	SKEWNESS(1)	-.291	-.336	
+				STRONGLY COARSE-SKEWED
0	SKEWNESS(2)	-.699		
0	KURTOSIS	.830	1.180	
+				LEPTOKURTIC



1

SAMPLE NO. DATE	MIDPOINT (PHI)	(GRAM)	WEIGHT PERCENT	CLASS LIMITS (PHI)	CUM PERCENT
B7678d 150501					
Station 76-78 LTT					
	-1.125	.970	.932	-1.000	.932
	-.875	.280	.269	-.750	1.200
	-.625	.460	.442	-.500	1.642
	-.375	.670	.643	-.250	2.286
	-.125	.640	.615	.000	2.900
	.125	1.150	1.104	.250	4.005
	.375	2.140	2.055	.500	6.060
	.625	2.520	2.420	.750	8.480
	.875	4.810	4.619	1.000	13.099
	1.125	7.540	7.241	1.250	20.340
	1.375	9.580	9.200	1.500	29.540
	1.625	15.330	14.722	1.750	44.262
	1.875	7.930	7.615	2.000	51.877
	2.125	19.060	18.304	2.250	70.181
	2.375	18.760	18.016	2.500	88.197
	2.625	9.000	8.643	2.750	96.840
	2.875	2.790	2.679	3.000	99.520
	3.125	.420	.403	3.250	99.923
	3.375	.080	.077	3.500	100.000
	3.625	.000	.000	3.750	100.000
	3.875	.000	.000	4.000	100.000

TOTAL WEIGHT (GRAMS) = 104.130

PERCENT FINER THAN 4.00 PHI = .00 PERCENT COARSER THAN -1.00 PHI = .00

0 MOMENT MEASURES:

MEAN = 1.772 STANDARD DEVIATION = .745 SKEWNESS = -.596 KURTOSIS = 1.953

0 DISPERSION = .420 STANDARD DEVIATION = .636 DEVIATION FROM NORMAL DISTR. = -14.65%

0 PERCENTILES:

1.	5.	16.	25.	50.	75.	84.	95.	99.
-.936	.371	1.100	1.377	1.938	2.317	2.442	2.697	2.951

GRAPHIC PHI PARAMETER	INMAN (1952)	FOLK AND WARD (1957)	
MEAN	1.771	1.827	
			MEDIUM SAND
STANDARD DEVIATION	.671	.688	
			MODERATELY WELL SORTED
SKEWNESS(1)	-.250	-.299	
			COARSE-SKEWED
SKEWNESS(2)	-.603		
KURTOSIS	.734	1.014	
			MESOKURTIC

APPENDIX F

APPENDIX F

Economics Study

APPENDIX F

ECONOMIC STUDIES

LIST OF TABLES

APPENDIX F

Supporting Computations for Section 4.3 "Retreat/Relocate Alternative"

The first three tables in this Appendix are the calculations for the summarized numbers in Section 4.3. Table F-1 breaks down the costs for relocating a house on the same lot, Table F-2 the same computations but for moving to a different lot (insufficient room remains on the same lot), and Table F-3 shows the cost breakdown by municipality.

In the analyses of the retreat/relocate alternative it is assumed that costs occur equally in each year of the 10 year study period; that construction costs escalate at 3 percent per year; that real estate costs escalate at 4.8 percent per year. Final costs for comparison with project costs are normalized to present value based on the discount factor for 30 year Treasury bonds as of February 24, 2000 as published in the Wall Street Journal.

The relocation costs used in the previous tables are supported in detail in Table F-9, showing the different relocation costs by community. The accumulation of these costs by year and type of relocation are further broken down in Table F-10. Thus F-10 feeds the supporting data into F-9, which then provides supporting data for the first three Tables F-1 through F-3.

Finally, the net present worth of all these relocation costs are summed in Table F-11 over the ten years.

Supporting Computations for Section 4.2 "Do-Nothing Alternative"

Impacts on Property Values

The number of oceanfront properties that will be lost under the 10-year project life are totaled in Table F-4 and the values totaled. The appropriate tax rates are then applied to determine the total property tax losses, broken down by community in each section of Table F-4. This is a government loss.

Table F-5 shows the lost property values by year and by community. These are losses to those in the special tax districts.

The present worth of the property tax losses are computed in Table F-6. **This value of $6.3 million is reported in the summary table in Section 4.2.**

In addition to the actual loss of property, there is a loss to the appreciated values, had the structures remained. The present worth of all lost properties, taking into account appreciation, are totaled by community in Table F-7. The listed property losses are losses in the Special Tax Districts, and the listed property tax losses are government losses.

All types of property loss are summarized in Table F-8. These include lost property, lost taxes, beach scraping, property repairs, and debris removal.

The relocation costs used in the previous tables are supported in detail in Table F-9, showing the different relocation costs by community.

Impacts to the Community (Carteret County) Economy

Tourist Expenditures – Total revenues generated from domestic tourism in Carteret County has been estimated by Carteret County Economic Development Council to be $208.55 million (1998) in "Facts on Carteret County Tourism" based on statistics provided by NC Department of Commerce. The proportion of tourist revenues in Carteret County that are generated on Bogue Banks has been estimated by the same sources as 84 percent. The proportion of recreational beaches on Bogue Banks that this beach-nourishment project is planned to improve is the ratio of this project length to the total beach length or 78 percent. Thus the maximum tourist expenditures that are in jeopardy if there is no recreational beach over the proposed project length is 0.84 x 0.78 x $208.55 million = $136.64 million annually or $1,366.4 million over the ten-year lifetime of the project. The prime tourist attraction in Bogue Banks is the beach. It is difficult to estimate the percent of tourists who would not come to Bogue Banks if the proposed project beach has little or no beach above high tide. Some tourists who come to the area do not use the beach. Those who do use the beach will increasingly crowd onto remaining healthy beach areas such as Atlantic Beach. However, a range of possibilities can be considered. For inclusion in the high and low estimates in Section 4.2, we propose a low limit of 10 percent and a high limit of 25 percent proportion of tourist population that will elect to go elsewhere. Thus the total lost tourist revenues over ten years would range between $136.64 million and $341.61 million. For the purpose of ascertaining who will experience these losses, lost tourism is broken down into the following categories.

Occupancy Tax – There is a 3 percent occupancy tax on all short-term (visitor) rentals. In fiscal year 1998-99 this generated $1,706,788 in Carteret County. Using the numbers in Tourist Expenditures above, losses of occupancy tax for one year would be 10-25 percent of 0.84 x 0.78 x $1,706,788. So the loss range over ten years is $1,118,287 to $2,795,718. This is a governmental loss.

Sales Tax – There is a 6 percent sales tax on non-housing expenditures. The Economic Development Council (reference publication listed above under Tourism Expenditures) estimates $20.05 million of these annual revenues are generated by tourists in Carteret County. Using the numbers in Tourist Expenditures above, losses of sales tax for one year would be 10-25 percent of 0.84 x 0.78 x $20,050,000. So the loss range over ten years is $13,136,000 to $32,840,000. This is a governmental loss.

Payroll – The tourism industry is Carteret County's largest industry. The Economic Development Council estimates this annual payroll at $48.99 million. Using the numbers in Tourist Expenditures above, losses of payroll in one year would be 10-25 percent of 0.84 x 0.78 x $48,990,000. So the loss range over ten years is $32,098,000 to $80,245,000. This is a private loss.

Other Tourist Expenditures – The remaining tourist expenditures (total minus tax and payroll) over the project portion of Bogue Banks are annually 0.84 x 0.78 x ($208.55 - $1.71 - $20.05 - $48.99). So the range of possible losses (10-25 percent of this value multiplied over ten years) is $90.287 million to $225.718 million. This is a private loss.

Recreational Losses – Losses to the environment are more difficult to quantify than economic losses. However, the Corps of Engineers has established procedures for estimating the value of a recreational beach to the general public. Procedures outlined in Engineering Regulation 1105-2-100 were followed. Some choice of methods is allowed under the regulation, but most nourishment projects designed by the Corps use example surveys of the beach-going public that have resulted in "use curves" based on surveys conducted in Florida that were later updated in the Myrtle Beach, SC, project (USACE, 1993). These studies compute the number of beach visits annually by each person (P) as $P = A \exp(B x)$ where A and B are empirical coefficients determined by surveys, and x is the travel distance between a community and the beach. The Florida study generated values of $A = 6.8$ and $B = -0.03$, and Myrtle Beach updated these to $A = 8$ and $B = -0.04$. The A value represents the annual number of beach visits made by a resident who is within walking distance of the beach. Using these values the annual number of beach visits made by residents of Carteret County was computed in Table F-12.

The annual visits total 310,181. To translate this into a dollar value, procedures are available for assigning "point" values to various recreational experiences associated with the amenities at a particular beach. Rather than follow these complex procedures which tends to result in variation in the final number of only 10-20 percent, we simply used the value computed in another study for Folly Beach, SC (USACE, 1991) which produced a value per visit of $3.44. Multiplying the number of annual visits by this value results in an annual recreational value to County residents of $1,067,022. The portion of Bogue Banks represented by this project is 78 percent, so the annual recreational value to residents is 0.78 x $1,067,022 or $832,277. Following the same logic outlined above for Tourist Expenditures, we propose that 10-25 percent of these visits will not occur because of the degraded beach. Ten to 25 percent of the above value multiplied over the ten-year project results in value of $832,277 to $2,080,693. This is an environmental/quality-of-life impact to the county.

Impacts to Owners in Special Tax Districts

Beach Scraping – Since Hurricane *Floyd* (September 1999), an estimated 80 percent of oceanfront properties in the proposed project area have scraped the beach and restored the foredune. Scraping was continuing on 1 March 2000, nearly six months after *Floyd*. Typical dimensions of scraping are 10-15 cubic yards per linear foot. Scraping is performed by skimming the upper 2–4 ft of dry beach by bulldozer and pushing it into a steep sloping dune (typically 1 on 4 seaward slope). Elevation of the top of the scraped dune generally coincides with the backshore escarpment elevation (typically 15-20 ft NGVD). Typical range of expenditures per 100-ft oceanfront lot have been $500–3000 per incident. Some owners have scraped nearly every year since 1995. While the crest elevation of the scraped dune is well above the 10-year or 25-year surge elevation, the protection is not equivalent because the remaining beach after scraping is narrower and less able to absorb wave energy. As a result, the scraped dune is exposed at the toe and vulnerable to scarping. This, in turn, leads to mass wasting of the scraped dune and the need to rescrape. As erosion continues under the no action alternative, the frequency of erosion and undermining of the artificial dunes will increase. For purposes of cost estimating, we assume that 50 percent of the beach will require scraping in any given year. Scraping 50 percent each year results in an annual cost of $250,000. Escalating and normalizing to present value is $ 2.2 million over ten (10) years: (Table F-8).

Reconstruction of Dune Walkovers – An estimated 80 percent of existing dune walkovers in the project area have been rebuilt since Hurricane *Floyd*. Many of these same property owners had to replace their walkovers after *Fran* and the other hurricanes of the late 1990s. The nature of repairs ranges from replacement of just a few steps at the base to entire reconstruction of support piles, observation decks and handicapped ramps. A majority of walkovers extend from relatively high backshore elevations (typically 15–20 ft NGVD), thus the support systems are elaborate in many cases. With increasing frequency of runup to the base of structures, repaired walkovers are usually improved and more expensive compared to the destroyed walkover. We estimate a range of expenditures per property is ~$200 to $10,000 after *Floyd*, with a typical cost around $3000, or approximately $2.2 million. Thus, the ten-year cost of walkover replacement due to storm erosion has a present value of $19.1 million (Table F-8). This is an impact to oceanfront property owners.

TABLE F-1

BOGUE BANKS BEACH NOURISHMENT
RETREAT/RELOCATE ALTERNATIVE
RELOCATE HOUSE ON EXISTING LOT

CSE Baird
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

Date: Feb. 28, 2000
By: J.W. Forman, Jr., P.E.

COST OPINION FOR RELOCATION OF BEACHFRONT RESIDENTIAL STRUCTURE
BASED ON TYPICAL HOUSE, 1350 S.F. FOOTPRINT
STRUCTURE MOVED ON EXISTING LOT

#	Item	Quant.	Unit	Unit Cost	Total Costs OH&P
A.	ADMINISTRATIVE				
A.	SITE WORK AND GENERAL CONSTRUCTION				
1.0	Fees and Permits	1	l.s.	$500.00	$500.00
2.0	Site Grading	1	l.s.	$2,000.00	$2,000.00
3.0	Demolition and Removal of Old Slab	1	l.s.	$300.00	$300.00
4.0	Abandon Old & Install New Septic System	1	l.s.	$3,000.00	$3,000.00
5.0	Water & Sewer Plumbing to New Structure	1	l.s.	$2,000.00	$2,000.00
SITE WORK & GENERAL CONSTRUCTION TOTAL					$7,800
B	MOVE AND RECONSTRUCT STRUCTURE				
1.0	House Preparation & Moving	1350	s.f.	$22.50	$30,375.00
2.0	Pile Driving Mobilization	1	l.s.	$1,000.00	$1,000.00
3.0	Treated Timber Piles 8x8x25	500	v.l.f.	$10.00	$5,000.00
4.0	Drive Timber Piles	500	v.l.f.	$12.50	$6,250.00
5.0	300 s.f. Conc. Slab 4" thk.	4	c.y.	$125.00	$500.00
6.0	Underhouse Construction	300	s.f.	$25.00	$7,500.00
7.0	Porch Replacement, Piles	125	v.l.f.	$22.50	$2,812.50
8.0	Timber Decking, Min. Framing, No Piles	540	s.f.	$25.00	$13,500.00
9.0	Electrical Wiring and Service	1	l.s.	$1,500.00	$1,500.00
10.0	HVAC Reinstallation	1	l.s.	$1,500.00	$1,500.00
MOVE AND RECONSTRUCT STRUCTURE TOTAL					$68,437.50
CONSTRUCTION TOTAL					$0.00
				USE	$78,000.00

TABLE F-2

BOGUE BANKS BEACH NOURISHMENT
RETREAT/RELOCATE ALTERNATIVE
RELOCATE HOUSE TO NON-OCEANFRONT LOT

CSE BAIRD
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

By: J.W. Forman, Jr., P.E.   Date: February 28, 2000

COST OPINION FOR RELOCATION OF BEACHFRONT RESIDENTIAL STRUCTURE
BASED ON TYPICAL HOUSE, 1350 S.F. HEATED FOOTPRINT, 1890 S.F. TOTAL ELEVATED
RELOCATE STRUCTURE TO OFF-SITE LOT, ABANDON EXISTING LAND

#	Item	Quant.	Unit	Unit Cost	Total Costs
A.	LAND PURCHASE AND ABANDONMENT				
Emerald Isle					
1.0	Cost for Abandonment of Exist Lot*	L.S.	1	$264,000.00	
	Purchase of New Lot**	L.S.	1	$126,000.00	**$390,000.00**
Pine Knoll Shores and Indian Beach					
	Cost for Abandonment of Exist Lot*	L.S.	1	$264,000.00	
	Purchase of New Lot**	L.S.	1	$175,000.00	**$439,000.00**
B.	SITE WORK AND GENERAL CONSTRUCTION, FOUNDATION RETROFIT				
1.0	Fees and Permits	1	l.s.	$ 500.00	$ 500.00
2.0	Site Grading	1	l.s.	$ 1,000.00	$ 1,000.00
3.0	Demolition and Removal of Old Slab	1	l.s.	$ 300.00	$ 300.00
4.0	Abandon Old & Install New Septic System	1	l.s.	$ 3,000.00	$ 3,000.00
5.0	Water & Sewer Plumbing to New Structure	1	l.s.	$ 2,000.00	$ 2,000.00
6.0	Electrical Wiring and Service	1	l.s.	$ 1,500.00	$ 1,500.00
7.0	HVAC Reinstallation	1	l.s.	$ 1,500.00	$ 1,500.00
8.0	Pile Driving Mobilization	1	l.s.	$ 1,000.00	$ 1,000.00
9.0	Treated Timber Piles 8x8x25	625	v.l.f.	$ 10.00	$ 6,250.00
10.0	Drive Timber Piles	400	v.l.f.	$ 12.50	$ 5,000.00
11.0	300 s.f. Conc. Slab 4" thk.	4	c.y.	$ 125.00	$ 500.00
12.0	Underhouse Construction	300	s.f.	$ 25.00	$ 7,500.00
13.0	Timber Decking, Min. Framing, No Piles	540	s.f.	$ 25.00	$ 13,500.00
SITE WORK AND GENERAL CONSTRUCTION, FOUNDATION RETROFIT TOTAL					**$ 44,000.00**
			Cost per Sq. Ft.		$ 32.59
C.	PREPARE AND MOVE STRUCTURE				
1.0	House Preparation & Moving	1350	s.f.	$ 25.00	$ 33,750.00
2.0	Electrical Secondary Power Temp Move	1	l.s.	$ 8,000.00	$ 8,000.00
PREPARE AND MOVE STRUCTURE TOTAL					**$ 42,000.00**
			Cost per Sq. Ft.		$ 31.11
CONSTRUCTION TOTAL					**$ 86,000.00**

COST SUMMARY

Emerald Isle - Relocate House to Non-Oceanfront Lot	**$ 390,000.00**
Pine Knoll Shores - Relocate House to Non-Oceanfront Lot	**$ 439,000.00**

* Abandonment Cost is Lost Value of Existing Homesite

** Based on assumption that replacement oceanfront lots are not available able for purchase. Owner would have to purchase replacement lot in intereior of island at market prices.

TABLE F-3

BOGUE BANKS BEACH NOURISHMENT
RETREAT/RELOCATE ALTERNATIVE
PROPERTY VALUE DATA

STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

By: J.W. Forman, Jr., P.E. Date: 28-Feb-00

Values for Existing Properties
Based on data provided by Carteret County Tax Office

Property	Type	Muni	Land Value	Building Value	Total Value	% Land	%Building	Sq. Ft. Land	Land Value per Sq. Ft
Bryant	S.F.	PKS	$ 218,500	$ 115,080	$ 333,580	65.5%	34.5%	27,929	$ 7.82
Oakley	S.F.	PKS	$ 255,200	$ 176,397	$ 431,597	59.1%	40.9%	47,808	$ 5.34
Zwerling	S.F.	S.P.	$ 153,450	$ 95,663	$ 249,113	61.6%	38.4%	32,536	$ 4.72
Zoeller	S.F.	E.I.	$ 261,660	$ 170,375	$ 432,035	60.6%	39.4%	19,822	$ 13.20
Nobles	S.F.	E.I.	$ 244,575	$ 75,148	$ 319,723	76.5%	23.5%	15,202	$ 16.09
Murphrey	S.F.	E.I.	$ 152,550	$ 56,919	$ 209,469	72.8%	27.2%	11,533	$ 13.23
Averages			**$ 214,323**	**$ 114,930**	**$ 329,253**	**66.02%**	**33.98%**		**$ 10.07**
Std. Deviations			**$ 49,700**	**$ 49,300**	**$ 91,600**	**7.12%**	**7.12%**		**$ 4.73**
		Use	**$ 264,000**	**$ 136,000**	**$ 400,000**	**66%**	**34%**		
<u>DELETED FROM SAMPLE</u>									
LAND ONLY PROPERTIES									
Barnett	L	PKS-C	$ 249,900.00		$ 249,900.00	100.0%		42,164	$ 5.93
Nassau Corp.	L	E.I.	$ 272,204.00		$ 272,204.00	100.0%		28,449	$ 9.57
EXTRAORDINARILY HIGH VALUE BUILDINGS									
Best	S.F.	PKS-C	$ 186,520.00	$ 286,762.00	$ 473,282.00	39.4%	60.6%	27,544	$ 6.77
Guthrie	S.F.	PKS-W	$ 241,595.00	$ 383,497.00	$ 625,092.00	38.6%	61.4%	37,100	$ 6.51

TABLE F-3

Off Beachfront Vacant Lot Values (Researched by Ron Martin, Appraiser, Allen Shelor Real Estate, Atlantic Beach, NC)

Emerald Isle		**Use**	**Average Costs**
Second Row lots	$ 200,000.00	$ 200,000	
Third Row	$102,000 to $125,000	$ 114,000	$ 126,333
Interior	$60,000 to $70,000	$ 65,000	
Pine Knoll Shores			
Interior	$40,000 to $60,000	$ 50,000	
Interior Canal	$150,000	$ 150,000	$ 175,000
Beachfront	$300,000 to $350,000	$ 325,000	

Abbreviations

Muni - Municipality

Salter Path	S.P.	**Type**	
Emerald Isle	E.I.	Single Family	S.F.
Pine Knoll Shores	PKS	Land Only	L

BOGUE BANKS BEACH NOURISHMENT
PROJECT ALTERNATIVE ANALYSES
DO-NOTHING ALTERNATIVE
Date: 28-Feb-00
By: J.W. Forman, Jr., P.E.

TABLE F-4

CSE BAIRD
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

TAX REVENUE LOSSES ASSOCIATED WITH LOSS OF OCEANFRONT PROPERTIES FOR DO-NOTHING ALTERNATIVE

Emerald Isle	Units	Property Values Land	Property Values Structure	Unit Value	Total Value
Single Family	156	$264,000	$136,000	$400,000	$62,400,000
Condominium	36		$150,000	$150,000	$5,400,000
Mobile Home Lots	17		$20,000	$20,000	$340,000

Tax Rates/$100 Value Town	Tax Rates/$100 Value County	Unit Tax Revenues Town	Unit Tax Revenues County	Per Annum Total Tax Rev. Value Town	Per Annum Total Tax Rev. Value County
$0.195	$0.50	$780	$2,000	$121,680	$312,000
$0.195	$0.50	$293	$750	$10,530	$27,000
$0.195	$0.50	$39	$100	$663	$1,700

Salter Path	Units	Property Values Land	Property Values Structure	Unit Value	Total Value
Single Family	15	$264,000	$136,000	$400,000	$6,000,000
Condominium	45		$150,000	$150,000	$6,750,000
Mobile Home Lots	7		$20,000	$20,000	$140,000

Tax Rates/$100 Value Town	Tax Rates/$100 Value County	Unit Tax Revenues Town	Unit Tax Revenues County	Per Annum Total Tax Rev. Value Town	Per Annum Total Tax Rev. Value County
$0.00	$0.50	$0	$2,000	$0	$30,000
$0.00	$0.50	$0	$750	$0	$33,750
$0.00	$0.50	$0	$100	$0	$700

Indian Beach	Units	Property Values Land	Property Values Structure	Unit Value	Total Value
Single Family	10	$264,000	$136,000	$400,000	$4,000,000
Condominium	32		$150,000	$150,000	$4,800,000
Mobile Home Lots	15		$20,000	$20,000	$300,000

Tax Rates/$100 Value Town	Tax Rates/$100 Value County	Unit Tax Revenues Town	Unit Tax Revenues County	Per Annum Total Tax Rev. Value Town	Per Annum Total Tax Rev. Value County
$0.170	$0.50	$680	$2,000	$6,800	$20,000
$0.170	$0.50	$255	$750	$8,160	$24,000
$0.170	$0.50	$34	$100	$510	$1,500

Pine Knoll Shores	Units	Property Values Land	Property Values Structure	Unit Value	Total Value
Single Family	4	$264,000	$136,000	$400,000	$1,600,000
Condominium	58		$150,000	$150,000	$8,700,000
Mobile Home Lots	0		$20,000	$20,000	$0

Tax Rates/$100 Value Town	Tax Rates/$100 Value County	Unit Tax Revenues Town	Unit Tax Revenues County	Per Annum Total Tax Rev. Value Town	Per Annum Total Tax Rev. Value County
$0.16	$0.50	$640	$2,000	$2,560	$8,000
$0.16	$0.50	$240	$750	$13,920	$43,500
$0.16	$0.50	$32	$100	$0	$0

TABLE F-5

BOGUE BANKS BEACH RENOURISHMENT
PROJECT LTERNATIVE ANALYSIS
DO-NOTHING ALTERNATIVE

CSE BAIRD
STROUD ENGINEERING, P.A.

BY: J.W. Forman, Jr., P.E.
DATE: 28-Feb-00

ANNUAL PROPERTY VALUE LOSS FOR LOST OCEANFRONT PROPERTIES ADJUSTED FOR INFLATION

Annual Real Estate Appreciation Rate* 4.8%

	Emerald Isle Property Value Per Year	Indian Beach	Salter Path	Pine Knoll Shores Property Value Per Year	County Property Value Per Year
Year					
1	$68,140,000	$12,890,000	$9,100,000	$10,300,000	$100,430,000
2	$71,410,720	$13,508,720	$9,536,800	$10,794,400	$105,250,640
3	$74,838,435	$14,157,139	$9,994,566	$11,312,531	$110,302,671
4	$78,430,679	$14,836,681	$10,474,306	$11,855,533	$115,597,199
5	$82,195,352	$15,548,842	$10,977,072	$12,424,598	$121,145,864
6	$86,140,729	$16,295,186	$11,503,972	$13,020,979	$126,960,866
7	$90,275,484	$17,077,355	$12,056,162	$13,645,986	$133,054,988
8	$94,608,707	$17,897,068	$12,634,858	$14,300,993	$139,441,627
9	$99,149,925	$18,756,128	$13,241,331	$14,987,441	$146,134,825
10	$103,909,121	$19,656,422	$13,876,915	$15,706,838	$153,149,297

*From County Tax Valuation for 1987 and 1997 Reassessments
** "Inflation is Not Dead Yet", Tim Grogan, Engineering News Record, Cost Report Summary, 9/27/99

TABLE F-6

BOGUE BANKS BEACH RENOURISHMENT
PROJECT LTERNATIVE ANALYSIS
DO-NOTHING ALTERNATIVE
BY: J.W. Forman, Jr., P.E.
DATE: 28-Feb-00

CSE BAIRD
STROUD ENGINEERING, P.A.

SUMMARY OF LOST PRESENT WORTH OF TAX REVENUES ASSOCIATED WITH DO-NOTHING ALTERNATIVE

Discount Rate** 6.125%

Tax Rate/$100 Cash Flow Year	Emerald Isle 0.195 Tax Revenues Per Year	Salter Path In County	Indian Beach 0.17	Pine Knoll Shores 0.16 Tax Revenues Per Year	County 0.5 Tax Revenues Per Year
1	$132,873	$0	$21,913	$16,480	$502,150
2	$139,251	$0	$18,597	$17,271	$526,253
3	$145,935	$0	$19,489	$18,100	$551,513
4	$152,940	$0	$20,425	$18,969	$577,986
5	$160,281	$0	$21,405	$19,879	$605,729
6	$167,974	$0	$22,433	$20,834	$634,804
7	$176,037	$0	$23,510	$21,834	$665,275
8	$184,487	$0	$24,638	$22,882	$697,208
9	$193,342	$0	$25,821	$23,980	$730,674
10	$202,623	$0	$27,060	$25,131	$765,746
Present Value	$1,256,509		$171,973	$155,843	$4,748,564
TOTAL NPV	$6,332,889				

**Discount Rate is Yield on 30 Year Treasury Bond, Latest Auction reported in Wall Street Journal, 2/24/2000

TABLE F-7

BOGUE BANKS BEACH NOURISHMENT
PROJECT ALTERNATIVE ANALYSES
DO-NOTHING ALTERNATIVE
Date: 28-Feb-00
By: J.W. Forman, Jr., P.E.

CSE BAIRD
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

Annual and Present Value Associated with
Reduced Appreciation and Tax Revenue Losses due to Reduced Appreciation

Discount Rate 6.125% Reduced Real Estate Appreciation Rate 2.00%

Emerald Isle

	Historic Appreciation Rate 4.580%	Reduced Appreciation Rate 2.580%	Value Difference	Revenue Loss 0.195	Pres. Worth Tax Val. Loss	Present Worth Value Loss
1	1,095,105,083	1,095,105,083	0	0	$0	$0
2	1,145,260,896	1,123,358,794	21,902,102	42,709	$40,244	$20,638,023
3	1,197,713,845	1,152,341,451	45,372,394	88,476	$78,558	$40,286,198
4	1,252,569,139	1,182,071,860	70,497,278	137,470	$115,015	$58,981,966
5	1,309,936,805	1,212,569,314	97,367,491	189,867	$149,685	$76,761,449
6	1,369,931,911	1,243,853,603	126,078,308	245,853	$182,636	$93,659,505
7	1,432,674,793	1,275,945,026	156,729,767	305,623	$213,934	$109,709,761
8	1,498,291,298	1,308,864,407	189,426,891	369,382	$243,642	$124,944,662
9	1,566,913,040	1,342,633,109	224,279,931	437,346	$271,821	$139,395,511
10	1,638,677,657	1,377,273,043	261,404,614	509,739	$298,530	$153,092,501
				Pres. Worth	$1,594,066	$817,469,576

Indian Beach

	Historic Appreciation Rate 4.580%	Reduced Appreciation Rate 2.580%	Value Difference	Revenue Loss 0.170	Pres. Worth Tax Val. Loss	Present Worth Value Loss
1	133,575,597	133,575,597	0	0	$0	$0
2	139,693,359	137,021,847	2,671,512	4,542	$4,279	$2,517,326
3	146,091,315	140,557,011	5,534,304	9,408	$8,354	$4,913,915
4	152,782,297	144,183,382	8,598,915	14,618	$12,230	$7,194,334
5	159,779,727	147,903,313	11,876,413	20,190	$15,917	$9,362,989
6	167,097,638	151,719,219	15,378,419	26,143	$19,421	$11,424,131
7	174,750,710	155,633,575	19,117,135	32,499	$22,749	$13,381,864
8	182,754,292	159,648,921	23,105,372	39,279	$25,908	$15,240,143
9	191,124,439	163,767,863	27,356,576	46,506	$28,905	$17,002,787
10	199,877,938	167,993,074	31,884,865	54,204	$31,745	$18,673,479
				Pres. Worth	$169,509	$99,710,967

TABLE F-7

Pine Knoll Shores

	Historic Appreciation Rate 4.580%	Reduced Appreciation Rate 2.580%	Value Difference	Revenue Loss 0.160	Pres. Worth Tax Val. Loss	Present Worth Value Loss
1	444,345,692	444,345,692	0	0	$0	$0
2	464,696,725	455,809,811	8,886,914	14,219	$13,398	$8,374,006
3	485,979,835	467,569,704	18,410,131	29,456	$26,154	$16,346,375
4	508,237,711	479,633,002	28,604,709	45,768	$38,292	$23,932,299
5	531,514,998	492,007,534	39,507,464	63,212	$49,834	$31,146,435
6	555,858,385	504,701,328	51,157,057	81,851	$60,805	$38,002,926
7	581,316,699	517,722,622	63,594,077	101,751	$71,225	$44,515,417
8	607,941,004	531,079,866	76,861,138	122,978	$81,115	$50,697,073
9	635,784,702	544,781,727	91,002,975	145,605	$90,497	$56,560,595
10	664,903,641	558,837,095	106,066,546	169,706	$99,389	$62,118,234
				Pres. Worth	$530,709	$331,693,360

Carteret County

	Historic Appreciation Rate 4.800%	Reduced Appreciation Rate 2.800%	Value Difference	Revenue Loss 0.500	Pres. Worth Tax Val. Loss	Present Worth Value Loss
1	1,673,026,372	1,673,026,372	0	0	$0	
2	1,753,331,638	1,719,871,110	33,460,527	167,303	$157,647	
3	1,837,491,556	1,768,027,502	69,464,055	347,320	$308,386	
4	1,925,691,151	1,817,532,272	108,158,880	540,794	$452,459	
5	2,018,124,326	1,868,423,175	149,701,151	748,506	$590,098	
6	2,114,994,294	1,920,739,024	194,255,270	971,276	$721,530	
7	2,216,514,020	1,974,519,717	241,994,303	1,209,972	$846,972	
8	2,322,906,693	2,029,806,269	293,100,424	1,465,502	$966,635	
9	2,434,406,214	2,086,640,844	347,765,370	1,738,827	$1,080,724	
10	2,551,257,713	2,145,066,788	406,190,925	2,030,955	$1,189,435	
				Pres. Worth	$6,313,886	

Total Revenue Loss Present Value	$8,608,170	
Total Value Loss Present Worth		$1,248,873,903

TABLE F-8

BOGUE BANKS BEACH NOURI CSE BAIRD
PROJECT ALTERNATIVE ANAL STROUD ENGINEERING, P.A.
DO-NOTHING ALTERNATIVE MOREHEAD CITY, NC

Date: 28-Feb-00
By: J.W. Forman, Jr., P.E.

CSE BAIRD
STROUD ENGINEERING, P.A.
MOREHEAD CITY, NC

Summary of Annual and Present Value of Beach Scaping, Beach Access Structure Repair, and Property Values and Lost Revenues due to Reduced Property Value Appreciation

Discount Rate 6.125%

Year	Beach Scraping Annual Costs	Structure Repair Annual Costs	Debris Removal Annual Costs	Lost Property Values	Lost Revenues Due to Lower Apprec.
1	$250,000	$2,184,000	$400,000	$0	$0
2	$257,500	$2,249,520	$412,000	$3,941,169	$26,946
3	$265,225	$2,317,006	$424,360	$7,758,301	$53,126
4	$273,182	$2,386,516	$437,091	$11,454,328	$78,556
5	$281,377	$2,458,111	$450,204	$15,032,122	$103,252
6	$289,819	$2,531,855	$463,710	$18,494,494	$127,230
7	$298,513	$2,607,810	$477,621	$21,844,196	$150,506
8	$307,468	$2,686,045	$491,950	$25,083,921	$173,094
9	$316,693	$2,766,626	$506,708	$28,216,305	$195,010
10	$326,193	$2,849,625	$521,909	$31,243,929	$216,269
Pres. Worth	$2,193,446	$19,161,948	$3,509,514	$163,068,766	$1,123,988
Total Present Worth		$189,057,663			

TABLE F-9

BOGUE BANKS BEACH NOURISHMENT — CSE BAIRD
PROJECT ALTERNATIVE ANALYSES — STROUD ENGINEERING
RETREAT / RELOCATION ALTERNATIVE
Date: 2/28/00 — By: J.W. Forman, Jr., P.E.

SUMMARY OF RELOCATION COSTS (YEAR 2000 DOLLARS)

Emerald Isle	Units	House Moving Costs	Abandon Ex. Lot Value	Buy New Lot Value	Site and Constr. Costs	Unit Relocation Costs	Total Relocation Costs
Single Family							
Move On Existing Lot	26	$ 34,000			$ 44,000	$ 78,000	$ 2,028,000
Relocate to New Lot	148	$ 42,000	$ 264,000	$ 136,000	$ 44,000	$ 486,000	$ 71,928,000
Condominium	0				$ -	$ -	$ -
M. H. Replacement							

Indian Beach	Units	House Moving Costs	Existing Land Value	New Land Value	Site and Constr. Costs	Unit Relocation Costs	Total Relocation Costs
Single Family							
Move On Existing Lot	0	$ 34,000			$ 44,000	$ 78,000	$ -
Relocate to New Lot	0	$ 42,000	$ 264,000	$ 136,000	$ 44,000	$ 486,000	$ -
Condominium	0				$ -	$ -	$ -
M. H. Replacement							

Pine Knoll Shores	Units	House Moving Costs	Existing Land Value	New Land Value	Site and Constr. Costs	Unit Relocation Costs	Total Relocation Costs
Single Family							
Move On Existing Lot	19	$ 34,000			$ 44,000	$ 78,000	$ 1,482,000
Relocate to New Lot	3	$ 42,000	$ 264,000	$ 175,000	$ 44,000	$ 525,000	$ 1,575,000
Condominium	51				$ 135,500	$ 135,500	$ 6,910,500
M. H. Replacement							
					PROJECT TOTALS		**$ 77,013,000**

BOGUE BANKS BEACH RENOURISHME CSE BAIRD TABLE F-10
PROJECT LTERNATIVE ANALYSIS STROUD ENGINEERING, P.A.
RELOCATE/RRETREAT ALTERNATIVE
DATE: 28-Feb-00 BY: J.W. Forman, Jr., P.E.

ANNUAL COSTS ASSOCIATED WITH RETREAT / RELOCATION ALTERNATIVE

Cost of Moving On-Site	$ 78,000	Condo Rebuild Costs	$127,500	Mobile Home Spaces Replacem	$40,000
Cost of Moving Off-Site	$ 86,000	Annual Land Appreciation Rate*	4.8%	Commercial Spaces Replaceme	$300,000
Abandoned Land value	$ 264,000	Annual Inflation Rate for Construc	3.0%	Mobile Home Inflation	3.0%
New Lot Value	$ 136,000				

	Emerald Isle				Pine Knoll Shores			
Units	91	156	36	17	37	4	58	0
Year	Move on Lot	Move Off Site	Rebuild Condo	M.H. Spaces	Move on Lot	Move Off Site	Rebuild Condo	M.H. Spaces
1	$709,800	$7,581,600	$459,000	$68,000	$288,600	$194,400	$739,500	$0
2	$731,094	$7,921,368	$472,770	$70,040	$297,258	$203,112	$761,685	$0
3	$753,027	$8,261,136	$486,953	$72,141	$306,176	$211,824	$784,536	$0
4	$775,618	$8,600,904	$501,562	$74,305	$315,361	$220,536	$808,072	$0
5	$798,886	$8,940,672	$516,609	$76,535	$324,822	$229,248	$832,314	$0
6	$822,853	$9,280,440	$532,107	$78,831	$334,566	$237,960	$857,283	$0
7	$847,538	$9,620,208	$548,070	$81,196	$344,603	$246,672	$883,002	$0
8	$872,964	$9,959,976	$564,512	$83,631	$354,942	$255,384	$909,492	$0
9	$899,153	$10,299,744	$581,447	$86,140	$365,590	$264,096	$936,776	$0
10	$926,128	$10,639,512	$598,891	$88,725	$376,558	$272,808	$964,880	$0
	Indian Beach				Salter Path			
	0	10	32	15	10	15	45	7
	Move on Lot	Move Off Site	Rebuild Condo	M.H. Spaces	Move on Lot	Move Off Site	Rebuild Condo	M.H. Spaces
1	$0	$486,000	$408,000	$60,000	$78,000	$729,000	$573,750	$28,000
2	$0	$507,780	$420,240	$61,800	$80,340	$761,670	$590,963	$28,840
3	$0	$529,560	$432,847	$63,654	$82,750	$794,340	$608,691	$29,705
4	$0	$551,340	$445,833	$65,564	$85,233	$827,010	$626,952	$30,596
5	$0	$573,120	$459,208	$67,531	$87,790	$859,680	$645,761	$31,514
6	$0	$594,900	$472,984	$69,556	$90,423	$892,350	$665,134	$32,460
7	$0	$616,680	$487,173	$71,643	$93,136	$925,020	$685,088	$33,433
8	$0	$638,460	$501,789	$73,792	$95,930	$957,690	$705,640	$34,436
9	$0	$660,240	$516,842	$76,006	$98,808	$990,360	$726,809	$35,470
10	$0	$682,020	$532,347	$78,286	$101,772	$1,023,030	$748,614	$36,534

*Valuations from County Tax Office for Years 1989 and 1997
** "Inflation is Not Dead Yet", Tim Grogan, Engineering News Record, Cost Report Summary, 9/27/99

TABLE F-11

BOGUE BANKS BEACH RENOURISHMENT
PROJECT LTERNATIVE ANALYSIS
RELOCATE/RRETREAT ALTERNATIVE
DATE: 28-Feb-00

CSE BAIRD
STROUD ENGINEERING, P.A.

BY: J.W. Forman, Jr., P.E.

NET PRESENT WORTH OF RELOCATION/RETREAT ALTERNATIVE

Discount Rate** **6.125%**

	ANNUAL COSTS OF RELOCATION, RECONSTRUCTION*			
Cash Flow Year	Single Family Relocate on Site	Relocate Off site	Condominiums Rebuild on Site	Rebuild M.H. Sites
1	$1,076,400	$8,991,000	$2,180,250	$156,000
2	$1,108,692	$9,393,930	$2,245,658	$160,680
3	$1,141,953	$9,796,860	$2,313,027	$165,500
4	$1,176,211	$10,199,790	$2,382,418	$170,465
5	$1,211,498	$10,602,720	$2,453,891	$175,579
6	$1,247,843	$11,005,650	$2,527,507	$180,847
7	$1,285,278	$11,408,580	$2,603,333	$186,272
8	$1,323,836	$11,811,510	$2,681,432	$191,860
9	$1,363,551	$12,214,440	$2,761,875	$197,616
10	$1,404,458	$12,617,370	$2,844,732	$203,545
Present Value	$9,444,103	$82,367,407	$19,129,046	$1,368,711
TOTAL NPV	$110,940,556			

**Discount Rate is Yield on 30 Year Treasury Bond, Latest Auction reported in Wall Street Journal, 2/24/2000

TABLE F-12. Estimates of beach visits by Carteret County residents. [P is the number of annual visits made by each person to the beach.]

Town	Distance (miles)	P	x	Population (1998)	=	Annual Visits
Atlantic	40	1.615		812		1311
Beaufort	6	6.923		10,820		68,090
Cedar Island	island	0		407		0
Davis	25	2.943		430		1265
Harkers Island	15	4.390		1363		5984
Harlowe	15	4.390		1289		5659
Marshallberg	25	2.943		621		1828
Merrimon	10	5.363		591		3170
Morehead City	6	6.293		16,283		102,649
Atlantic Beach not in project		0		2308		0
Indian Beach	0	8		177		1416
Pink Knoll Shores	0	8		1543		12,344
Newport	15	4.390		18,135		79,613
Sea Level	35	0.247		649		160
Smyrna	20	3.595		843		3031
Stacy	32	2.224		434		965
Straits	30?	2.410		2129		5131
White Oak	30?	2.410		1179		2841
Williston	30?	2.410		288		694
Swansboro	35	0.247		7391		1826
Emerald Isle	0	8		1548		12,384
				68,833		310,181

APPENDIX G

APPENDIX G

Littoral Processes

APPENDIX G — LITTORAL PROCESSES

APPENDIX G1. PREVIOUS STUDIES

A substantial amount of literature exists on Outer Banks beaches, some of it specific to Bogue Banks. Generally there are two types of data that are fairly plentiful: monitoring studies of Beaufort Inlet by the Corps of Engineers and geological studies of the Outer Banks as student theses at various universities.

The Corps of Engineers studies on Beaufort Inlet are so numerous that Beaufort is used as the Corps' example of how to evaluate inlets in their Engineering Manual "Coastal Inlet Hydraulics and Sedimentation" (USACE, 1995). There is a substantial amount of bathymetric profile data for the inlet, and more recently, beach profiles for Atlantic Beach. What is generally missing are "coastal process" measurements, that is, waves, currents, tides, and sediment transport.

The student theses from Duke University, North Carolina State University, and University of North Carolina are rich in information about the geology of the islands themselves (hundreds of core samples taken on various barrier islands and sometimes profiles of the beach), but they are quite sparse in information for the underwater portion of the beach. Core samples and beach profiles generally end at the water line.

Many of the findings in the literature relevant to a Bogue Banks beach-nourishment project are listed in Table G1.

TABLE G1. Literature Summary — Historical Documents

Thesis on relict inlet locations — 1962. UNC. Fisher, J.J., Geomorphic expression of former inlets along the Outer Banks of North Carolina, 120 pp.

- Summary of former inlets in NC, as detected by geomorphology
- Distribution of relict inlets for entire outer banks shown in Figure 4
- Aerial photo of 3 Atlantic Beach relict inlets in Figure 5
- 1860 map of Atlantic Beach relict channels, Figure 6
- Opening history of Beaufort Inlet, p. 88
- Opening history of Bogue Inlet, pp. 88-89
- Opening history of Bogue relict inlet #1, pp. 89-90
- Opening history of Bogue relict inlet #2, p. 90

Study on hurricane impacts on Bogue Banks — 1966. USACE. Beaufort Inlet to Bogue Inlet, North Carolina. US House Document No. 479, 89th Congress.

- Survey of hurricane damages
- Recommends flood dike for west side of New River. Other protections not economically feasible
- 8 hurricanes listed, 1953-60, p. 16
- Hurricane surges, 1953-60, p. 17
- Hurricane tracks, 1953-60, p. 18
- Hurricane damages, 1953-60, p. 19

Dissertation on geologic history of Bogue Banks (UNC Chapel Hill) — 1967. UNC. Fisher, J.J. Development pattern of relict beach ridges, Outer Banks barrier chain, North Carolina, 247 pp.

- Maps of 300+ relict beach ridges on Bogue Banks, with 7 sequences (Fig. 53)
- Sequential development of Bogue Banks, Fig. 57
- Soil map for Bogue Banks, Fig. 58

NCSU study on North Carolina beach erosion — 1973. NCSU. Knowles, C.E., J. Langfelder, and R. McDonald. A preliminary study of storm-induced beach erosion for North Carolina. NCSU Rept. No. 73-5, 14 pp. + figs.

- Topographic surveys along each fishing pier
- Storm surge levels recorded and plotted as function of return frequency
- Design surge levels and breaking-wave depths, Table 1
- Estimated beach recession for 25 yr storm (21 ft), 50 yr (162 ft), 100 yr (220 ft) at Bogue Banks, Table 2
- Plot of storm surge versus return period (Fig. 1)

Thesis on Shackleford Banks geology and subsurface sediments — 1975. Duke. Susman, K.R. Post-Miocene subsurface stratigraphy of Shackleford Banks, Carteret County, North Carolina, 70 pp + app.

- Sediment-size statistics, radiocarbon dates, and fauna count for core samples within Shackleford Banks (Tables 1-3)
- Schematic cross-section of Shackleford, Fig. 4

Morehead City harbor general design memorandum — 1976. USACE. Morehead City Harbor, North Carolina, General Design Memorandum, USACE-Wilmington, 41 pp. + app A-F.

- Recommended increasing navigation channel depth to 40 ft in harbor and inlet and 42 ft in ocean approach.
- Proposed disposing of sediment along 4000 ft of Shackleford by hopper, initial disposal via pipeline dredge on the eastern 5000 ft of Atlantic Beach, and later disposal via pipeline for additional 25,000 ft west of the 5000 ft
- Inlet migration and throat width, pp. B2-3
- Table of dredging volumes through 1974, pp. B5-6
- Hurricane surge and winds for *Donna*, 1960, table, p. B8
- Table of tidal currents, p. B10
- Cumulative dune-line location for entire island, p. B17
- Hydrographic surveys since 1839 showing channel, plate B1
- 8 beach profile transect taken well offshore in 1958 and 1972, plates B6-B9
- Appendix C: longshore transport analysis from ship-based winds
- Attachment D1: boring logs
- D6-D7: grain-size information. **Reaches shown on Plate D-3. Reach P (inner harbor) has retention of 60% (Ra of 1.67); Outermost (ocean) Reach Hc has retention of 68% (Ra of 1.47); composite retention for all of H(a-c) is 80% (Ra of 1.25). Thus 1.25 is best estimate of beach-fill material Ra. Native material is rather fine, with mean of 2.52 phi (0.17 mm) and standard deviation of 0.77 phi.**
- Sediment transport conclusions: (1) transport is to the east (75%), (2) shoaling occurs more on the west side of the channel (68% of the channel shoaling), (3) bypassing efficiency of the inlet dropped from 52% to 28% after dredging, (4) net transport is about 14% of the gross

Thesis study of sediments and geology of Bogue Banks — 1977. UNC, Goff, W.T. Sedimentation in a modern tidal inlet: Bogue Inlet, North Carolina, 117 pp + app.

- Analysis of 244 bottom samples, 20 can cores, 9 trenches in Bogue Inlet
- Sketch of inlet geomorphics compared to Hayes' model, Fig. 2 and 3
- Mean tide range at Bogue (71 cm) and Beaufort (96 cm), p. 11
- Bathymetric map, Fig. 5
- Inlet migration maps, Fig. 7
- Sediment size-distribution map, Fig. 8
- Percentage shell content, Fig. 13
- Transport paths inferred from ripple/sand-wave geometry, Fig. 18
- Sediment environment map, Fig. 26
- Sediment environment vertical cross-section Fig. 28 (cross-shore)
- Fig. 29 (longshore)

Thesis on geology and sediments of Outer Banks — 1977. Duke. Moslow, T.F. Quaternary evolution of Core Banks, North Carolina, from Cape Lookout to New Drum Inlet, 171 pp.

- Analysis of many core samples from within Core Banks, nothing south of Cape Lookout
- Radiocarbon dating, macrofauna counts, and analysis of each depositional environment

- Comparison of relict and modern inlets, p. 108
- Rates of landward migration of Core Banks, 50-100 m/century, p. 102

Thesis on coastal process measurements in Beaufort Inlet — 1977. Duke. Sarle, L.L. Processes and resulting morphology of sand deposits within Beaufort Inlet, Carteret County, North Carolina, 152 pp.

- Storm frequencies, p. 14, 1.64 hurricanes per year for Bogue Banks
- Monthly wind roses, p. 19
- Data collected: surveys, fathometer, tidal currents, and grab samples
- Fathometer traverses all in Sound, locations p. 27, results, p. 98
- Tide measurement locations, p. 29
- Sediment sample locations, p. 31
- Tidal velocity data summary, p. 34
- Average curves for spring, neap, mean tides, p. 36
- Sedimentary structure flow-indicator classification, p. 40
- Tidal velocity curves for each station, p. 45-54
- Sketch of pre-dredging model of Beaufort Inlet, p. 57
- Western growth rate of Shackleford Spit, p. 66
- Morphological classifications of underwater topography: map p. 74, sketch p. 84
- Aerial photo with tidal current directions superimposed, p. 135
- Conclusion: tidal current velocities increased because of narrowing of inlet by stabilizing Fort Macon State Park and western growth of Shackleford, p. 139
- Conclusion: dredging causes sediment to be transported seaward and deposited in deeper water, where it is not available for beaches, p. 139

Thesis on geology and sediments for Core Banks — 1978. Duke. Herbert, J.R. Post-Miocene stratigraphy and evolution of northern Core Banks, North Carolina, 140 pp.

- Sediment size analysis, geological history, and inlet cross-sections, all north of New Drum Inlet

Thesis on sedimentation of Shackleford Banks — 1979. Duke. Berelson, W.M. Barrier island evolution and its effect on lagoonal sedimentation; Shackleford Banks, Back Sound, and Harkers Island: Cape Lookout National Seashore, 220 pp.

- Textural and size analysis of core samples throughout and landward of Shackleford, but no data offshore

Thesis on sediments in Bogue Banks — 1980. Duke. Steele, G.A. Stratigraphy and depositional history of Bogue Banks, North Carolina, 220 pp.

- 42 bore-hole locations on Bogue, p. 10 (none offshore)
- No prevailing longshore transport direction, except at eastern end, where sand accumulates on west side of jetty (p. 13)
- Monthly wind roses, p. 15
- Tide discussion, p. 16; maximum ebb in Beaufort 116 cm/s, flood 106 cm/s; tidal prism of Bogue Sound 80 million cubic meters
- Dune-line change along entire island, 1964-71, p. 18
- Sediment analyses: faunal counts, lithology, radiocarbon dating, size
- Detailed discussion of geologic history, by community, pp. 91-142
- Summary of Bogue Banks forming, pp. 165-167

Planning brochure on options for stabilizing Bogue Inlet — 1980. USACE. Planning Brochure for Bogue Banks Stage II Study, 21 pp.

- Summarizes Phase II study for inlet stabilization
- p. 20 summarizes plans; bottom line is that only channel deepening (by only 2 ft from 6 ft to 8 ft) is economically justified; all structural alternatives examined were not economical

North Carolina erosion task force report — 1984. NCDNRCD. Coastal Resources Commission's Outer Banks Erosion Task Force Report, 29 pp.

- Evaluated the following alternatives for responding to coastal erosion: (1) hardening (seawalls), (2) trapping (groins), (3) nourishment, (4) dune building, (5) beach pushing (scraping), and (6) relocating threatened buildings. General cost comparisons were made:

Sandbags	$125-250/ft/yr
Bulkheads	$25-50/ft/yr
Revetments	$5-15/ft/yr
Groins	$12-25/ft/yr
Breakwaters	$60+/ft/yr
Beach pushing	$200/ft/yr
Nourishment	$240/ft/yr

- Determined that federal nourishment projects have taken 15-18 years to authorize, with a minimum of eight years.
- Conclusions: an unobstructed public beach is essential to the continued vitality of the tourism industry.
- Beach nourishment is the preferred response to erosion.

Sedimentation study of Shackleford Banks/Cape Lookout — 1984. Marine Geology. Heron, S.D., T.F. Moslow, W.M. Berelson, J.R. Herbert, G.A. Steele, and K.R. Susman. Holocene sedimentation of a wave-dominated barrier-island shoreline: Cape Lookout, North Carolina, Vol. 60, pp. 413-434.
- Process/response model of wave-dominated barrier islands in sand-rich environments with 5 parts of model in Fig. 8
- Per Nummedal et al. (1977) classification, area has relative to the rest of the southeastern United States: high waves, small tidal range, little ebb-tidal delta, and large inner shoal area
- Waves average 1.7 m height with 2 m exceeded 30% of the year, more than anywhere else in southeastern United States (Nummedal, Fig. 2)
- Bogue summarized in section lower-energy depositional limb with vertical sequence of sediments in Fig. 15

Vibracore data and interpretation for Bogue Banks — 1985. Marine Geology. Hine, A.C. and S.W. Snyder. Coastal lithosome preservation: evidence from the shoreface and inner continental shelf off Bogue Banks, North Carolina, Vol. 63, pp. 307-330.
- Analysis of Bogue shelf based on drill holes on Bogue Banks, 125 vibracores on shelf, and seismic data
- Much of sand deposits removed from shelf, but paleochannels with sand identified (fig. 2)
- Isopach map of Quaternary deposit thicknesses, fig 6, shows sands confined very close to shore and within the paleochannels
- Shoreface is narrow, generally 12 m deep and 500-800 m wide

Morehead City harbor improvement feasibility report and environmental assessment — 1990. USACE. Feasibility report and environmental assessment: Morehead City harbor improvement, Morehead City, North Carolina, App. A-F.
- Coastal engineering information in Appendix C contains:
  - Tides (IIB)
  - Changes in shoreline volumes (IID), including historical rates (Table 20) and recent (since dredging) rates (Table 21); Fort Macon recent erosion is explained as erosion of the large (1.2 million cy) nourishment placed in 1978
  - Longshore transport calculations in Section IIE and later are all based on wind hindcasts and are thus suspect
- Channel boring logs are in Appendix D

Morehead City general design memorandum (updated) — 1992. USACE. Design memorandum and environmental assessment: Harbor improvement, Morehead City, North Carolina, 50 pp. + App. A-M.
- Project encompasses deepening of outer harbor, extending ocean approach dredging, and enlarging harbor
- Proposed disposal for inner harbor is via pipeline to Brand Island, with pumpout to Atlantic Beach every 8-10 years; deposit outer harbor material on nearshore berm at 20 ft contour
- Disposal alternatives and their unit costs in Table 15, p. 37
- Analyzed potential for nearshore berm to move using Hands/Allison figure and WIS hindcast data to determine currents (p. C12); results suggest active motion; also applied LTD program, which also suggested active motion of berm (p. C13).
- Appendix D contains bore logs and sieve analyses, but no computation of composite size and overfill ratios

Shoreline erosion methods and maps — 1997. NCDEHNR. Benton, S.B., C.J. Bellis, M.F. Overton, J.S. Fisher, J.L. Hench, and R. Dolan. North Carolina long term average annual rates of shoreline change: methods report 1992 update, 20 pp. + app A-F.

- Uses both wet/dry line and vegetation line to estimate shoreline changes; latest update is 1992; previous updates in 1986 and 1980
- Bogue USGS maps are Q19-Q22 and SNC54-65; SNC photogrammetry available for Bogue in 1943, 1959, 1980, 1986, and 1992

Preliminary 111 evaluation on causes of erosion at Pine Knoll Shores — 1998. USACE. Preliminary Section 111 evaluation, Morehead City Harbor/Pine Knoll Shores, North Carolina, 15 pp. + figs.

- Lists dredging history in Tables 1 and 2
- Beach disposal volumes and locations, p. 3
- Pine Knoll Shores interests claim disruption of westerly LST by navigation channel and also increased flow (and thus sediment) into harbor because of increased tidal prism
- The results of the two previous LST studies are summarized below:
  1) The Corps of Engineers 1976 study compared two time periods relative to navigation-channel maintenance, before (1854-1936) and after (1960-1974) and concluded: (a) sediment transport is to the east (75%), (b) shoaling occurs more on the west side of the channel (68% of the channel shoaling), (c) bypassing efficiency of the inlet dropped from 52% to 28% after dredging, and (d) the net transport is about 14% of the gross.
  2) The Corps of Engineers 1990 study concluded that (a) the gross transport rate was about 600,000 cy/yr greater than shown in the 1976 study, but (b) the net transport proportion was about the same as in the previous study, in this case 78% of the total.
- The current study uses updated 1993 WIS hindcasts that show sufficiently changed wave-direction predictions from the past studies, that the transport direction may be from west to east. The use of the updated hindcasts in LST equations was not performed in this preliminary phase of the study, but postponed till the next phase.
- Tidal ranges increased 0.1-0.4 ft in the Sound after the 40 ft project deepening, thus increasing the tidal prism and flow rates.
- Analysis of Corps profiles uses both wet/dry line and vegetation line demarcations to examine shoreline erosion rates
- Conclusions: (1) Pine Knoll Shores has higher erosion rates than areas further west along Bogue. (2) WIS hindcast updates suggest the possibility of westward LST. (3) Tidal prism has increased, suggesting the possibility of increased sediment trapping in the inlet. These three factors plus annual removal of 325,500 cy by the harbor project suggest a possible impact on the beach. Further study was recommended.

Wave hindcast study on erosion impacts of Morehead City navigation channel maintenance — 1998. UNC. Roessler, T.S. Effects of offshore geology and the Morehead City Harbor project on Eastern Bogue Banks, North Carolina, 112 pp.

- General conclusion: dredging has increased the tidal prism, thereby increasing tidal velocities and ebb-tidal delta to move seaward. This increases gradients in longshore currents during storms and thus increases erosion.
- Maps of Beaufort Inlet channel since 1850, Fig. 2
- Inlet location now stable, since western side is jettied
- Dredging has occurred since 1911; inner harbor now dredged every two years, outer channel every year
- Dredging location and disposal sites, Fig. 4; volumes, Table 1
- Beach profiles collected monthly over two years on 13 transects in AB and PKS
- Longshore currents computed from offshore winds, RCPWAVE wave model, and Komar's longshore current equation
- Erosion for AB 1958-1972, Fig. 7
- Beach nourishment volumes changes, 1986 and 1994, Fig. 9
- Measured erosion rates of nourishment sand, 1996-1998, Fig. 10
- Volumetric and linear erosion rates from this study and NCDCM, Fig. 14
- Hurricane-induced erosion, Fig. 23
- Recent bathymetric map, Fig. 31; maps from 1854, 1925, and recent, Fig. 34

- Summary of effects of dredging, p. 860
- Conclusions:
  - Net longshore sediment transport is to the west
  - During hurricanes disposal area decreased longshore currents on beach
  - Progradation of ebb-tidal delta caused by dredging increases erosion at PKS
  - Dredging alters longshore currents from large storms and may increase erosion

Historical beach profile data set
- 1998. UNC. Bogue Banks historical beach profile data set; digital files provided by T.S. Roessler.
- 1978. USACE (Wilmington). Bogue Banks historical beach profile data set provided by Tom Jarrett

USACE/Pine Knoll Shores (PKS) — series of correspondence (various dates) — USACE. Correspondence between USACE-Wilmington, Pine Knoll Shores, Carteret County, and NCDEHNR contain the following relevant information.
- Cost-sharing documents provided by County show annual estimated cost of harbor-depth maintenance of $5,000,000 federal and $50,000 state. Sand is piped to Brandt Island, and is periodically pumped to nourish Atlantic Beach.
- Federal feasibility study is underway to determine whether federal navigation maintenance is eroding Bogue Banks (specifically Pine Knoll Shores). Expenditures on study to date total $54,000. Completion of study to cost $400,000 more, 50/50 federal/state cost split. Nourishment project estimated at $1,678,000 federal and $904,000 state costs.
- Proposed plastic pipeline plan for nourishing Bogue submitted by Bill Price to Carteret County. Feasibility of using small-diameter plastic pipe was evaluated by a rental company that has not performed beach nourishment. Phone check with a company specializing in beach nourishment confirms that the material and diameter would not withstand required pressure and stresses imposed by sand slurry.
- Series of correspondence between USACE-Wilmington, Pine Knoll Shores, and Sen. Helms provides the following information regarding possible use by PKS of sand dredged from the harbor and navigation channel:
  1) Option 1 is for direct pumping from Beaufort Inlet via ocean-certified dredge. Additional cost for 1 million cubic yards is estimated at $2.75-$4 million
  2) Option 2 is hoppers with direct pumpout capability with additional cost for 1 millon cubic yards at $4 million
  3) Option 3 is transport by pumpout hopper and later redistribution by dredge and pipeline, additional cost at $5-6 million
  4) Total available sand in harbor and range A (approach channel) is typically 1.6 millon cubic yards
  5) Corps says their surveys show stable or accretionary beaches for 6.5 miles west of Beaufort Inlet, since beach has been nourished
  6) PKS does not have full public beach access and is thus not currently eligible for 50/50 cost sharing of the additional costs under WRDA 1986
  7) Brandt Island disposal reaches capacity every 8-10 years and is not expected to be used as nourishment source again until 2002-4.
- State DEHNR cost-sharing with local governments for areas allowing public access can be up to 75% of non-federal costs for construction and 50% for preliminary studies and engineering. Typical state contributions in other NC beach nourishment projects ranged from $105,000 to $6,000,000. Detailed cost-sharing breakdowns with these other local governments are enclosed in the gathered materials.

APPENDIX G2. DIMENSIONS OF LITTORAL ZONE (Depth of Closure)

The dimensions of the active area of the littoral zone are of interest, since nourishment projects are supposed to move sediment from regions where it is not part of the beach system to locations where it will help build the active beach. If the nourishment sand were to simply be moved from one location to another within the beach system, then it is questionable whether such a project has a significant net value. To answer this question, standard coastal engineering practice is to determine the "depth of closure" where sequential beach profiles at the same location "close" to the same offshore location, indicating very infrequent motion.

Closure depth is sometimes erroneously referred to as the "depth of no motion" in some publications. The standard definition (Hallermeier, 1978) is the depth beyond which there is active seabed motion for an average of only 12 hours per year. This standard definition has been incorporated into the standard texts, such as the Shore Protection Manual (CERC, 1984).

To be confident of the results, we used several different methods of determining depth of closure. Described below are six methods, three of them computational methods using different wave databases, and three of them empirical geological evidence specific to this site.

1. From Nearshore Hindcast Wave Data

Closure depth is supposed to be computed from wave databases **nearshore**, that is in the general vicinity or depth at which closure is often found, typically in the 30 to 50 ft range. A de facto standard that has arisen is the 10-meter depth, for two reasons. The Corps of Engineers has its Phase III Wave Information Study stations at 10m depth. Also, the national field testing center for coastal engineering, the USACE Field Research Facility in Duck, North Carolina, has its permanent wave-measuring array at 10m depth. That station makes measurements of both waves and the resulting changes in beach topography, so tests of depth-of-closure methods are made with those data.

The data used in these computations were the Phase III 10m-depth hindcast waves at Stations 96 and 97 (USACE, 1983). Stations 95-97 are along Bogue Banks, with Station 97 for the western third, 96 the middle third, and 95 the eastern. Our project does not encompass nourishment for the eastern third. The 12-hour-per-year data were selected as the 80 highest readings out of the 58,440 predictions each year. This database averages all years during 1956-75, but does not include hurricanes. The 80th highest wave height was selected by interpolation between the tabulated bands and was determined to be 2.63m for Station 96 (mid-Bogue) and 2.47m for Station 97 (western Bogue). Wave periods were computed by weighting the periods in each height band by the number of occurrences in each band and produced 8.82 sec for #96 and 8.74 sec for #97.

There are two accepted equations for computing depth-of-closure:

(Hallermeier, 1978) $d_l = 2.28\ H_e - 68.5\ (H_e^2 / g\ T_e^2)$

(Birkemeier, 1985) $d_l = 1.75\ H_e - 57.9\ (H_e^2 / g\ T_e^2)$

where d_l is closure depth, H_e the extreme wave height (12 hrs/yr), T_e the associated wave period, and g the acceleration of gravity.

The latter method was determined from a study correlating measured waves with depth of observed motion at the North Carolina FRF site. Considering the proximity of that site to Bogue Banks suggests it is more appropriate for this project. Furthermore, the measurement methods were cruder and less accurate in the earlier study. The results from both equations in feet below MLW are:

Mid-Bogue:	Hallermeier 17.6 ft (5.38m)	Birkemeier 13.4 ft (4.08m)
Western Bogue:	Hallermeier 16.6 ft (5.07m)	Birkemeier 12.6 ft (3.85m)

2. From UNC Measured and Modeled Storm Waves

A University of North Carolina study (Roessler, 1998) shoaled the deep-water WIS database (Station 46, 1975-93) over bathymetry with the model RefDif. That work examined the resulting currents and potential sediment transport for the **average** wave conditions in that database. In addition to that main part of the study, certain storm wave conditions were modeled using brief visual measurements of the waves. The storm-wave input data were H = 3.0 m, D = 158 TN, and T = 15 sec. These storm waves were generated by the simultaneous combined distant departure of Hurricane *Bonnie* and approach of Hurricane *Fran*. Inserting these numbers in the two equations yields depth of closure of 21.5 ft (6.56m) (Hallermeier) and 16.4 ft (5.01 m) (Birkemeier).

3. From UNC Modeled Hurricane Waves

The same UNC study (Roessler, 1998) modeled the direct effects of Hurricanes *Bertha* and *Fran* for the conditions when they were in the immediate vicinity of Bogue Banks. These very brief extreme conditions produced results that varied somewhat along the study area, but which were fairly unvarying for the study area west of Atlantic Beach, with wave heights of about 7 m and period of 15 sec. (This result of 7m wave height is expected for the most extreme condition possible, because it is the highest wave that can possibly exist in the depths modeled, referred to as "depth limited".) The results from the two equations are 47 ft (14.44m) (Hallermeier) and 36 ft (10.96m) (Birkemeier).

4. Measured Closure Depths at Duck

The results presented thus far are predictions from equations, whereas measurements of both waves and resulting seabed motion were made at the reasonably close site of Duck, North Carolina (on the exposed open-coast Outer Banks close to the Virginia border). The results are reproduced here as Table G2-1 and Figure G2-1. Equation (1) in the table is Hallermeier and (2) is Birkemeier. Equation (3) is a simpler less accurate version of the Birkemeier equation. The results indicate a range of depths between 3.9 and 6.4m. These "ground truth" measurements appear to validate use of the Birkemeier equation results computed in Section 1 above for Bogue of 3.8 to 4.1m. It is expected that results for Bogue would be on the low end of the measured values at Duck, since Bogue is a south-facing beach protected from more of the wave climate than the east-facing Outer Banks site at Duck.

TABLE G2-1. Wave and limit depth data (from Birkemeier, 1985). [Note: 1 m = 3.281 ft]

Closure Estimate (1)	Wave Data: Date (2)	Wave Data: H (m) (3)	Wave Data: T (sec) (4)	Limit Depth (d_l) in Meters Below MLW: Measured (5)	Predicted (Eq. 1) (6)	Best Fit (Eq. 2) (7)	Best Fit (Eq. 3) (8)
1	08/20/81	3.3	10.2	4.0	6.8	5.2	5.2
2	10/12/81	2.7	6.8	3.9	5.1	3.8	4.2
3	10/31/81	2.3	9.3	4.3	4.8	3.7	3.6
4	11/14/81	3.9	12.9	6.4	8.3	6.3	6.1
5	11/25/81	3.0	8.4	5.0	6.0	4.5	4.7
6	01/01/82	2.9	10.9	4.8	6.1	4.7	4.5
7	10/12/82	2.4	12.0	4.2	5.2	4.0	3.8
8	10/24/82	3.8	10.8	5.2	7.8	5.9	6.0
9	11/23/82	2.5	14.0	4.3	5.5	4.2	3.9
10	12/13/82	3.7	10.0	6.1	7.5	5.7	5.8

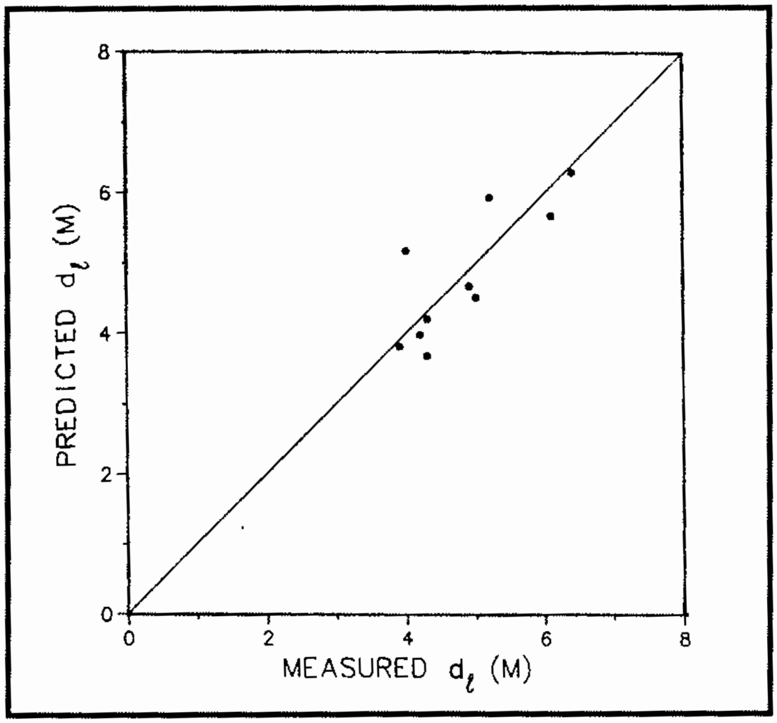


FIGURE G2-1. Best-fit comparison between predicted (Eq. 2) and measured d_l (from Birkemeier, 1985).

5. UNC Sediment Texture Study (Reed, 1997)

For this thesis, measurements were made of the color, texture, and size distribution of beach sand, shelf sand, and nourishment sand from Pine Knoll Shores to Shackleford Banks. The nourishment sand was from navigation-channel and harbor dredging projects by the Corps of Engineers. The excavation and delivery methods of the nourishment sand were similar to those proposed for this project, although the sand in the Corps project was significantly finer than that proposed in this project. Numerous surface grab samples enabled classification of sand type on the bed, and the results are reproduced here as Figure G2-2. The important point for this project is the solid line separating the native or replenishment sands from the shelf sands. The fact that the shelf sands are staying in place and not moving onto the beach in any quantifiable amounts suggests that the bounding line is one measure of the depth of closure.

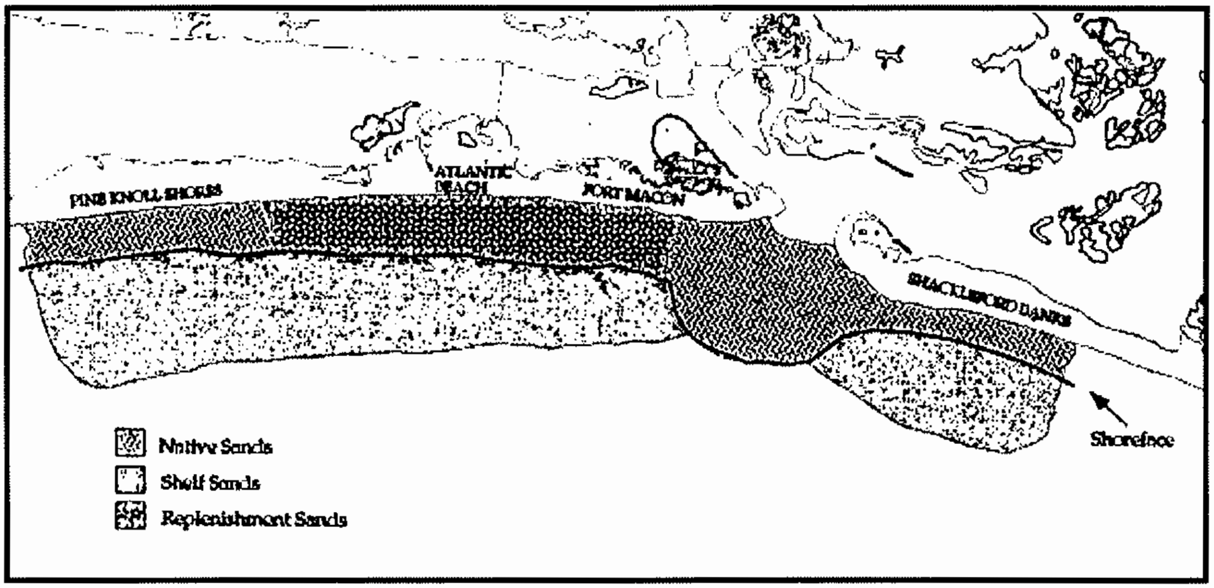


FIGURE G2-2. Interpretive map of offshore sediment distribution during the spring 1997 sampling period.

The figures in the thesis do not show bathymetric contours, so to estimate the bounding depths from the figures, we computed a scale conversion factor between the thesis figures and NOAA Chart #11543. Each 1.4 unit of distance on the NOAA chart equals 1 in the thesis figures, and this enabled us to determine depths of the solid bounding line at the following locations alongshore:

At the western end of the study area, d_l = 33 ft.
At the Pine Knoll Shores/Atlantic Beach border, d_l = 33 ft.
Along the line formed by the causeway to the mainland, d_l = 32 ft.
At the Atlantic Beach/Fort Macon border, d_l = 24 ft.

The latter two sites are east of and outside of the proposed project area.

The appropriateness of the contour data presented in Figure G2-2 for use in determining depth of closure is addressed in the thesis. Our professional opinion is that the data presented in the thesis are valid and useful and that the following opinions regarding their usefulness are incorrect and the result of misinterpretation of valid data (Reed, 1997, p. 66):

"The interpretive maps of offshore sediment distribution (Figures 17 A and B) may appear to indicate a closure depth, however this is only a result of the limitations of contour maps. . . . the stratigraphy of the cores (Cores #1-6), are better able to represent the history of sediment transport. Also, most sediment is transported offshore, past the designated "closure depth" during brief, but significant, storm events that are best recorded in the shallow stratigraphy and rippled scour depressions features."

In rebuttal to the three sentences above:

1) No evidence is presented in the thesis invalidating the results in the contour maps. Great care was taken in classifying the sediment types, and large numbers of grab samples allowed detailed delineation of sediment boundaries.

2) In three of the very small number of six cores taken, there are coarse shelly layers that are properly classified as to type of sediment, but their source is identified as "storm event" with no evidence to support that cause. Similar deposits were found in many of our core samples, which previous studies (Hine and Snyder, 1985) correctly identify as lag deposits from relict inlets and times of lowered sea level. No mechanism is identified in the thesis (e.g., computation of threshold velocities) for producing these deposits with current conditions.

3) The final sentence refers to sidescan sonar images collected by Thieler (1997), which identify linear ridges of coarser deposits. Those images of sand waves are consistent with the relict flows and conditions identified by Hine and Snyder (1985). Again, no mechanism is proposed in the thesis for causing these features under current conditions.

6. Non-motion of Nearshore Berm

The most conclusive hard evidence of the depth at which significant seabed motion occurs is the lack of motion of the Corps of Engineers' nearshore berm, a mound of dredged sediment disposed offshore of Atlantic Beach. The intended concept was to use the Beaufort Inlet navigation channel's dredged sediments for a beneficial purpose of feeding the beaches, rather than dumping the materials offshore in much deeper water where they would not move. Unfortunately, the originally intended placement depth of 18ft MLW was changed to 25-30 ft (USACE, 1994, p. 11), and the result from the monitoring survey is little motion, "little" meaning less than the error in survey methods. This confirms that **sediment deeper than 30 ft will not contribute to the beach** system.

Conclusions

1) Hindcast data of extreme (12hr/yr) conditions produce depths of closure between 13 and 18 ft MLW.

2) Measured storm conditions produce closure depths between 16 and 22 ft.

3) During the few hours that hurricanes are present in the immediate vicinity, closure depth has been computed as 36 ft.

4) The limit of sediment activity was measured at a nearby but more open-coast site at between 3.9 m and 6.4 m (13-21 ft).

5) Mapping sediment types by color, texture, and size result in a boundary between beach and shelf sands between 32 and 33 ft depths.

6) The Corps of Engineers nearshore berm off of Atlantic Beach in 25-30 ft depths has not exhibited significant motion and has not contributed sediment to the beach.

APPENDIX G3. WAVES

Databases of wave climate were utilized for the purposes of (1) characterizing the site, (2) use in final design of beach fill sections and berm heights, (3) use in computing potential longshore sediment transport (summarized in the next Appendix G4), and (4) changes in waves on the beach caused by dredging the borrow sites. Only the last item will be detailed here.

Several different estimates of the wave climate have been computed by the US Army Corps of Engineers over the years. All of these data have come from models relating offshore winds to the waves that they create. There is no wave database for the Bogue Banks area. As a measure of how inaccurate this method of computing waves from winds is, note that the resulting annual average sum of wave energy flux along the beach has changed direction, as the Corps uses different methods over the years for estimating the winds. Thus the current methods are incapable of resolving the question of total longshore wave-energy flux. Nevertheless, this database is thought to be somewhat more reliable for relative changes. That is, comparisons of percent changes in the same database under different scenarios are likely to be more accurate than the actual values of wave-energy flux.

The Corps' Wave Information Study data of waves computed from wind models is divided into separate data sets by: (1) location or "Station," (2) depth or "Phase," and (3) time period.

1) For the computations below, we used Station 45, which is the station directly south of Bogue (at 34° 15' latitude, 77° 00' longitude and 27 m depth). The next closest station, #46, is offshore of Atlantic Beach.

2) WIS data appear in three Phases. Phase I is in deep water. These waves are then refracted in to form the databases at the Phase II stations, typically in 20-30 m depths. Along some coasts data are refracted into Phase III stations at 10m depth. Up-to-date Phase III data for the Atlantic Coast do not exist. (The only Phase III data are in old reports using hindcast methods that are no longer used.) Thus we used the Phase II data for wave-energy computations.

3) Data have been hindcast for two time periods: 1956-75 and 1976-95. The two databases are not directly comparable, since different methods for estimating the winds and shoaling the waves were used. Furthermore, a statistical average of hurricane-generated waves were included in the 1976-95 database, but not in the earlier one. The wave-energy comparisons we made used the more recent 1976-95 database. We used this database to compare before-and-after dredging scenarios for the **relative** change in wave heights and energies. However, caution should be used in accepting the longshore energy fluxes computed from this database, since independent analyses (Reed, 1997; CERC, 1984, Table 4-7) suggest the longshore fluxes are unrealistically high.

The Automated Coastal Engineering System (ACES) program was used to shoal the waves from the offshore Phase II station 45 into the borrow areas. The subroutine "Linear Wave Theory with Snell's Law" was used. The main limitation of this program is that it assumes depth contours are straight and parallel. For the depths offshore of borrow area A this is a reasonable assumption, but is less so the closer to shore one approaches. The other main assumption is that wave data of different periods (or wavelengths) and direction can be shoaled separately and then recombined ("linear superposition"). Compared to the other assumption of parallel contours, this assumption is quite good for the depths we used in the model, since we did not shoal waves inshore of the innermost borrow area B. A graphical representation of the shoaling process is illustrated in Figure G3-1. Note that as the waves cross various depth contours as they approach the coast, the wave crests turn to become more parallel with the coast. As this happens, the wave heights (and energies), wave angles, and energy fluxes change.

Borrow area A is between depths 50 ft and 40 ft, and B is between 40 ft and 30 ft. Thus the first step was to shoal the WIS wave data from 27m (88.6 ft) to 50 ft. From CERC's website, the WIS datafile "au2percnt.045" was used as input. Only the directional bands from which it is possible for waves to approach Bogue Banks were used. WIS uses numbered bands to identify directions. Bands 6 through 12 produce waves that are within the half of the compass facing the beach. The angle of the shoreline for this application was measured as 171d for "shore normal" for the section of Bogue at borrow areas A and B-1 (approximately at the Salter Path/Emerald Isle border). Inputs into the shoaling model were the WIS statistics of mean wave height and period (Hmo and Tp), depth, wave directions, shoreline angle, and bottom slope from NOAA charts. Outputs for the wave conditions at the seaward side of borrow area A (depth of 50 ft) are shown in Table G3-1. As expected in these still relatively deep depths, wave heights decrease slightly, and energy flux remains constant.

The next step was to shoal waves over the existing topography in borrow area A. The results in Table G3-2 still show little change in total wave heights and energy flux.

The change in conditions if 6 ft of borrow area A is dredged is shown in Table G3-3. The results show a wave height increase of 0.2 ft, an increase in height of 2%, an increase in energy of 4%, and an increase in longshore energy flux of 9%.

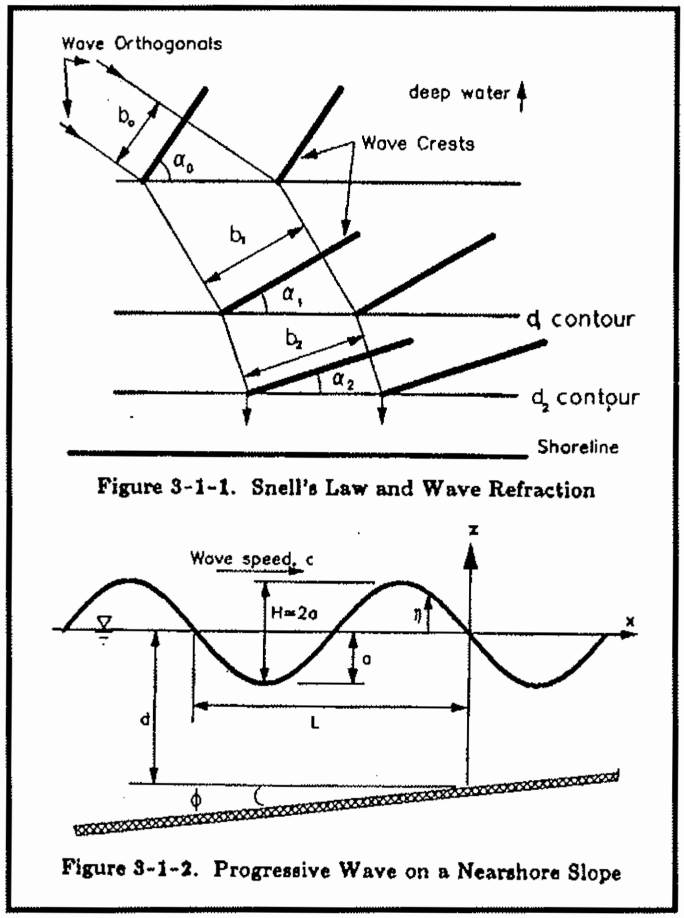


FIGURE G3-1.

The maximum dredging of borrow area A is not expected to be as large as 6 ft. That case was computed to show an extreme condition. The maximum anticipated dredging of the borrow area is 4 ft. The results for that scenario are listed in Table G3-4 and show a 1% increase in wave height of 0.1 ft, an energy increase of 2.5%, and an energy flux increase of 6%. Like the 6 ft scenario, this one should be viewed as unrealistically extreme, since the entire borrow area will not be dredged to this depth. Only localized areas within the delineated borrow area limits would experience this extreme of sediment removal.

The most realistic scenario for dredging is a 2 ft cut in borrow area A. The results in Table G3-5 show a 0.6% increase in wave height of 0.1 ft, a 1% increase in energy, and a 3% increase in energy flux.

To examine the effects of dredging the nearshore borrow areas B, the existing conditions in borrow area B1 were first computed and are listed in Table G3-6. Since the waves are now shoaling over shallower water, energy is being used in the shoaling process, and there are decreases in all relevant quantities of height, energy, and flux.

The maximum expected cut in borrow area B is 4 feet. The scenario of dredging B but not dredging A is investigated in Table G3-7. Results show less than 1% increase in wave height of less than 0.1 ft, a 1.5% increase in energy, and a 9% increase in energy flux.

The combined effect of dredging both borrow areas A and B is investigated in Table G3-8. The most likely scenario of dredging 2 ft in A and 4 ft in B was computed, and results show only 0.7% increase in wave height of less than 0.1 ft, a 1.5% increase in energy, and an 8% to 9% increase in energy flux. Note that the combined effect of dredging both borrow areas is **less** than the effect of dredging B alone. The reason for this is that the changes in topography caused by the dredging are spread out over a longer distance. The less abrupt change felt by the waves results in less change to the waves.

The final conclusions to this investigation are that:

1) Maximum anticipated dredging of the borrow areas will result in a **temporary** increase in wave heights at the landward edge of the borrow areas of somewhat less than 1% or less than 0.1 ft. The potential for longshore transport of sediment will also temporarily increase by several percent. The reason that these changes are temporary is that currents will smooth out the changes in topography by moving sand in the longshore direction to "even out" the changes.

2) Conclusions regarding the several percent increase in longshore sediment transport are suspect, because of the poor quality of the model wave data, illustrated by enormous changes in the wave database for different time periods and methods used by the Corps of Engineers in producing the Wave Information Study hindcast databases.

TABLE G3-1. Waves at the seaward edge of borrow area A (depth = 50 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right, the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 88.6 ft to 50 ft depth. 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename SEA45U.OUT

Waves outside borrow area A

WIS Band		6 (112.5°)		7 (135°)		8 (157.5°)	
Period (sec)		8.9		7.3		8.0	
% Occurrence		22.8		6.1		15.0	
% within 90°		34.9		9.3		22.9	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	3.281	2.836	3.281	3.095	4.921	4.693
Energy	E (ft-lb/ft^2)	86.093	64.318	86.093	76.624	193.708	176.153
Energy Flux	P (ft-lb/ft-s)	2304	1735	1999	1882	3955	3933
	% E	8.3	7.2	8.3	8.6	18.6	19.8
Wave Angle	α (°)	58.5	46.051	36	30.733	13.5	12.054

WIS Band		9 (180°)		10 (202.5°)		11 (225°)	
Period (sec)		6.8		5.9		5.5	
% Occurrence		7.7		6.1		4.8	
% within 90°		11.8		9.3		7.3	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.921	4.666	4.265	4.027	4.593	4.277
Energy	E (ft-lb/ft^2)	193.708	174.098	145.497	129.702	168.742	146.288
Energy Flux	P (ft-lb/ft-s)	-3582	-3575	-2241	-2205	-2376	-2253
	% E	18.6	19.6	14.0	14.6	16.2	16.2
Wave Angle	α (°)	-9	-8.234	-31.5	-29.954	-54	-51.697

WIS Band		12 (247.5°)		Totals	
Period (sec)		5.2			
% Occurrence		2.9		65.4	
% within 90°		4.4			
		In	Out	In	Out
Wave Height	H (ft)	4.593	3.911	11.418	10.546
Energy	E (ft-lb/ft^2)	168.742	122.329	1042.583	889.512
Energy Flux	P (ft-lb/ft-s)	-2246	-1742	-2187	-2225
	% E	16.2	13.8		
Wave Angle	α (°)	-76.5	-72.476		

TABLE G3-2. Existing conditions in borrow area A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 40 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right, the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 50 ft to 40 ft depth over borrow area A. 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 4045U.OUT

Borrow area A existing condition

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.4		5.2		6.3	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.836	2.774	3.095	3.080	4.693	4.680
Energy	E (ft-lb/ft^2)	64.318	61.565	76.624	75.862	176.153	175.164
Energy Flux	P (ft-lb/ft-s)	1735	1608	1882	1837	3933	3922
	% E	7.2	7.4	8.6	9.1	19.8	21.0
Wave Angle	α (°)	46.051	41.529	30.733	28.310	12.054	11.267

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.3		5.1		5.2	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.666	4.626	4.027	3.924	4.277	4.083
Energy	E (ft-lb/ft^2)	174.098	171.141	129.702	123.143	146.288	133.343
Energy Flux	P (ft-lb/ft-s)	-3575	-3571	-2205	-2177	-2253	-2147
	% E	19.6	20.5	14.6	14.7	16.4	16.0
Wave Angle	α (°)	-8.234	-7.758	-29.954	-28.609	-51.697	-49.428

WIS Band		12		Totals	
Period (sec)		5.2			
H_b (ft)		5.1			
		In	Out	In	Out
Wave Height	H (ft)	3.911	3.457	10.546	10.223
Energy	E (ft-lb/ft^2)	122.329	95.605	889.512	835.823
Energy Flux	P (ft-lb/ft-s)	-1742	-1424	-2225	-1952
	% E	13.8	11.4		
Wave Angle	α (°)	-72.476	-68,396		

TABLE G3-3. 6 ft cut in borrow area A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 40 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 50 ft to 46 ft depth (6 ft cut). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 4645U.OUT

6 ft dredging borrow area A

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.4		5.2		6.6	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.836	2.807	3.095	3.085	4.693	4.682
Energy	E (ft-lb/ft^2)	64.318	63.025	76.624	76.139	176.153	175.351
Energy Flux	P (ft-lb/ft-s)	1735	1683	1882	1865	3933	3929
	% E	7.2	7.3	8.6	8.8	19.8	20.2
Wave Angle	α (°)	46.051	44.324	30.733	29.834	12.054	11.769

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.3		5.1		5.2	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.66	4.645	4.027	3.986	4.277	4.206
Energy	E (ft-lb/ft^2)	174.098	172.594	129.702	127.072	146.288	141.485
Energy Flux	P (ft-lb/ft-s)	-3575	-3574	-2205	-2196	-2253	-2217
	% E	19.6	19.9	14.6	14.6	16.4	16.3
Wave Angle	α (°)	-8.234	-8.064	-29.954	-29.498	-51.697	-50.949

WIS Band		12		Totals		
Period (sec)		5.2				
H_b (ft)		5.1				
		In	Out	In	Out	Percent Change
Wave Height	H (ft)	3.911	3.741	10.546	10.415	+1.9% (+0.19 ft)
Energy	E (ft-lb/ft^2)	122.329	111.923	889.512	867.589	+3.8%
Energy Flux	P (ft-lb/ft-s)	-1742	-1620	-2225	-2130	+9.1%
	% E	13.8	12.9			
Wave Angle	α (°)	-72.476	-71.113			

TABLE G3-4. 4 ft cut in borrow area A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 40 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 50 ft to 44 ft depth (4 ft cut). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 4445U.OUT

4 ft dredging of borrow area A

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.4		5.2		6.6	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.836	2.795	3.095	3.082	4.693	4.679
Energy	E (ft-lb/ft^2)	64.318	62.467	76.624	75.982	176.153	175.135
Energy Flux	P (ft-lb/ft-s)	1735	1658	1882	1856	3933	3926
	% E	7.2	7.3	8.6	8.9	19.8	20.4
Wave Angle	α (°)	46.051	43.421	30.733	29.351	12.054	11.612
WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.3		5.1		5.2	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.666	4.637	4.027	3.965	4.277	4.167
Energy	E (ft-lb/ft^2)	174.098	171.977	129.702	125.746	146.288	138.875
Energy Flux	P (ft-lb/ft-s)	-3575	-3573	-2205	-2190	-2253	-2196
	% E	19.6	20.1	14.6	14.7	16.4	16.2
Wave Angle	α (°)	-8.234	-7.970	-29.954	-29.232	-51.697	-50.500
WIS Band		12		Totals			
Period (sec)		5.2					
H_b (ft)		5.1					
		In	Out	In	Out	Percent Change	
Wave Height	H (ft)	3.911	3.649	10.546	10.350	+1.2% (+0.13 ft)	
Energy	E (ft-lb/ft^2)	122.329	106.509	889.512	856.691	+2.5%	
Energy Flux	P (ft-lb/ft-s)	-1742	-1556	-2225	-2075	+6.3%	
	% E	13.8	12.4				
Wave Angle	α (°)	-72.476	-70.303				

TABLE G3-5. 2 ft cut in borrow area A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 40 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 50 ft to 42 ft depth (2 ft cut). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 4245U.OUT

2 ft dredging of borrow area A

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.4		5.2		6.6	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.836	2.784	3.095	3.080	4.693	4.678
Energy	E (ft-lb/ft^2)	64.318	61.979	76.624	75.887	176.153	175.066
Energy Flux	P (ft-lb/ft-s)	1735	1633	1882	1847	3933	3924
	% E	7.2	7.3	8.6	9.0	19.8	20.7
Wave Angle	α (°)	46.051	42.490	30.733	28.843	12.054	11.445

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.3		5.1		5.2	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.666	4.630	4.027	3.944	4.277	4.126
Energy	E (ft-lb/ft^2)	174.098	171.486	129.702	124.431	146.288	136.155
Energy Flux	P (ft-lb/ft-s)	-3575	-3572	-2205	-2184	-2253	-2173
	% E	19.6	20.3	14.6	14.7	16.4	16.1
Wave Angle	α (°)	-8.234	-7.868	-29.954	-28.936	-51.697	-49.995

WIS Band		12		Totals		
Period (sec)		5.2				
H_b (ft)		5.1				
		In	Out	In	Out	Percent Change
Wave Height	H (ft)	3.911	3.554	10.546	10.285	+0.6% (+0.06 ft)
Energy	E (ft-lb/ft^2)	122.329	101.048	889.512	846.052	+1.2%
Energy Flux	P (ft-lb/ft-s)	-1742	-1490	-2225	-2015	+3.2%
	% E	13.8	11.9			
Wave Angle	α (°)	-72.476	-69.399			

TABLE G3-6. Existing conditions in borrow area B1. "In" statistics are the waves at the landward edge of borrow area A (depth = 40 ft), and "Out" are the waves at the landward edge of borrow area B1 (depth = 30 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 40 ft to 30 ft depth. 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 3045U.OUT (uses borrow area A existing conditions' output as input)

Borrow area B1 (existing conditions)

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.9		5.6		7.1	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.774	2.759	3.080	3.107	4.680	4.733
Energy	E (ft-lb/ft^2)	61.575	60.868	75.862	77.225	175.164	179.182
Energy Flux	P (ft-lb/ft-s)	1608	1492	1837	1788	3922	3908
	% E	7.4	7.6	9.1	9.7	21.0	22.5
Wave Angle	α (°)	41.529	36.212	28.310	25.197	11.267	10.184

WIS Band		9		10		11	
Period (sec)		6.8					
H_b (ft)		6.7					
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.626	4.645	3.924	3.838	4.083	3.855
Energy	E (ft-lb/ft^2)	171.141	172.607	123.143	117.826	133.343	118.881
Energy Flux	P (ft-lb/ft-s)	-3517	-3566	-2177	-2134	-2147	-1992
	% E	20.5	21.6	14.7	14.8	16.0	14.9
Wave Angle	α (°)	-7.758	-7.069	-28.609	-26.397	-49.428	-45.473

WIS Band		12		Totals	
Period (sec)		5.2			
H_b (ft)					
		In	Out	In	Out
Wave Height	H (ft)	3.457	2.974	10.233	9.985
Energy	E (ft-lb/ft^2)	95.605	70.725	835.823	797.314
Energy Flux	P (ft-lb/ft-s)	-1424	-1107	-1952	-1611
	% E	11.4	8.9		
Wave Angle	α (°)	-68.396	-61.729		

TABLE G3-7. 4 ft cut in borrow area B, with no dredging in A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge (depth = 34 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right, the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 40 ft to 34 ft depth (4 ft cut). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 3445U.OUT (uses borrow area A's existing condition output as input)

Dredging borrow area B (4 ft cut)

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.8		5.5		6.9	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.774	2.758	3.080	3.089	4.680	4.701
Energy	E (ft-lb/ft^2)	61.575	60.822	75.862	76.333	175.164	176.740
Energy Flux	P (ft-lb/ft-s)	1608	1537	1837	1808	3922	3914
	%E	7.4	7.5	9.1	9.4	21.0	21.8
Wave Angle	α (°)	41.529	38.451	28.310	26.540	11.267	10.660

WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.6		5.5		5.5	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.626	4.627	3.924	3.868	4.083	3.947
Energy	E (ft-lb/ft^2)	171.141	171.260	123.143	119.642	133.343	124.613
Energy Flux	P (ft-lb/ft-s)	-3571	-3569	-2177	-2153	-2147	-2060
	%E	20.5	21.2	14.7	14.8	16.0	15.4
Wave Angle	α (°)	-7.758	-7.375	-28.609	-27.410	-49.428	-47.302

WIS Band		12		Totals		
Period (sec)		5.2				
H_b (ft)						
		In	Out	In	Out	Percent Change
Wave Height	H (ft)	3.457	3.163	10.233	10.060	+0.8% (+0.075 ft)
Energy	E (ft-lb/ft^2)	95.605	79.998	835.823	809.408	+0.8%
Energy Flux	P (ft-lb/ft-s)	-1424	-1229	-1952	-1752	+8.8%
	%E	11.4	9.9			
Wave Angle	α (°)	-68.396	-64.745			

TABLE G3-8. 4 ft cut in borrow area B, with 2 ft cut in A. "In" statistics are the waves at the seaward edge of borrow area A (depth = 50 ft), and "Out" are the waves at the shoreward edge of borrow area B (depth = 34 ft). Statistics for each directional band are listed, with the angle of wave approach shown as an azimuth (degrees clockwise of north). Statistics include wave height H, wave energy E, longshore energy flux P, the percent energy %E that each direction represents compared to the total energy, and the wave angle alpha (α). At the bottom right, the height H, energy E, and energy flux P are summed for the total values within the spectrum.

Shoaling from 42 ft to 34 ft depth (2 ft cut in A and 4 ft cut in B). 1976-1995 (with hurricanes). Station 45. Shore normal = 171°. Filename 34AB45U.OUT (uses borrow area A's 2-ft-cut output as input)

Dredging both borrow areas A (2 ft cut) and B (4 ft cut)

WIS Band		6		7		8	
Period (sec)		8.9		8.0		7.3	
H_b (ft)		6.9		5.6		7.0	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	2.784	2.758	3.080	3.089	5.678	4.700
Energy	E (ft-lb/ft^2)	61.979	60.853	75.887	76.309	175.066	176.688
Energy Flux	P (ft-lb/ft-s)	1633	1538	1847	1808	3924	3913
	% E	7.3	7.5	9.0	9.4	20.7	21.8
Wave Angle	α (°)	42.490	38.452	28.843	26.539	11.445	10.660
WIS Band		9		10		11	
Period (sec)		6.8		5.9		5.5	
H_b (ft)		6.7		5.5		5.6	
		In	Out	In	Out	In	Out
Wave Height	H (ft)	4.630	4.627	3.944	3.867	4.126	3.947
Energy	E (ft-lb/ft^2)	171.486	171.212	124.431	119.614	136.155	124.624
Energy Flux	P (ft-lb/ft-s)	−3572	−3568	−2184	−2152	−2173	−2060
	% E	20.3	21.2	14.7	14.8	16.1	15.4
Wave Angle	α (°)	−7.868	−7.375	−28.936	−27.410	−49.995	−47.302
WIS Band		12		Totals			
Period (sec)		5.2					
H_b (ft)							
		In	Out	In	Out	Percent Change	
Wave Height	H (ft)	3.554	3.163	10.285	10.059	+0.7% (+0.074 ft)	
Energy	E (ft-lb/ft^2)	101.048	79.996	846.052	809.296	+1.5%	
Energy Flux	P (ft-lb/ft-s)	−1490	−1229	−2015	−1750	+8.6%	
	% E	11.9	9.9				
Wave Angle	α (°)	−69.399	−64.745				

APPENDIX G4. LITTORAL TRANSPORT

Previous Transport Studies

Several studies have been performed by both the Corps of Engineers and the University of North Carolina to estimate the potential for longshore sediment-transport:

1) The Corps of Engineers 1976 study compared two time periods relative to Beaufort Inlet navigation-channel maintenance, before (1854-1936) and after (1960-1974). The results vary considerably over time, as shown in Table G4-1. But the overall results from the study concluded: (a) sediment transport is to the east (75%), (b) shoaling occurs more on the west side of the channel (68% of the channel shoaling), (c) bypassing efficiency of the inlet dropped from 52% to 28% after dredging, and (d) the net transport is about 14% of the gross. These results suggest that the dredged channel at Beaufort Inlet is blocking some (about half) of the longshore transport and that this impact should be felt more on Shackleford than Bogue, since net transport is to the east. The dataset used for these computations was a series of shipboard observations of winds, which in turn were used in models to predict the waves they create. The fact that this dataset was abandoned by the Corps several years later is an indication of its quality.

2) In 1990, the Corps of Engineers updated its previous study with a different set of wind data, but from the same time period of 1956-1975. That study concluded that (a) the gross transport rate was about 600,000 cy/yr greater than shown in the 1976 study, but (b) the net transport proportion was about the same as in the previous study, in this case 78% of the total or gross transport, and still to the east. Results are summarized below in Table G4-2.

TABLE G4-1. Results of the 1976 sediment budget analysis. [*Negative transport quantities indicate drift moving in opposite direction from assumed in the analysis. **Negative bypassing quantities indicate transport into the inlet by tidal currents. [From USACE, 1999]

Time Period	Easterly Sand Trans. from Bogue Banks (cy/yr)	Westerly Sand Trans. from Shackleford Banks (cy/yr)	Bypassing to the East (cy/yr)	Bypassing to the West (cy/yr)
1854-1936	702,000	239,000	492,000	133,000
1936-1952	1,720,000	584,000	1,241,000	234,000
1952-1960	*−400,000	**−136,000	−518,000	88,000
1960-1974	641,000	218,000	238,000	121,000
1936-1974	378,000	128,000	60,000	−66,000

TABLE G4-2. Results of the 1990 sediment budget analysis. [From USACE, 1999]

Time Period	Easterly Sand Trans. from Bogue Banks (cy/yr)	Westerly Sand Trans. from Shackleford Banks (cy/yr)	Bypassing to the East (cy/yr)	Bypassing to the West (cy/yr)
1980-1988	1,130,000	328,000	898,000	−113,000

3) The Corps is currently performing an updated hindcast study, and results are not yet available.

4) Roessler (1998) performed a very similar study as the Corps, but used a very different set of wind data (the 1976-1993 Station 46 WIS dataset), a different wave-shoaling model (REF/DIF), and a slightly different set of digitized topographic data (UNC, 1998). He reached the following conclusions:

- **"Net longshore current velocity (and hence transport) in the study area is to the west.** Modeled fairweather and storm wave conditions based on USACE Hindcast Wave data indicated that the net longshore transport at eastern Bogue Banks is to the west."

- **"Although approximately 17 million cubic meters of sediment were removed from the active littoral system by offshore disposal, the offshore disposal area appeared to actually decrease both velocities and gradients in longshore current velocity during simulations of Hurricanes *Bertha* and *Fran* and potentially decrease erosion rates.** The offshore disposal area actually decreased longshore current velocities in some locations by up to 50 percent during Hurricane *Bertha* and up to 65 percent during Hurricane *Fran*."

- **"According to model results, the nearshore berm had a minimal effect on the refraction and diffraction of fairweather waves; however, during storm events the potential for cross-shore transport (perpendicular to the shoreline) was much greater.** REF/DIF results agree with USACE predictions that the nearshore berm will have a very limited effect on fairweather waves."

- **"Inlet orientation had only minor effects on wave refraction/diffraction processes during fair weather and storm conditions."**

- **"Although the offshore disposal area decreased gradients in longshore current velocity, the overall effect of dredging Beaufort Inlet, which caused the ebb tidal delta to prograde seaward, was to increase gradients in longshore current velocity during simulations of Hurricanes *Bertha* and *Fran*.** REF/DIF results suggested that the progradation of the ebb tidal delta of Beaufort Inlet caused by dredging likely increases erosion rates in certain locations of the study area including Pine Knoll Shores. During storm conditions, steeper gradients in longshore current velocity were predicted for the recent bathymetry when compared to model runs for bathymetry from 1854 and 1925. These steep gradients in longshore current velocities were reflected in the erosion and accretion patterns following Hurricanes *Bertha* and *Fran*."

- **"Eastern Bogue Banks is susceptible to high erosion from storm waves approaching from the south, and longshore current velocities are altered by the progradation of the ebb tidal delta of Beaufort Inlet when simulated storm waves approach from the southeast.** When large storm waves (greater than 4.5 m) approach Bogue Banks from a direction less than 137 degrees, calculated longshore current velocities are altered throughout most of the study area which can potentially lead to higher erosion rates. When storms waves approach Bogue Banks from between 140 and 179 degrees, calculated longshore current velocities are changed in the vicinity of Atlantic Beach and Fort Macon State Park which can also potentially increase erosion rates especially at eastern Atlantic Beach and Fort Macon State Park."

Transport Computations for This EIS

We performed a similar type of analysis of potential longshore sediment transport along Bogue Banks to:

1) Investigate the variation of the transport along the entire island. (The Corps and UNC studies were for Atlantic Beach, Beaufort Inlet, and Shackleford Banks, since those were the areas being considered for Corps dredging and nourishment projects.)

2) Determine the sensitivity of the results to data source. We compared the variation in transport results for the different WIS time periods (1956-75 and 1976-95) and for different stations (45 and 46), by using exactly the same procedures for both time periods and both stations.

3) Determine the sensitivity of the results to wave shoaling method (i.e., simple linear shoaling vs. models such as RCPWave that account for the effects of nonparallel seabed contours).

We calculated potential for longshore sediment transport for both time periods and both wind-data stations. In addition, computations were performed at several different stations along the island listed in Table G4-3. The angle of "shore normal" was measured from NOAA charts for each location. "Shore normal" is the azimuth angle perpendicular to the beach, as illustrated in Figure G4-1. We did not perform wave-shoaling computations as a part of these longshore transport computations, since the Corps had already done so, and our intention was to determine how much the results depended on whether the waves were shoaled. Longshore sediment-transport theory says that if the seabed contours are straight and parallel, then no shoaling is necessary, because the longshore energy flux will remain the same. The transports were computed using the Longshore Sediment Transport module in the Automated Coastal Engineering System (ACES). The wave data inputs were in "CEDRS" format as obtained from the WIS datasets on the US Army Corps of Engineers' Coastal Engineering Research Center's website.

TABLE G4-3 Shore normal from NOAA chart 11543.

	Longitude	Normal Azimuth
West end of Emerald Isle west	77°04.5'	162°
Mid Emerald Isle west	77°02.0'	165°
Mid Emerald Isle central	76°59.0'	169°
Mid Emerald Isle east	76°56.0'	169°
Salter Path/Emerald Isle boundary	76°54.0'	169°
Mid Salter Path/Indian Beach	76°53.0'	171°
Salter Path/Indian Beach/Pine Knoll Shores boundary	76°52.0'	170°
Mid Pine Knoll Shores West	76°51.0'	172°
Mid Pine Knoll Shores East	76°49.0'	172°
Pine Knoll Shores/Atlantic Beach boundary	76°47.0'	173°
Mid Atlantic Beach	76°45.0'	180°
Atlantic Beach/Fort Macon boundary	76°42.0'	187°

The results for each combination of ten locations along the island, two time periods, and two WIS stations are listed as the 40 longshore transport rates in Table G4-4. Using the standard sign convention for transport, for an observer standing on the beach, transport to his right is positive, to his left negative. For Bogue Banks, this means positive transport is to the west. The **results** can be summarized as follows:

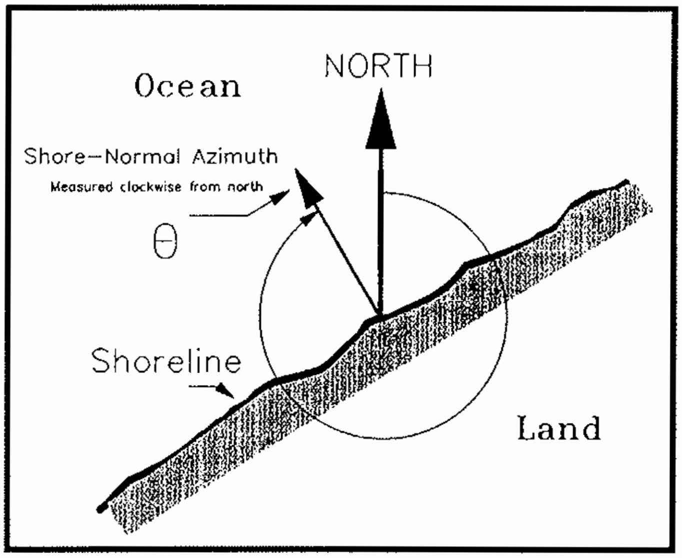


FIGURE G4-1. Definition diagram for shore-normal azimuth.

1) The results for the 1956-75 time period are directly comparable to the second Corps of Engineers study, which used the same input data. As found in the Corps study, the Station 45 data (directly south of Bogue Banks) generate longshore sediment transport **toward the east at every station** along the island. Numerical values decrease from a maximum 560,000 cy/yr at the west end of the island to 260,000 cy/yr at the eastern border of Atlantic Beach (next to Fort Macon).

TABLE G4-4. Longshore sediment transport rates from WIS hindcast data. Positive transport is to the west, negative to the east. Longitudes are in Table G4-3. [*No hurricanes. **Includes hurricanes.]

	Station 46		Station 45	
Location along Bogue Banks	**1956-1975***	**1976-1995****	**1956-1975***	**1976-1995****
West end of Emerald Isle	-450,446	550,895	-560,710	349,854
Emerald Isle west	-398,140	618,708	-552,180	424,298
Emerald Isle central	-319,330	700,821	-546,002	509,601
Emerald Isle east	-285,766	724,094	-543,051	538,883
Salter Path/Emerald Isle boundary	-300,105	716,366	-547,583	520,170
Mid Salter Path/Indian Beach	-269,473	734,851	-533,379	562,452
Salter Path/Indian Beach/Pine Knoll Shores boundary	-242,748	755,330	-523,024	582,884
Pine Knoll Shores West	-129,940	841,233	-471,172	670,450
Pine Knoll Shores East	-7,927	934,084	-405,011	750,221
Pine Knoll Shores/Atlantic Beach boundary	285,997	1,186,473	-258,183	938,429

2) For the same 1956-75 time period Station 46 data (southeast of Bogue Banks) generate transport which has **somewhat smaller transport values (about 20% less)** until a point in the middle of Atlantic Beach is reached. At that point the transport is essentially zero. East of that point the data generate results that are geologically impossible: transport is to the west. This would require sediment to be piling up in the middle of Atlantic Beach, which it is not. Most likely, the model is generating unrealistic results for eastern Atlantic Beach and Fort Macon, because of the nonlinear bathymetric topography in that area, which violates the basic assumption of the shoaling model. For

this station, the values range from a high of 450,000 cy/yr at the west end of Bogue Banks to zero in the middle of Atlantic Beach. [For the record, the results that we do not believe show: to the east of that point, transport is back to the west, increasing from the mid-Atlantic Beach nodal point of zero transport to 286,000 cy/yr westward transport at the border with Fort Macon.]

3) The computations for the time period 1975-95 are directly comparable to the University of North Carolina study, which used essentially the same database. (Since that study, the WIS data were changed only slightly by adding two more years of data during 1994-95.) As found in the UNC study, transport is **to the west everywhere** along the island (although the UNC study was only for the eastern half of Bogue). Our values of longshore transport for Station 46 (the same as used by UNC) ranged from a minimum of 551,000 cy/yr at the western end of Bogue to a maximum of 1,186,000 cy/yr at the Fort Macon border.

4) The results for the 1975-95 time using Station 45, directly south of Bogue, were qualitatively similar to the Station 46 runs, but the values **(all transport to the west)** ranged from a minimum of 350,000 cy/yr at the west end of the island to 938,000 cy/yr at the Fort Macon border.

Conclusions which can be made from these results include:

1) Error in the wave data results in inability to predict even the direction of longshore transport, since opposite directions are predicted for all locations, depending on which datasets are used.

2) Because of change in beach orientation, transport necessarily becomes more and more westward-directed as one progresses to the east end of Bogue.

3) Results are far more dependent on input wave data than on what wave-shoaling model is used, or even if a shoaling model is used at all.

4) Although different methods were used to determine the WIS wave data for the two time periods, the only significant difference in which winds were "counted" in modeling the waves was the presence of hurricanes. The 1956-75 datasets do not include hurricanes, whereas the 1976-95 datasets do. This may account for the change in predicted net transport direction for most of the island from eastward (1956-75, no hurricanes) to westward (1976-95, with hurricanes).

5) Other independent methods of determining longshore sediment transport, such as measuring dispersal of nourishment sand (Reed, 1997) show small values of net transport in the Atlantic Beach area. This places doubt on all the WIS hindcast results, which tend to show high transports.

APPENDIX G5. EROSION RATES

Erosion rates are important in determining environmental impacts for the following reasons:

- Nourishment volumes are computed so as to counteract the natural erosion for a specified number of years. Erosion rates are used in computing the needed nourishment volumes.

- The severity of erosion is the most important indicator of how fast detrimental impacts will occur to the economy and infrastructure, if the "no action" option continues.

- The rate of erosion will determine how long beneficial impacts will last for both humans and plant/animals (e.g., increased dry beach width for turtle nesting).

Estimates of erosion rates have been obtained from two types of data analysis: linear retreat of shorelines seen in aerial photographs, and comparisons of profile surveys of the beach. The latter method is far more accurate, but also far more expensive. The available data from both methods on Bogue Banks will be described below, but the best method of determining erosion (a comparison of two comprehensive surveys) is not possible, since there have not been multiple surveys of most of the island.

Most of the studies described below are comparisons of "lines" on aerial photographs. Typically, there are two such lines that are identifiable: a high-tide or "wet/dry" line and a dune or "vegetation" line. Regardless of which line is identified and compared between successive photograph dates, this linear shoreline change (ft/yr) must then be translated into a volumetric erosion/accretion rate in cubic yards per year (cy/yr). There are various rules of thumb for doing so, but site-specific determination of the conversion factor is more accurate than rules of thumb. The site-specific conversions are computed by comparing the two types of rates (linear and volumetric) for that site and then dividing the results to determine the conversion factor. This exercise was performed by the Corps of Engineers (USACE, 1976, p. C-10), and for Bogue Banks 1 ft/yr equates to 1.3 cy/yr.

Long-Term Linear Erosion Rates (COE & NCSU)

Several recent studies of aerial photography have been performed to determine recent erosion rates, but for long-term erosion there are two important studies, one conducted by an agency of the Corps of Engineers called the Beach Erosion Board in 1948, and a study conducted by North Carolina State University. The BEB study determined erosion along the entire island between the dates 1854 and 1933. Of course, this study did not use aerial photography, but instead relied on surveys by the National Ocean Survey of certain topographic contour lines. Starting from the eastern end of Bogue at Beaufort Inlet, the BEB measured erosion averaging 0.14 ft/yr for the first mile, 0.90 ft/yr of accretion for the next two miles, and 1.14 ft/yr erosion for the remaining 7 miles. The Corps of Engineers uses different rates from the BEB study, depending on the location of the proposed project. But clearly the most appropriate number for this EIS is the 1.14 ft/yr erosion for the island west of Atlantic Beach. Using the USACOE conversion factor of 1.3 over our project length of 88,760 feet results in an **erosion rate of 132,000 cy/yr during 1854-1933.**

NCSU measured locations of vegetation lines and wet/dry lines on aerial photographs from 1939, 1953, 1958, 1964, and 1971. The vegetation or dune-line results (USACE, 1976, p. B-15) for the long-term period of 1939-71 were 4.2 ft/yr erosion for the easternmost 32,000 feet of Bogue and 2.9 ft/yr for the remainder. Multiplying the latter rate by 1.3 and our project length of 88,760 feet produces an **erosion rate of 335,000 cy/yr during 1939-1971.**

Beach Erosion from Aerial Photos (COE & NCDCM)

North Carolina's Division of Coastal Management updates shoreline erosion rates from aerial photographs about every 6 years. Erosion maps for Bogue Banks are available for 1980, 1986, and 1992. The resulting erosion rates are computed as changes from the baseline set of photos from 1938. So the results are averages from 1938 until the update. We tabulated the 1980 and 1992 erosion rates for each of our beach-profile stations along the island for comparison. The plotted erosion/accretion values for the two time periods (1938-80 and 1938-92) are shown in the upper half of Figure G5-1.

The Corps of Engineers performed similar analyses in a study of effects of their dredging projects (USACE, 1999). They measured the changes in both types of linear indicators: the wet/dry line and the vegetation line. We tabulated these results alongside our survey results for use in computing nourishment volumes. The Corps' rates are plotted in the lower half of Figure G5-1.

Beach Erosion from Comparison of Surveys (COE & CSE)

Repetitive beach surveys, encompassing the entire littoral zone, are the best means of determining how much sand is lost or gained along the beach (NAS, 1995). Bogue Banks, unfortunately, does not have an extensive data base of historical surveys. One island-wide survey by the USACE in 1978 allowed comparisons to low-tide wading depth (~−4 ft NGVD) with 60 of our profile lines. USACE profiles were superimposed on our present surveys and analyzed for changes. By extrapolating profile cross-sections over one foot of shoreline ("unit width") or from one profile to the next, a measure of the sand volume change can be obtained. The two sets of profiles, plotted for the entire island, are presented at the end of this appendix.

Figure G5-2 presents our summary of **estimated volumetric rates**, based on best-available data (bold-faced values in Table G5-1).

All five of the methods described above were tabulated for each profile line (1-111) shown in Figures G5-1 and G5-2. Starting with profile line 1 at the western end of Bogue Banks and working east, we tabulate below the results for each of the island "reaches" (separated by solid vertical lines on both figures). Since volumetric methods are considered more accurate, the numbers from that method were generally selected as most appropriate. When those values differed drastically from the other methods, the method which most closely matched the volumetric method, namely the Corps wet/dry line, was selected. The selected value for each reach is in boldface in Table G5-1.

Clearly there are large discrepancies between individual methods and reaches. However, there are some trends. Generally, the Volume Change method and the COE Wet/Dry Line methods were consistent. The two methods that used vegetation lines over roughly the same time period were also consistent: the NCDCM 1992 and COE vegetation lines. Some choice had to be made as to the most reliable estimates for each reach.

The computed **volumes on each of the 111 profile lines are in Table G5-2**. The volumes are all relative to the Stroud survey baseline. Each profile volume computation was started at the listed "offset" distance from the baseline and ended at the listed "cutoff" distance from the baseline.

Plots of each profile are included at the end of this appendix in Annex G1.

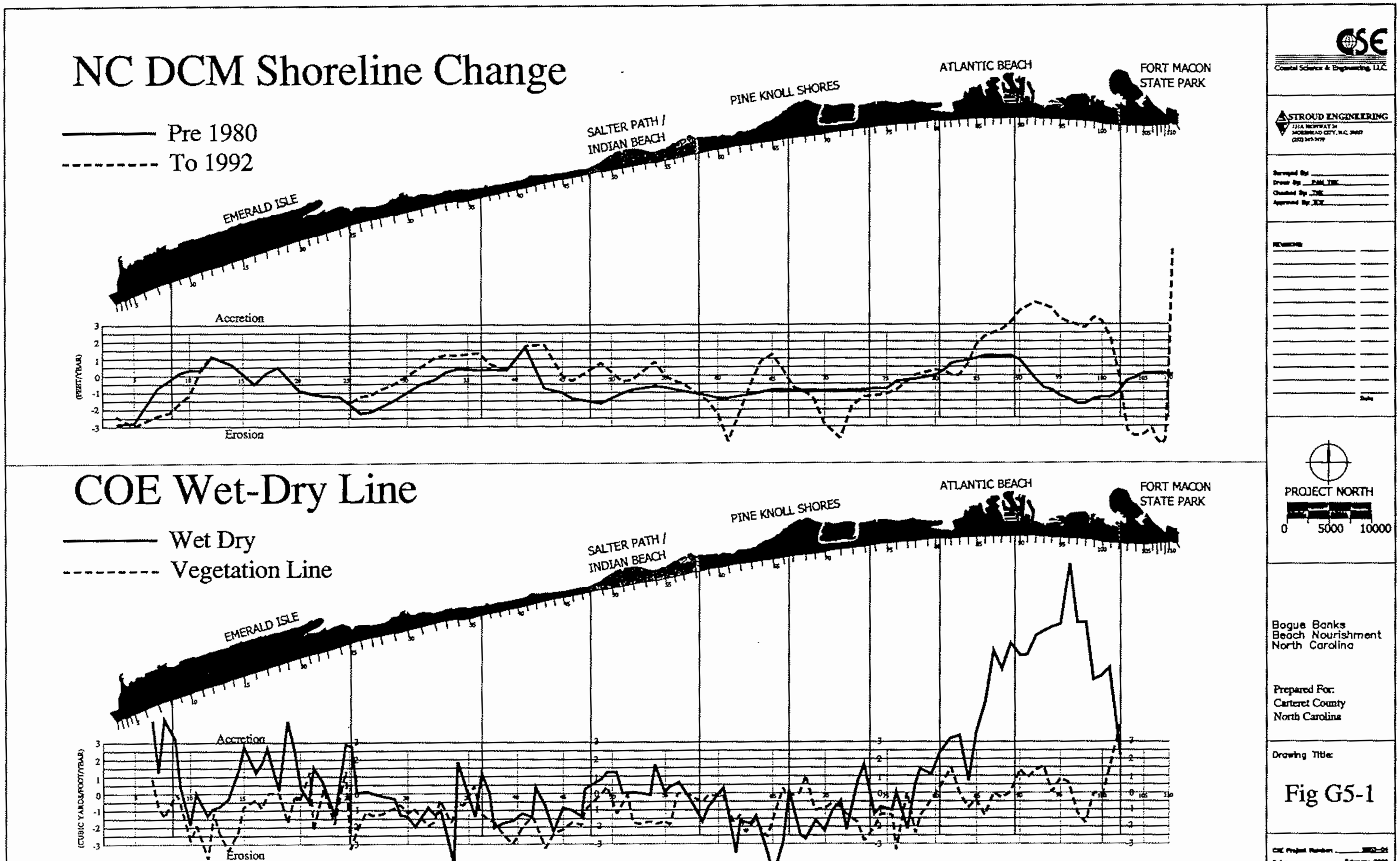
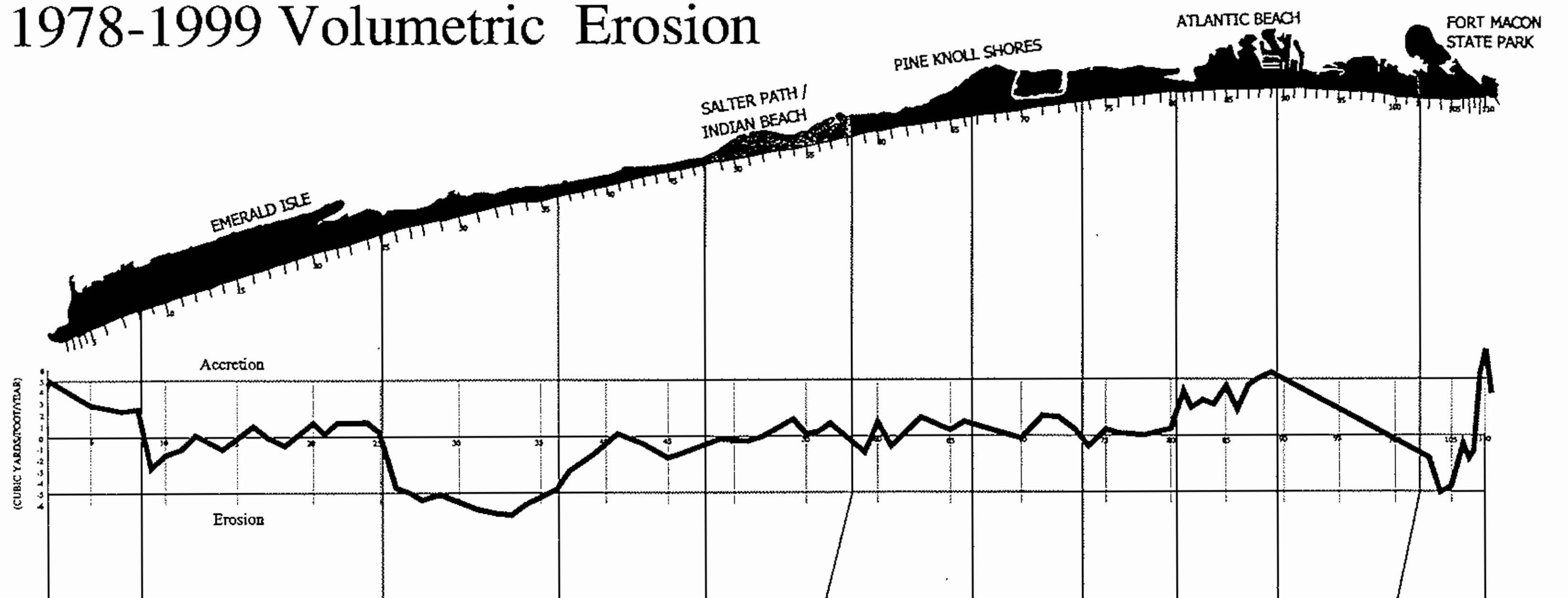


FIGURE G5-1. Linear shoreline change rates for Bogue Banks compiled by the State of North Carolina (upper) and the USACE (lower), based on analysis of aerial photography.

1978-1999 Volumetric Erosion



Accreting 3.15 cy/ft/yr	Very Slow Erosion 0.11 cy/ft/yr	Slow Erosion 0.78 cy/ft/yr	Moderate Erosion 1.62 cy/ft/yr	Stable	Slow Erosion 0.34 cy/ft/yr Note: Used NCDENR pre 1992 rates.	Stable	Moderate Erosion 1.87 ct/ft/yr	Very Slow Erosion 0.40 cy/ft/yr	Stable	Slow Erosion 0.88 cy/ft/yr Note: Used NCDENR pre 1980 rates.	Rapid Erosion 2.62 cy/ft/yr	Accretion
		Note: Difference in Corps baseline in this reach gives high erosion rates (above). Corps Wet/Dry line analysis used instead.						With Continuing Corps Nourishment: Stable	Accreting 3.79 cy/ft/yr	Accreting 3 to 9 cy/ft/yr		

Volume Change Rates 1978 - 1999
(to 4 ft depth, from comparison of
1978 COE profiles and 1999
CSE profiles)

KEY

<0.5 cy/ft/yr	Very Slow Erosion
0.5-1.0 cy/ft/yr	Slow Erosion
1-2 cy/ft/yr	Moderate Erosion
>2 cy/ft/yr	Rapid Erosion

FIGURE G5-2. Volumetric erosion rates estimated to the outer bar, based on (1) extrapolation of comparative wading depth profiles and (2) extrapolation of linear shoreline movement (vegetation lines and dry-sand/wet-sand lines on aerial photography).

Coastal Science & Engineering, LLC

STROUD ENGINEERING

PROJECT NORTH

0 5000 10000

Bogue Banks Beach Nourishment North Carolina

Prepared For:
Carteret County
North Carolina

Drawing Title:

Fig. G5-2

TABLE G5-1. Summary of Bogue Banks erosion rates. (Positive values are accretion, negative erosion. "Best" values are in boldface.) The boldface values for Atlantic Beach are postnourishment. For prenourishment rates, use the 1938-80 NCDCM study numbers. [*Variable low erosion rates resulted in selection of "zero" rate or a stable beach.]

Project	Reach	COE/CSE Volume Change 1978-99 (cy/ft/yr)	NCDCM Shoreline Change 1938-92 (ft/yr)	USACE NCDCM Shoreline Change 1938-80 (ft/yr)	USACE Shoreline Change 1978-93 Wet-Dry (ft/yr)	Shoreline Change 1978-93 Vegetation (ft/yr)
1-8	Emerald Isle-Inlet	**3.15**	-2.48	-1.68	3.93	-0.03
9-25	Emerald Isle-West	**-0.11**	-0.47	-0.65	0.82	-1.21
26-36	Emerald Isle-Central	-5.67	0.16	-0.82	**-0.78**	-1.06
37-48	Emerald Isle-East	**-1.62**	0.68	-0.28	-1.09	-2.01
49-58	Salter Path/Indian Bch*	0.21	0.01	-0.91	-0.09	-1.23
59-66	PineKnollShores West	0.38	-2.60	-1.27	**-0.57**	-0.94
67-73	PineKnollShores East	1.05	-1.87	-0.90	**-1.84**	-0.96
74-80	PKS/AB border*	0.09	-0.56	-0.40	-0.07	-1.64
81-89	Atlantic Beach West	**3.79**	1.48	0.94	4.52	-0.10
90-102	Atlantic Beach East	No 1978 Data	3.19	-0.88	**9.85**	0.73
103-108	Fort Macon	**-2.62**	-3.63	0.00	7.37	0.53
109-111	Beaufort Inlet	**5.18**	1.13	0.03	11.10	1.03

Table G5-2. Profile Volumes for 1999 CSE/Stroud Survey of Bogue Banks on 111 Lines

(page 1 of 2)

Station	Baseline Offset (ft)	Cutoff (ft)	Distance to Next (ft)	Top to 9 ft. Unit Volume (cy/ft)	9 to 2 Volume (cy/ft)	2.0 to -4.0 Volume (cy/ft)	-4.0 to -11 Volume (cy/ft)	+9 to -11 Volume (cy/ft)	Normalized Unit Volume vol/avg vol	Normalized +9 to -4 vol/avg vol
1	75	None	559	0.00	31.56	114.88	218.56	365.00	2.16	2.73
2	184	None	563	0.00	44.28	112.10	244.69	401.07	2.37	2.91
3	78	None	2199	0.00	47.16	81.62	220.68	349.46	2.06	2.40
5	194	None	2988	0.00	23.59	61.00	195.85	280.44	1.66	1.58
7	60	None	1464	0.00	20.72	57.27	145.22	223.21	1.32	1.45
8	71	None	1317	0.00	21.79	45.46	138.54	205.79	1.22	1.25
9	-19	None	1249	0.00	18.86	41.38	138.14	198.38	1.17	1.12
10	31	None	1519	0.00	14.78	41.16	152.05	207.99	1.23	1.04
11	69	None	1260	0.00	13.67	35.45	118.26	167.38	0.99	0.91
12	81	None	1343	0.00	11.19	32.70	108.59	152.48	0.90	0.82
13	80	None	1206	0.00	12.84	37.85	124.05	174.74	1.03	0.94
14	62	None	1349	0.00	12.72	41.46	132.18	186.36	1.10	1.01
15	61	None	1463	0.00	6.26	34.88	111.69	152.83	0.90	0.77
16	67	None	1444	0.00	5.88	38.50	115.69	160.07	0.95	0.83
17	67	None	1431	0.00	11.12	41.27	124.66	177.05	1.05	0.98
18	77	None	1136	0.00	11.81	43.52	122.49	177.82	1.05	1.03
19	62	None	1513	0.00	9.08	39.04	113.80	161.92	0.96	0.90
20	78	None	1112	0.00	7.58	38.81	116.21	163.60	0.97	0.88
21	68	None	1105	0.00	9.13	42.57	109.04	160.74	0.95	0.96
22	74	None	1104	0.00	7.43	37.74	120.56	165.73	0.98	0.84
23	69	None	1633	0.00	11.35	36.63	111.15	159.13	0.94	0.89
24	74	None	1120	0.00	12.16	37.31	107.13	156.60	0.93	0.92
25	71	None	1400	0.00	9.78	40.27	117.17	167.22	0.99	0.93
26	61	None	1335	4.10	16.07	40.02	113.00	169.09	1.00	1.04
27	51	None	1099	0.00	13.17	41.56	113.57	168.30	0.99	1.02
28	57	None	1670	0.00	13.43	45.85	136.87	196.15	1.16	1.10
29	76	None	1642	0.00	10.91	41.19	107.12	159.22	0.94	0.97
30	70	None	1658	0.00	12.96	39.04	108.63	160.63	0.95	0.97
31	57	None	1642	0.00	14.44	43.25	113.10	170.79	1.01	1.07
32	61	None	1364	0.00	8.04	36.10	102.34	146.48	0.87	0.82
33	55	None	1396	0.00	10.63	40.26	111.44	162.33	0.96	0.95
34	91	None	1279	0.00	11.35	41.66	105.44	158.45	0.94	0.99
35	24	None	1460	0.00	5.92	35.06	112.95	153.93	0.91	0.76
36	34	None	1112	0.00	8.07	36.26	110.41	154.74	0.91	0.83
37	87	None	1110	0.00	9.59	38.49	121.24	169.32	1.00	0.90
38	123	None	1103	0.00	9.22	34.07	107.19	150.48	0.89	0.81
39	126	None	1096	0.00	10.21	36.17	108.19	154.57	0.91	0.86
40	103	None	1095	0.00	15.76	41.76	113.91	171.43	1.01	1.07
41	124	None	1118	0.00	10.24	39.50	111.89	161.63	0.95	0.93
42	93	None	1080	0.00	11.55	38.04	106.74	156.33	0.92	0.92
43	120	None	1102	0.00	10.46	40.80	120.37	171.63	1.01	0.95
44	108	None	1107	0.00	7.16	33.86	105.78	146.80	0.87	0.76
45	111	None	1097	0.00	9.35	33.02	101.60	143.97	0.85	0.79
46	102	None	1101	0.00	11.77	40.44	109.73	161.94	0.96	0.97
47	134	None	780	0.00	7.95	37.78	113.77	159.50	0.94	0.85
48	149	None	1571	0.00	9.50	36.02	118.90	164.42	0.97	0.85
49	133	None	1222	0.00	12.06	37.24	118.41	167.71	0.99	0.92
50	69	None	1283	0.00	20.60	36.79	112.43	169.82	1.00	1.07
51	40	None	1242	0.00	9.73	23.80	117.10	150.63	0.89	0.62
52	47	None	2735	0.00	12.74	25.04	122.65	160.43	0.95	0.70
54	75	None	1165	0.00	12.53	36.51	120.19	169.23	1.00	0.91
55	113	None	1194	0.00	11.12	28.36	113.61	153.09	0.90	0.74
56	60	None	1055	-0.30	7.87	23.85	108.54	140.26	0.83	0.59
57	64	None	1526	0.00	7.60	33.80	113.11	154.51	0.91	0.77
58	85	None	1488	0.00	10.27	29.82	112.58	152.67	0.90	0.75
59	61	None	1208	0.00	9.16	24.97	119.02	153.15	0.90	0.64
60	70	None	1206	0.00	6.18	25.11	114.47	145.78	0.86	0.58
61	21	None	2671	0.00	6.60	30.00	116.15	152.75	0.90	0.68
63	53	None	1284	0.00	8.19	29.01	110.75	147.95	0.87	0.69
64	42	None	1329	0.00	7.82	30.24	105.34	143.40	0.85	0.71
65	40	None	1242	0.00	9.47	34.79	112.60	156.86	0.93	0.82
66	50	None	2723	0.00	13.36	39.44	122.46	175.26	1.04	0.98
68	27	None	1029	0.00	9.66	28.36	109.07	147.09	0.87	0.71
69	52	None	1244	0.00	9.35	29.19	117.32	155.86	0.92	0.72
70	43	None	1896	0.00	11.19	29.74	126.94	167.87	0.99	0.76
71	68	None	1400	0.00	8.06	25.34	119.61	153.01	0.90	0.62
72	61	None	1429	0.00	12.58	27.48	117.09	157.15	0.93	0.75
73	43	None	1217	0.00	11.84	30.50	116.53	158.87	0.94	0.79
74	46	None	1500	0.00	12.65	31.47	132.41	176.53	1.04	0.82
75	111	None	1111	0.00	10.03	32.39	112.07	154.49	0.91	0.79
76	50	None	1290	0.00	11.66	35.31	108.59	155.56	0.92	0.87
77	65	None	948	0.00	13.52	39.57	107.92	161.01	0.95	0.99
78	63	None	1444	0.00	13.75	41.06	120.80	175.61	1.04	1.02
79	102	None	900	0.00	15.01	45.71	129.57	190.29	1.12	1.13

Table G5-2. Profile Volumes for 1999 CSE/Stroud Survey of Bogue Banks on 111 Lines
(page 2 of 2)

Station	Baseline Offset	Cutoff	Distance to Next	Top to 9 ft. Unit Volume	9 to 2 Volume	2.0 to -4.0 Volume	-4.0 to -11 Volume	+9 to -11 Volume	Normalized Unit Volume	Normalized +9 to -4
	(ft)	(ft)	(ft)	(cy/ft)	(cy/ft)	(cy/ft)	(cy/ft)	(cy/ft)	vol/avg vol	vol/avg vol
80	75	None	1097	0.00	15.73	47.60	125.85	189.18	1.12	1.18
81	71	None	707	0.00	18.82	48.96	132.09	199.87	1.18	1.26
82	74	None	998	0.00	11.37	41.07	120.29	172.73	1.02	0.98
83	77	None	1012	0.00	12.35	38.37	121.92	172.64	1.02	0.94
84	77	None	1000	0.00	14.92	48.05	120.86	183.83	1.09	1.17
85	74	None	1001	0.00	17.50	51.05	123.51	192.06	1.13	1.28
86	52	None	1000	0.00	21.43	53.60	125.74	200.77	1.19	1.40
87	85	None	994	0.00	18.92	54.38	131.21	204.51	1.21	1.36
88	77	None	1008	0.00	26.39	57.27	181.78	265.44	1.57	1.56
89	146	None	1099	0.00	18.88	51.77	117.44	188.09	1.11	1.32
90	132	None	912	0.00	18.54	42.54	135.88	196.96	1.16	1.14
91	99	None	1000	0.00	17.49	46.41	113.53	177.43	1.05	1.19
92	122	None	1000	0.00	14.72	45.36	114.68	174.76	1.03	1.12
93	95	None	892	0.00	15.57	49.55	108.19	173.31	1.02	1.21
94	-10	None	1024	0.00	39.29	77.25	152.22	268.76	1.59	2.17
95	149	None	996	0.00	18.27	41.90	131.77	191.94	1.13	1.12
96	118	None	999	0.00	18.63	43.79	124.55	186.97	1.10	1.16
97	67	None	1000	0.00	18.36	37.19	145.63	201.18	1.19	1.03
98	112	None	1025	0.00	4.15	27.63	127.53	159.31	0.94	0.59
99	-8	None	973	0.00	16.03	59.66	177.90	253.59	1.50	1.41
100	10	None	1004	0.00	18.85	51.11	145.98	215.94	1.28	1.30
101	66	None	1001	0.00	18.71	46.24	145.69	210.64	1.24	1.21
102	64	None	1016	0.00	13.15	39.22	141.66	194.03	1.15	0.98
103	21	None	975	0.00	8.43	37.98	123.62	170.03	1.00	0.86
104	48	None	993	0.00	10.53	30.19	123.03	163.75	0.97	0.76
105	157	None	999	0.00	2.97	20.07	73.65	96.69	0.57	0.43
106	152	None	531	0.00	9.78	27.15	143.81	180.74	1.07	0.69
107	139	None	471	0.00	8.40	25.58	99.57	133.55	0.79	0.63
108	178	None	533	0.01	6.26	23.58	83.81	113.65	0.67	0.56
109	130	None	460	0.00	10.85	27.34	86.73	124.92	0.74	0.71
110	171	None	721	0.00	18.21	32.37	91.37	141.95	0.84	0.94
111	280	None	0	0.00	24.25	44.66	96.82	165.73	0.98	1.28
			Averages	0.04	13.54	40.36	122.89	170.03	1.00	1.00
					sub to -4	53.89				

NOTES #4 & #6 Not Surveyed
#53 & #62 & #67 Frt Stk Lost - Not Recoverable

Beach Erosion Analysis used to determine Nourishment Requirement

Significantly, up to four data sources confirm relatively low rates of shoreline change over the past 5-20 years. Highest erosion rates were found for the following areas: Fort Macon State Park, Pine Knoll Shores, and Emerald Isle-East. Some reaches were found to be stable, meaning only minor erosion or accretion (e.g., Emerald Isle-West, Salter Path/Indian Beach), and some were accreting (e.g., Emerald Isle-Inlet and Atlantic Beach due to nourishment).

Similarly, where no comparative data are available, the "profile volume" can be calculated between reference contours by extrapolating a two-dimensional cross-section over a particular length of beach. Figure G5-3 illustrates the concept and shows how some sections may have less than or more than the normal volume of a viable healthy beach in a particular area.

Profile volumes were computed for several representative portions of the active beach:

- *"Dry beach"* from the base of the foredune/seawall to approximately mean high water (+9 ft to +2.5 ft NGVD).
- *"Wet beach"* to wading depth (from +2.5 ft to -5.0 ft NGVD).
- *"Underwater"* to the outer bar (from -5.0 ft to -10 ft NGVD).

These standard boundaries allowed comparisons of beach condition from place to place and helped identify specific reaches where there was less sand than desirable for a "healthy" beach.

Figure G5-4 shows the variation in sand volumes to low-tide wading depth in relation to the average for the entire island. Thus, 1.0 represents the average volume, 0.5 means there is only half as much sand in that beach area, and 1.5 means there is one and one-half times as much sand as average. While Figure G5-4 reflects considerable variation from place to place along the shoreline, it is obvious that most of Emerald Isle, Indian Beach, Salter Path, and Pine Knoll Shores have less than the average beach sand volume. These differences are easier to visualize when groups of profile lines are averaged as in Figure G5-5.

For purposes of preliminary planning, we used historical erosion rate data, profile volumes, and political boundaries to delineate nine shoreline reaches, varying from about one mile in length (state park) to about five miles in length (Emerald Isle-West and Atlantic Beach). Figure G5-5 shows the average profile volume by reach between the foredune and -10 ft contour (to the outer bar). The dry beach volume is reflected in the upper portion of each bar, and the wading zone is reflected in the middle portion.

The island-wide trend is apparent with two reaches standing out as the "healthiest" at present--Emerald Isle-Inlet and Atlantic Beach. The western end of Emerald Isle (profiles 1-8) generally has a wide dry-sand beach, broad low-tide terrace, and shallow water nearshore associated with the ebb-tidal delta of Bogue Inlet. Its typical volume to -10 ft is at least twice the average for the island. Atlantic Beach has considerably more sand in the profile at all contour intervals, reflecting the effect of repeated beach fills by the USACE in recent years. The state park and Pine Knoll Shores-West contained the lowest sand volumes along the project shoreline.

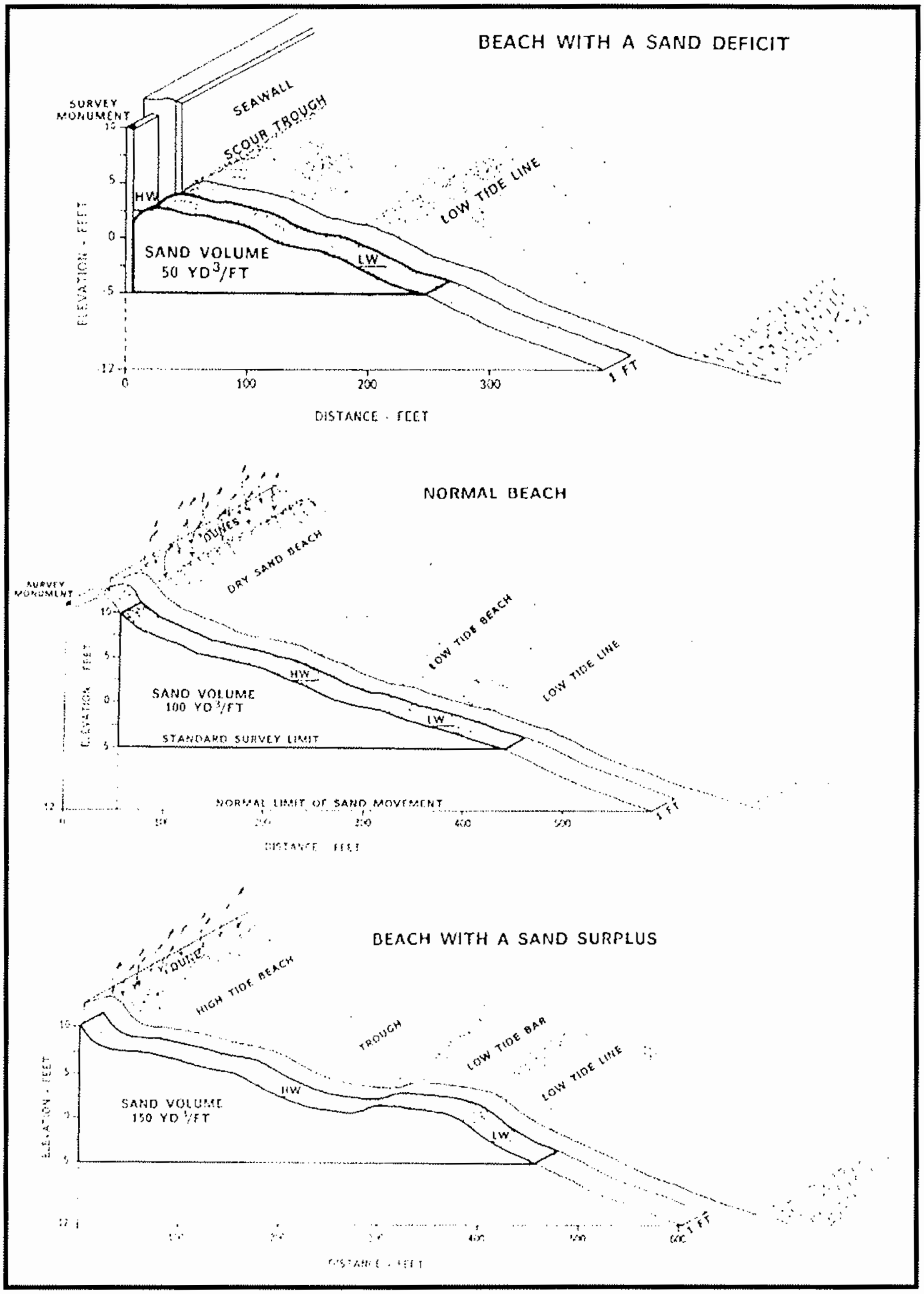


FIGURE G5-3. The concept of profile volumes (i.e., the sand volume contained in a unit length of shoreline between the dunes/seawall and representative underwater contours). In the absence of comparative data, profile volumes provide an objective measure of the beach condition from one place to another. [From Kana, 1990]

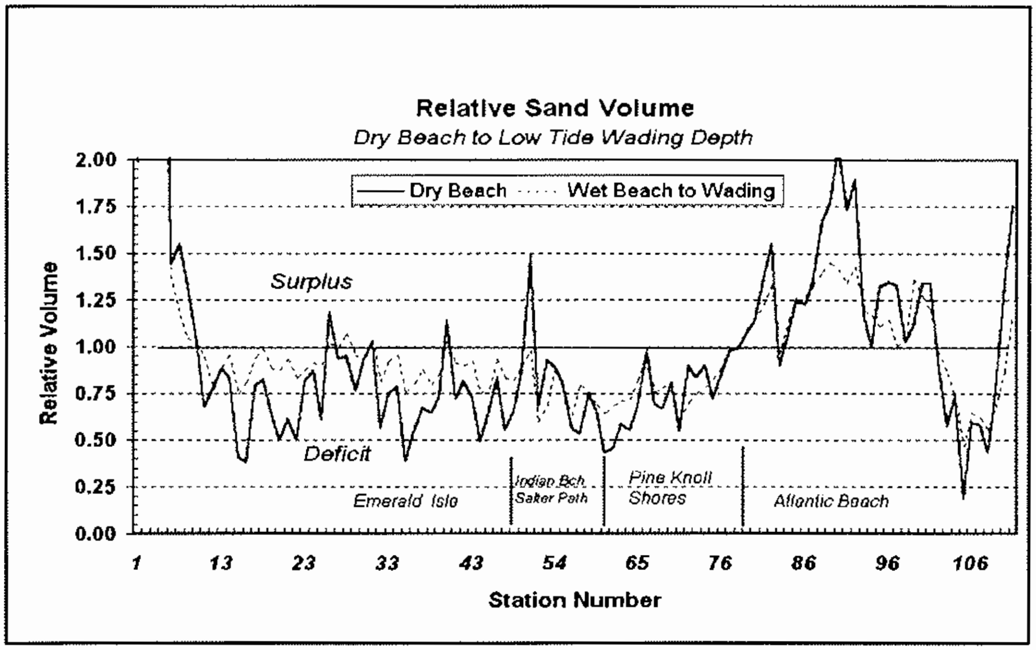


FIGURE G5-4. Relative sand volume on the beach between the foredune and low-tide wading depth from Bogue Inlet (profile 1) to Beaufort Inlet (profile 111). The average for all profiles is 1.0. A value of 0.5 means that point along the shoreline contains half as much sand as the average. A value of 1.5 means the area contains 1.5 times the average. Numerous factors produce variations in beach volumes, including rhythmic shoreline topography, dune scraping, encroachment of shore-protection structures, etc.

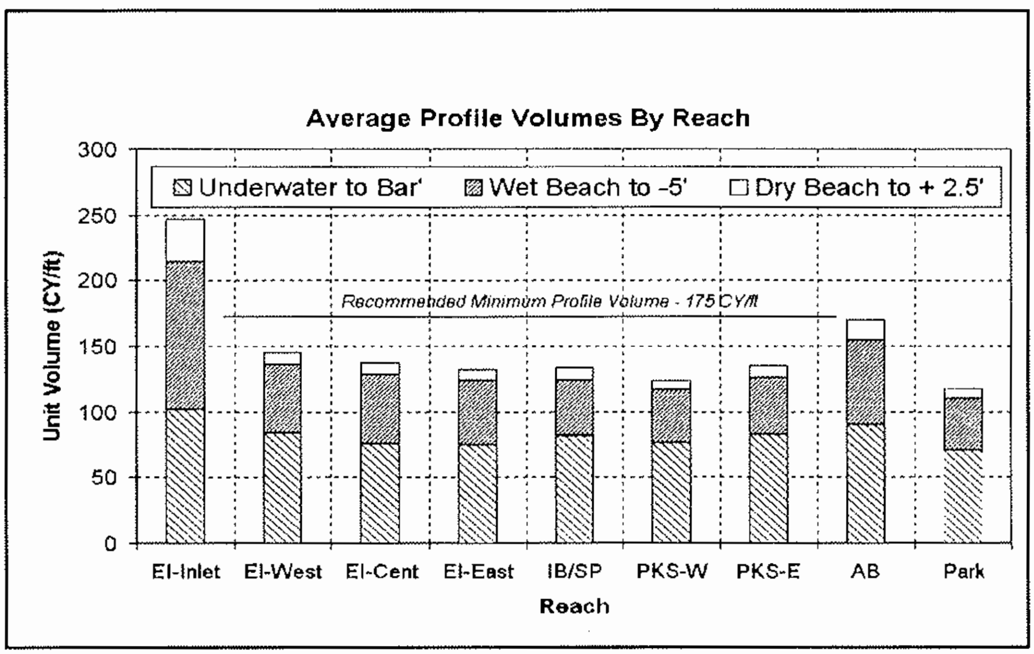


FIGURE G5-5. Average profile volumes by reach along Bogue Banks in June 1999.

If profile volumes reflect the condition of the beach from place to place (assuming similar sediments and exposures to waves and currents), they can be used to quantify sand deficits with respect to some ideal beach condition. A number of analytical and numerical techniques are generally used to define a healthy beach/dune profile for a particular level of storm protection. Erosion models, such as S-BEACH used by the USACE, allow prediction of the expected sand volume losses or dune recession during storms of a particular size. While these models are important design tools and should be a part of any final analysis, they are limited by the availability of coastal process data which are needed to "drive" the models.

For this preliminary study, which was budget-limited, we used an empirical approach for estimating an ideal "minimum" profile volume. We located Bogue Banks profiles where there was more-than-average sand volume and reviewed the beach and backshore conditions for evidence of long-term stability, wide berms for recreation, and extra sand nearshore. We also obtained hurricane erosion data for *Bertha* (June 1996) and *Fran* (September 1996) which showed short-term sand losses to low-tide averaging ~8-15 cubic yards per foot (cy/ft). [Note: This range was also confirmed by re-surveys of 18 of our profile lines after Hurricane *Floyd* during the week of September 20, 1999.] Based on these criteria, we established a threshold minimum profile volume of 175 cy/ft (Fig. G5-5). While this is not a value based on determination of a particular level of storm protection, it is one that reflects the site-specific conditions of Bogue Banks. Based on experience elsewhere, it reflects a level which we believe will provide adequate protection for ~10-year return-period events.

Once a minimum profile volume is established, it is a straightforward procedure to compute the volume deficit at each point along the shoreline. Figure G5-5 shows that, on average, six reaches fall below the minimum volume--Emerald Isle-West, Emerald Isle-Central, Emerald Isle-East, Indian Beach/Salter Path, Pine Knoll Shores-West, and Pine Knoll Shores-East. Atlantic Beach, on average, presently contains nearly the minimum sand volume and can be used as a practical guide to what other reaches would look like if they were nourished as proposed in the present plan. By extrapolating the volume deficit over representative shore lengths, a measure of **initial** fill-volume requirement is obtained.

The actual amount of nourishment recommended consists of **three components**. It begins with the **volume deficit** and then takes into account the long-term **erosion** rate and the **quality of borrow area** sediment. For the present study, our team provided estimates of the additional sand needed over a 5-year, 10-year, and 20-year period to accommodate background erosion. These amounts were calculated by applying the site-specific erosion rates shown in Table G5-1 over the representative time periods. A final adjustment was made to account for variations in the quality of borrow material. For example, a borrow area with a fill ratio of 1.1 will require about 10 percent more nourishment than the volume requirement; a borrow area with a fill ratio of 2.0 will require twice as much nourishment. While these adjustments may seem confusing at first, they are important because of the wide differences in performance of various borrow areas. This last adjustment puts projects using alternate borrow areas on an equal basis and allows fairer comparisons of cost. For example, one million cubic yards of sand that have a fill ratio of 1.1 will perform much better than two million cubic yards that have a fill ratio of 4.0. Unfortunately, differences in borrow material quality are often ignored, leading to widely varying opinions regarding project performances.

In short, we developed a detailed beach condition survey, historical erosion rate data, and borrow area sediment quality data to establish:

- Initial profile volume deficit for six reaches.

- 5-year, 10-year, and 20-year volume requirements to accommodate the long-term background erosion.

- Additional nourishment volume for each borrow area to provide the equivalent performance of native beach sediments.

Implications of the Analysis

The present study confirms a moderately large sand deficit along much of Bogue Banks compared to an "ideal" minimum healthy beach. It also confirms relatively low average erosion rates during the past ~20 years, although the quality of historical data is only fair. We did not locate any data which could be used to quantify changes in erosion rates over time or demonstrate accelerated erosion as a result of recent hurricanes. Nevertheless, empirical evidence suggests that the beach has not recovered from erosion produced by *Bertha*, *Bonnie*, and *Fran* and that it remains in a deteriorated state. (The dry beach and foredune were further eroded during *Floyd* as this report was being finalized.) Although there are insufficient data to prove a cause-and-effect relationship between Corps dredging projects and erosion, some evidence from academic studies (Roessler, 1998) does show the following effects:

- Increased flow through the inlet and thus increased transport of sediment into the harbor.
- Alteration of currents at Atlantic Beach and Pine Knoll Shores.
- Periodic removal of sediments from the littoral system by dredging (sand that would otherwise eventually end up on the beach).

To determine any erosion caused by dredging requires wave-and-current data for computing longshore sediment transport.

The shoreline data that we have examined do support several conclusions:

1) Net longshore transport rates are low along Bogue Banks, otherwise there would be large-scale variations in the erosion rates from one place to another and larger accumulations of sand near Bogue Inlet.

2) Net transport is to the west along Emerald Isle, producing accumulation at Bogue Inlet.

3) Net transport rates and directions along Atlantic Beach remain uncertain.

4) Pine Knoll Shores is eroding at a higher rate than adjacent reaches and may be supplying sand to Salter Path as well as to Atlantic Beach, acting as a zone over which net transport approaches zero.

APPENDIX G6. REFERENCES CITED

Birkemeier, W.A. 1985. Field data on seaward limit of profile change. Jour. Waterway Port, Coastal and Ocean Engineering, Vol. III(3), pp. 598-602.

CERC. 1984. *Shore Protection Manual.* 4th Edition, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Vir.; U.S. Government Printing Office, Washington, D.C., 2 vols.

Hallermeier, R.J. 1978. Uses for a calculated limit depth to beach erosion. In Proc. 16th Coastal Engineering Conf, ASCE, New York, NY, Vol. II, pp. 1493-1512.

Hine, A.C., and S.W. Snyder. 1985. Coastal lithosome preservation: evidence form the shoreface and inner continental shelf off Bogue Banks, North Carolina. *Marine Geology*, Vol. 63, pp. 307-330.

Kana, T.W. 1990. *Conserving South Carolina Beaches Through the 1990s: A Case for Beach Nourishment.* South Carolina Coastal Council, Charleston, SC, 33 pp.

NAS. 1995. *Beach Nourishment and Protection.* Committee on Beach Nourishment and Protection, Marine Board, Commission on Engineering and Technical Systems, National Research Council; National Academy Press, National Academy of Sciences, Washington, DC, 334 pp.

Reed, A. 1997. Sediment distribution patterns offshore of a replenished beach: Atlantic Beach and Fort Macon State Park, North Carolina. Unpubl. M.S. Thesis, Univ. North Carolina, Chapel Hill, 74 pp. + app.

Roessler, T.S. 1998. Effects of offshore geology and the Morehead City harbor project on eastern Bogue Banks, North Carolina. M.S. Thesis, Univ. North Carolina, Chapel Hill, 112 pp.

Thieler, R. 1997. Side scan sonar mosaics. Appendix 5 in A. Reed. 1997. Sediment distribution patterns offshore of a replenished beach: Atlantic Beach and Fort Macon State Park, North Carolina. Unpubl. M.S. Thesis, Univ. North Carolina, Chapel Hill, 74 pp. + app.

UNC. 1998. Bogue Banks historical beach profile data set. Digital files provided by T.S. Roessler, Univ. North Carolina, Chapel Hill. (See Roessler, 1998, in App. A)

USACE. 1976. General design memorandum: Morehead City Harbor, North Carolina. Wilmington District, USACE, 41 pp. + app.

USACE. 1978. Bogue Banks historical beach profile data set. Digital files provided by Tom Jarrett, Wilmington District, U.S. Army Corps of Engineers.

USACE. 1993. Beach erosion control and hurricane wave protection: Carolina Beach and vicinity area south project, New Hanover County, North Carolina. Final Environmental Impact Statement, U.S. Army Corps of Engineers, 55 pp. + attachment (June).

USACE. 1994. Environmental assessment — designation and use of a placement area for underwater nearshore berm: Morehead City harbor project, Morehead City, North Carolina. U.S. Army Corp of Engineers, Wilmington Dist., 18 pp. + figs. + app (August 1994).

USACE. 1994. Finding of no significant impact — designation and use of a placement area for underwater nearshore berm: Morehead City harbor project, Morehead City, North Carolina. U.S. Army Corps of Engineers, Wilmington Dist., 6 pp. + figs. + app (December 1994).

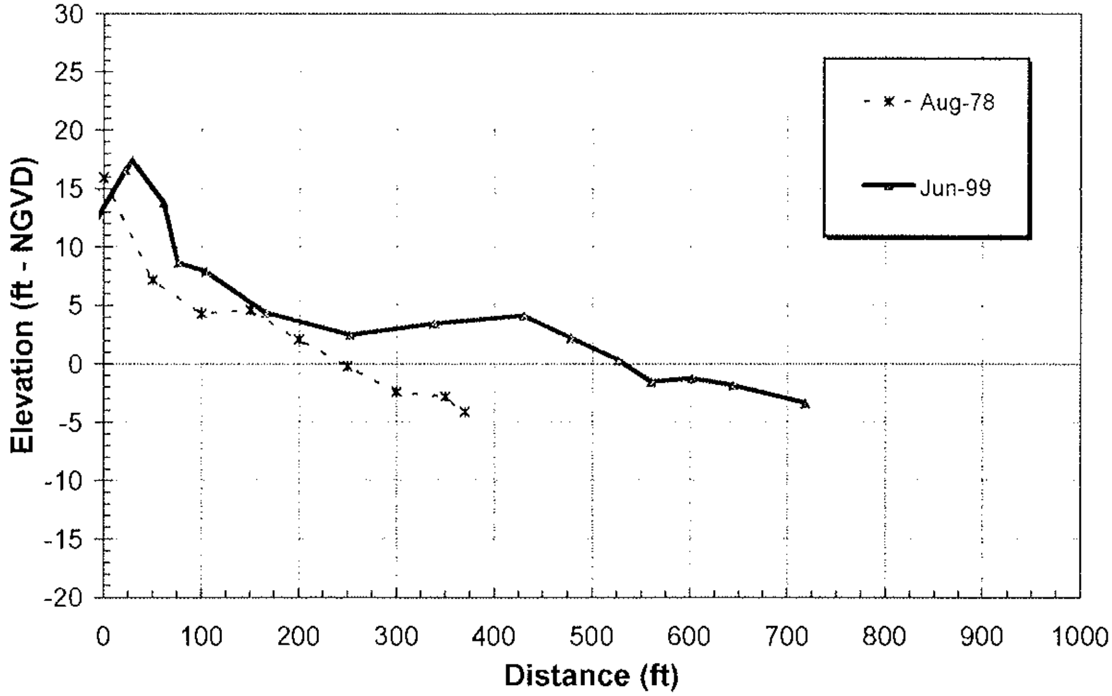
USACE. 1995. Engineering and design: coastal inlet hydraulics and sedimentation. Department of the Army, U.S. Army Corps of Engineers, Manual No. 1110-2-1618, 7 chapters, 4 apps.

USACE. 1999. Preliminary Section 111 evaluation, Morehead City Harbor/Pine Knoll Shores, North Carolina. Provided by Tom Jarrett, Wilmington District, U.S. Army Corps of Engineers.

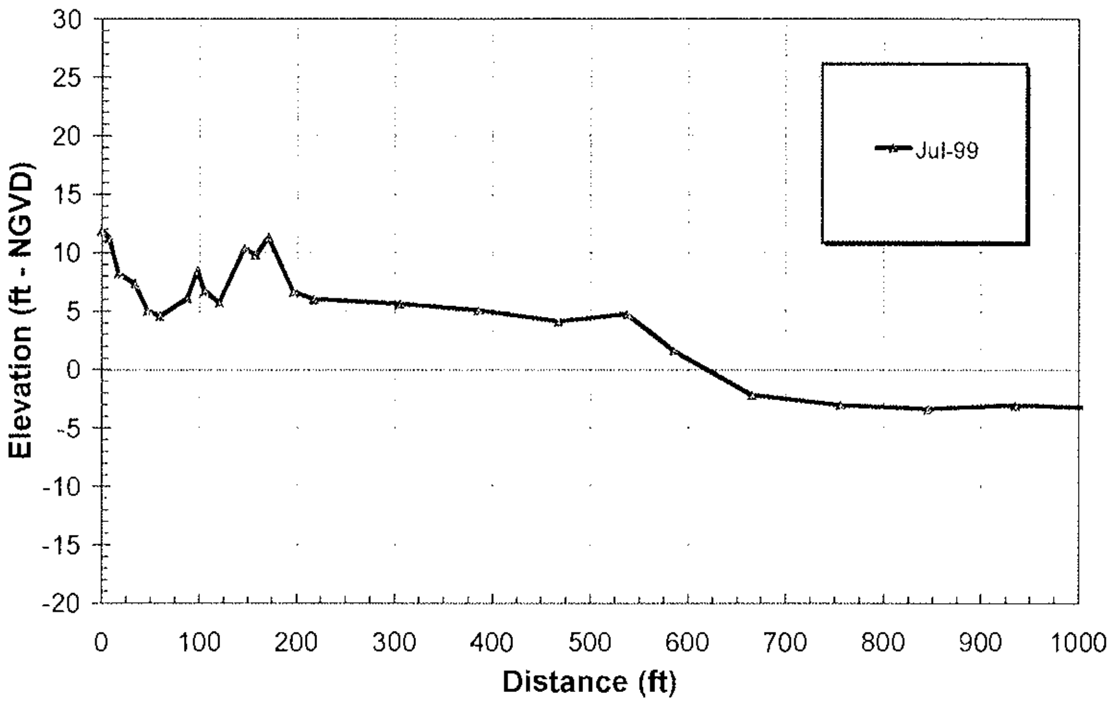
ANNEX G-1

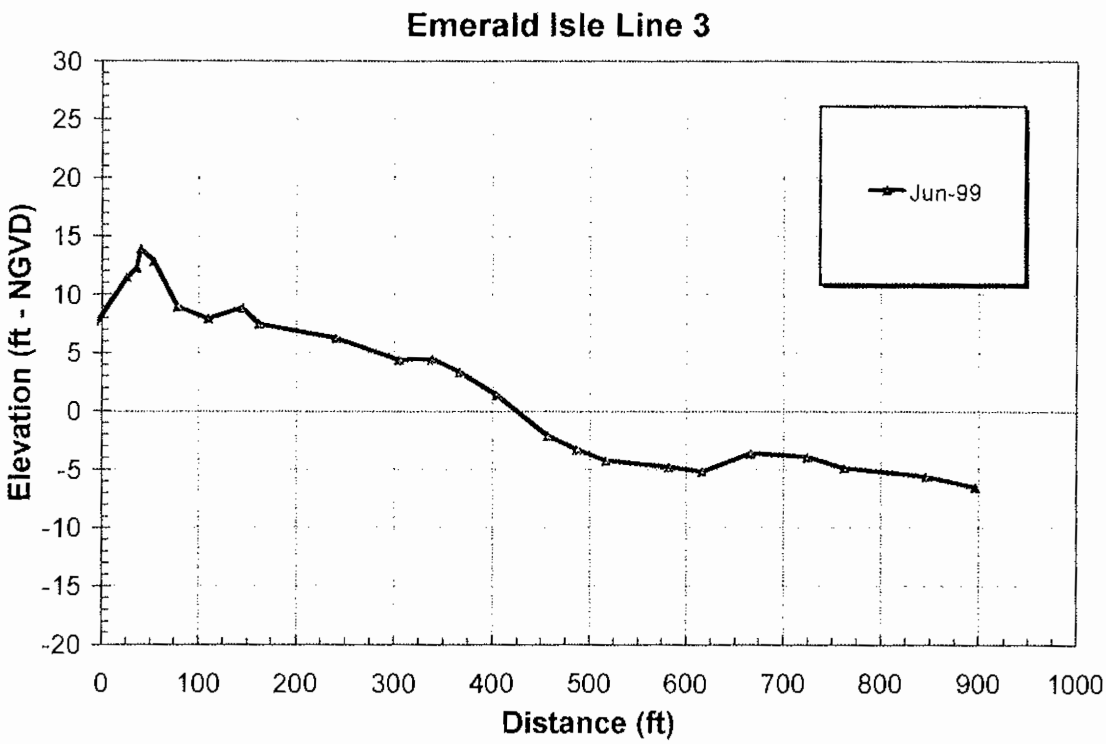
Beach Profile Plots

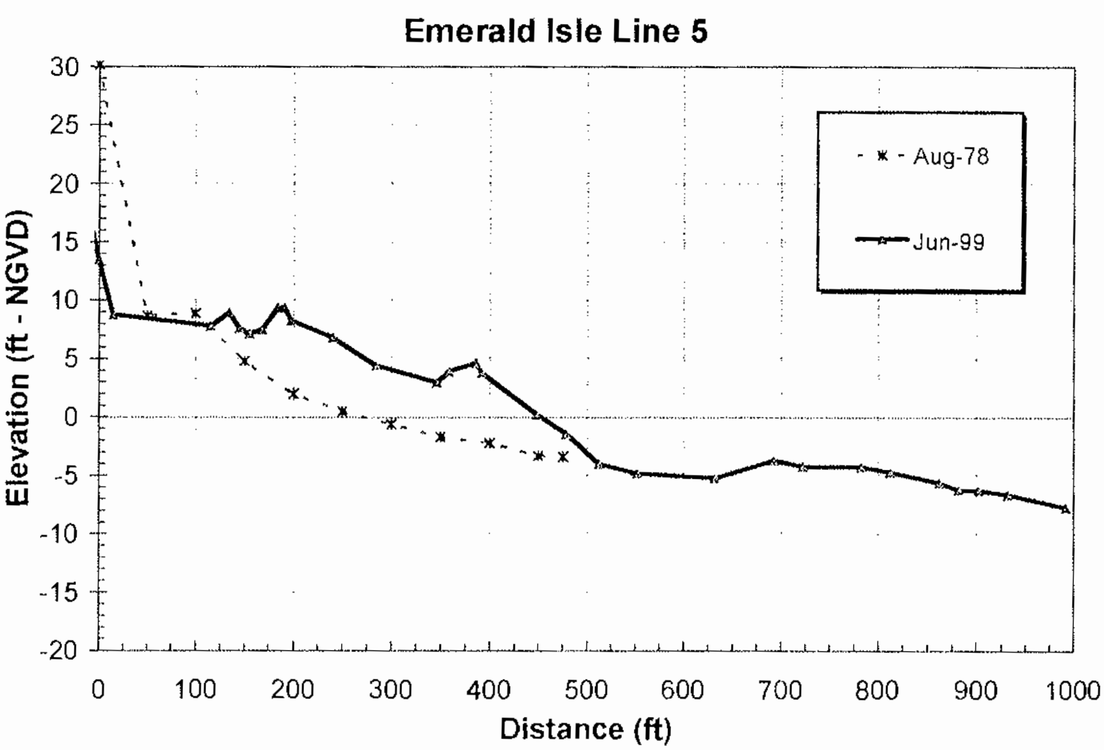
Emerald Isle Line 1

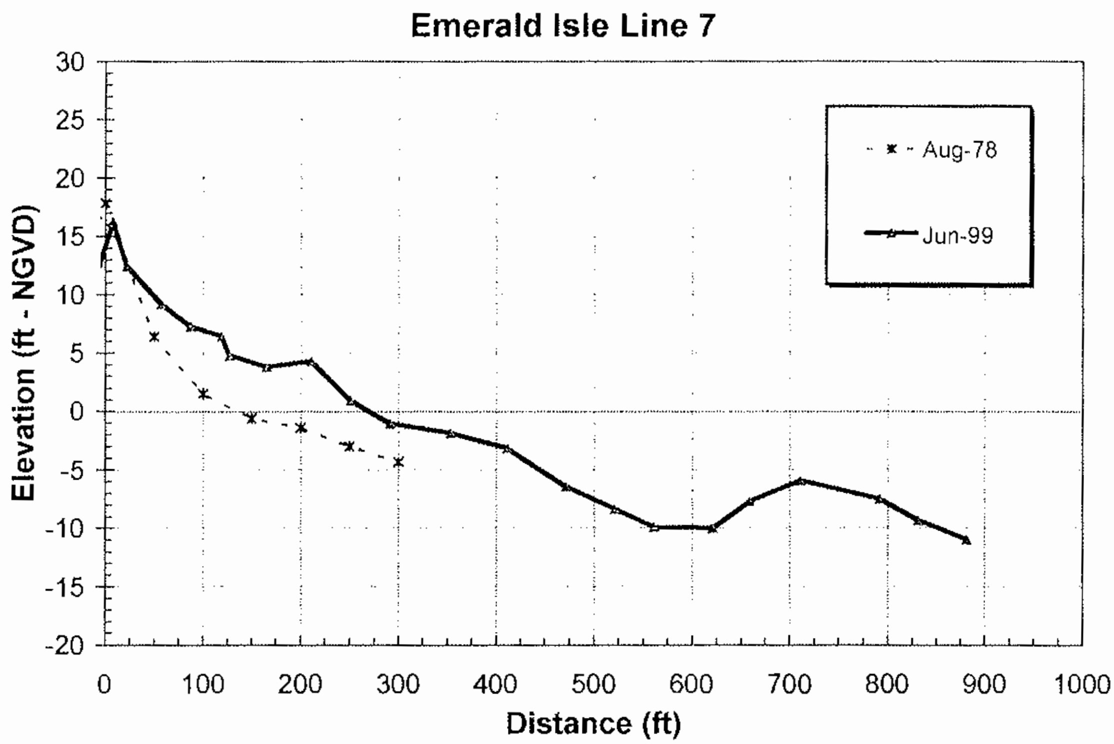


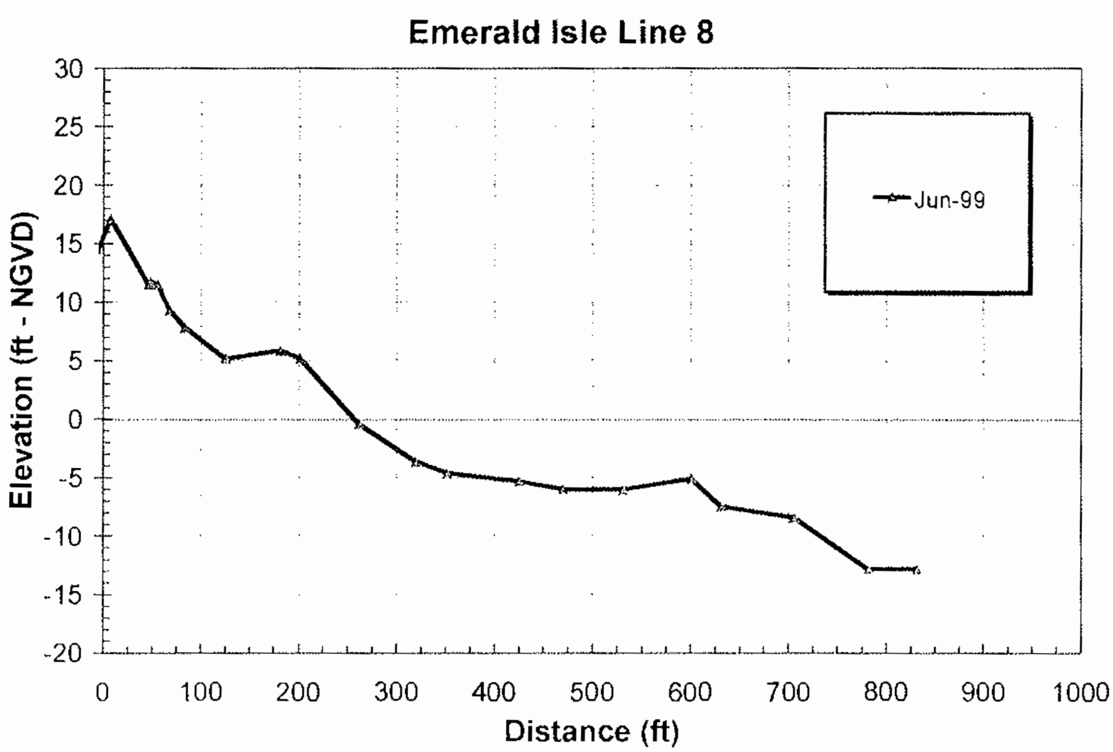
Emerald Line 2

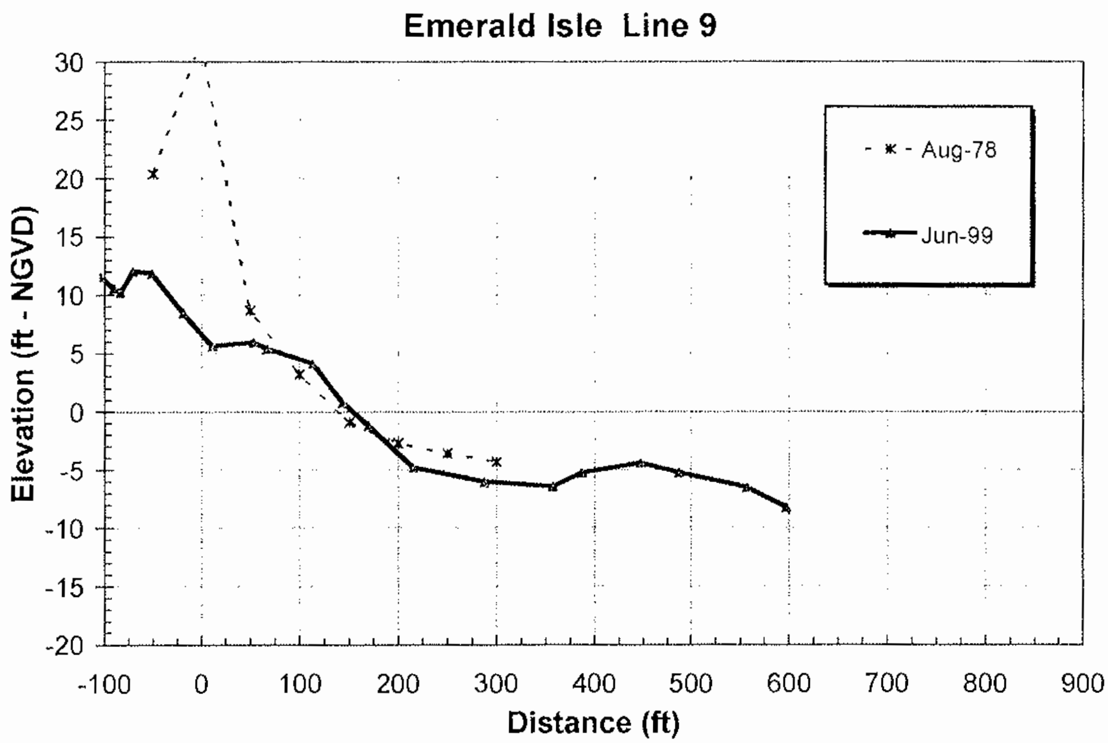



Emerald Isle Line 3
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

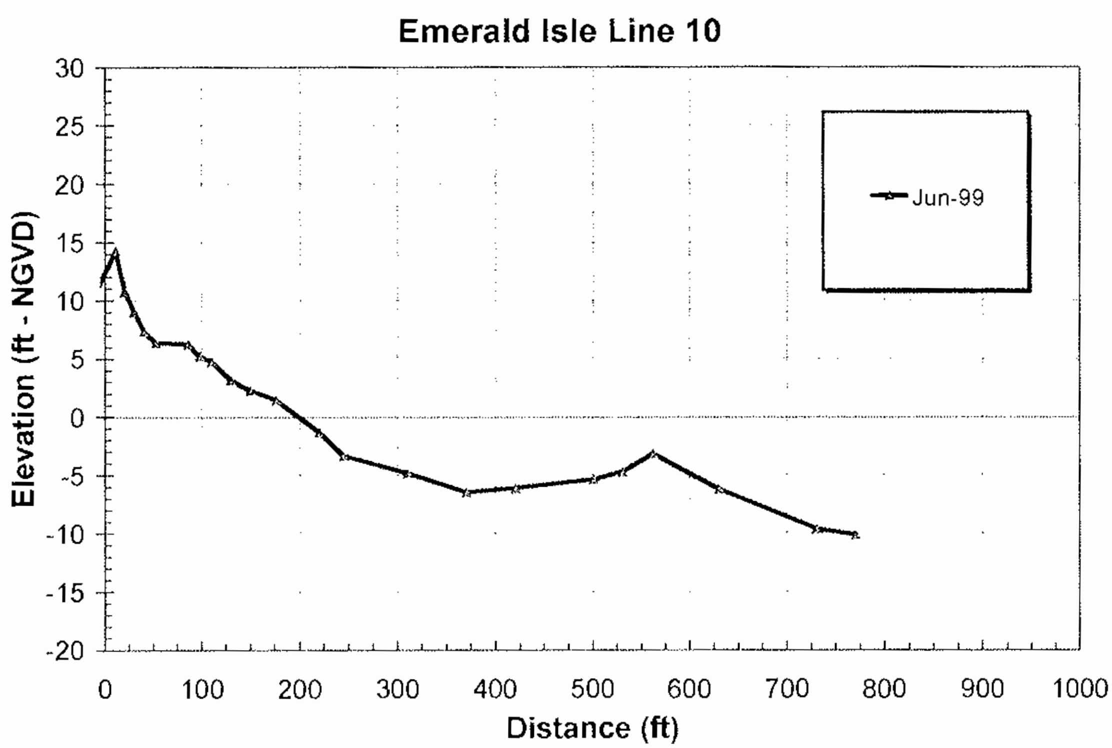

Emerald Isle Line 5
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle Line 7
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

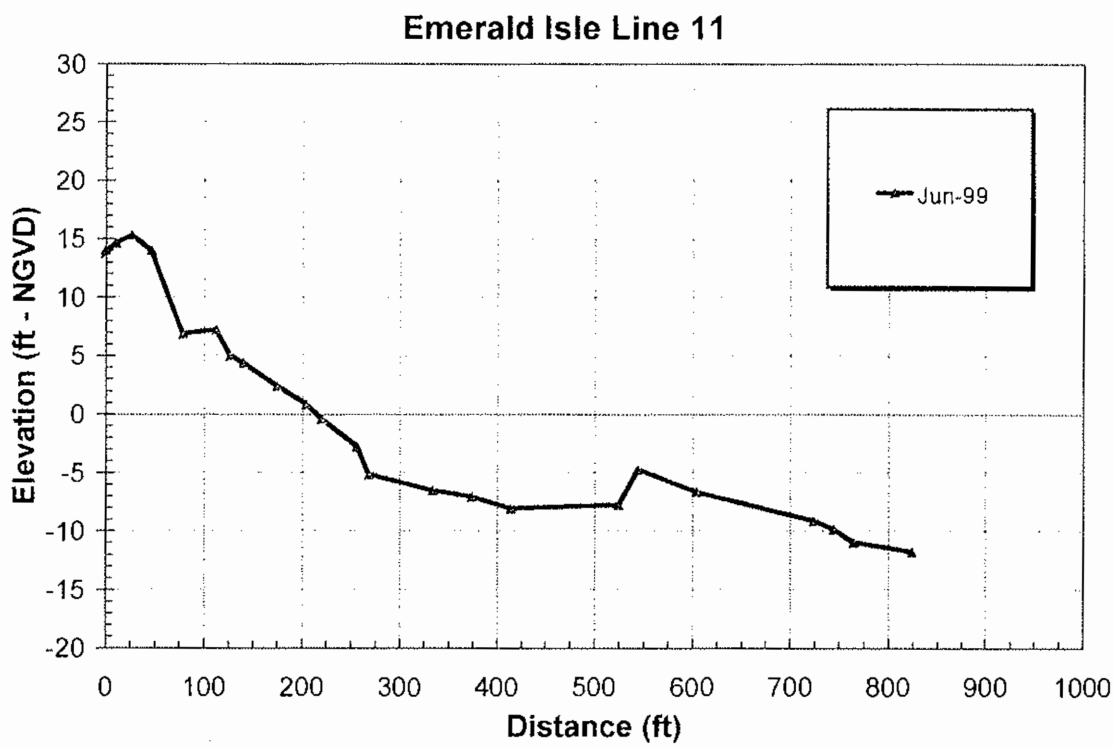

Emerald Isle Line 8
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)



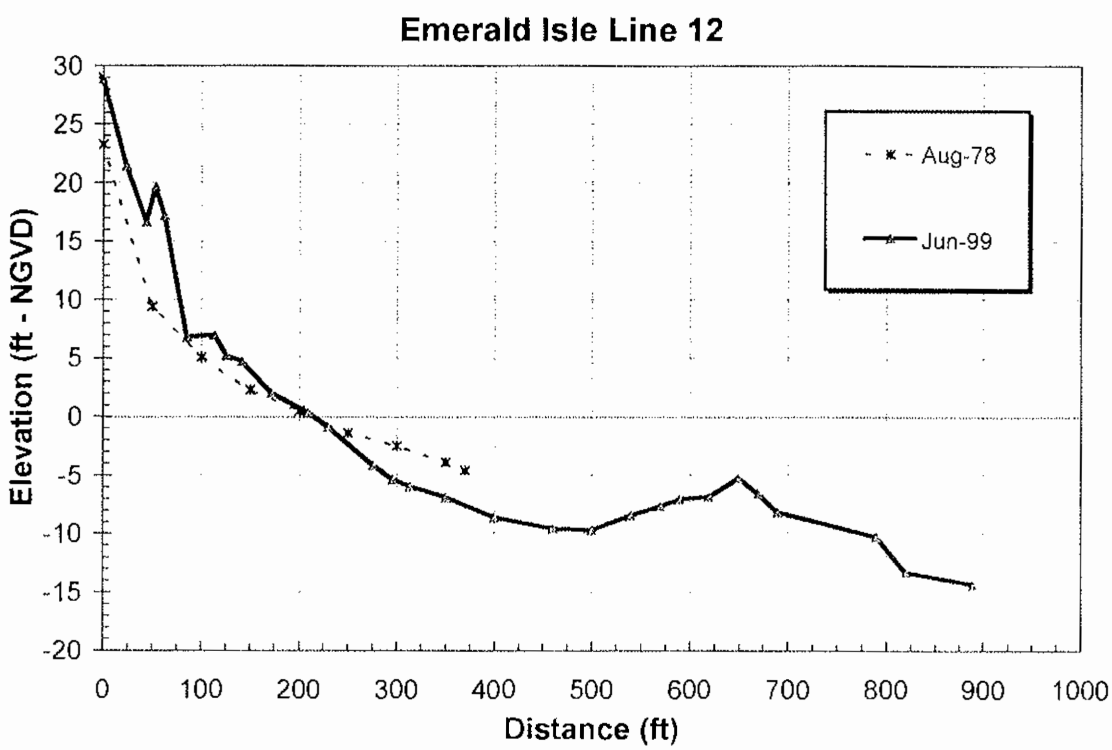
Emerald Isle Line 9
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
-100
0
100
200
300
400
500
600
700
800
900



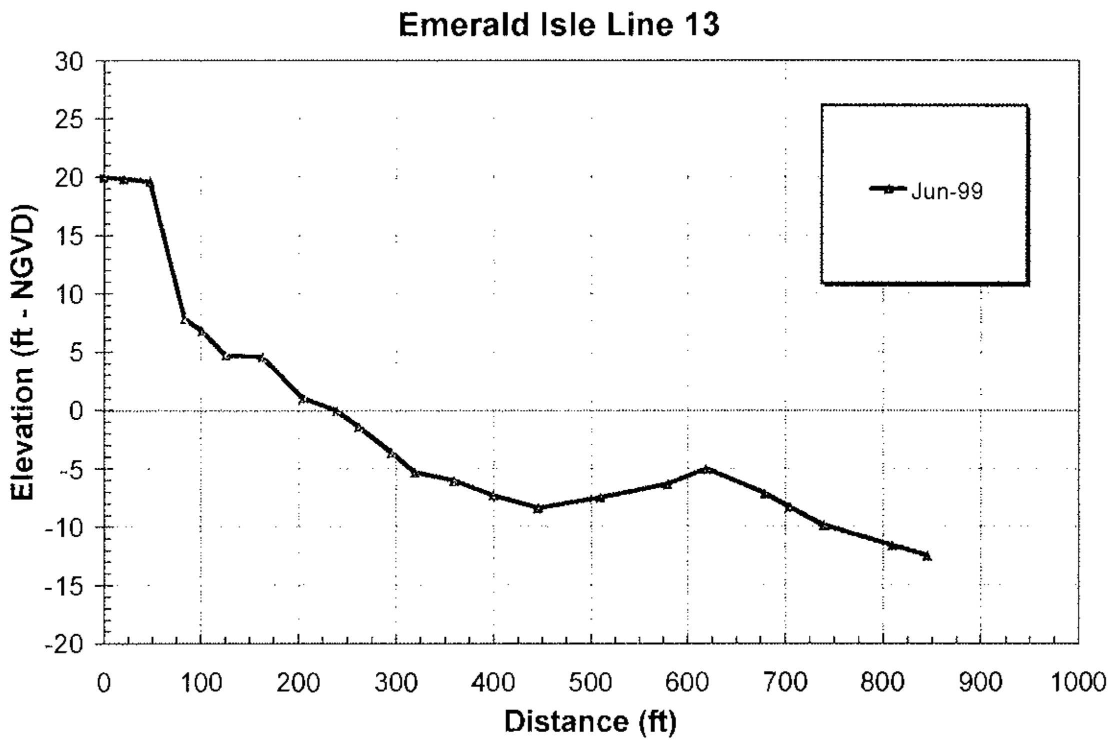
Emerald Isle Line 10
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

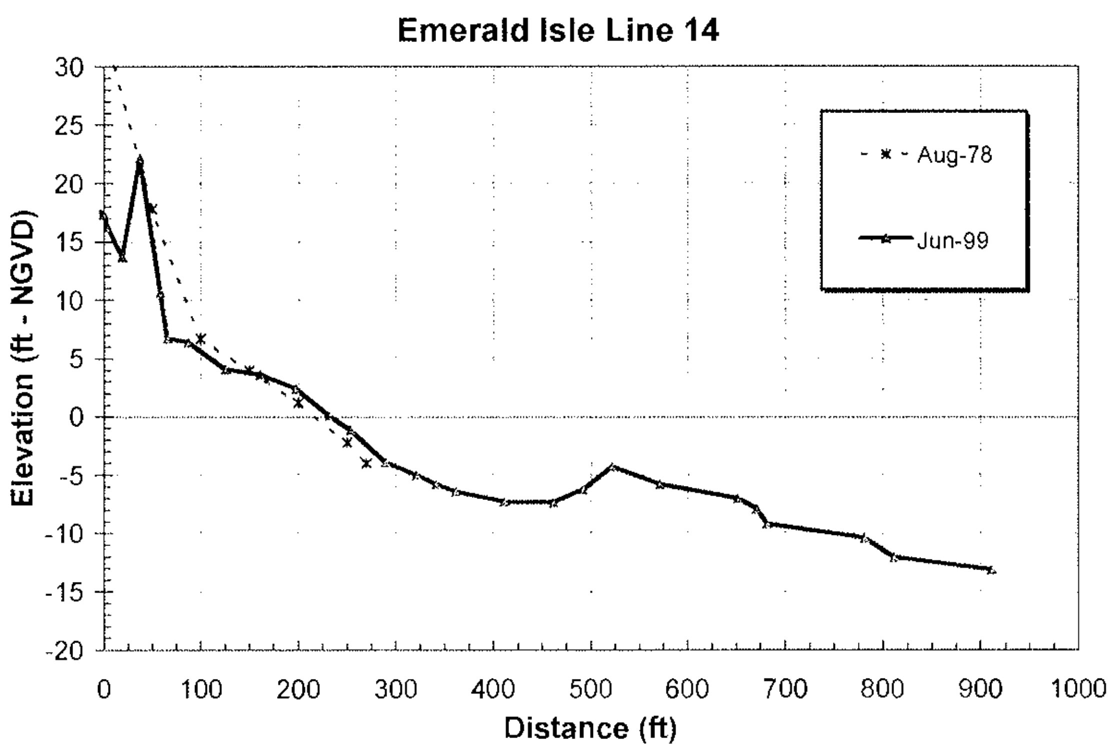


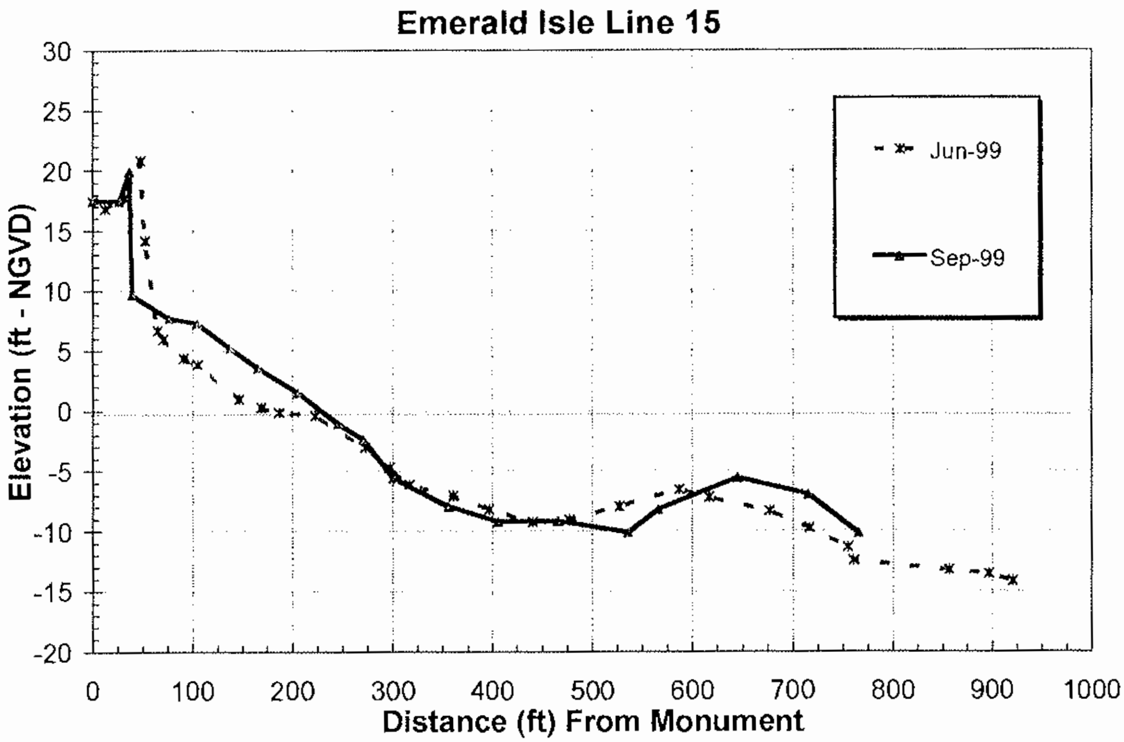
Emerald Isle Line 11
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

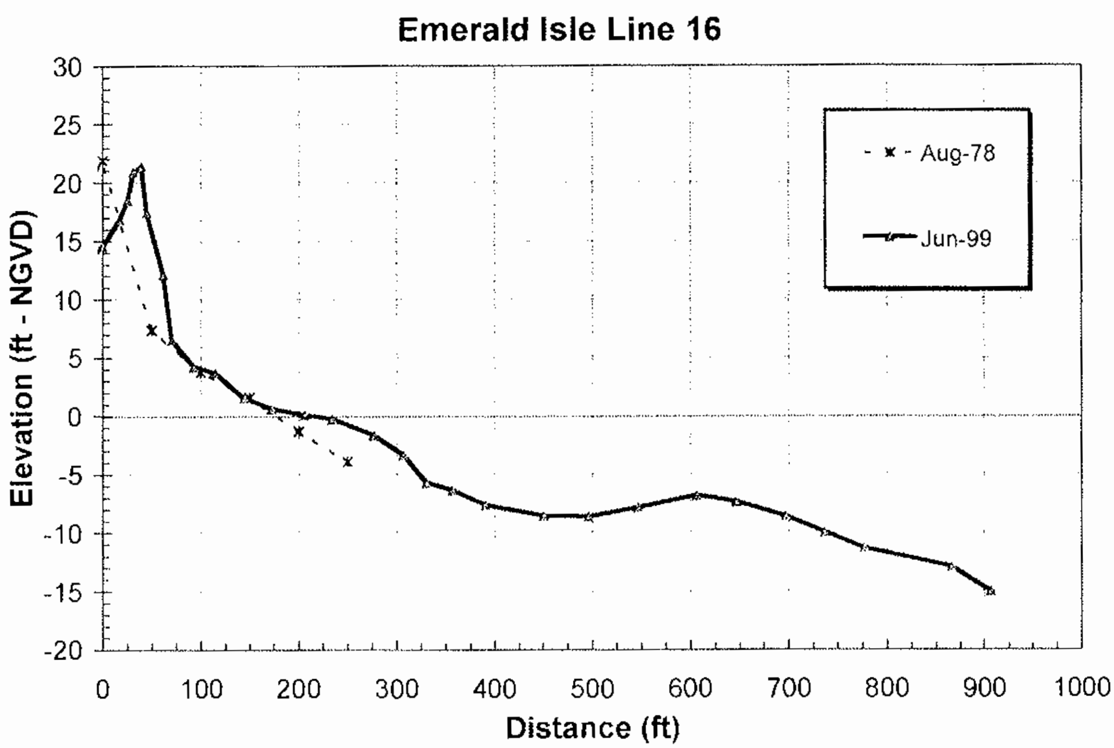


Emerald Isle Line 12
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

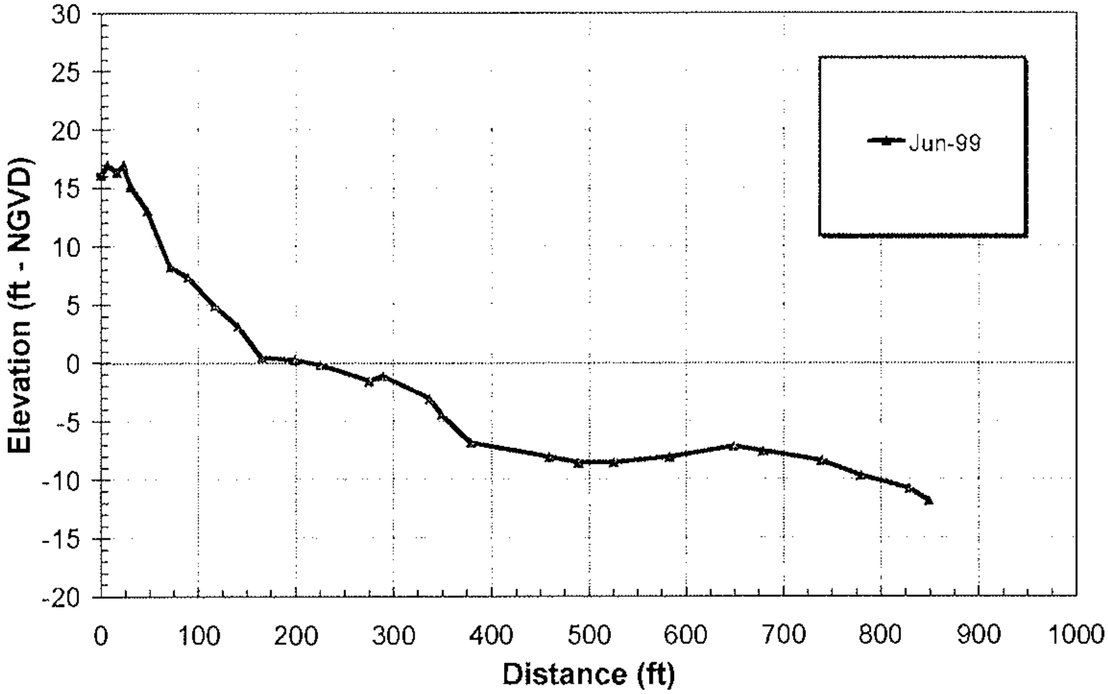

Emerald Isle Line 13
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle Line 14
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

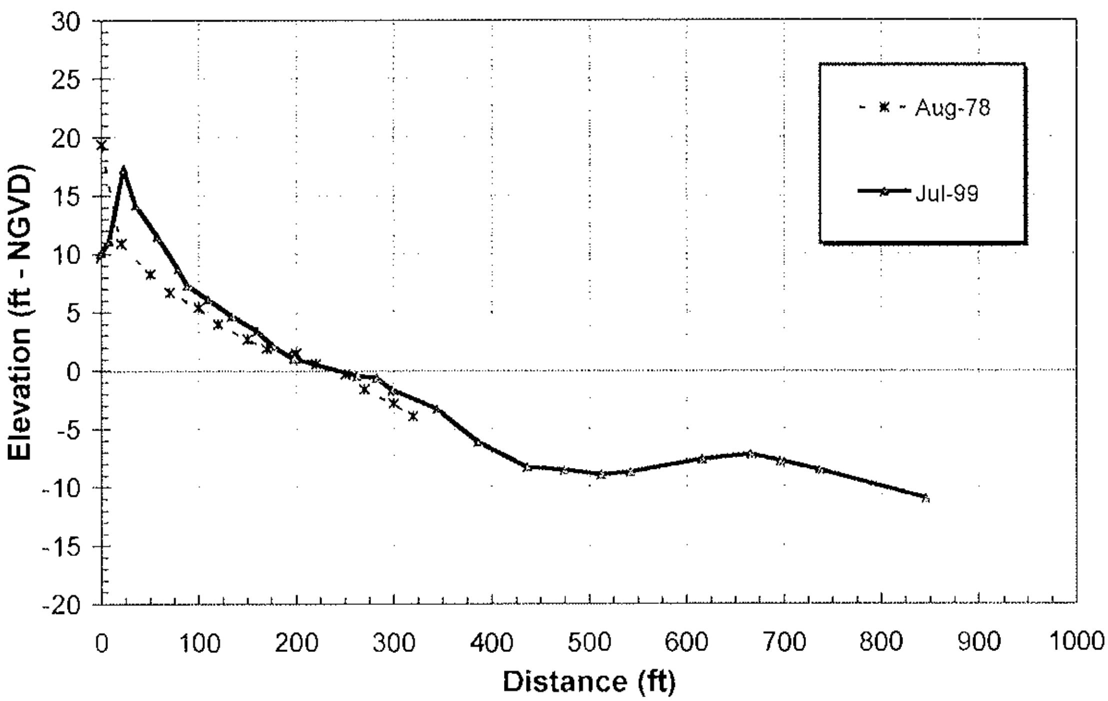

Emerald Isle Line 15
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

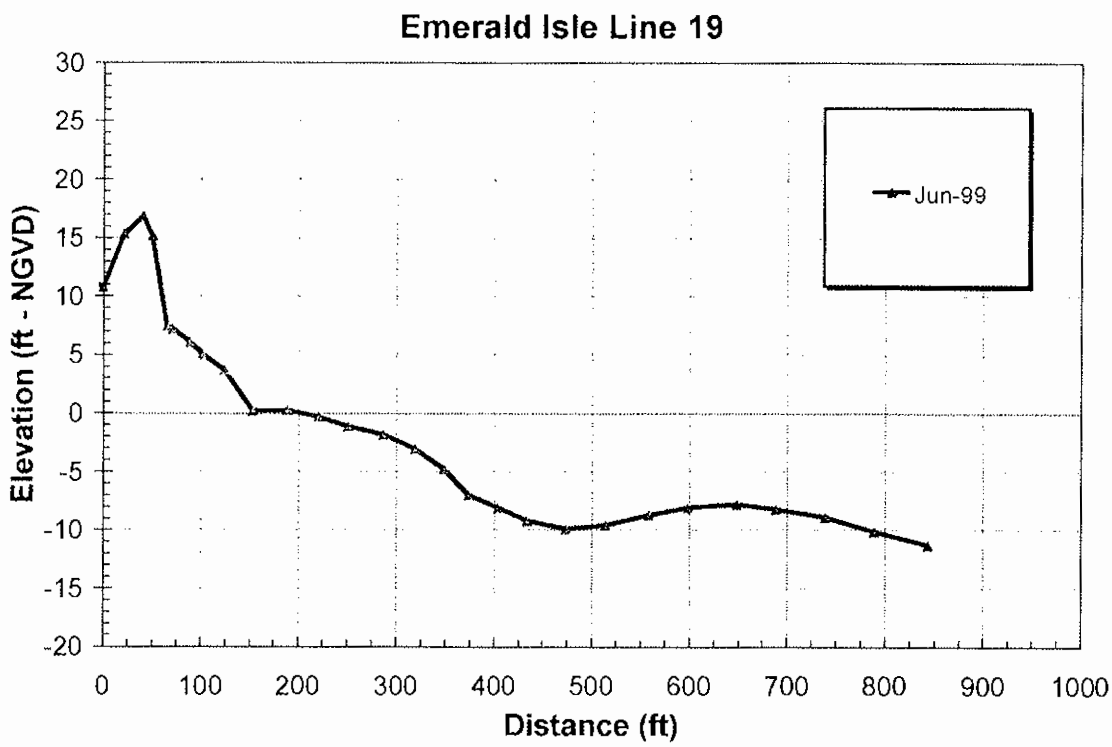

Emerald Isle Line 16
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

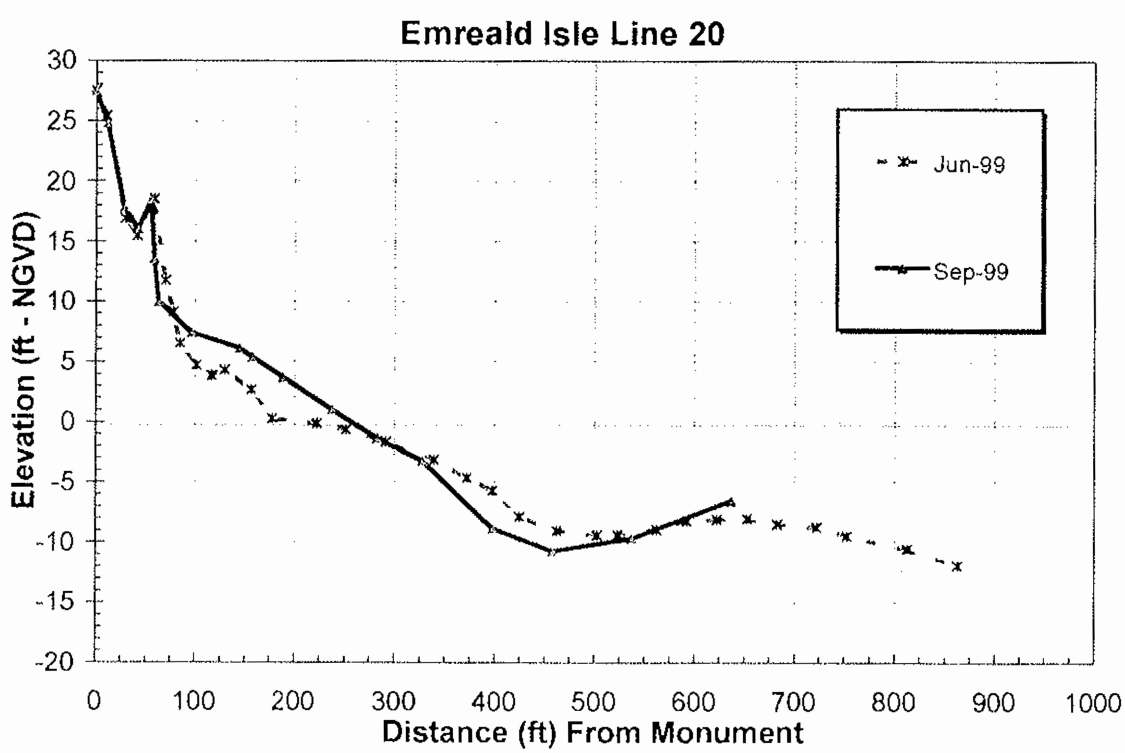
Emerald Isle Line 17

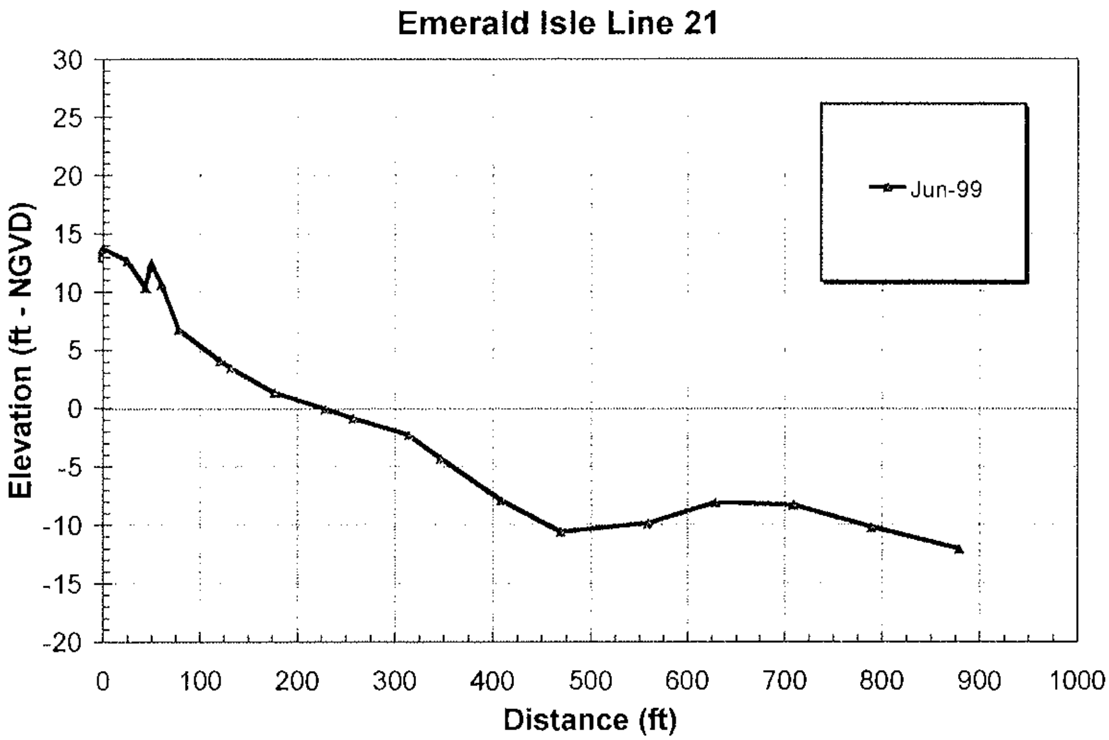


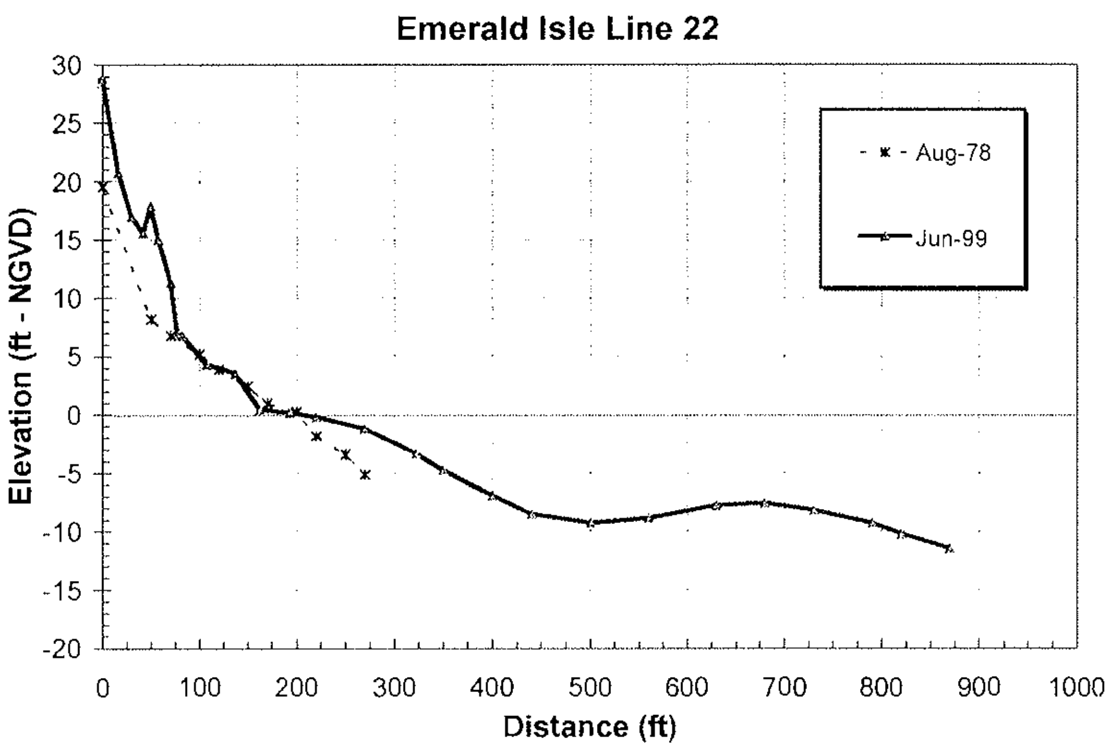
Emerald Isle Line 18

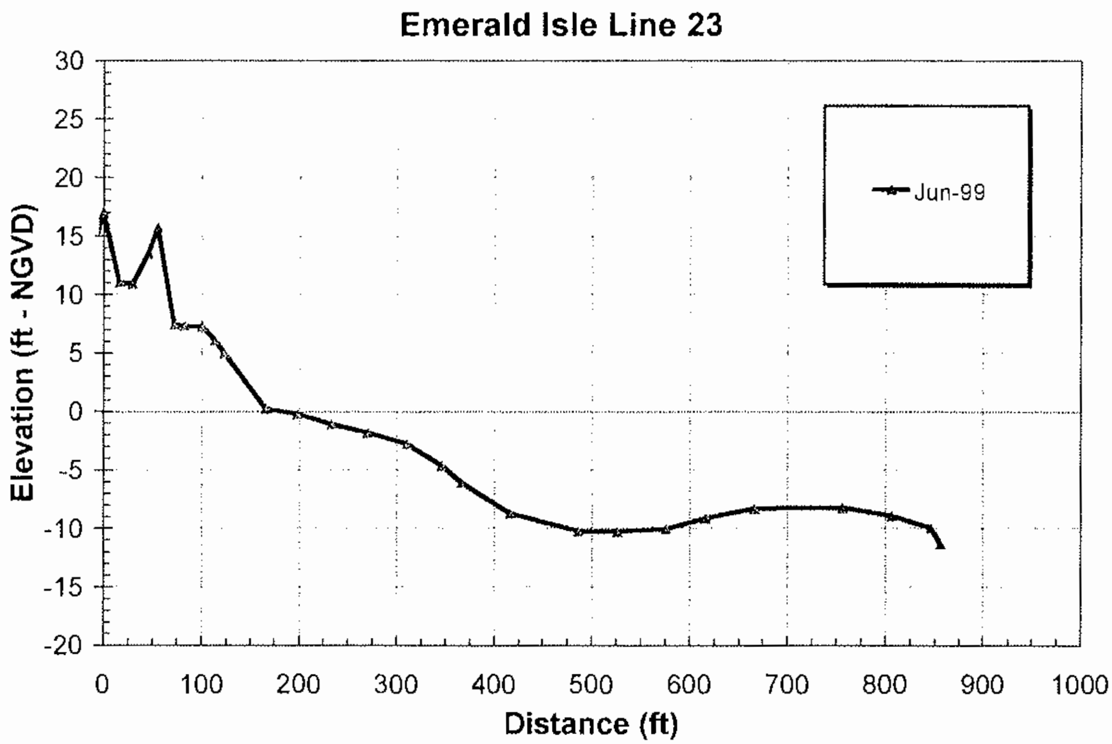


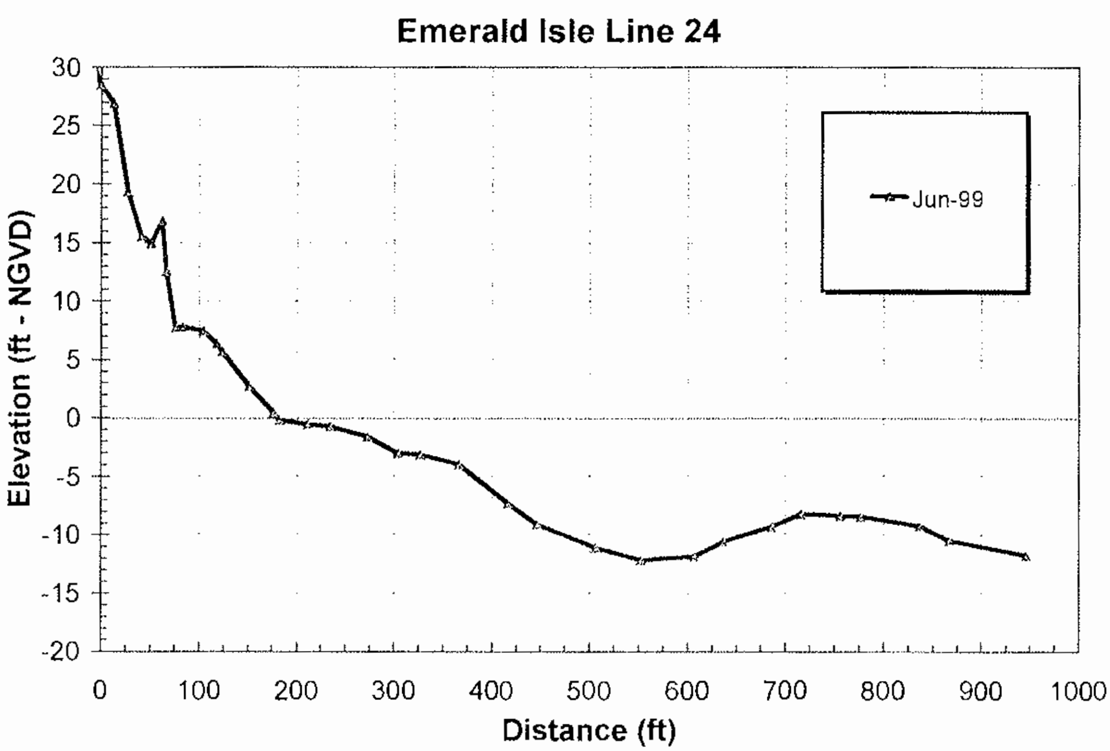

Emerald Isle Line 19
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

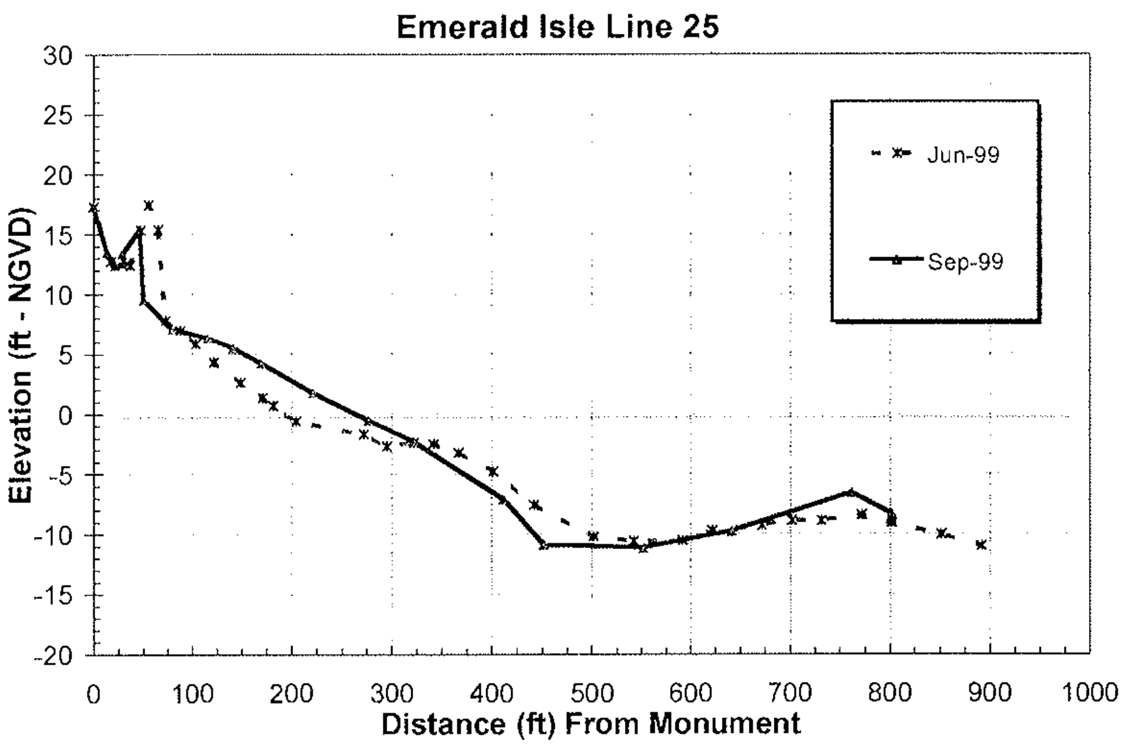

Emreald Isle Line 20
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

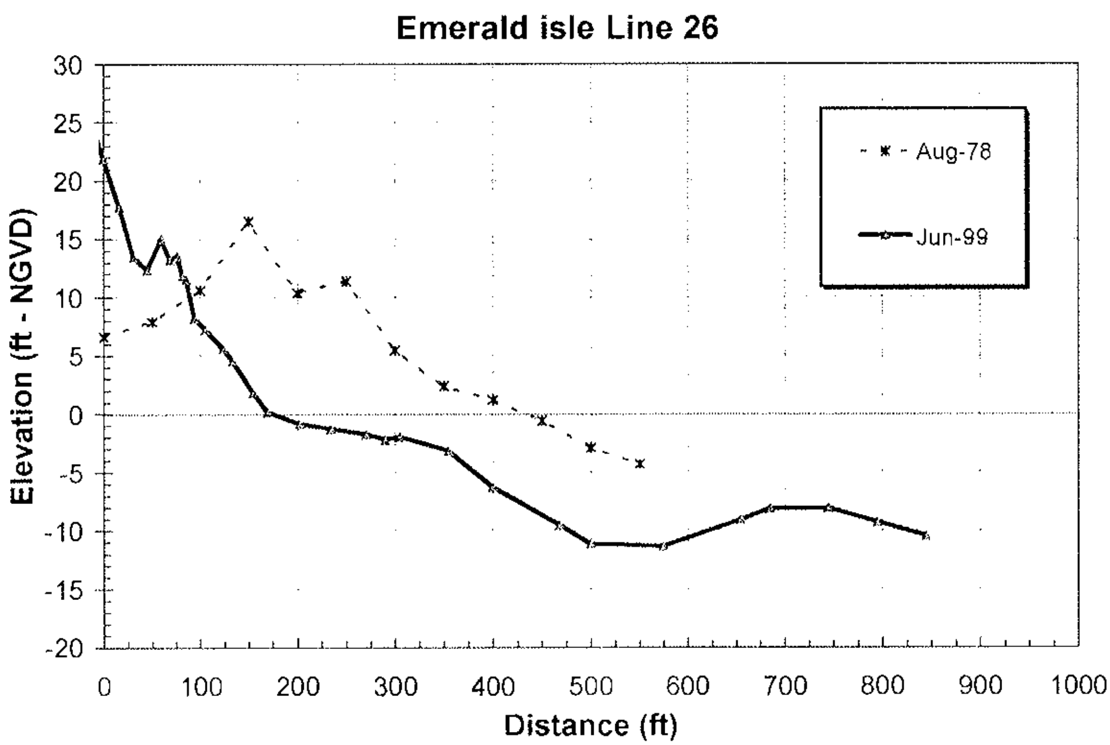

Emerald Isle Line 21
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

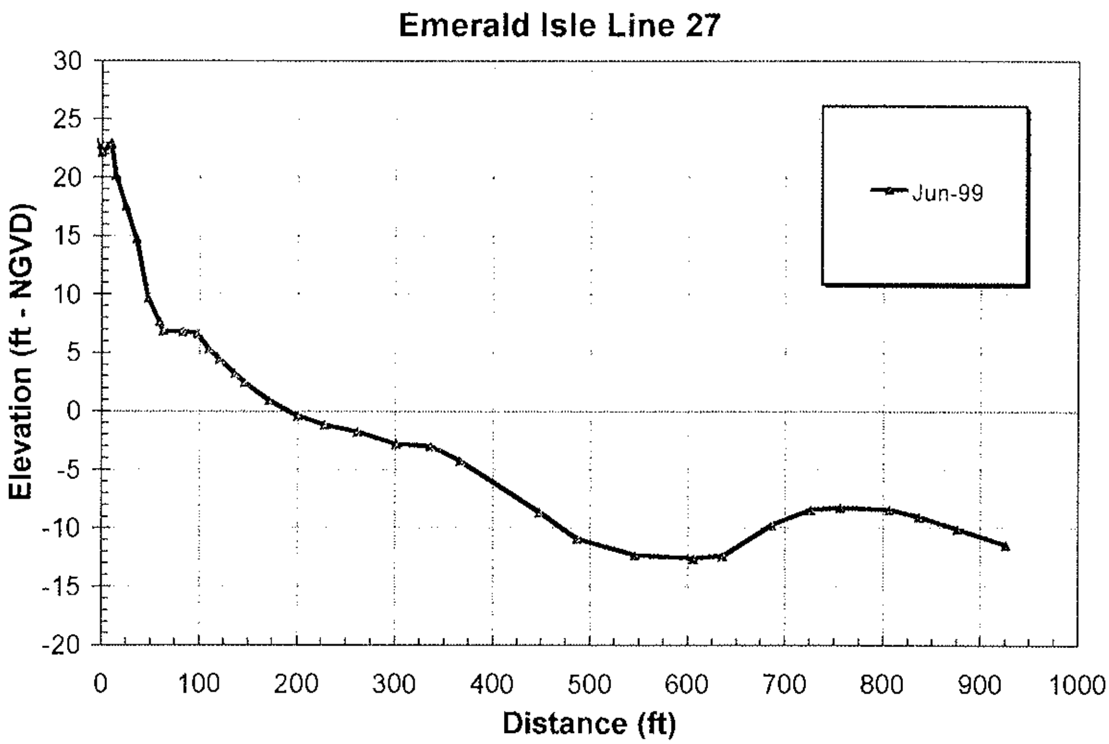

Emerald Isle Line 22
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle Line 23
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

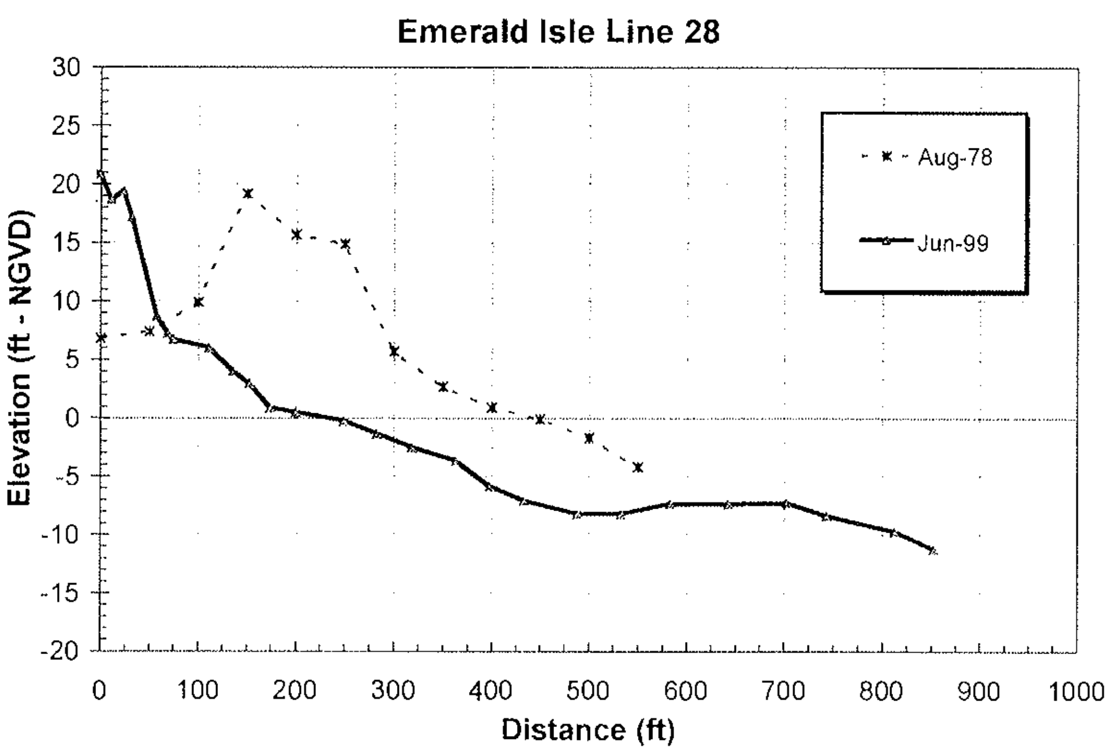

Emerald Isle Line 24
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle Line 25
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Sep-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

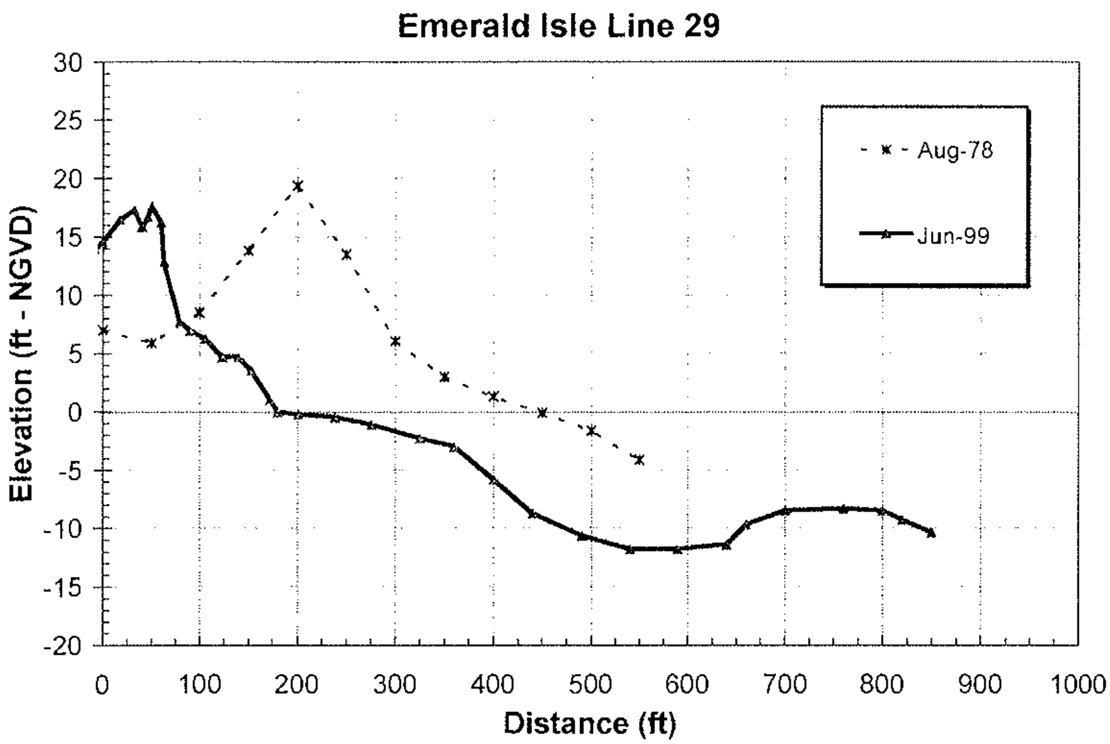

Emerald isle Line 26
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

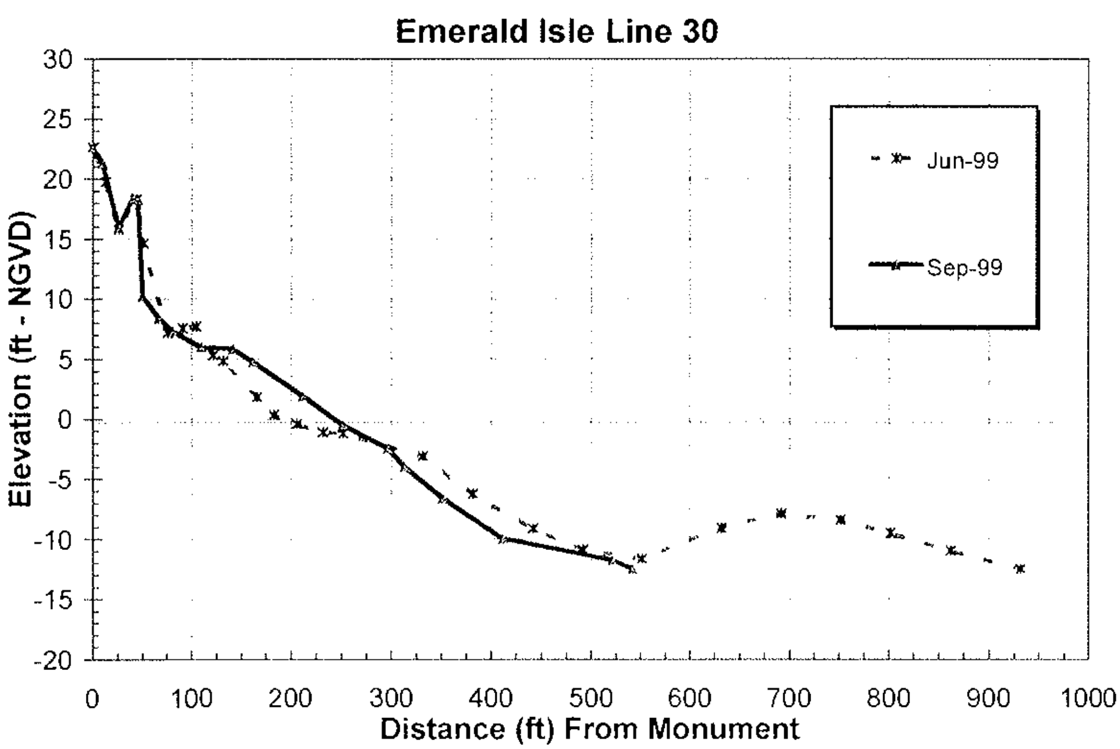


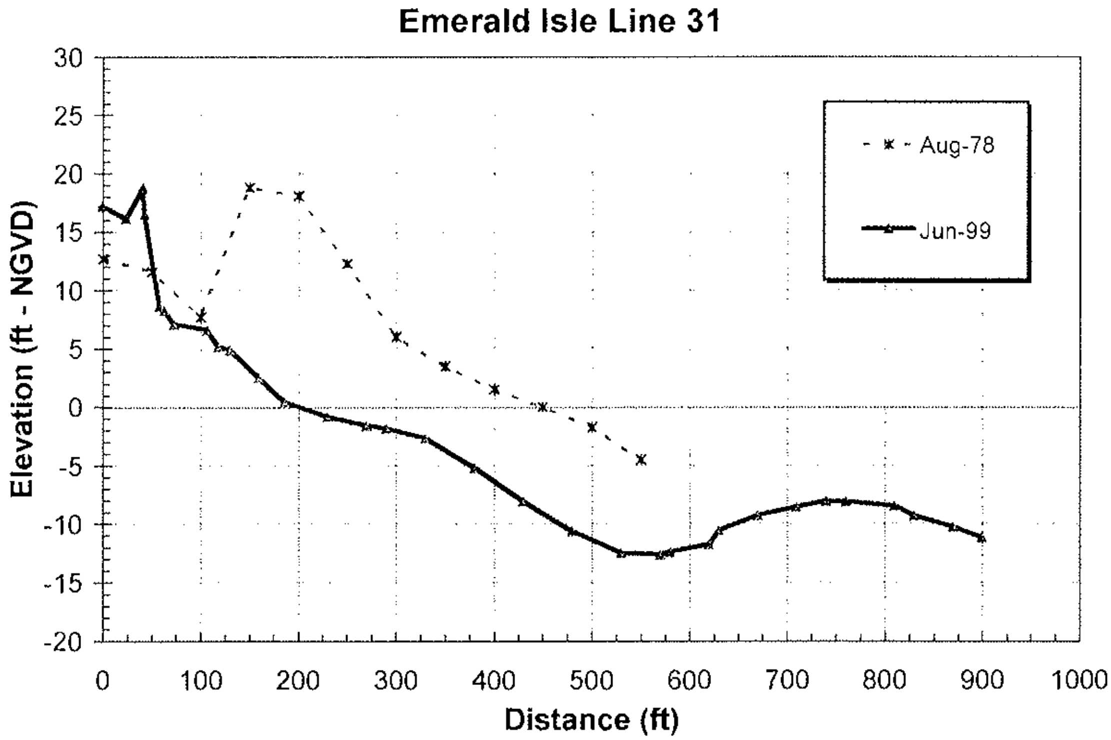
Emerald Isle Line 27
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

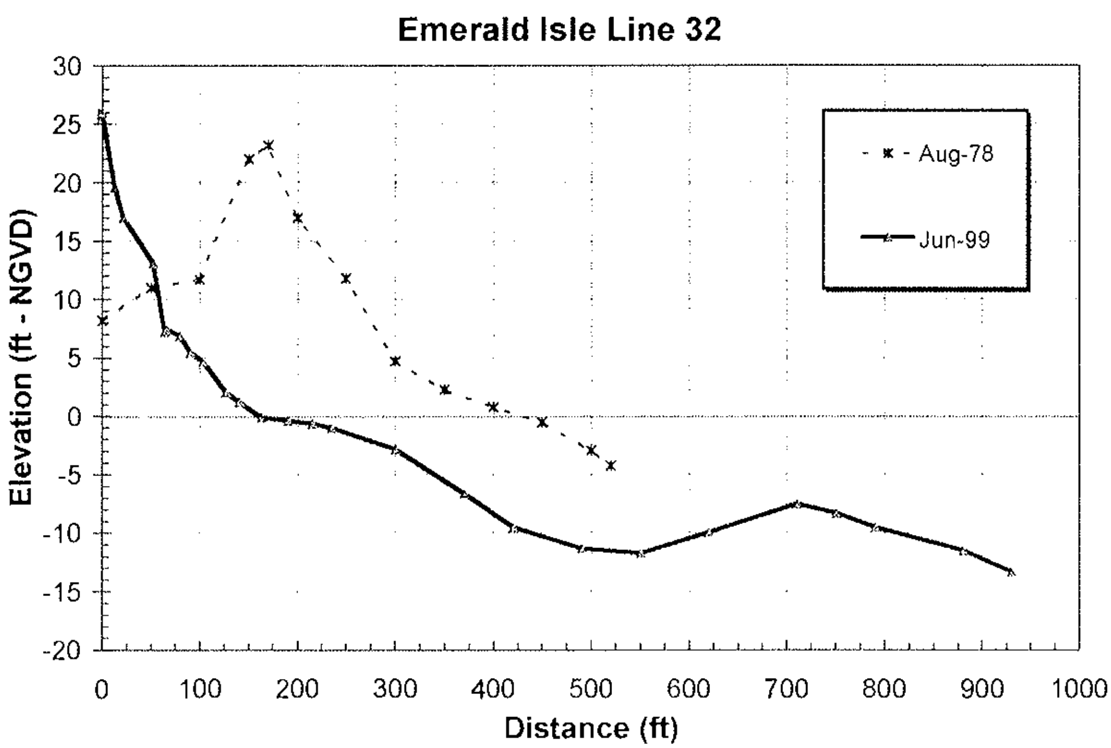


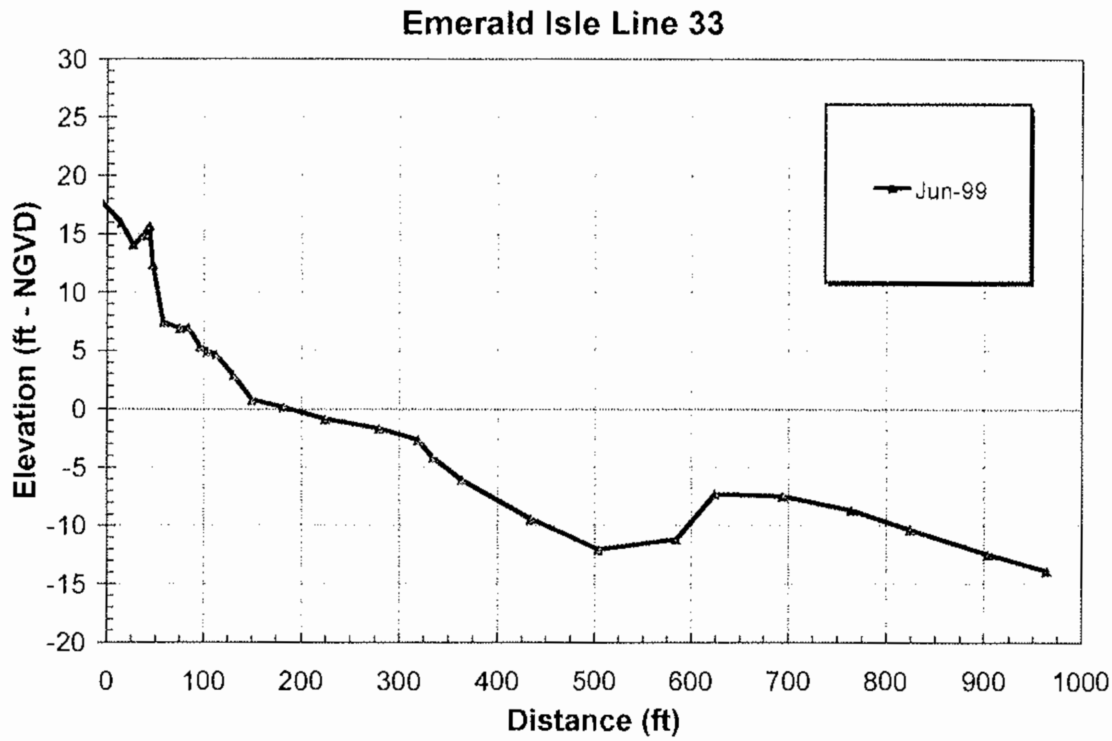
Emerald Isle Line 28
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

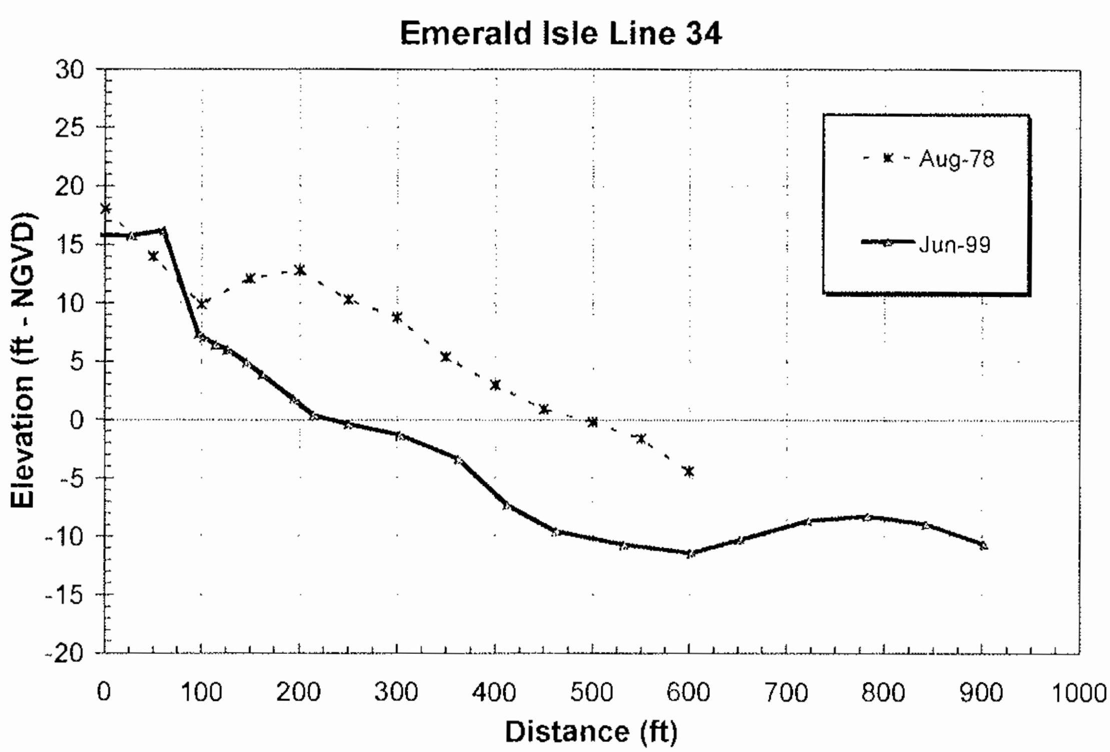

Emerald Isle Line 29
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

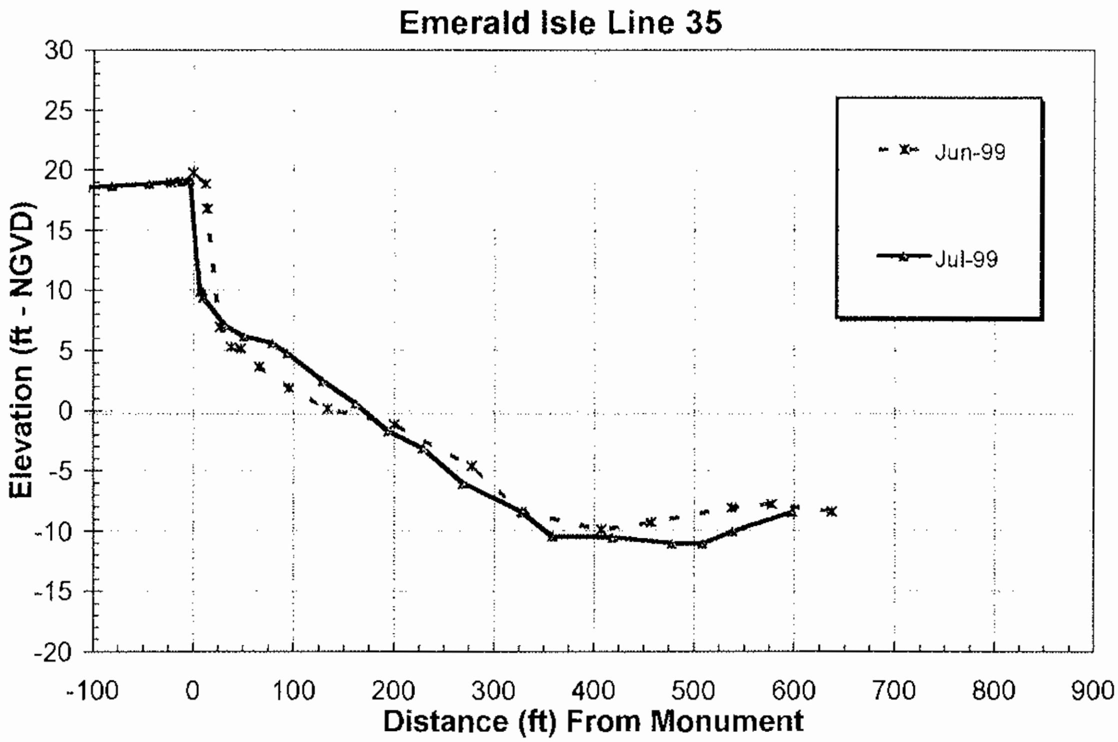

Emerald Isle Line 30
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

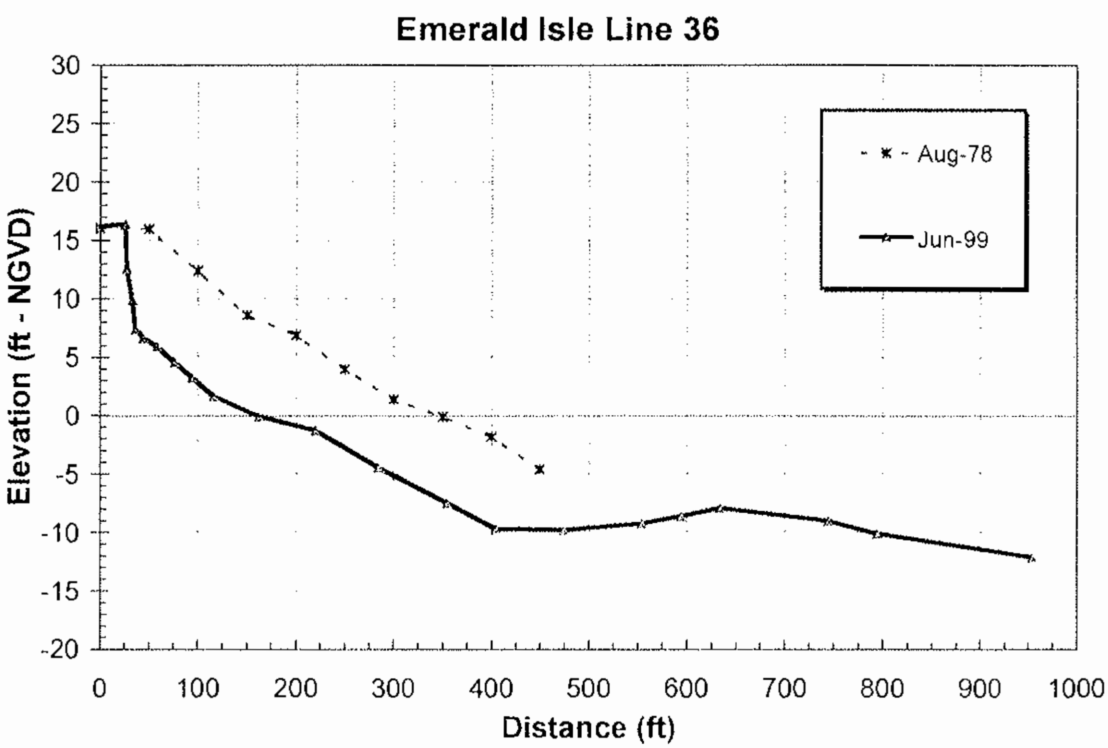

Emerald Isle Line 31
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

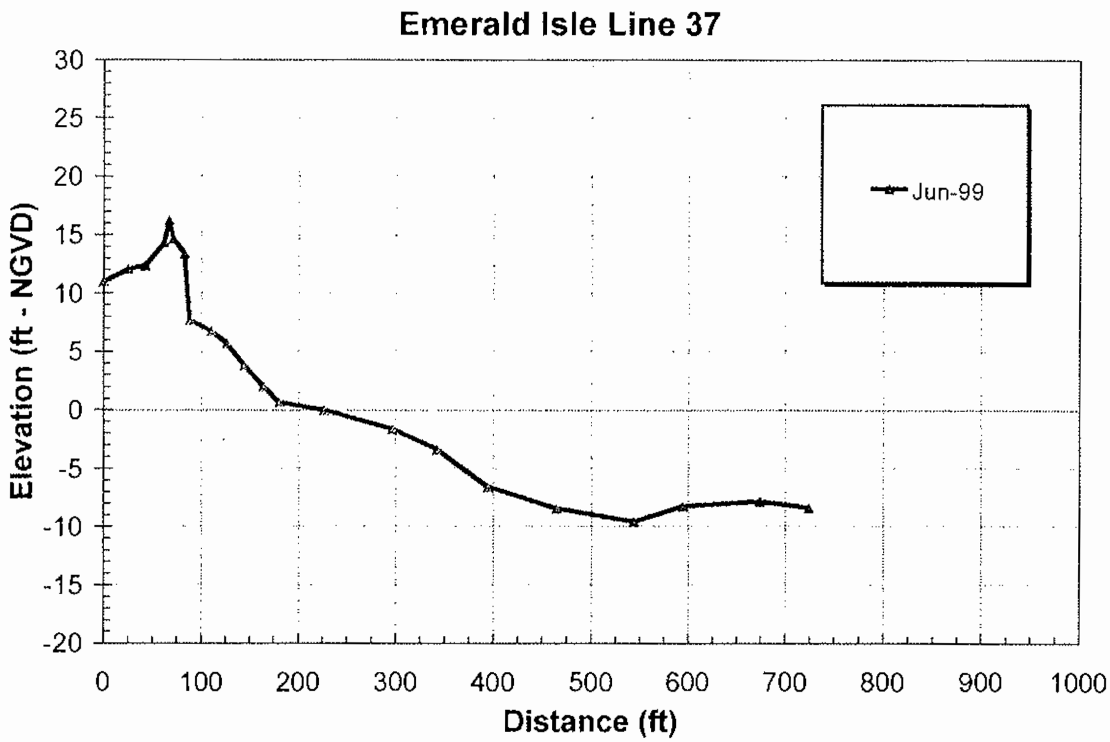

Emerald Isle Line 32
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

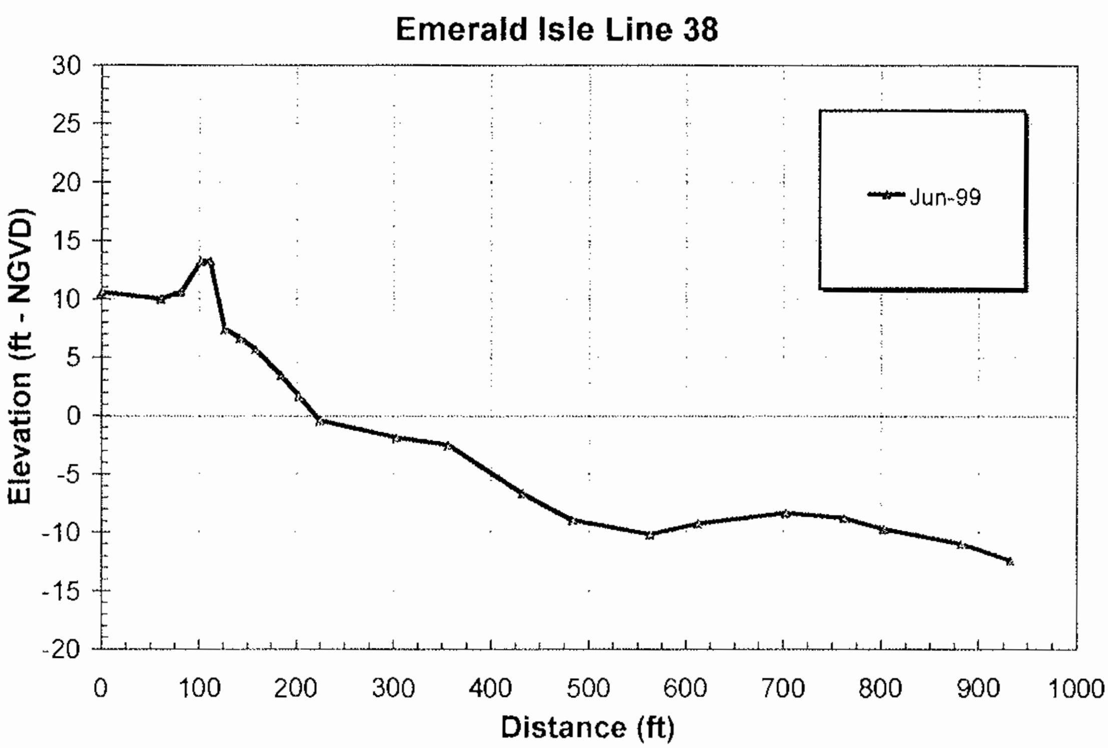

Emerald Isle Line 33
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

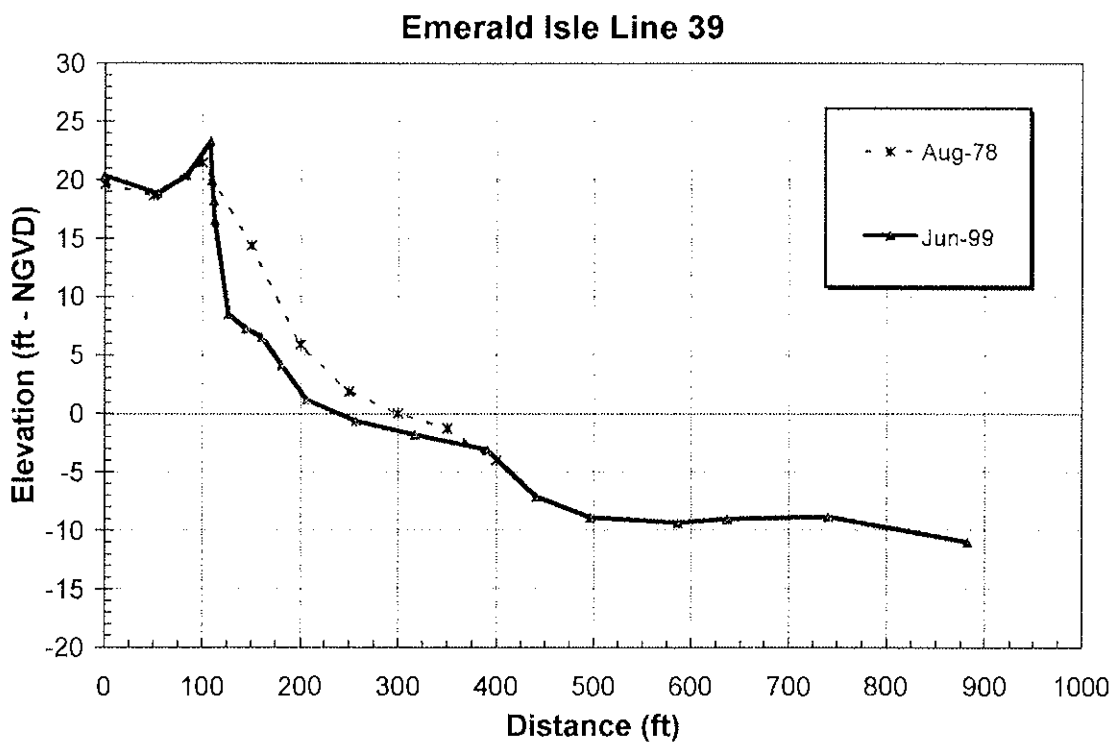

Emerald Isle Line 34
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle Line 35
Jun-99
Jul-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
-100
0
100
200
300
400
500
600
700
800
900

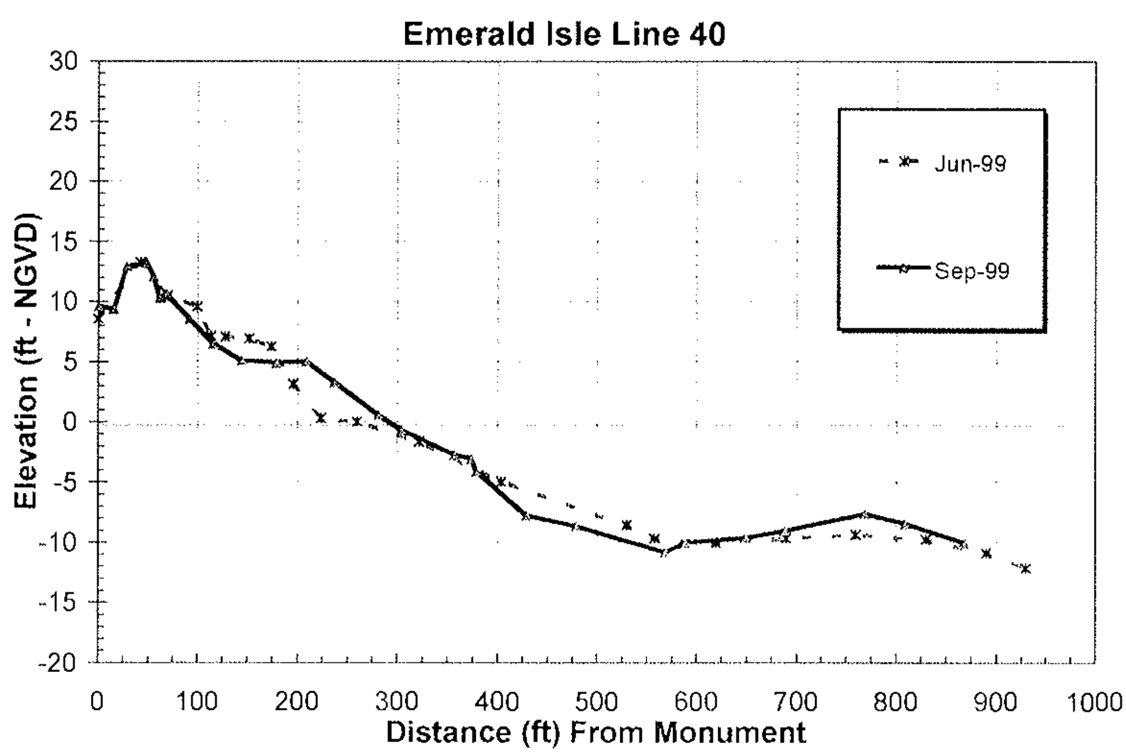

Emerald Isle Line 36
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Emerald Isle Line 37
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

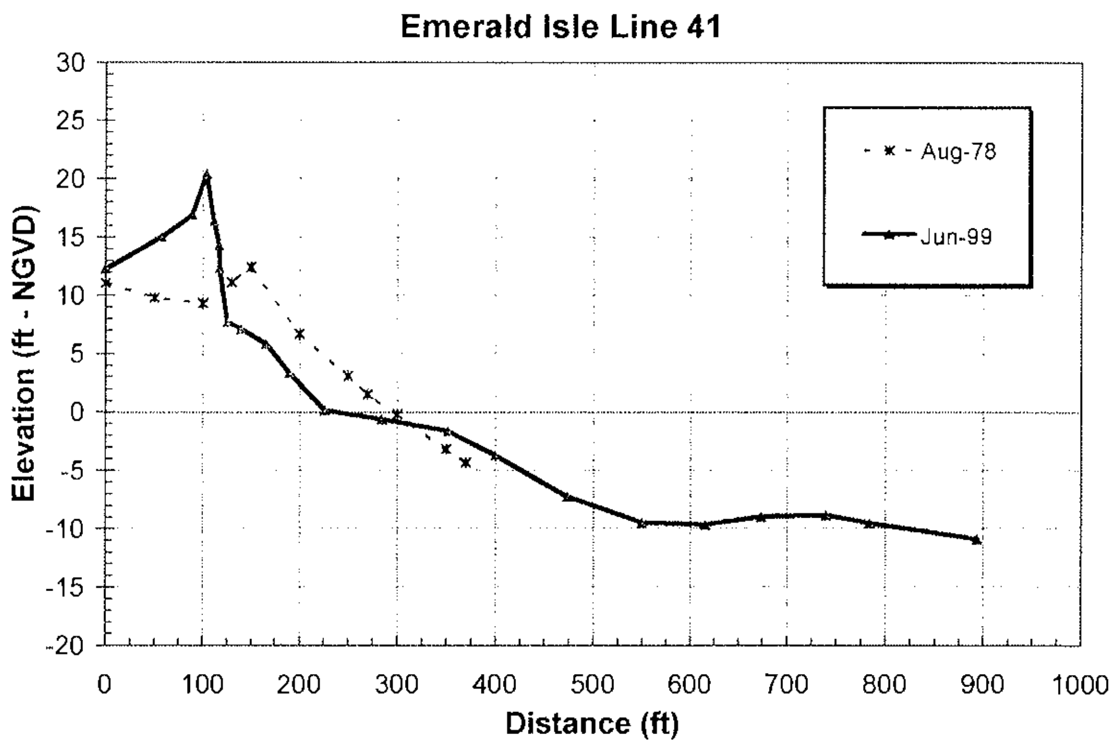

Emerald Isle Line 38
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

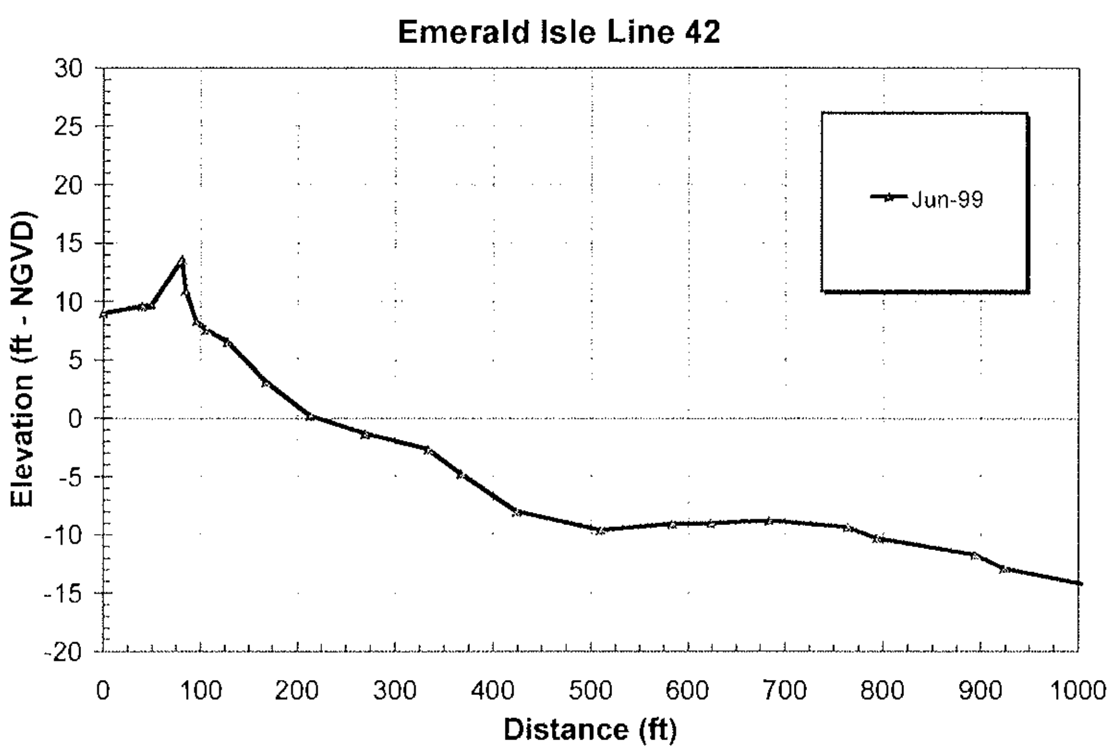


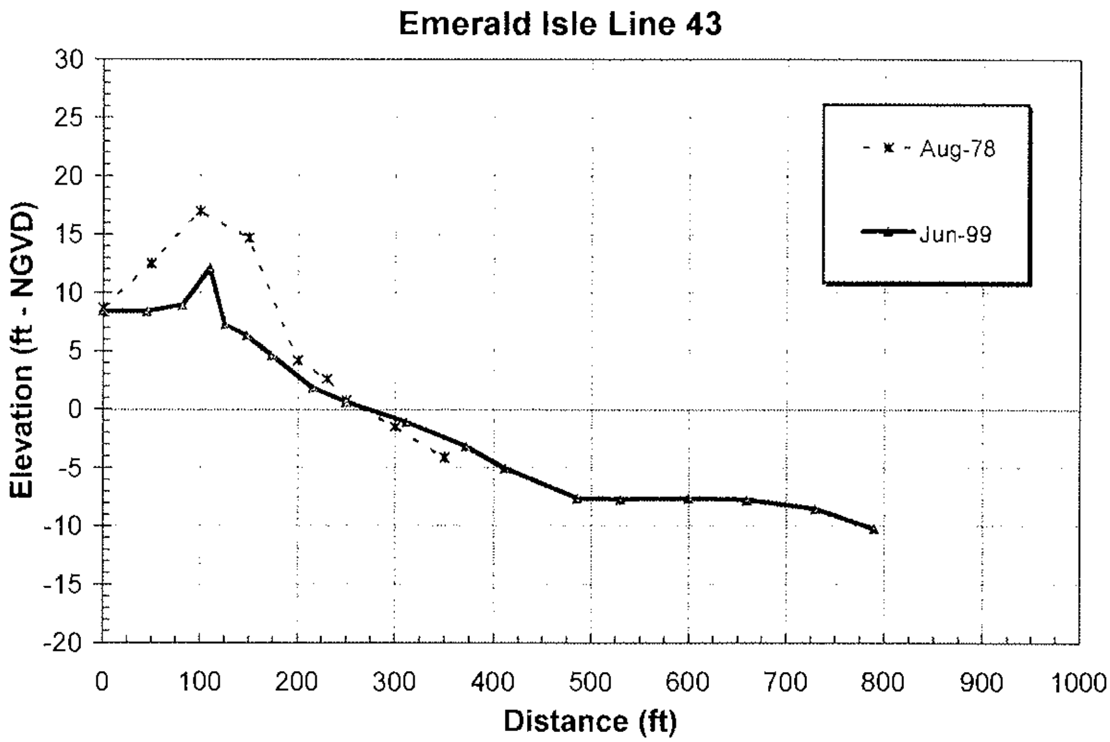
Emerald Isle Line 39
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

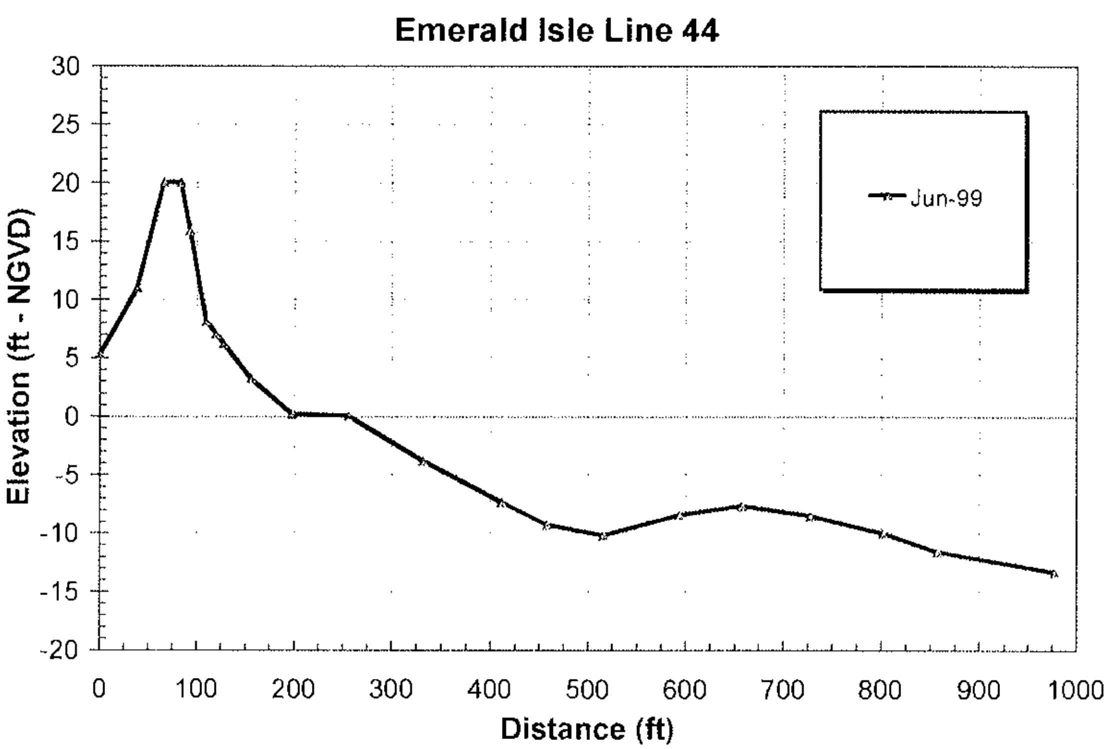


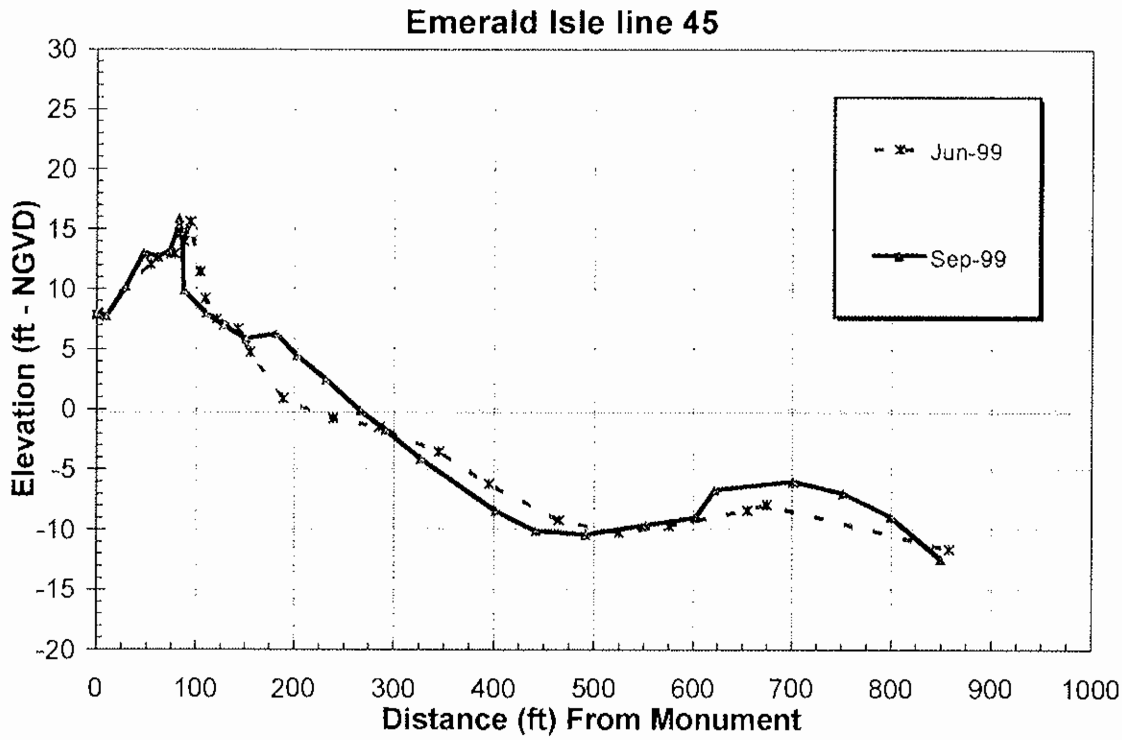
Emerald Isle Line 40
Jun-99
Sep-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

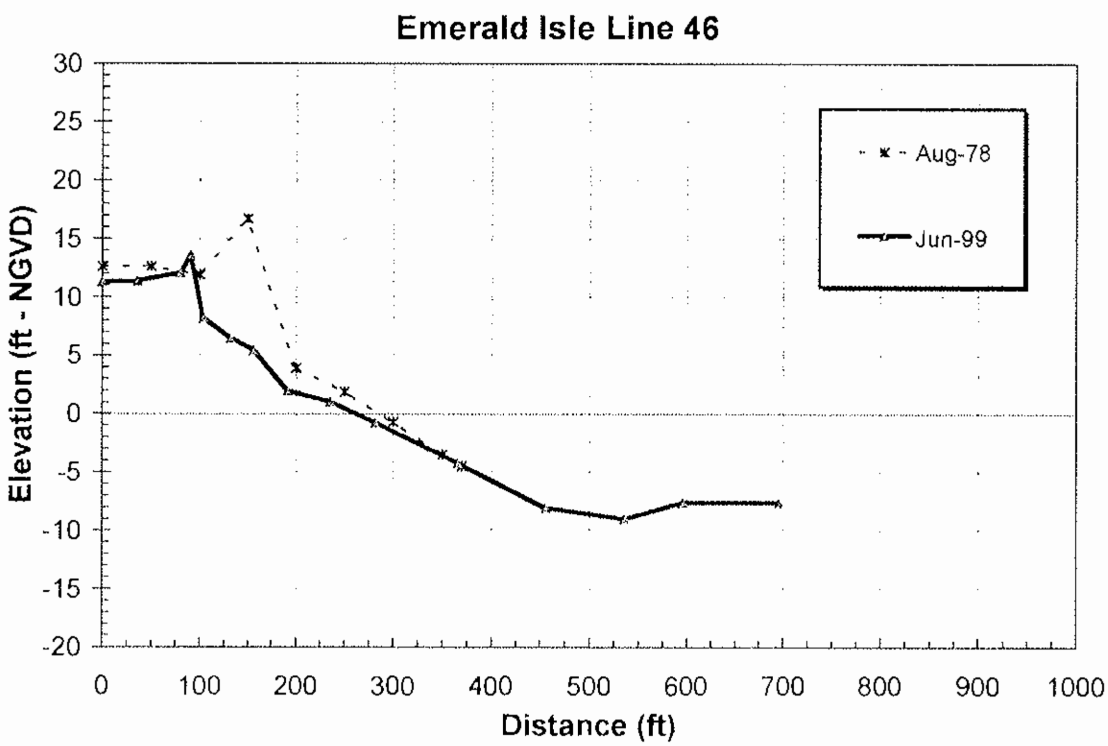

Emerald Isle Line 41
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

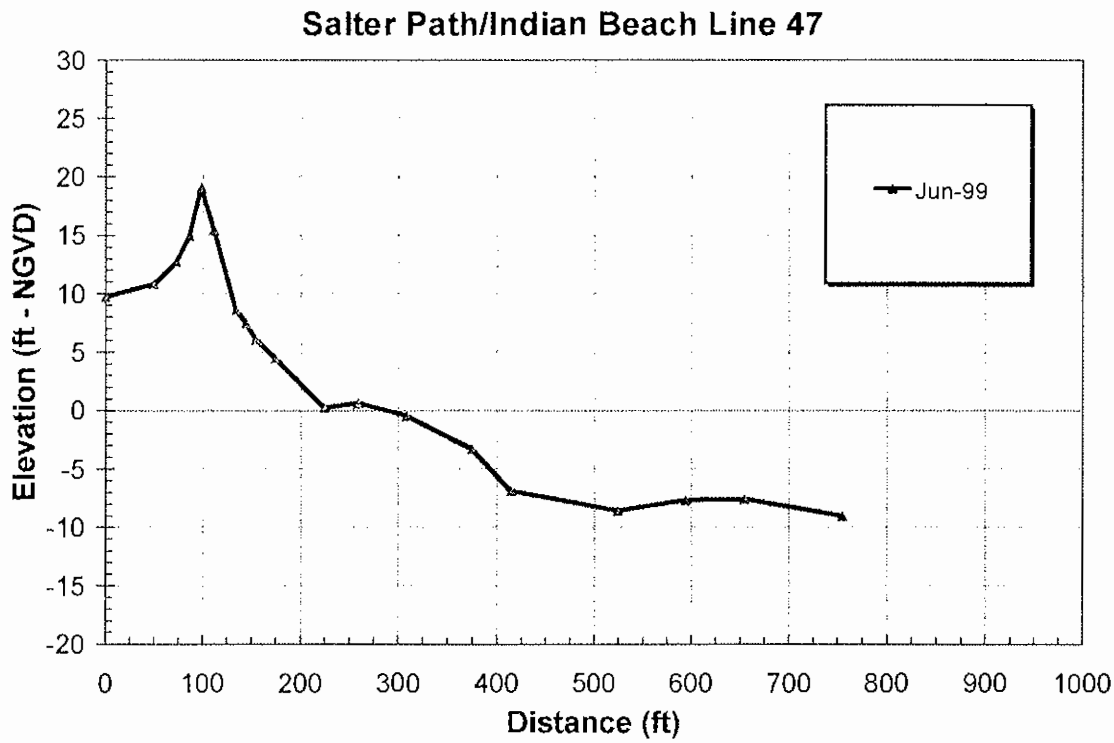

Emerald Isle Line 42
Elevation (ft - NGVD)
Distance (ft)
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

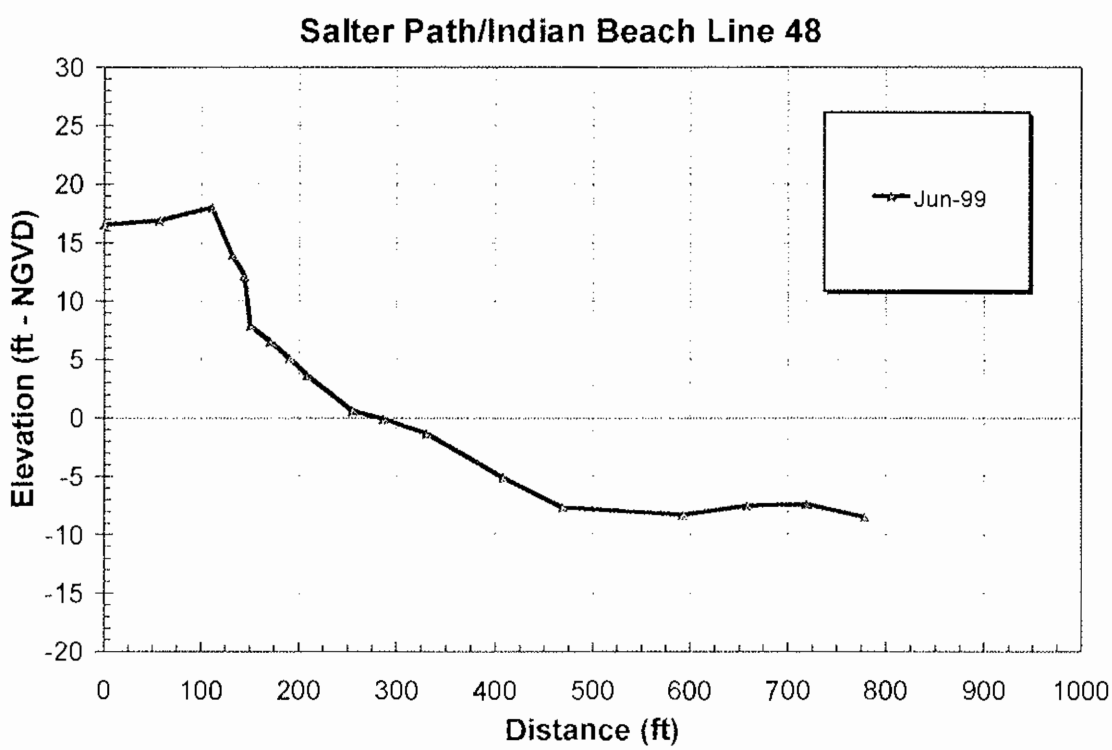

Emerald Isle Line 43
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

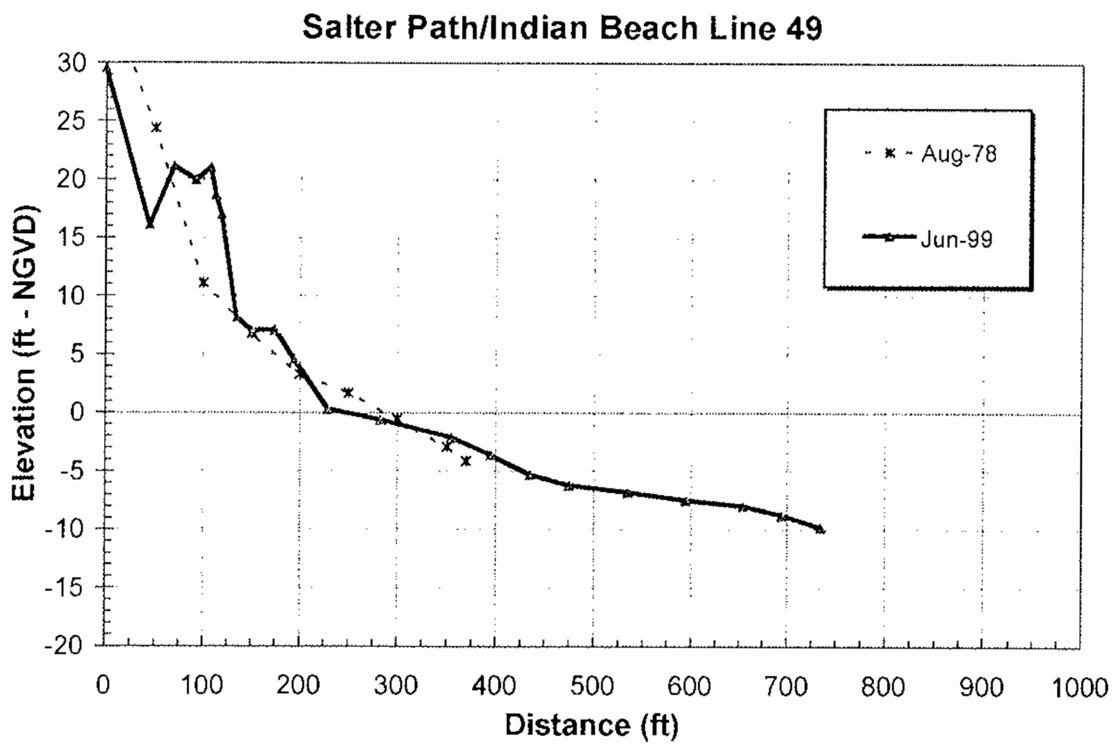

Emerald Isle Line 44
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

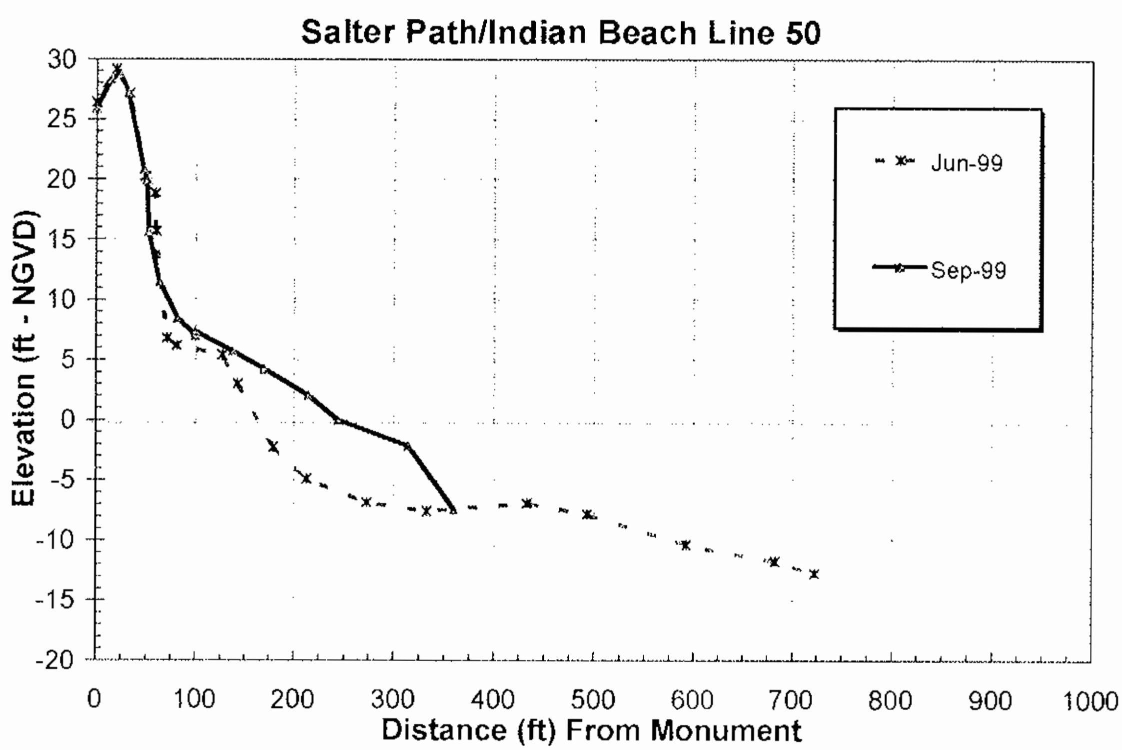

Emerald Isle line 45
Jun-99
Sep-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

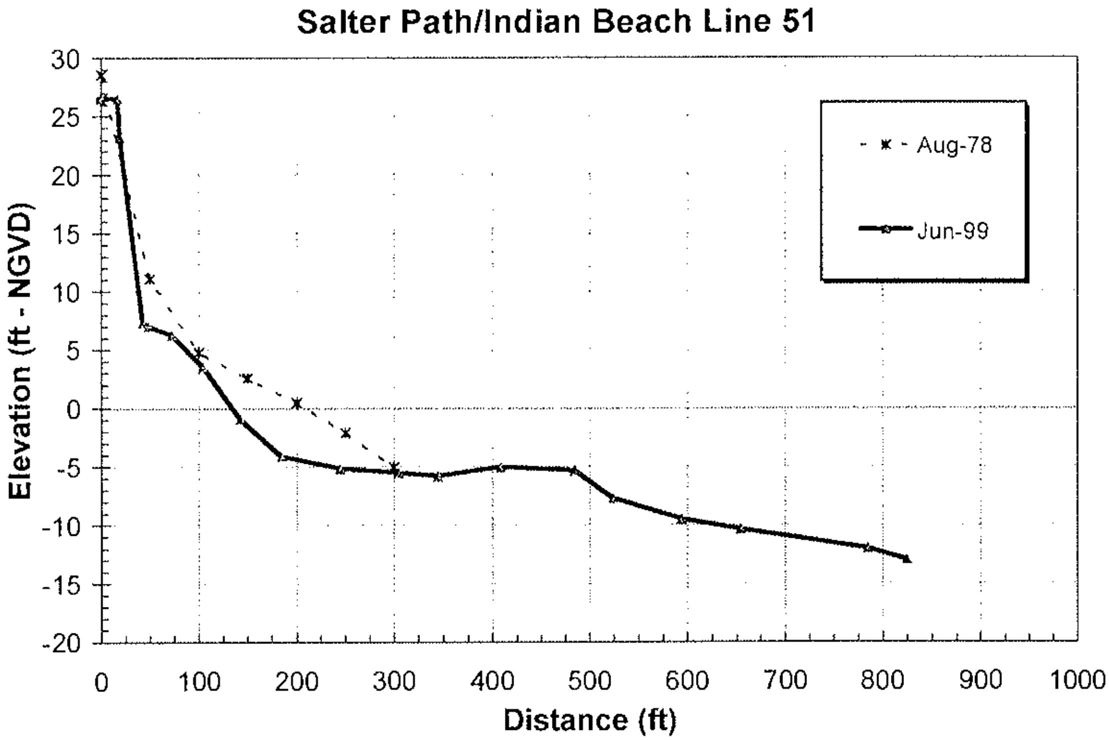

Emerald Isle Line 46
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

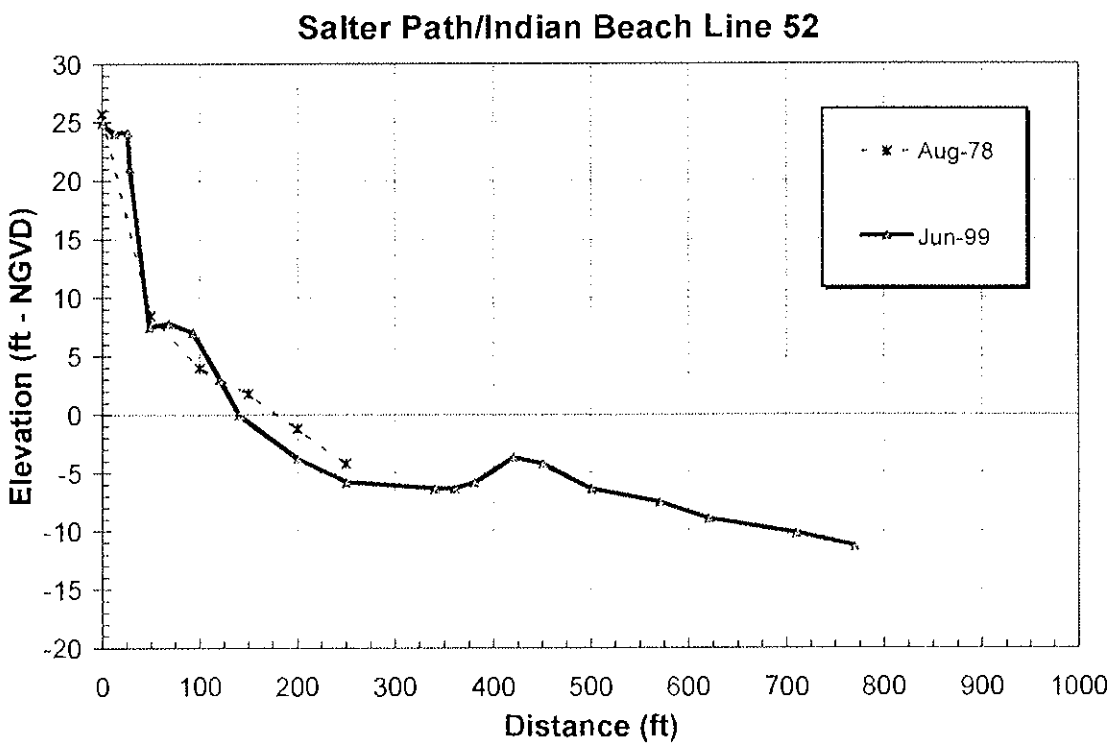

Salter Path/Indian Beach Line 47
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

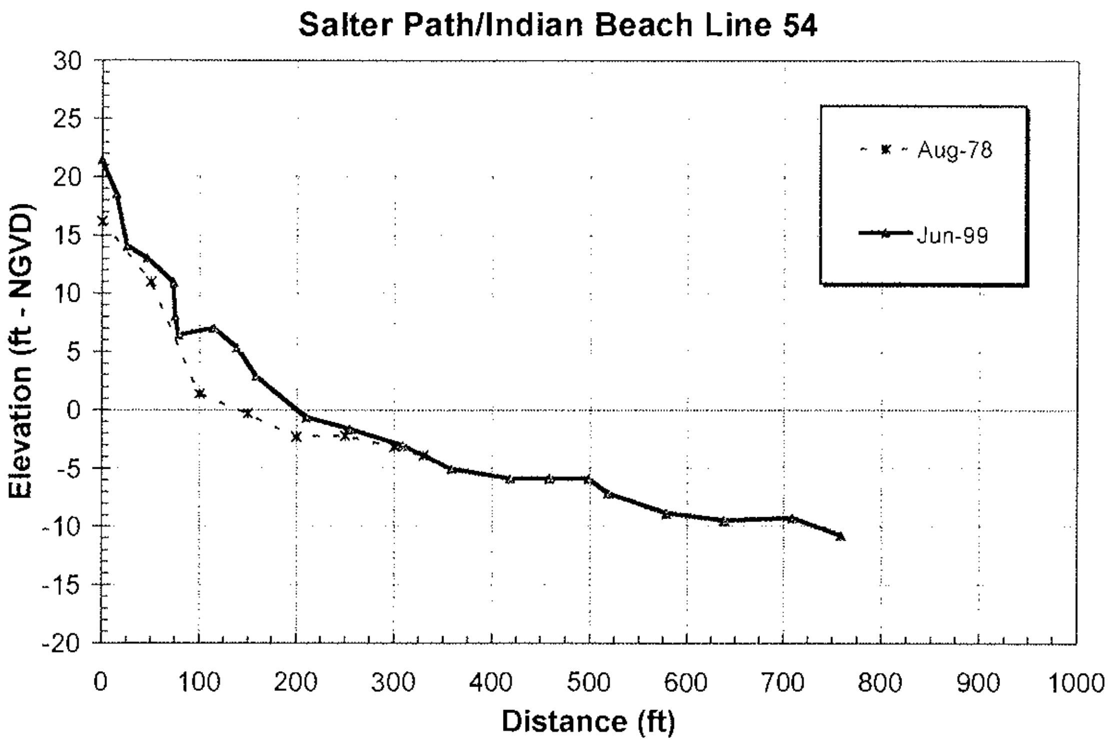

Salter Path/Indian Beach Line 48
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

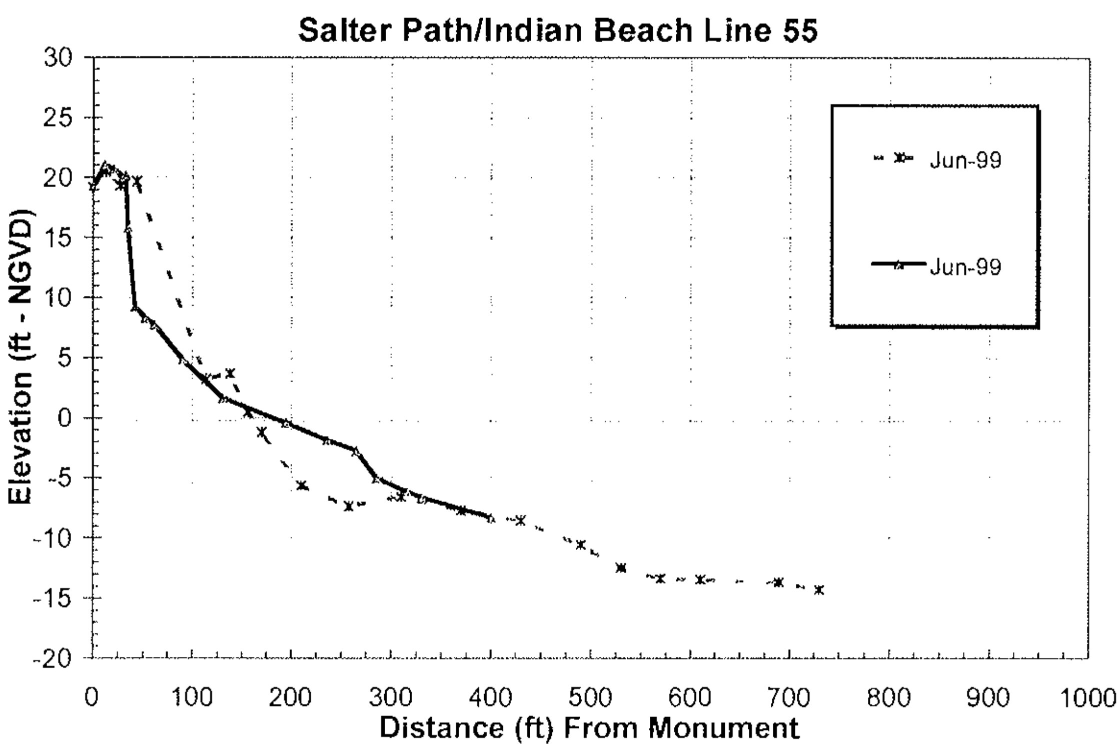

Salter Path/Indian Beach Line 49
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

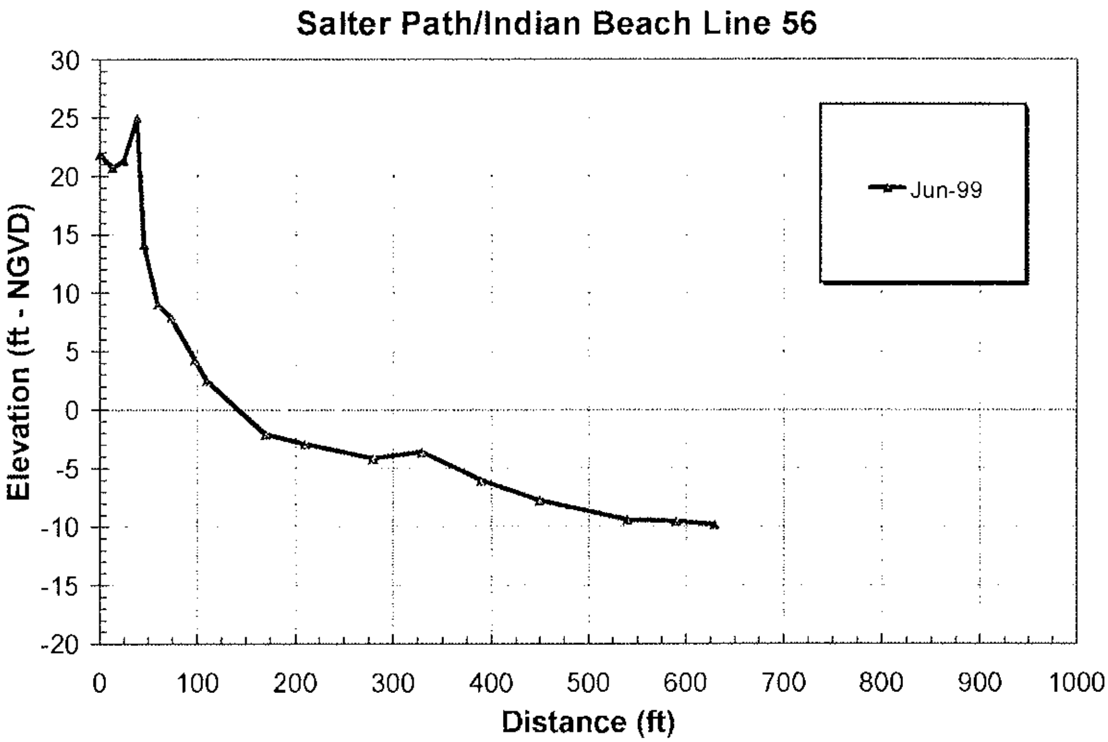

Salter Path/Indian Beach Line 50
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Sep-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Salter Path/Indian Beach Line 51
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

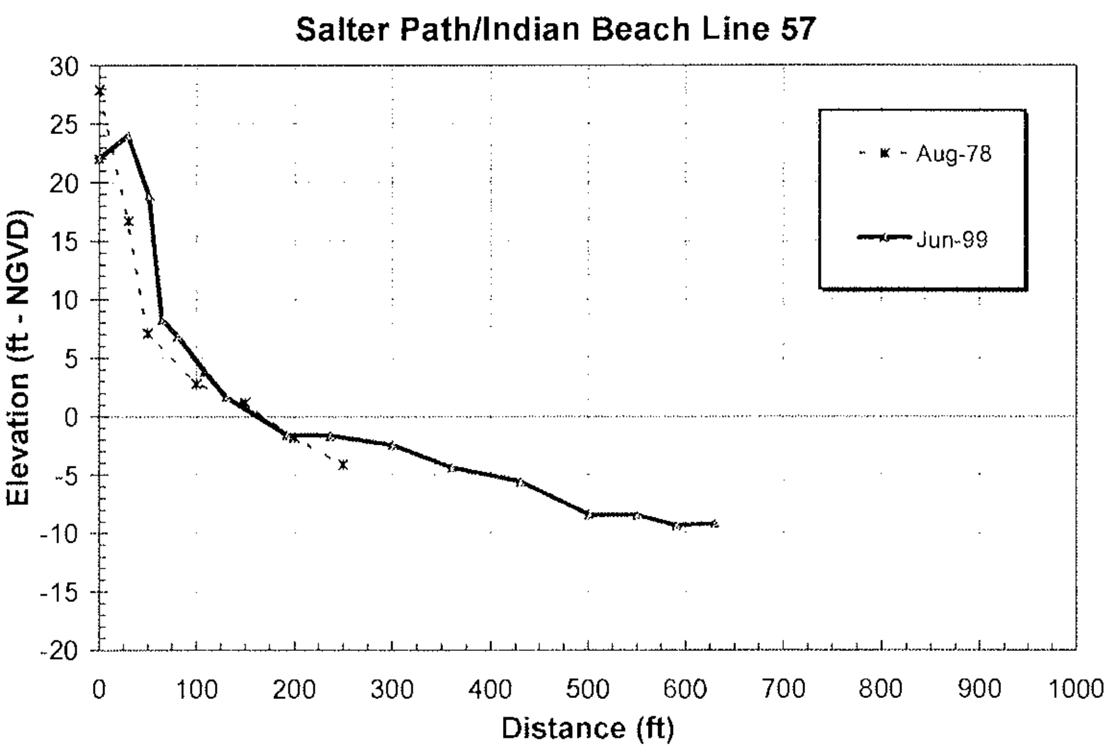

Salter Path/Indian Beach Line 52
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Salter Path/Indian Beach Line 54
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

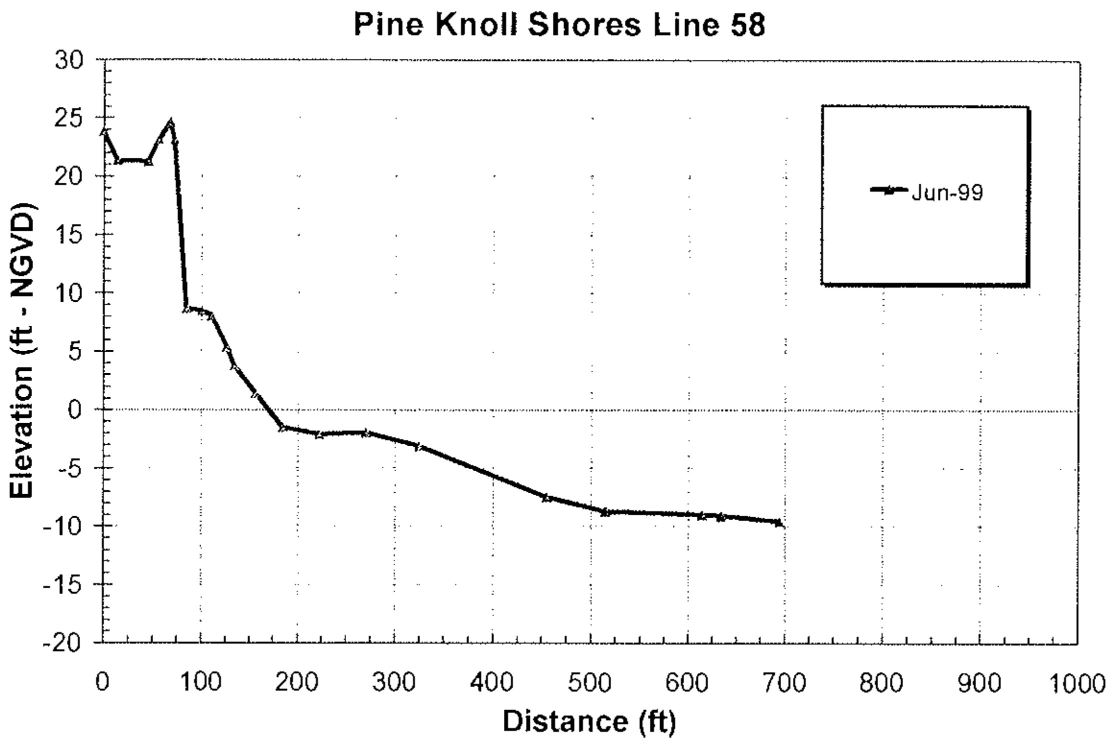

Salter Path/Indian Beach Line 55
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

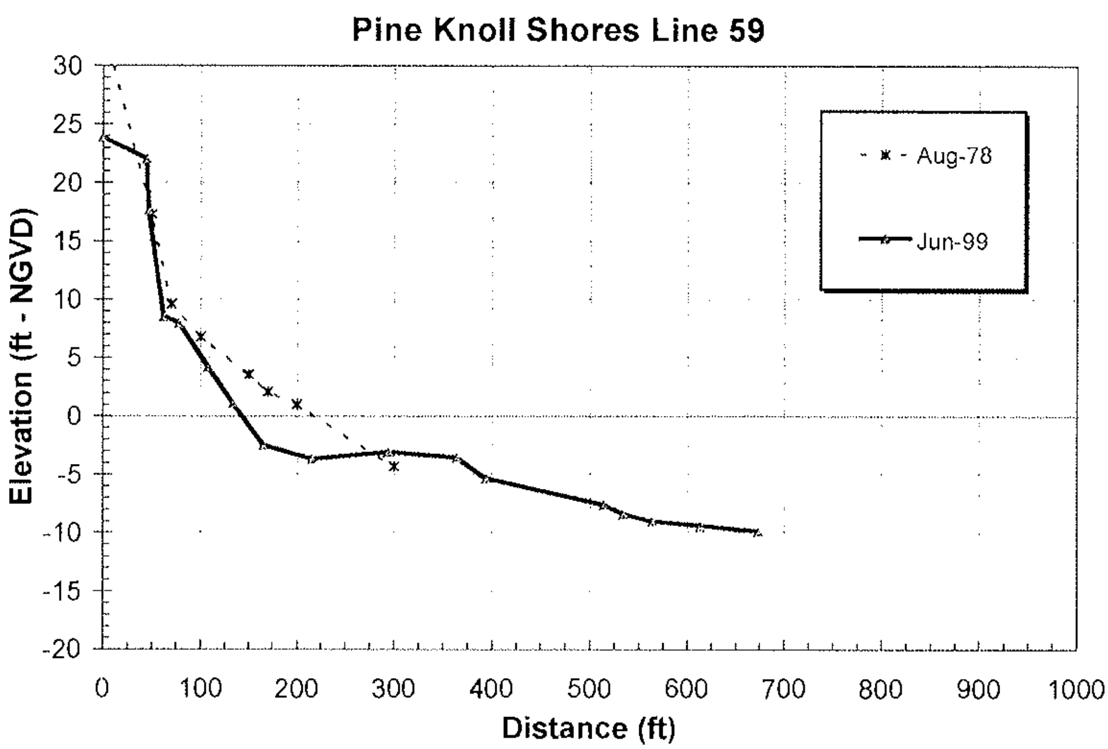


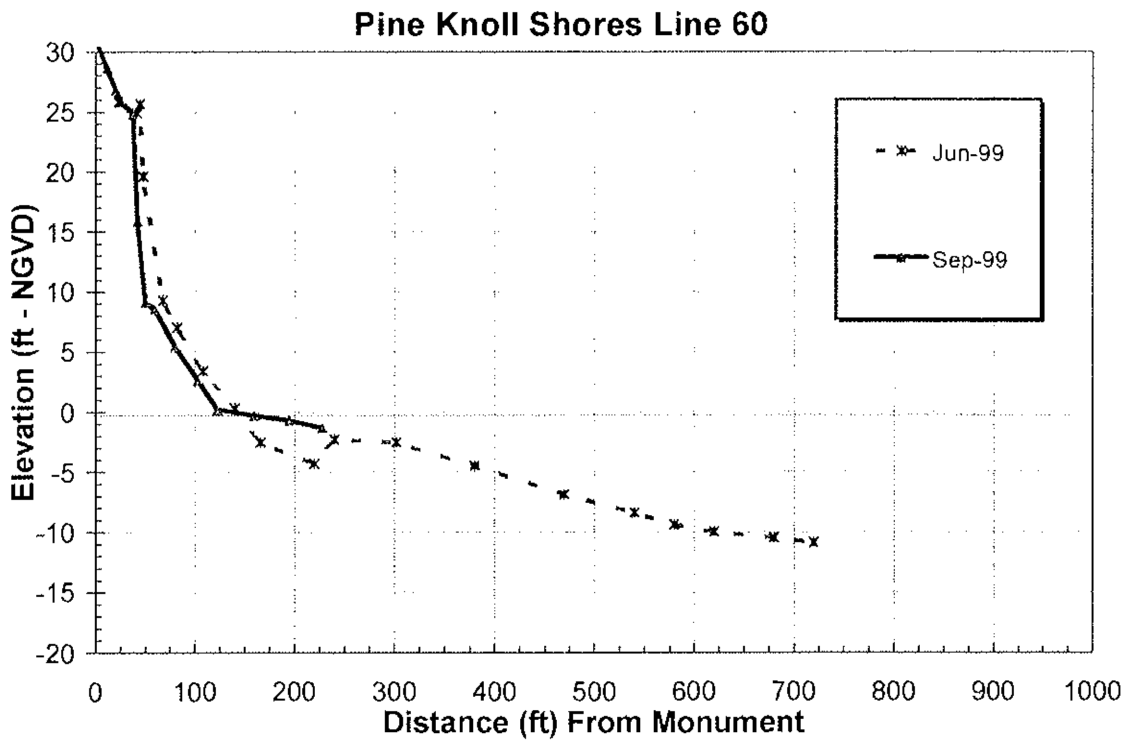
Salter Path/Indian Beach Line 56
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

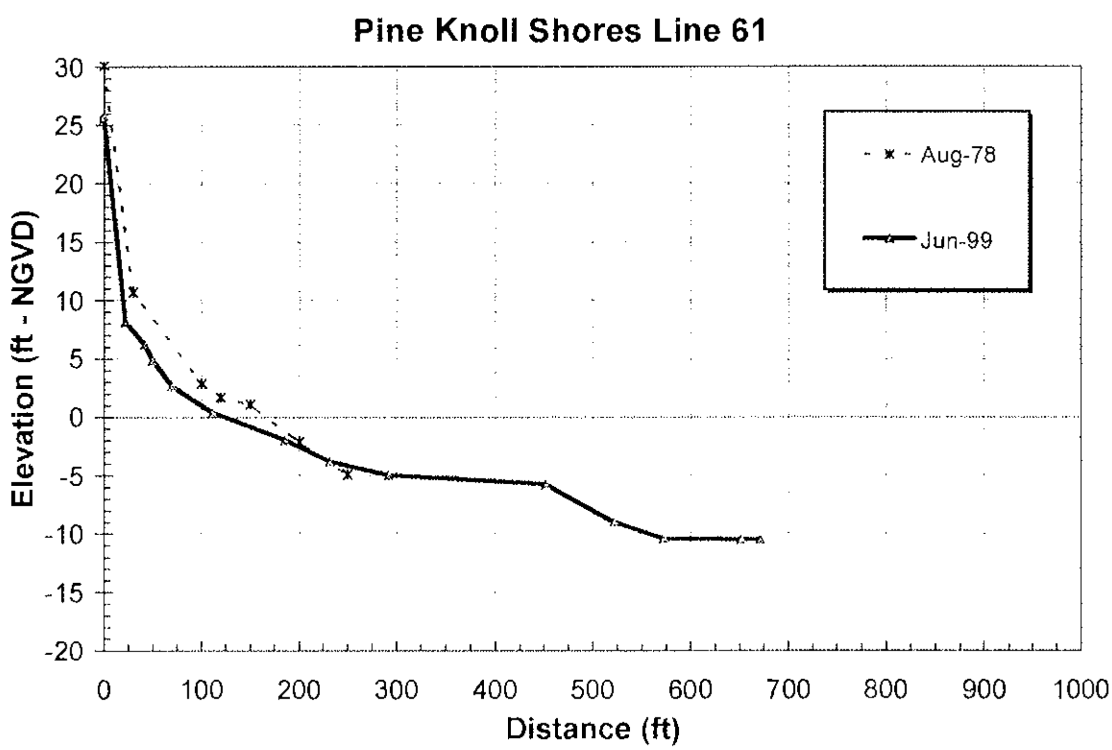


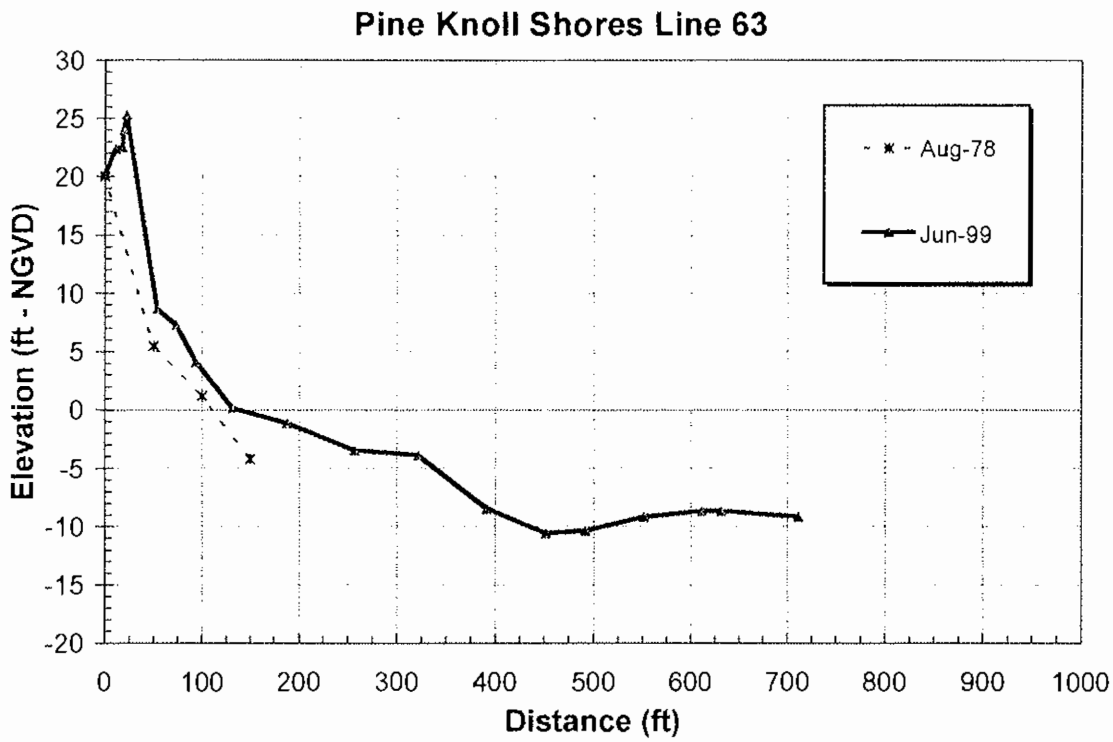
Salter Path/Indian Beach Line 57
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

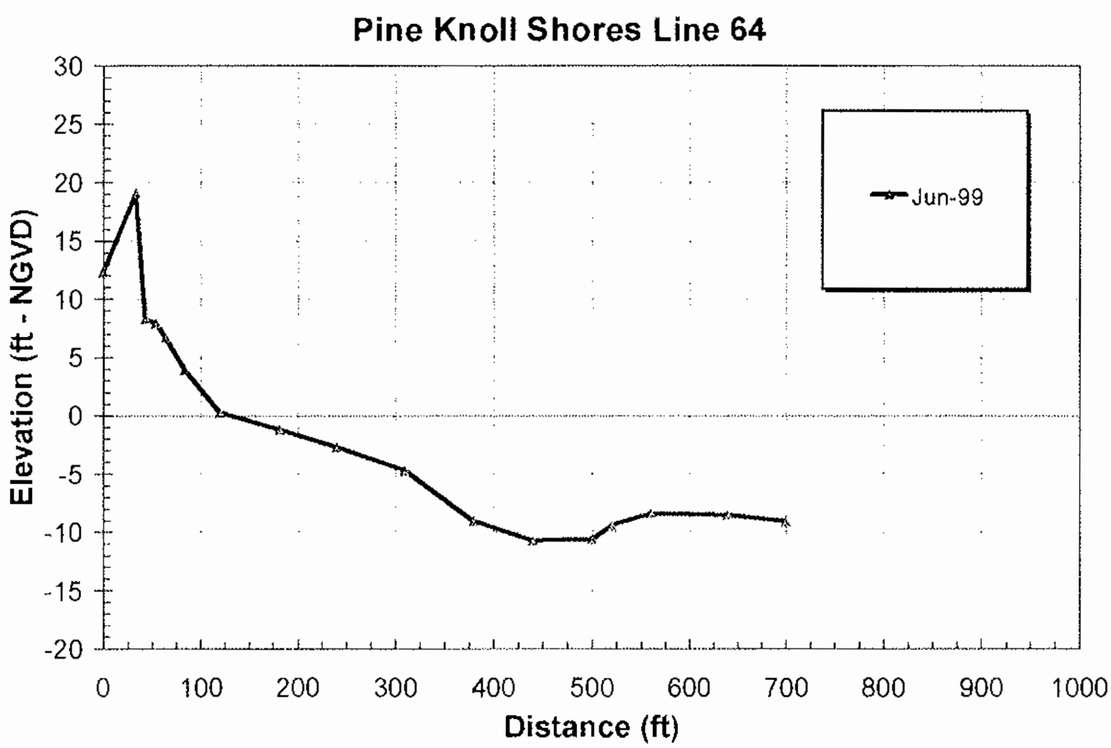

Pine Knoll Shores Line 58
Elevation (ft - NGVD)
Distance (ft)
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

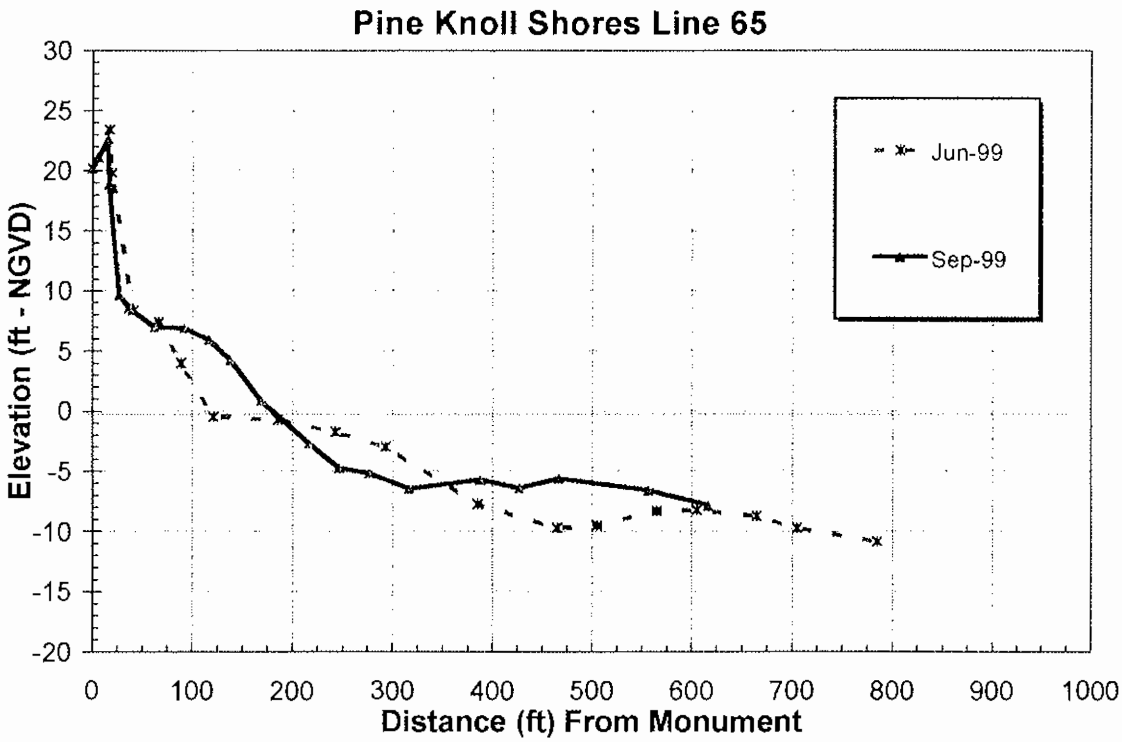

Pine Knoll Shores Line 59
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

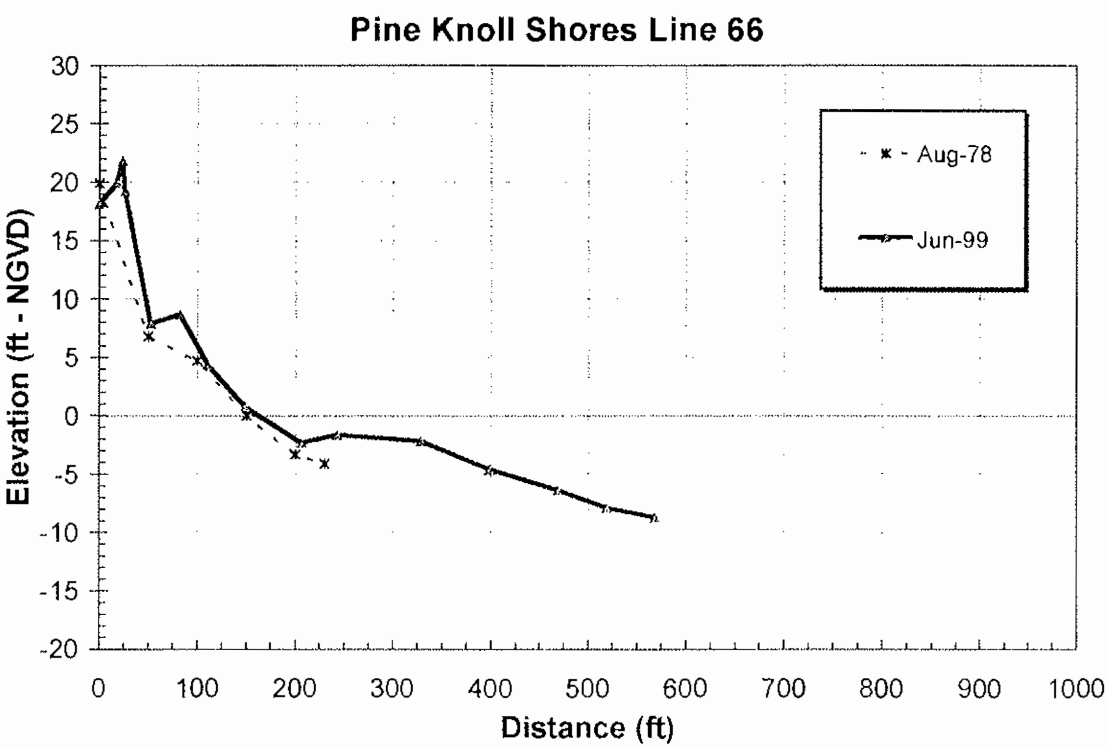

Pine Knoll Shores Line 60
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Sep-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

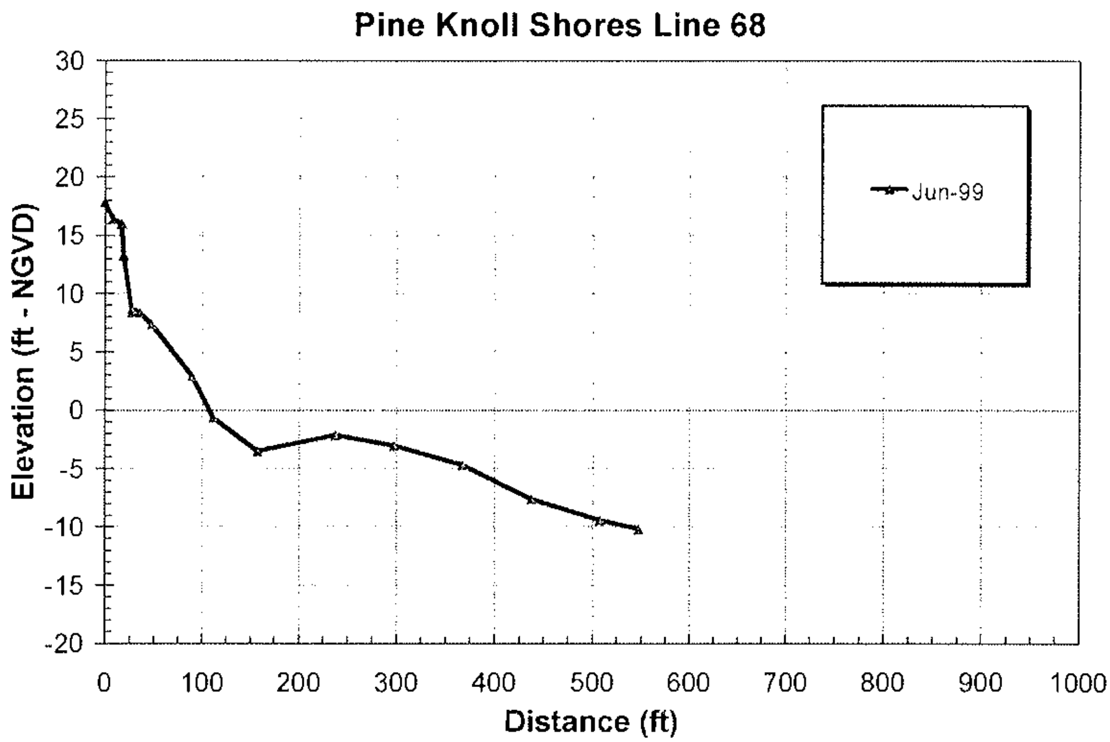

Pine Knoll Shores Line 61
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Pine Knoll Shores Line 63
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

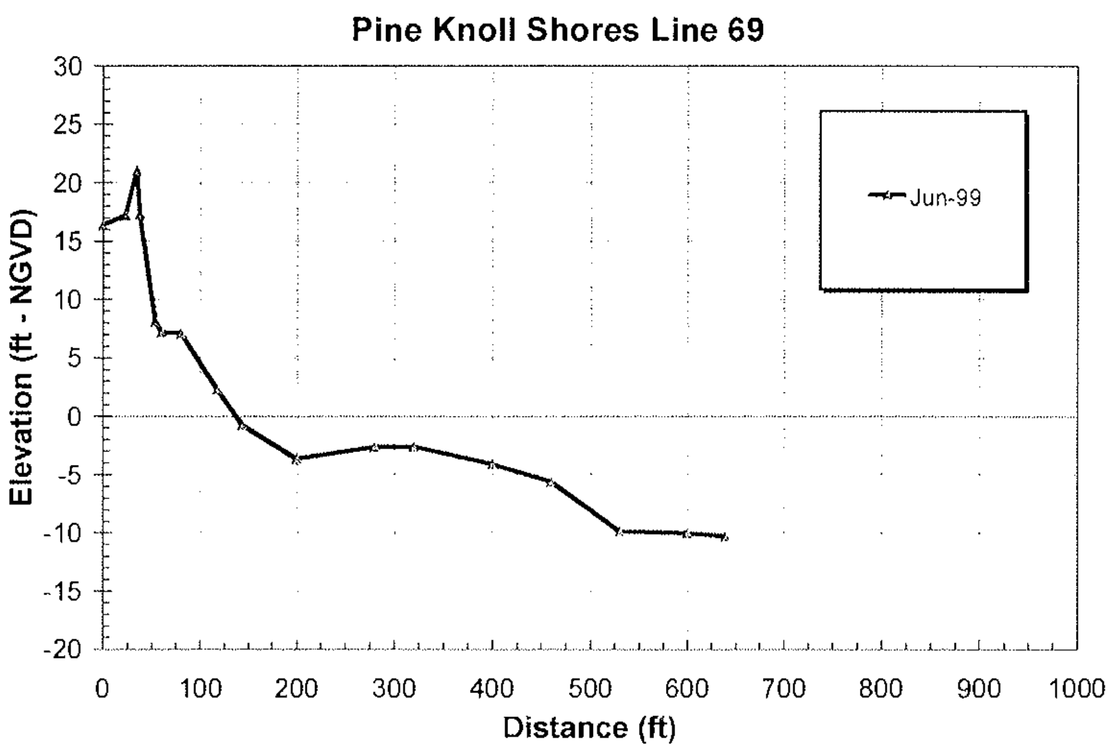

Pine Knoll Shores Line 64
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Pine Knoll Shores Line 65
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

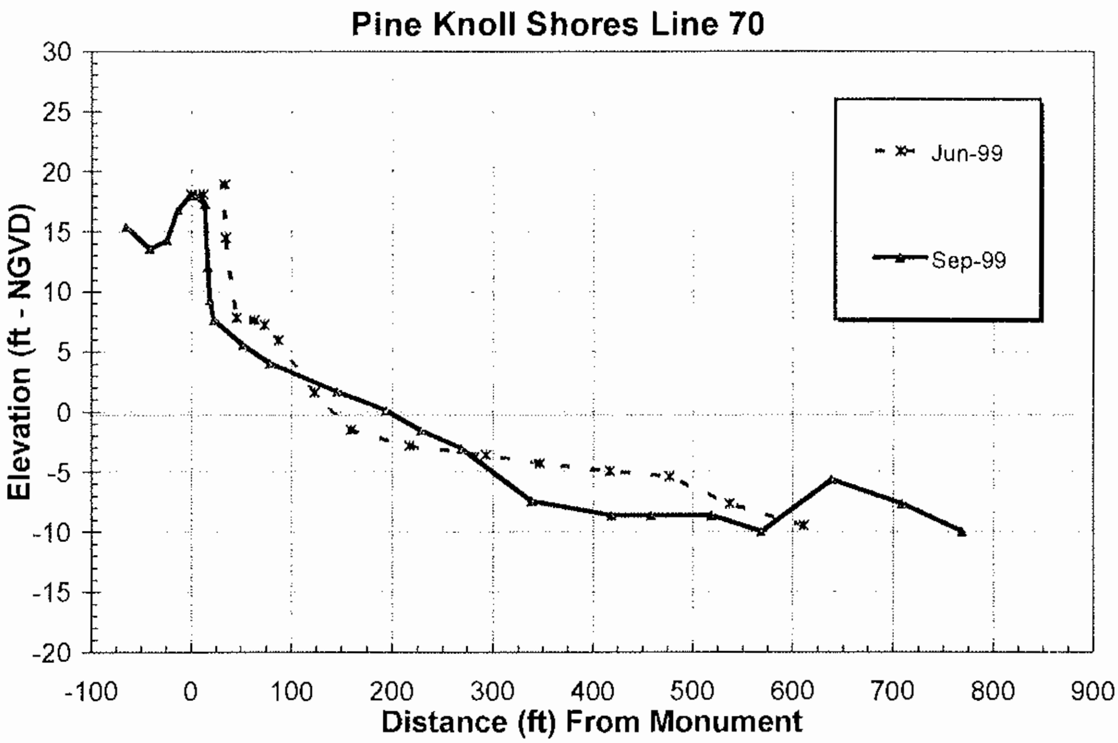

Pine Knoll Shores Line 66
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

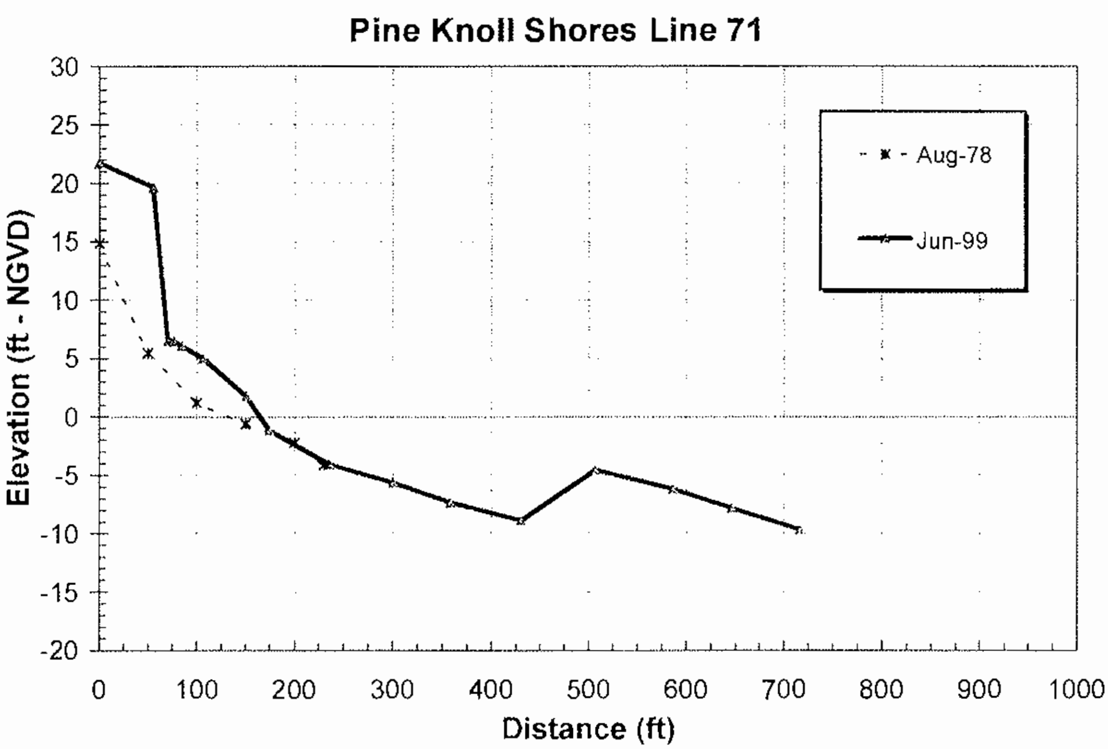


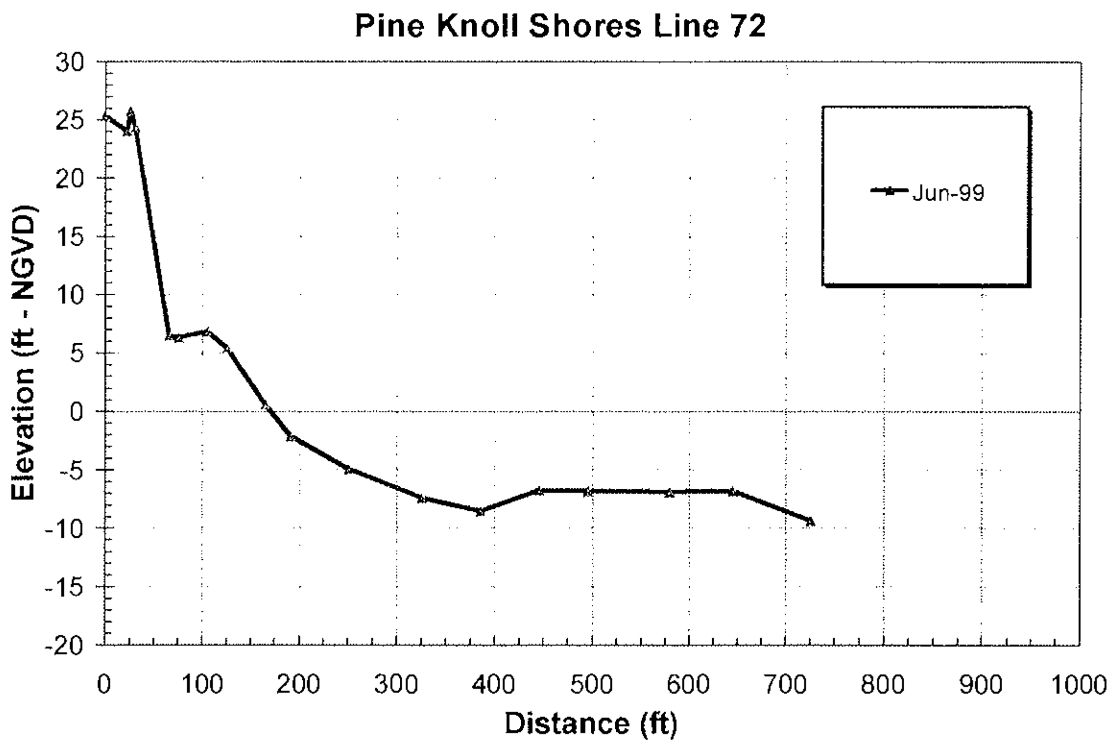
Pine Knoll Shores Line 68
Elevation (ft - NGVD)
Distance (ft)
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

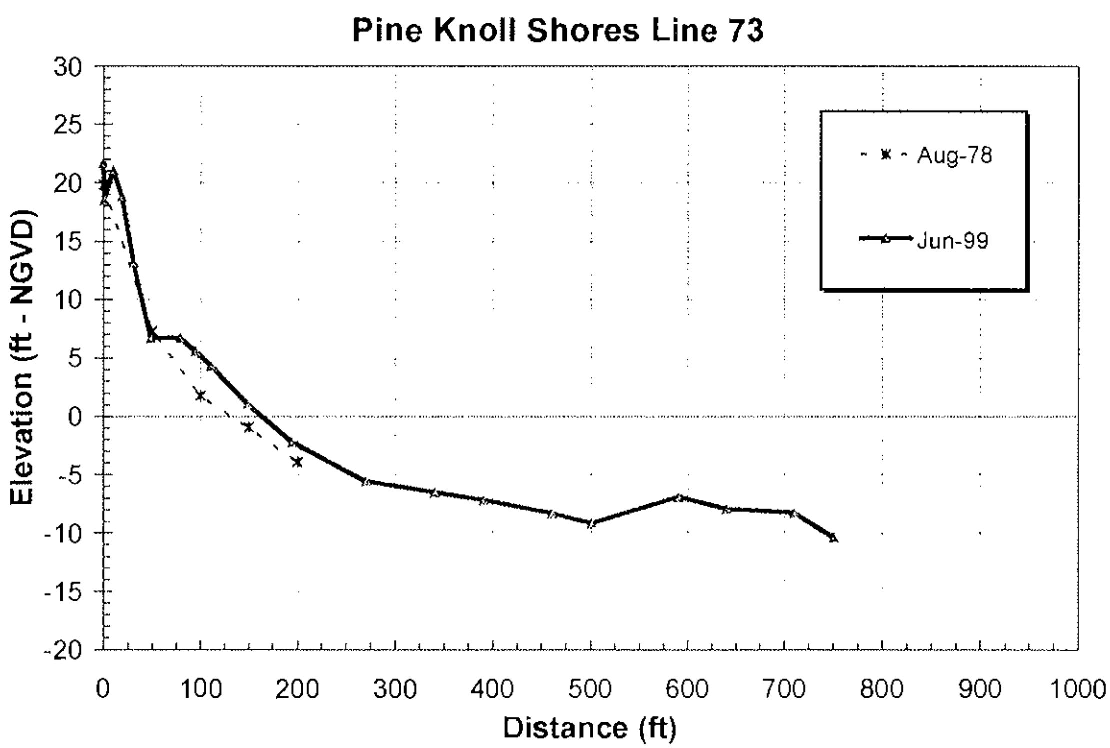


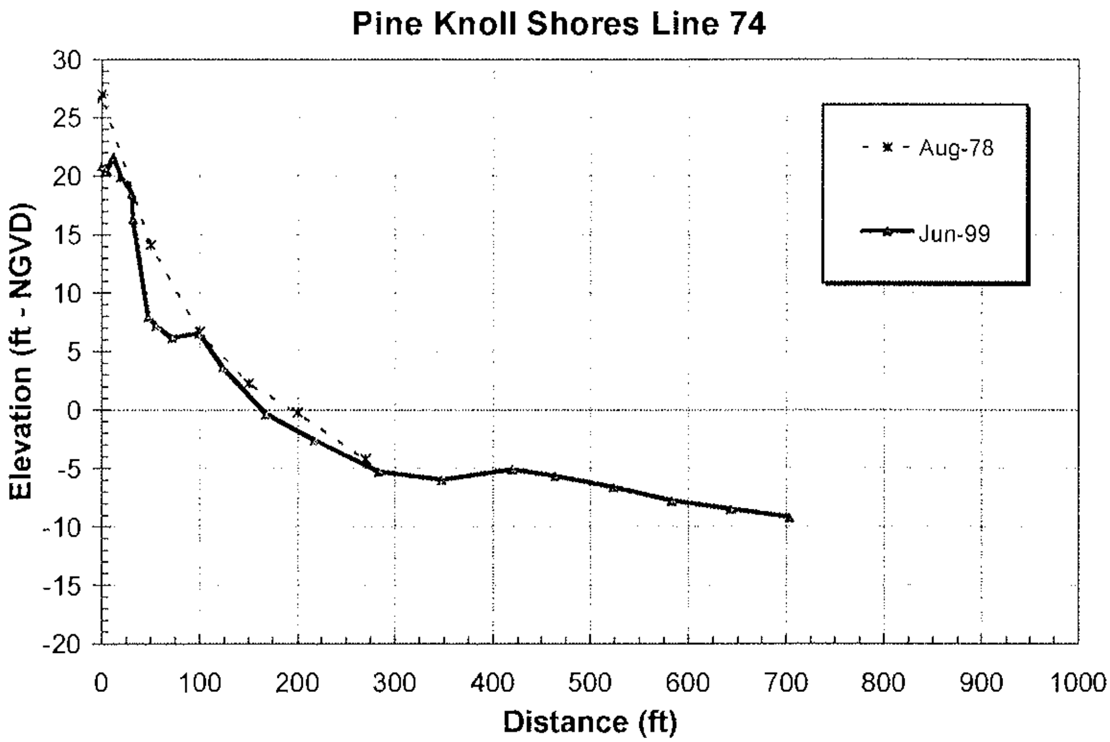
Pine Knoll Shores Line 69
Elevation (ft - NGVD)
Distance (ft)
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

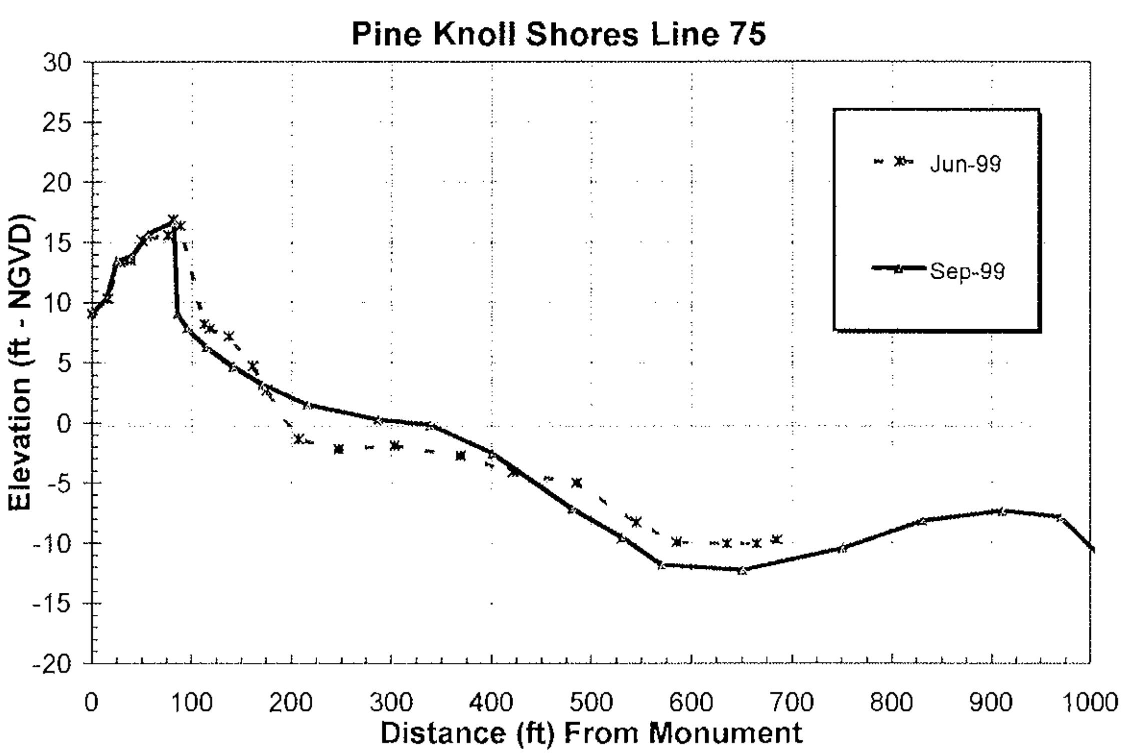

Pine Knoll Shores Line 70
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Sep-99
30
25
20
15
10
5
0
-5
-10
-15
-20
-100
0
100
200
300
400
500
600
700
800
900

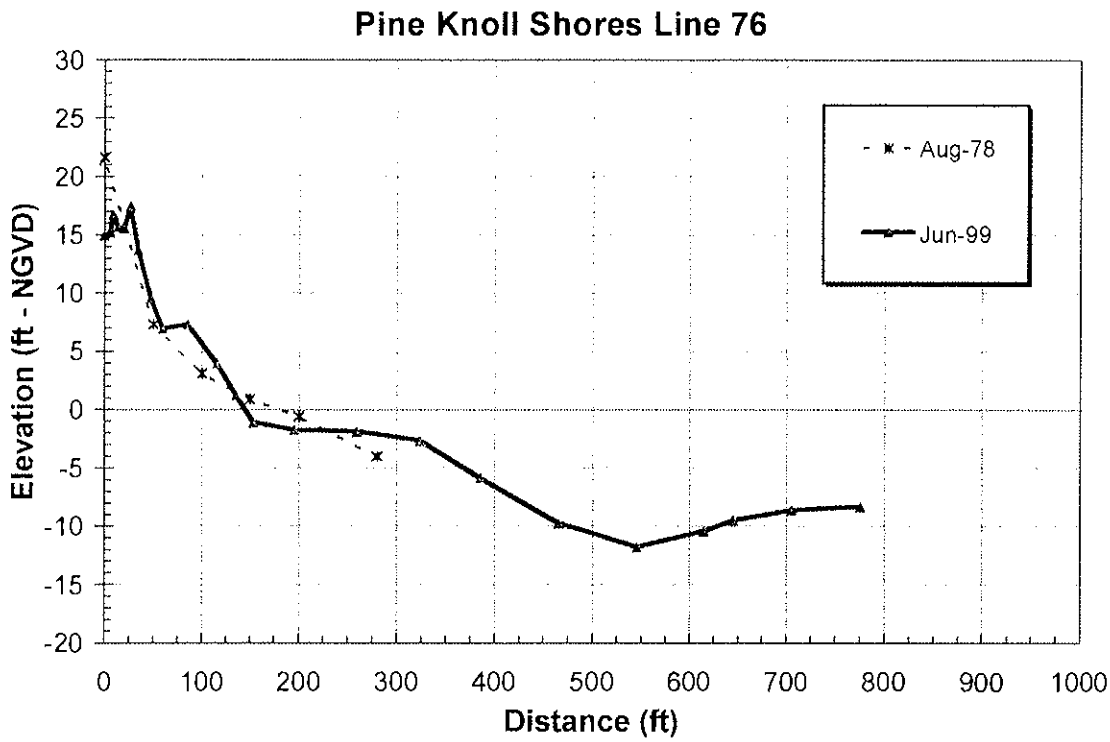

Pine Knoll Shores Line 71
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

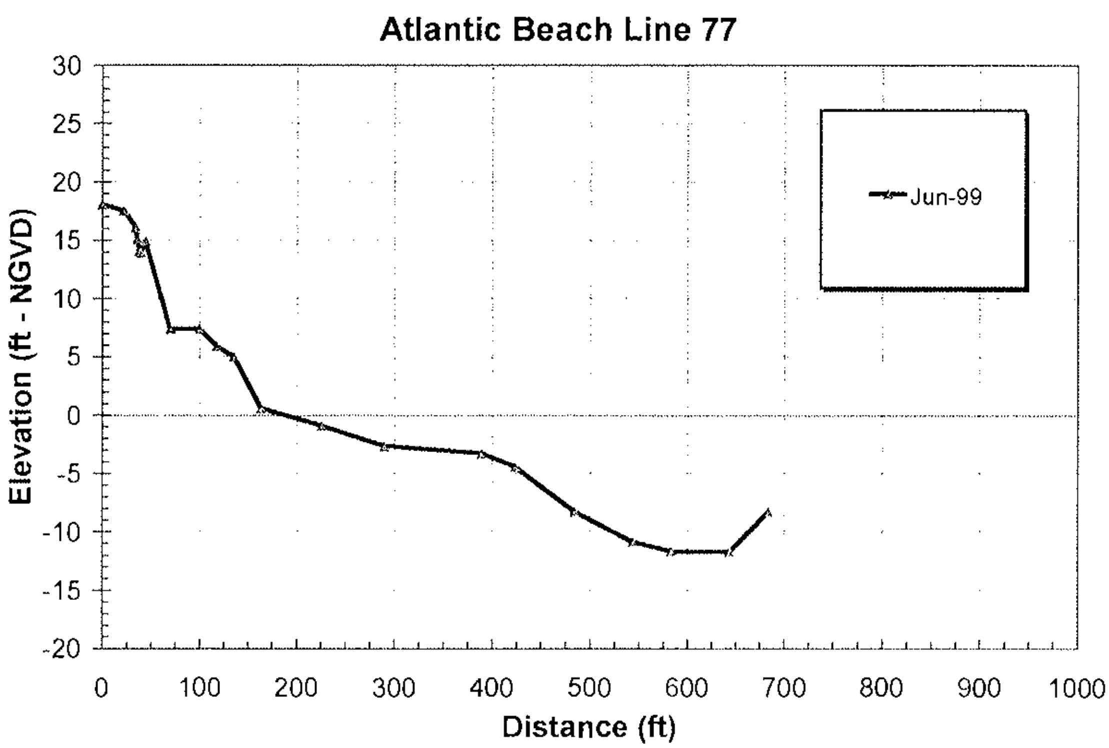

Pine Knoll Shores Line 72
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

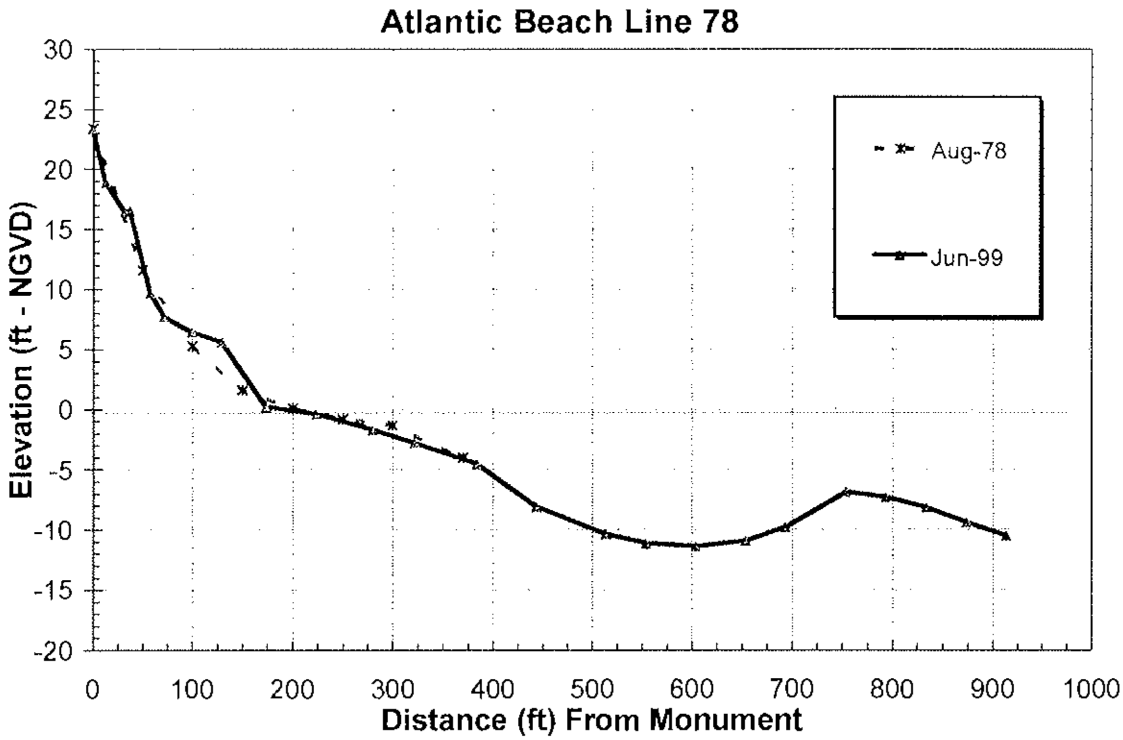

Pine Knoll Shores Line 73
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

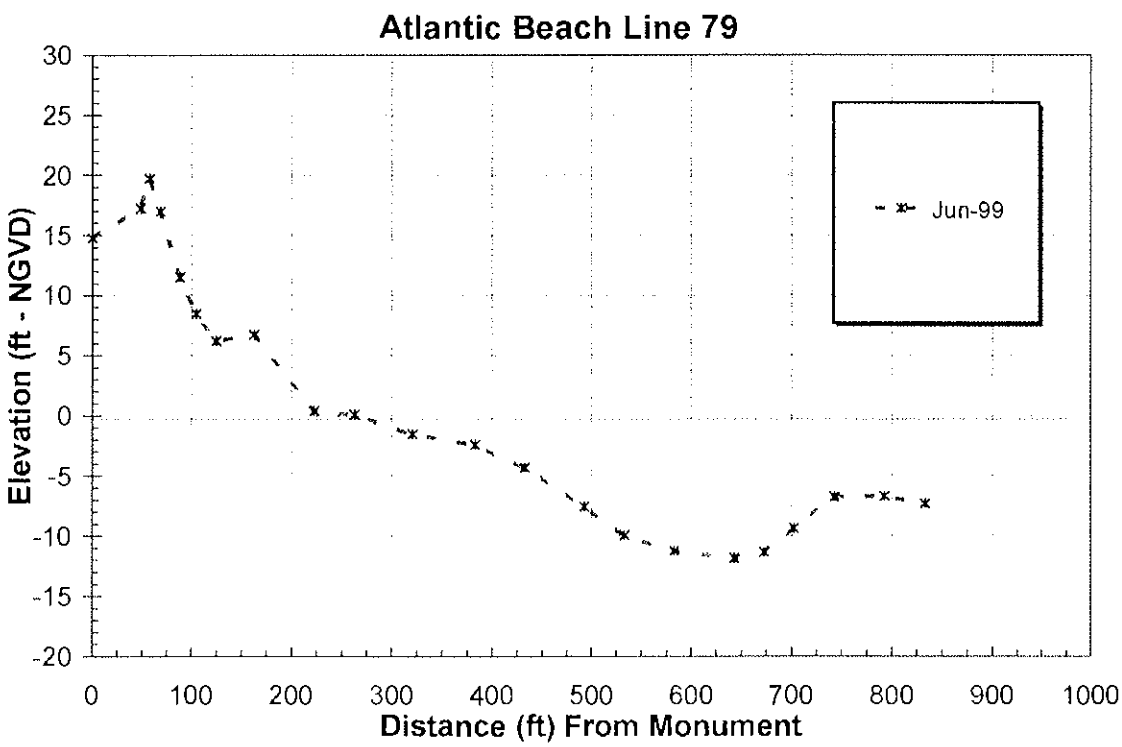

Pine Knoll Shores Line 74
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)

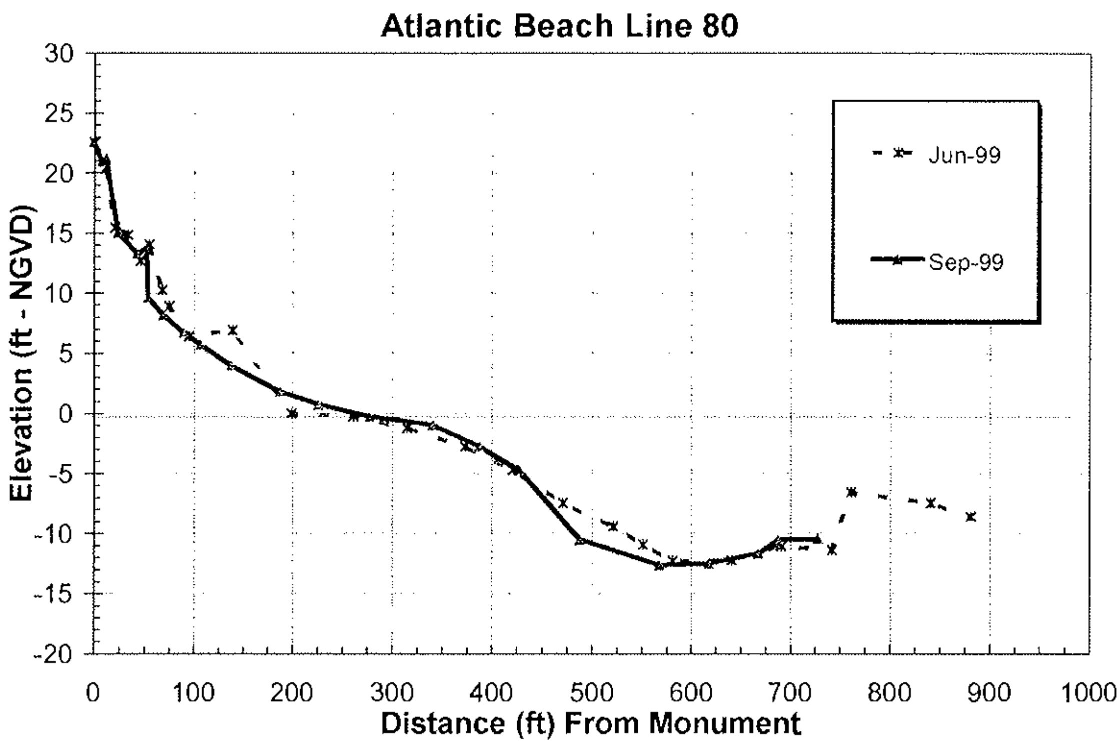

Pine Knoll Shores Line 75
Jun-99
Sep-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

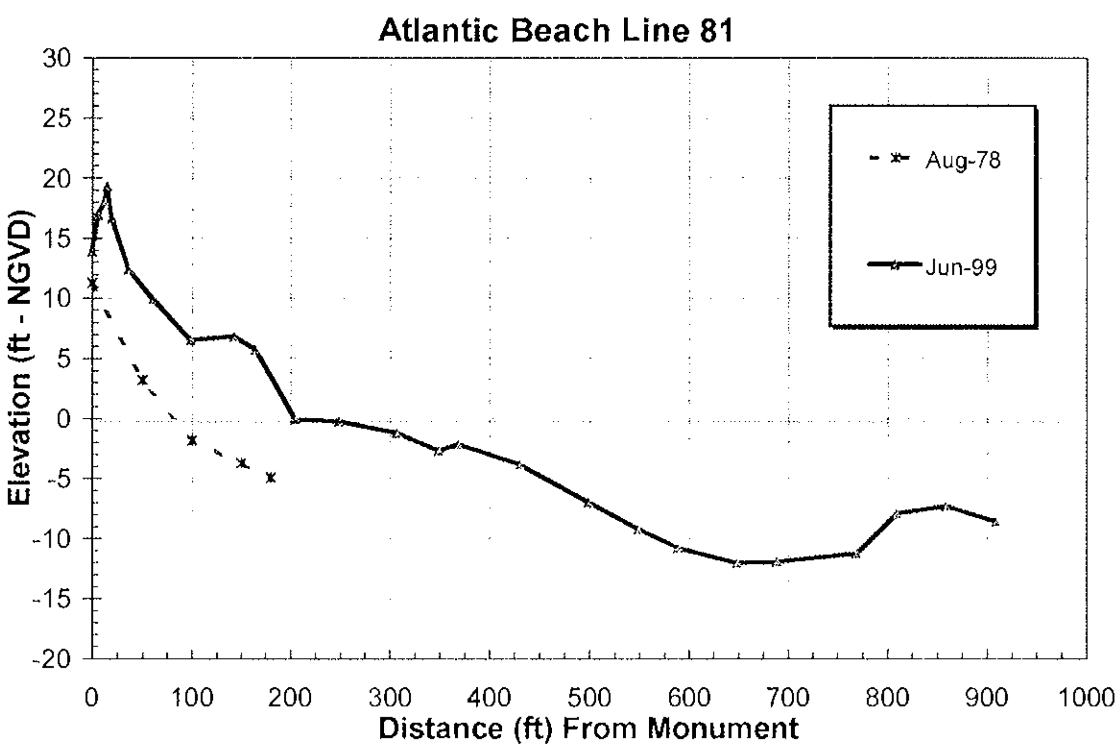

Pine Knoll Shores Line 76
Elevation (ft - NGVD)
Distance (ft)
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

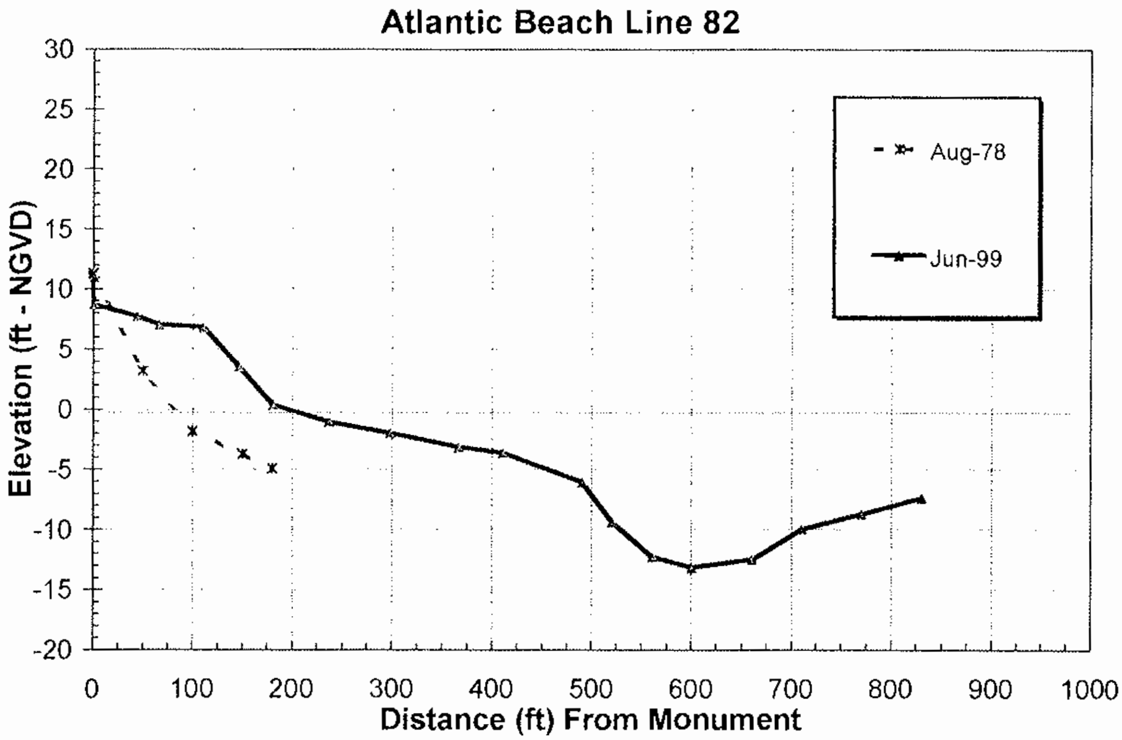

Atlantic Beach Line 77
Elevation (ft - NGVD)
Distance (ft)
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

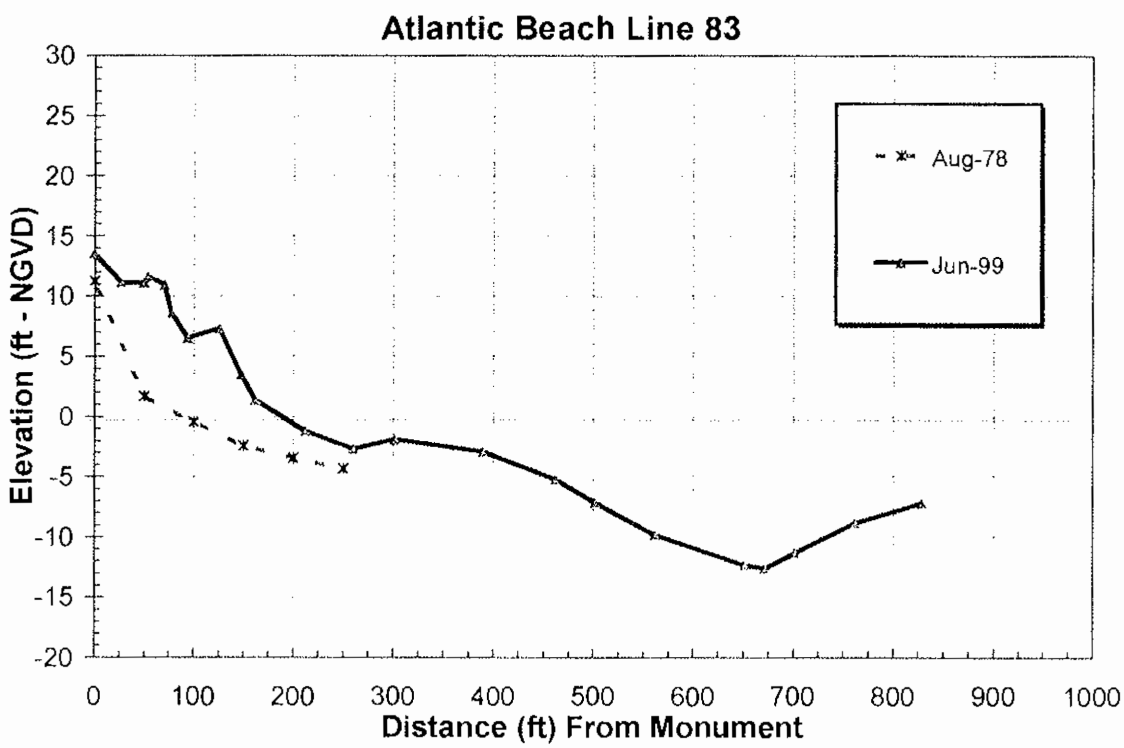

Atlantic Beach Line 78
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

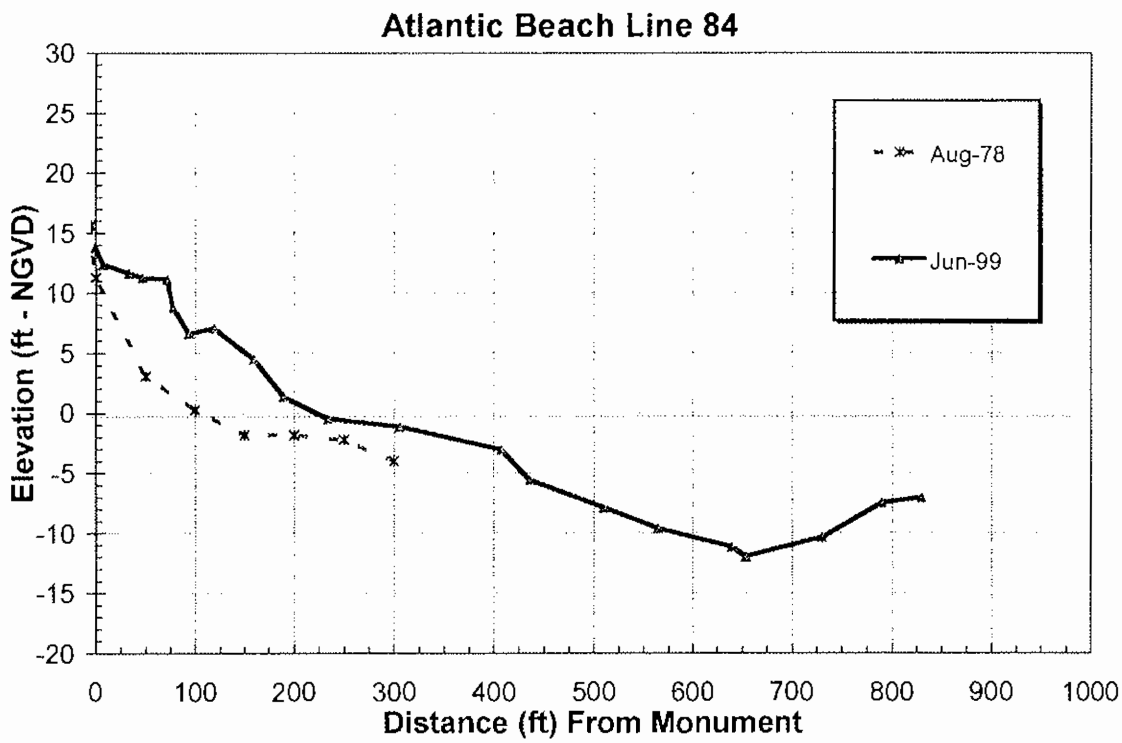

Atlantic Beach Line 79
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

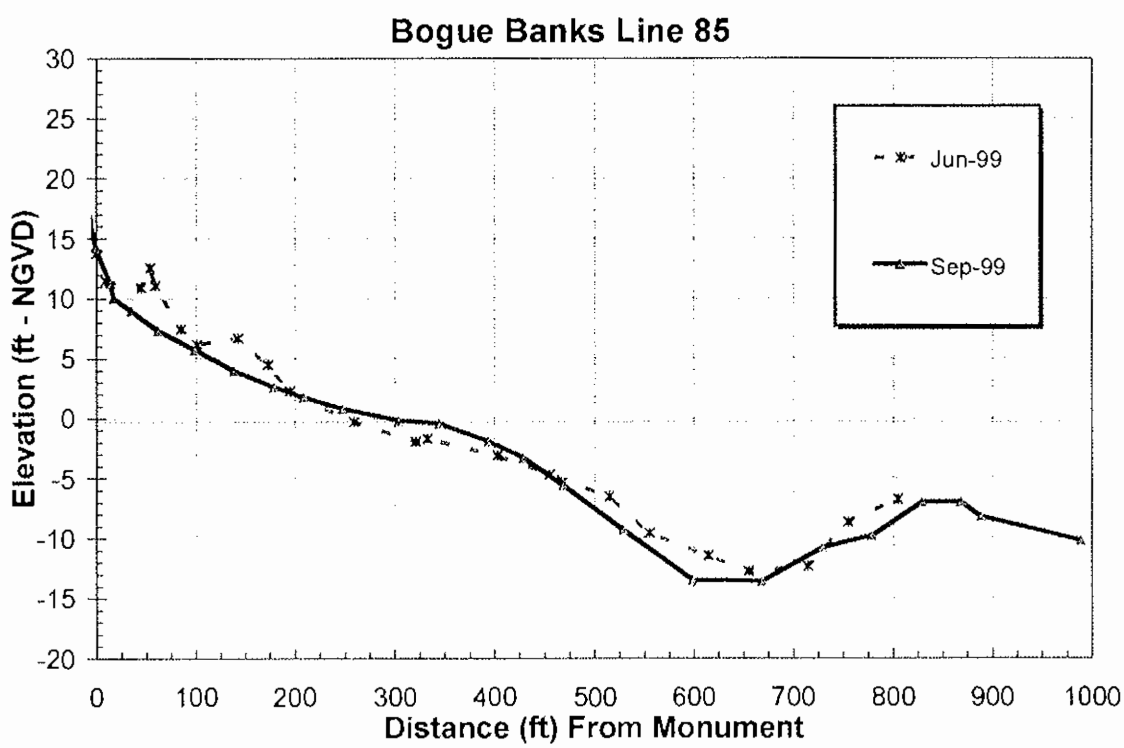

Atlantic Beach Line 80
Jun-99
Sep-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

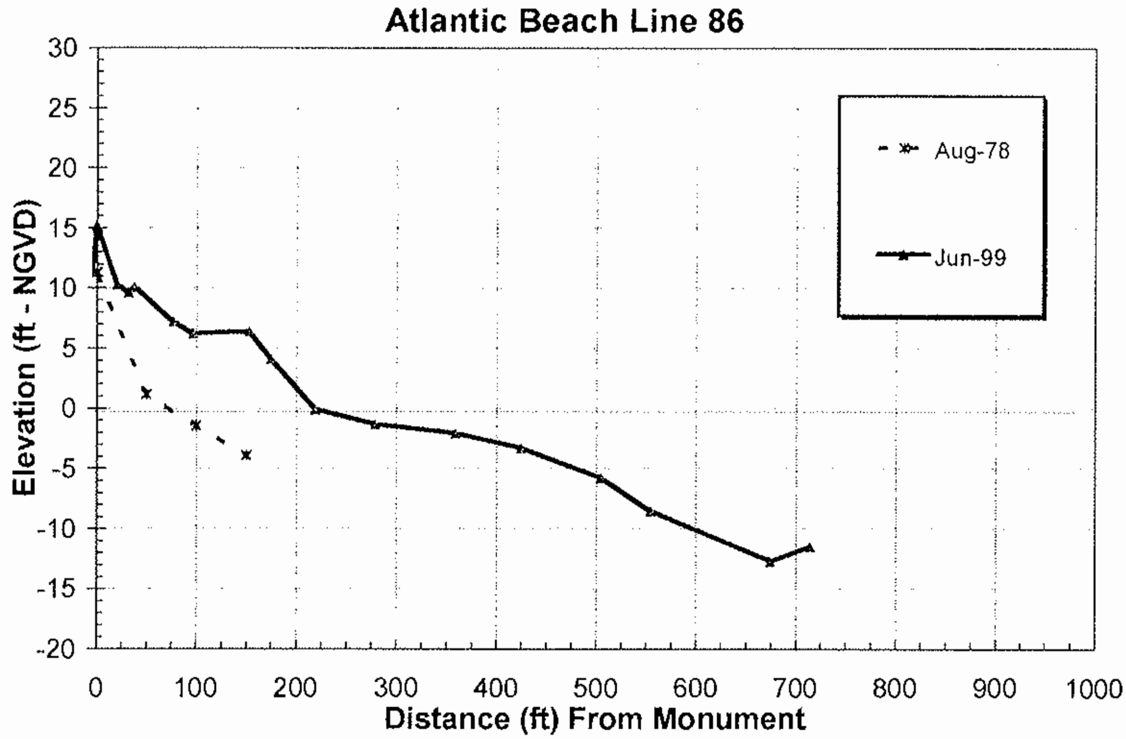

Atlantic Beach Line 81
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

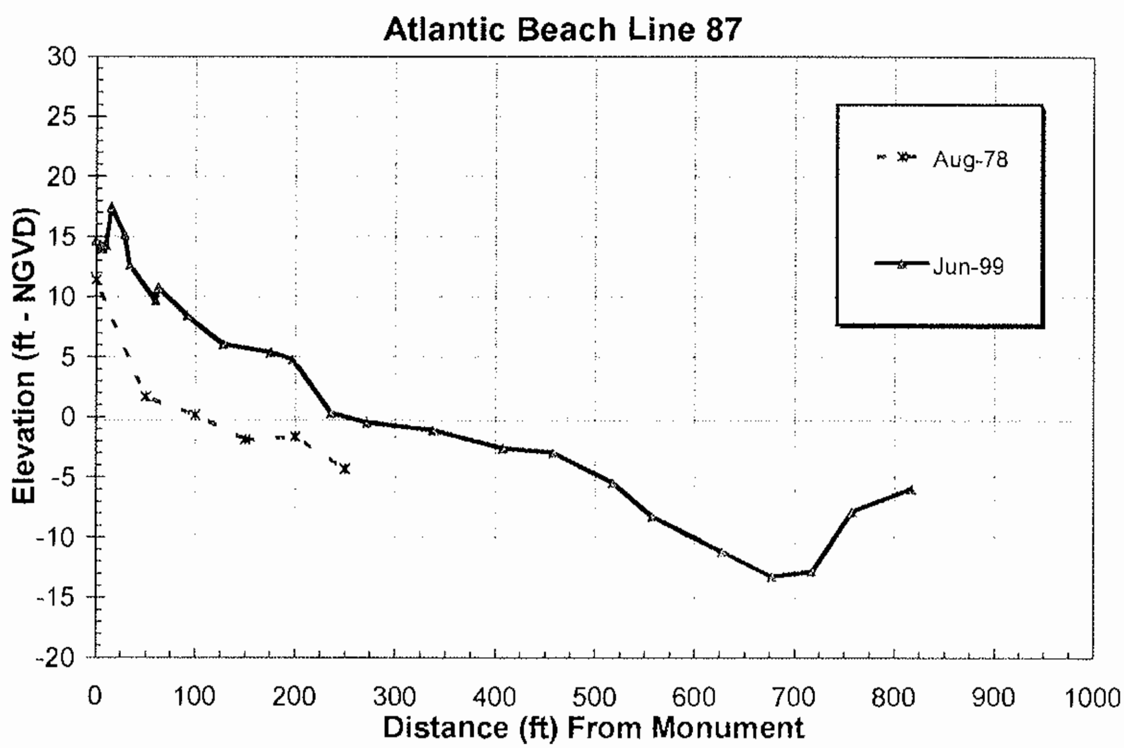

Atlantic Beach Line 82
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

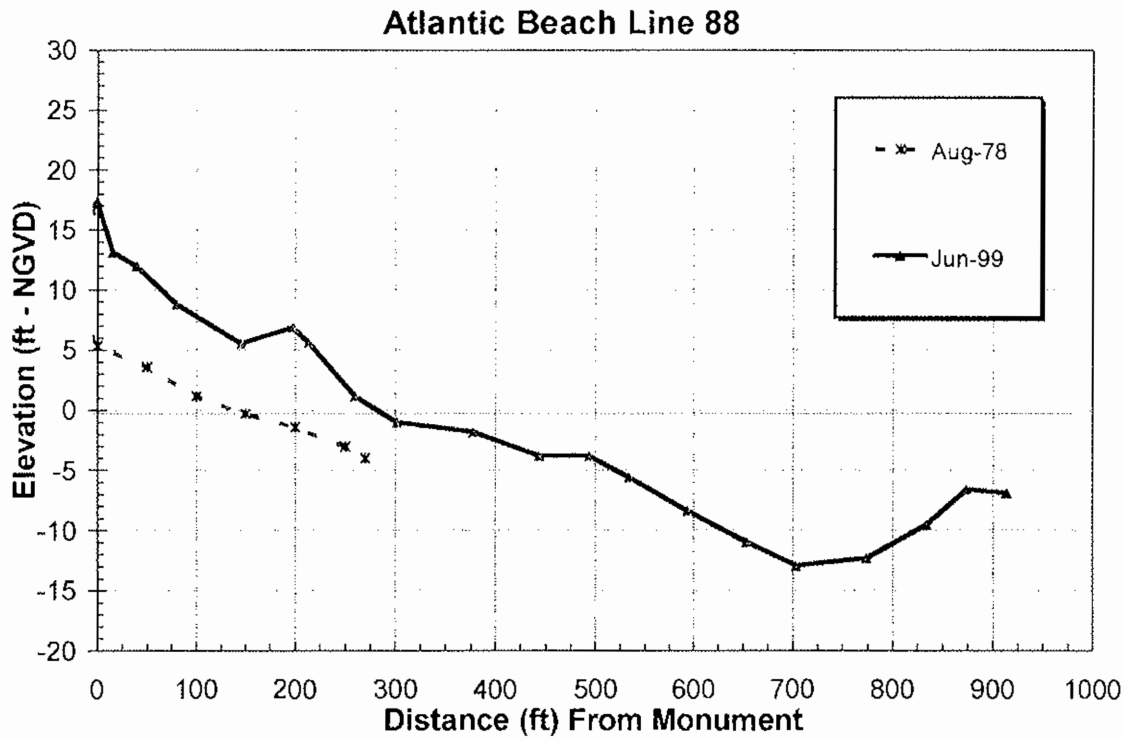

Atlantic Beach Line 83
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

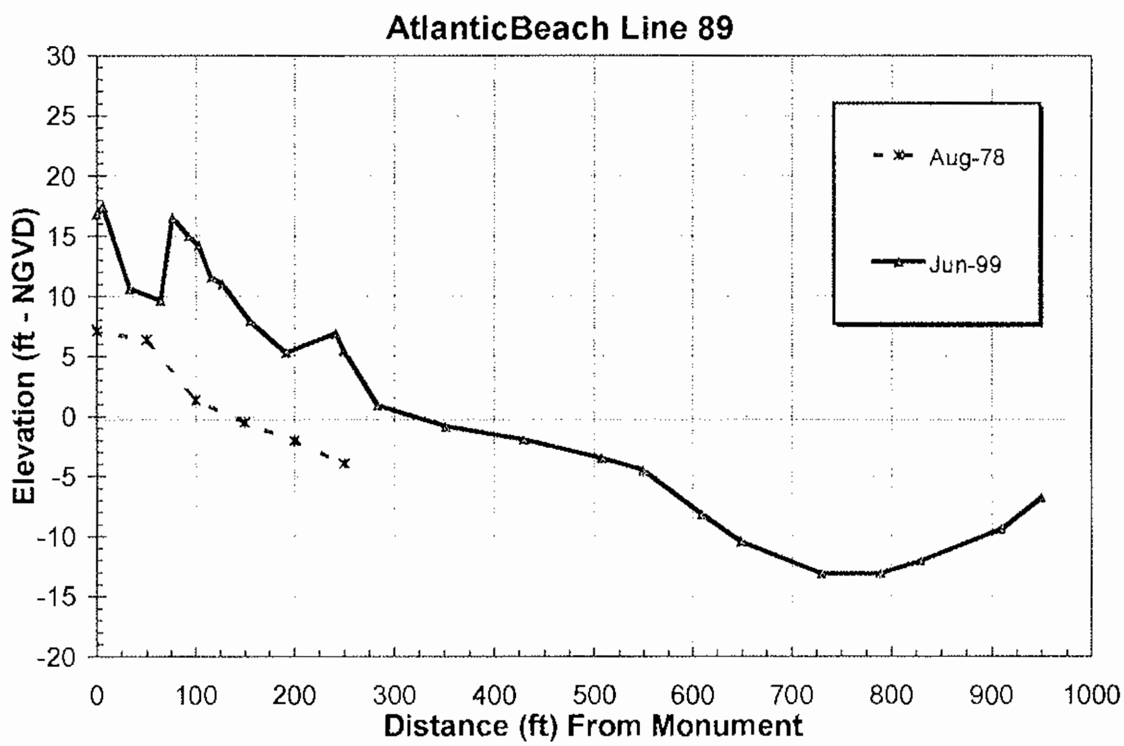

Atlantic Beach Line 84
Aug-78
Jun-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

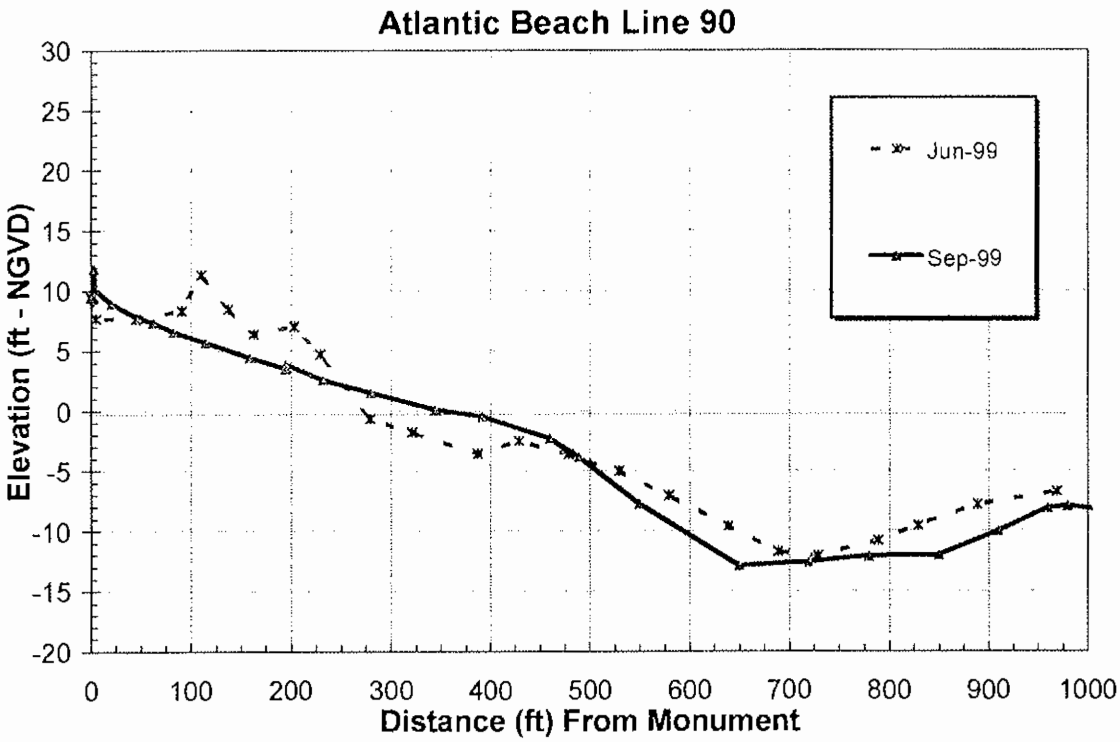

Bogue Banks Line 85
Jun-99
Sep-99
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument

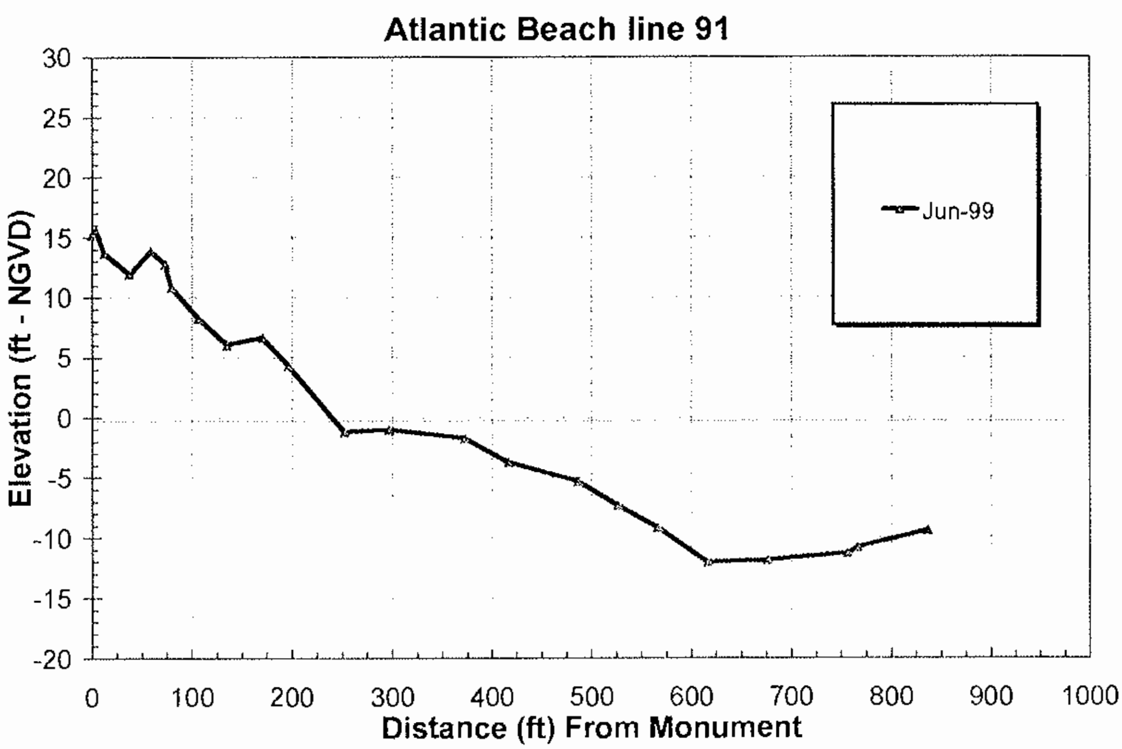

Atlantic Beach Line 86
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

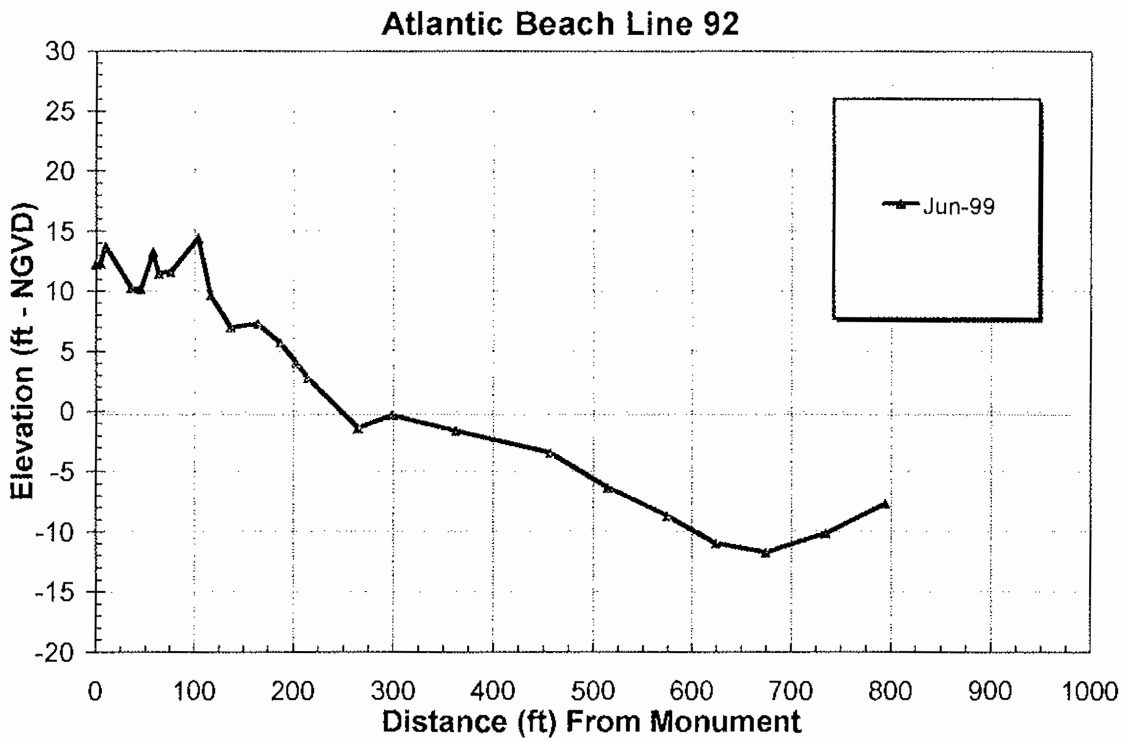

Atlantic Beach Line 87
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Atlantic Beach Line 88
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

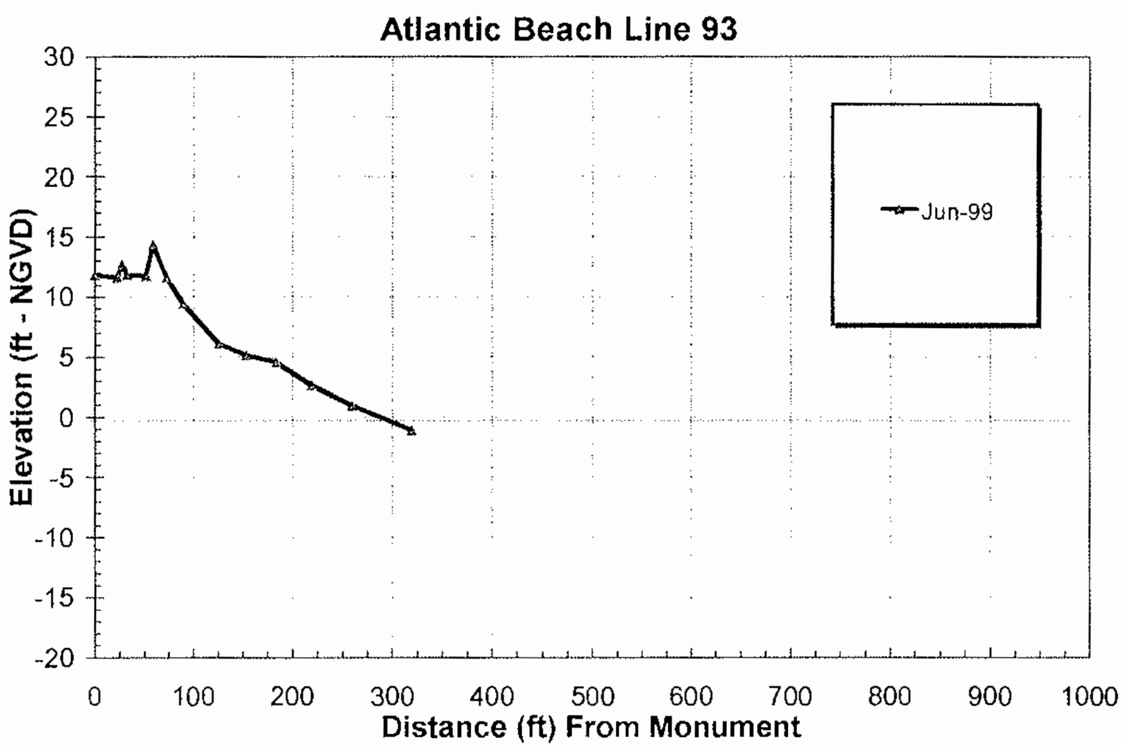

AtlanticBeach Line 89
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Atlantic Beach Line 90
Jun-99
Sep-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

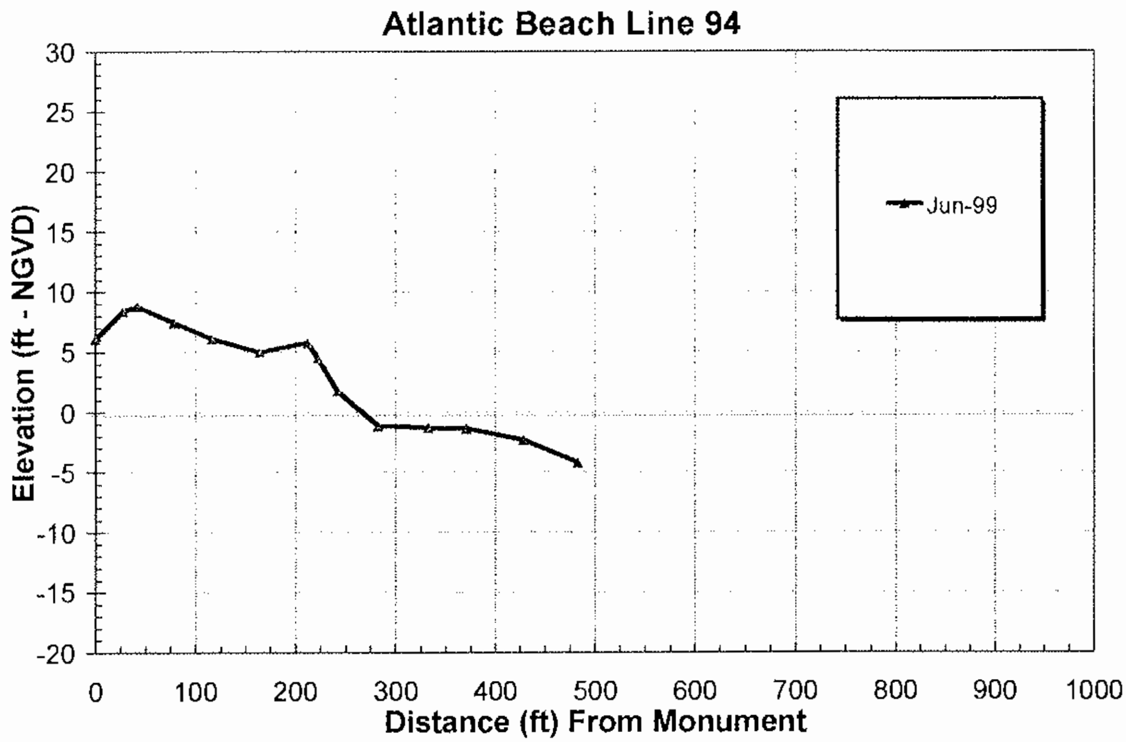

Atlantic Beach line 91
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



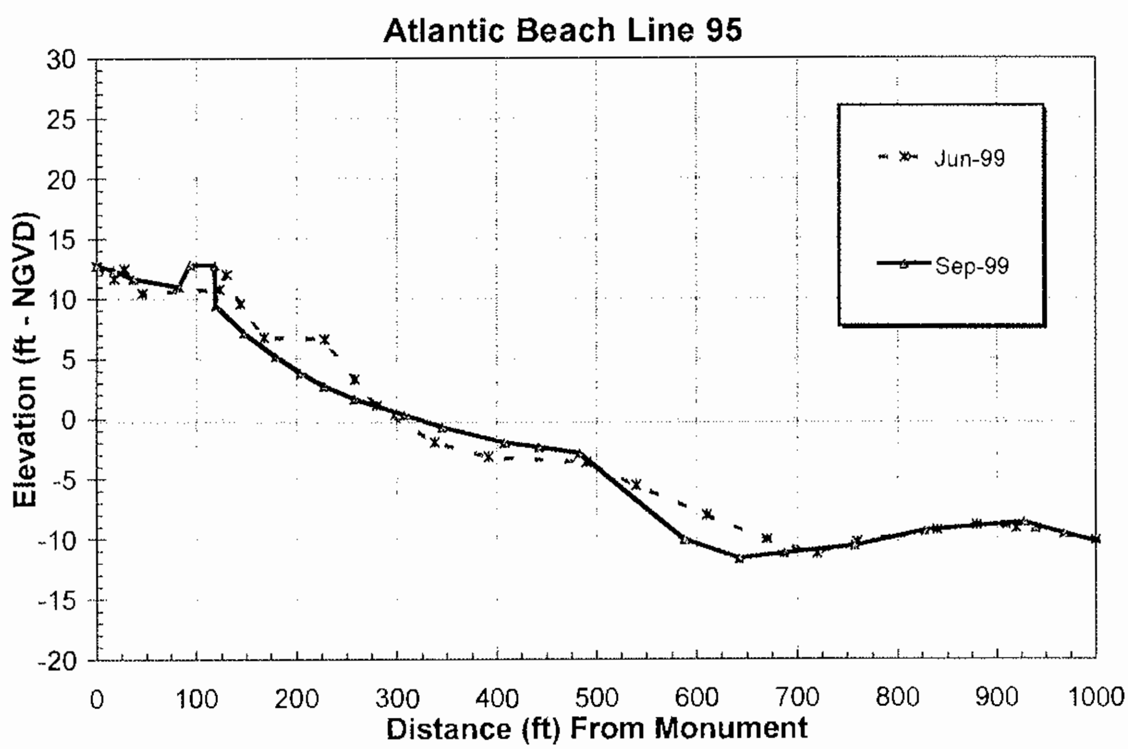
Atlantic Beach Line 92
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument



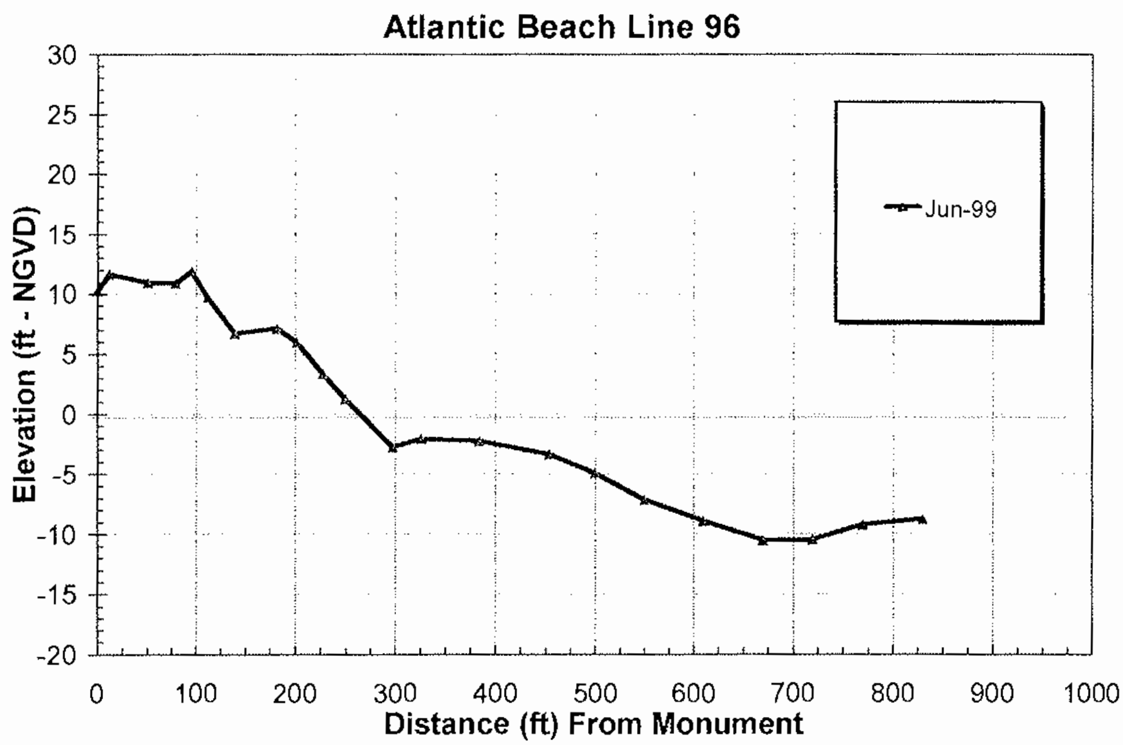
Atlantic Beach Line 93
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument

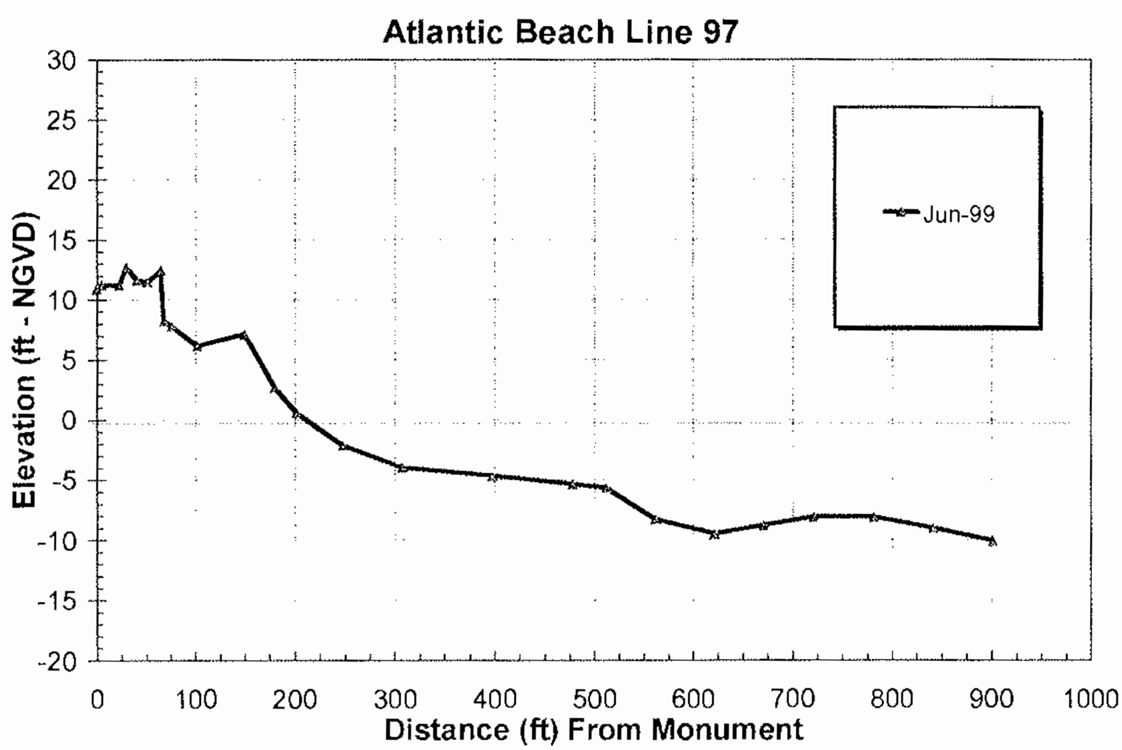


Atlantic Beach Line 94
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

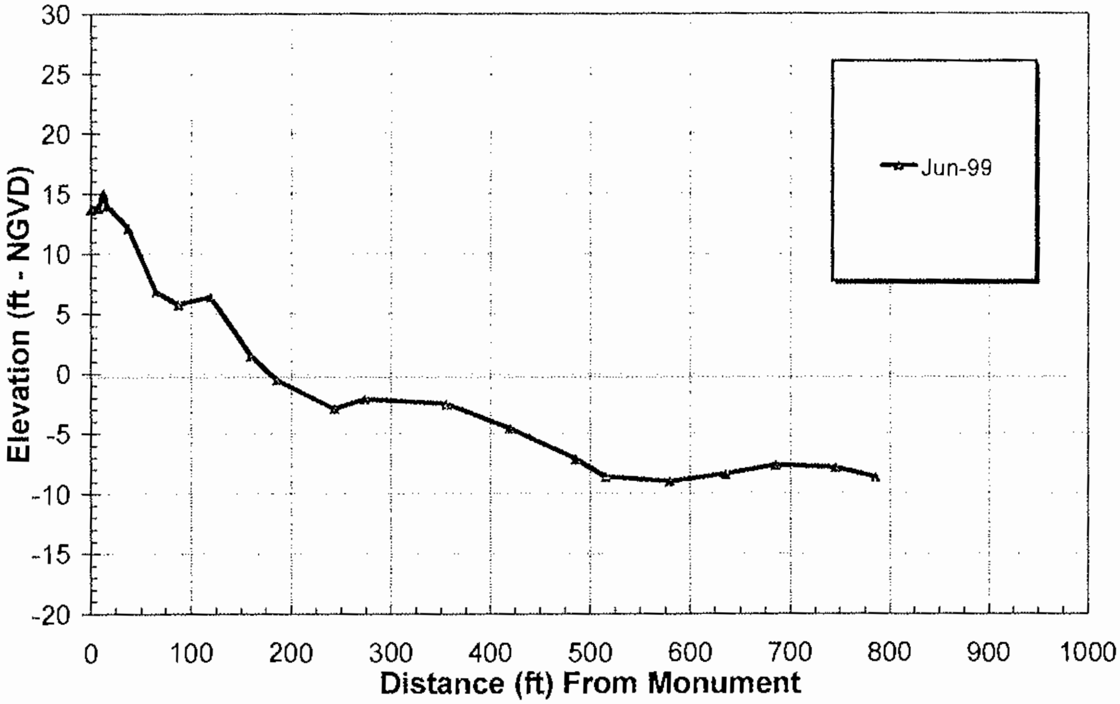


Atlantic Beach Line 95
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Sep-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

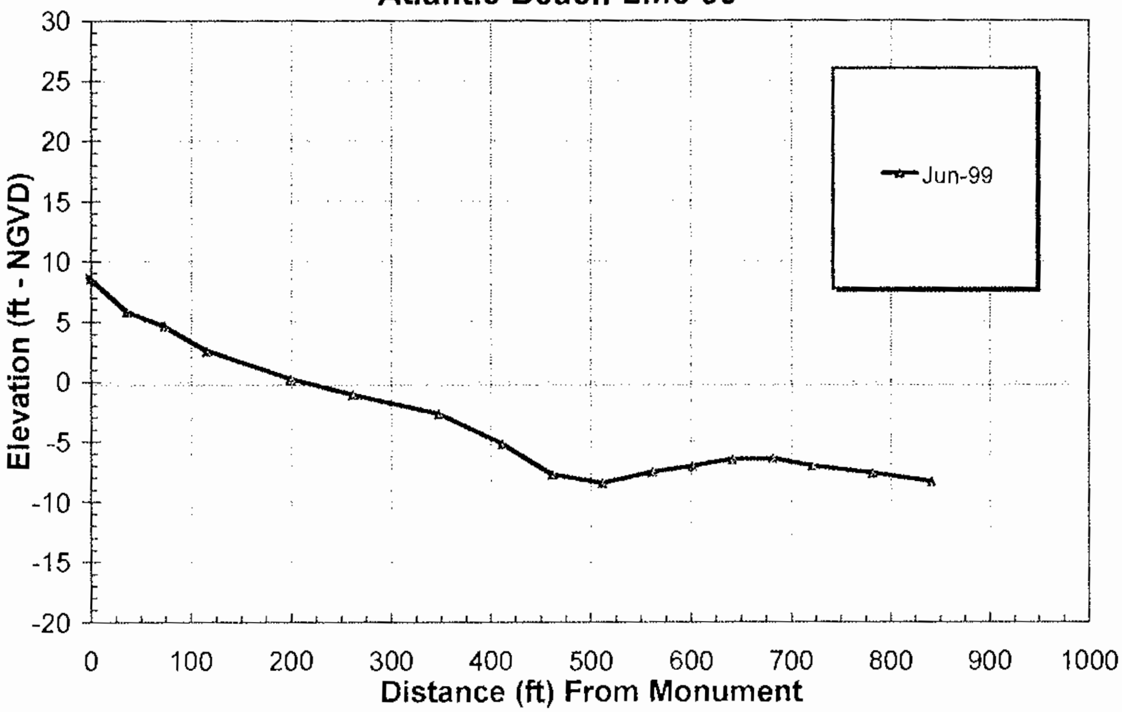

Atlantic Beach Line 96
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

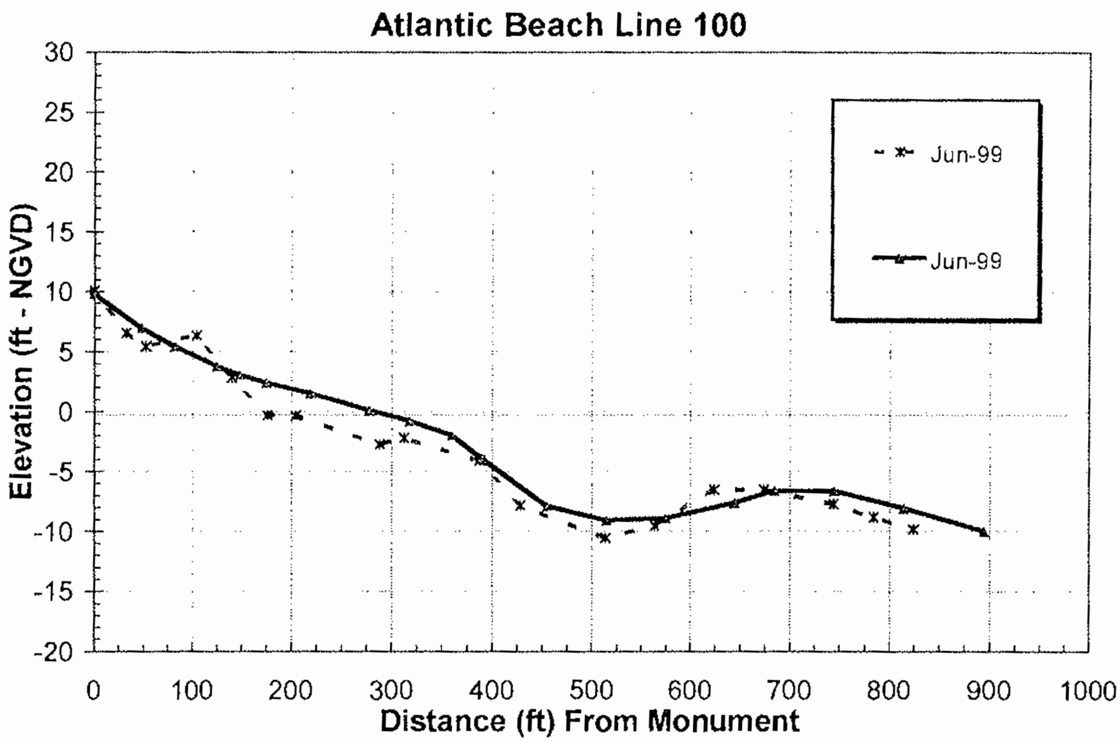

Atlantic Beach Line 97
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

Atlantic Beach Line 98

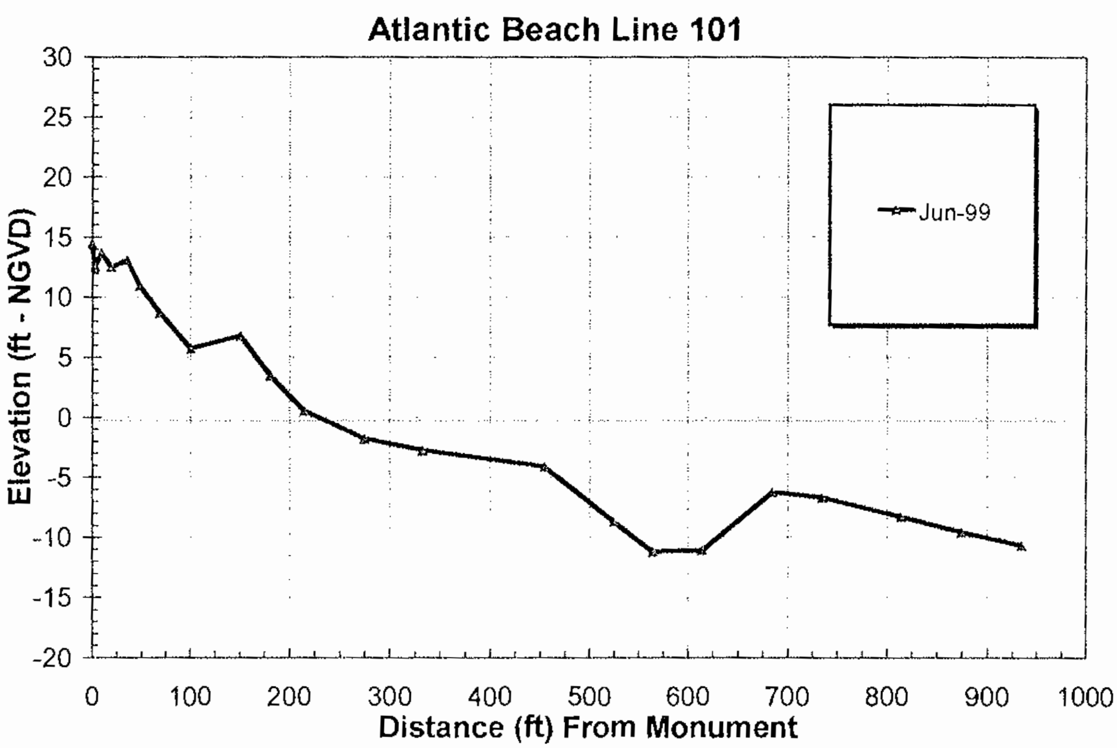


Atlantic Beach Line 99

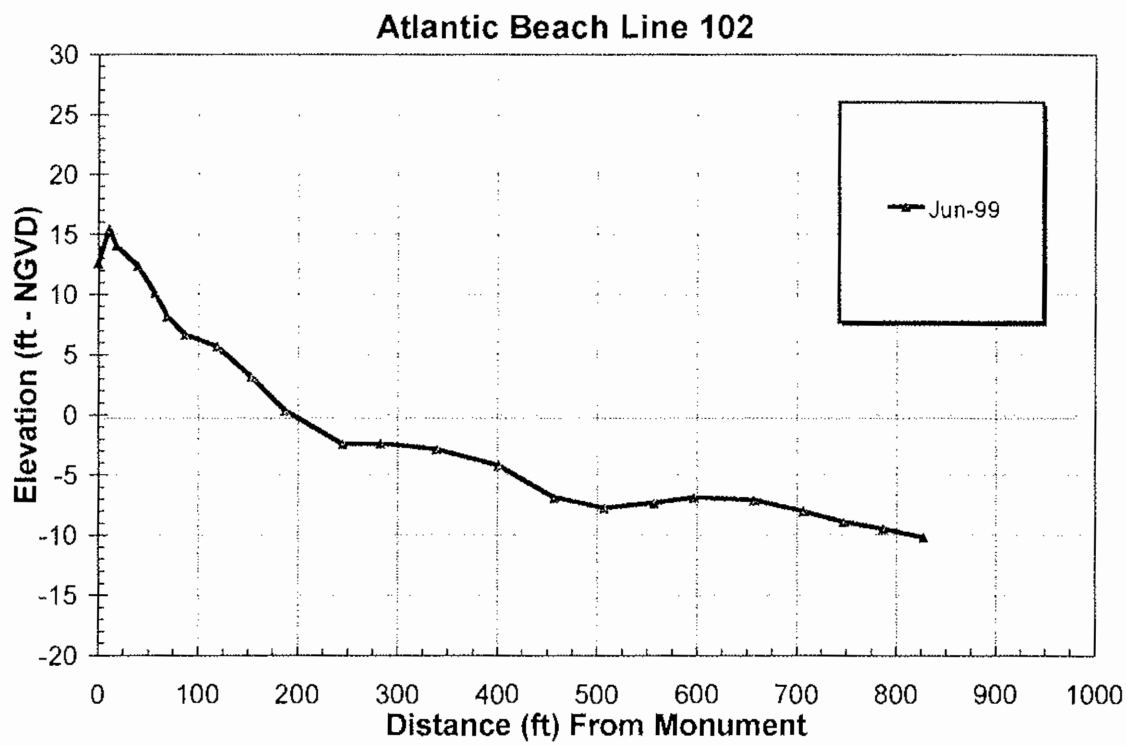


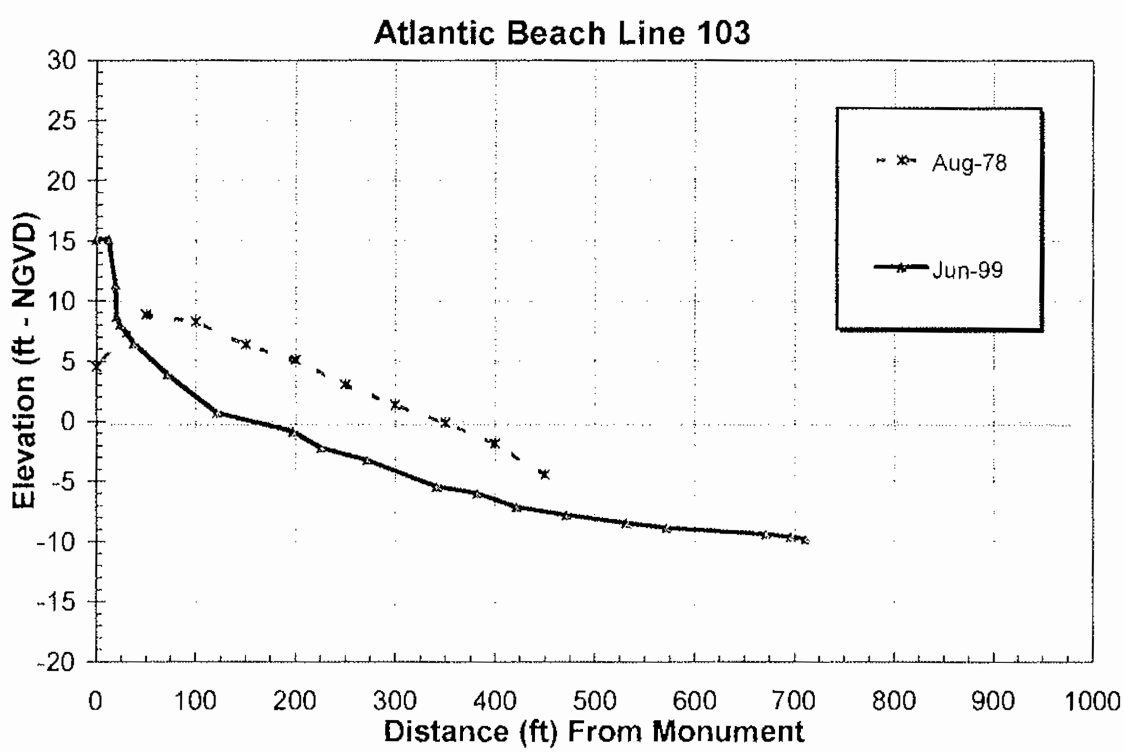


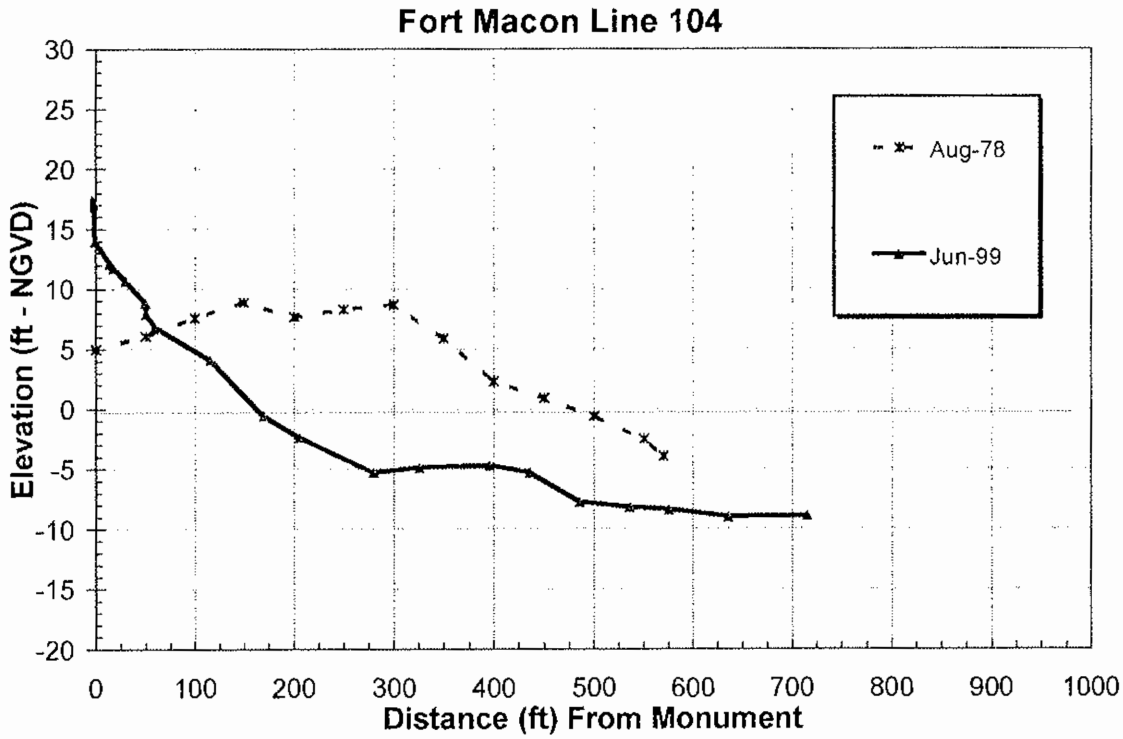
Atlantic Beach Line 100
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



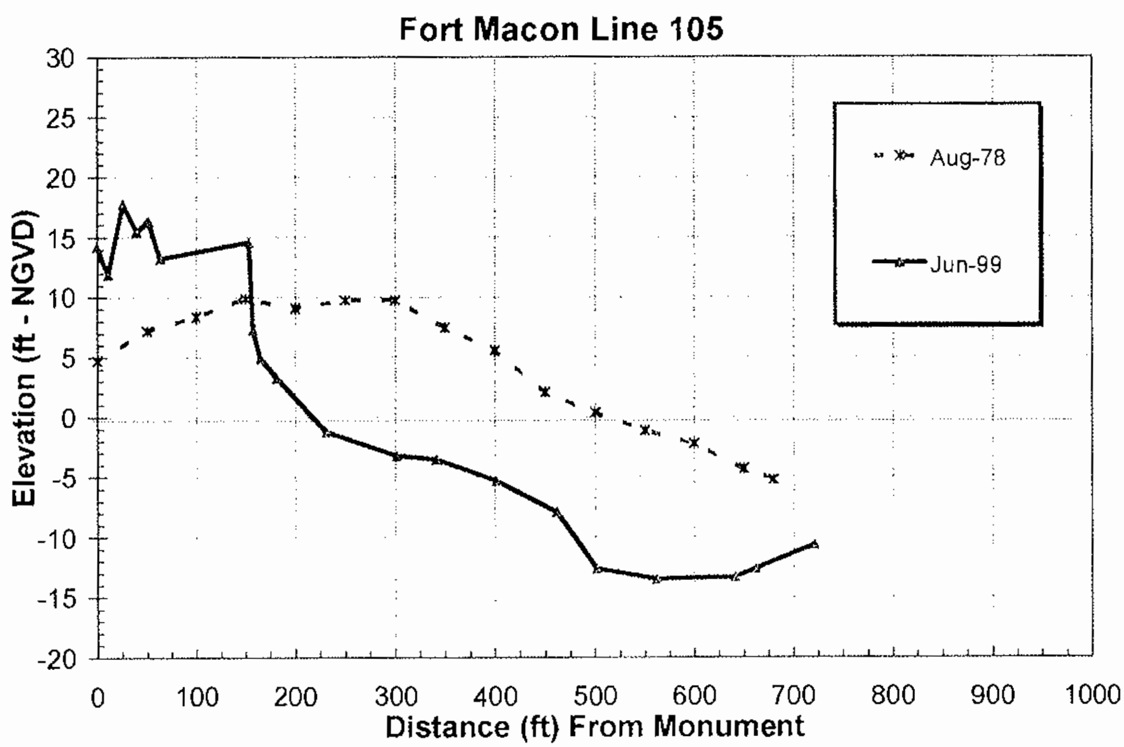
Atlantic Beach Line 101
Elevation (ft - NGVD)
Distance (ft) From Monument
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Atlantic Beach Line 102
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

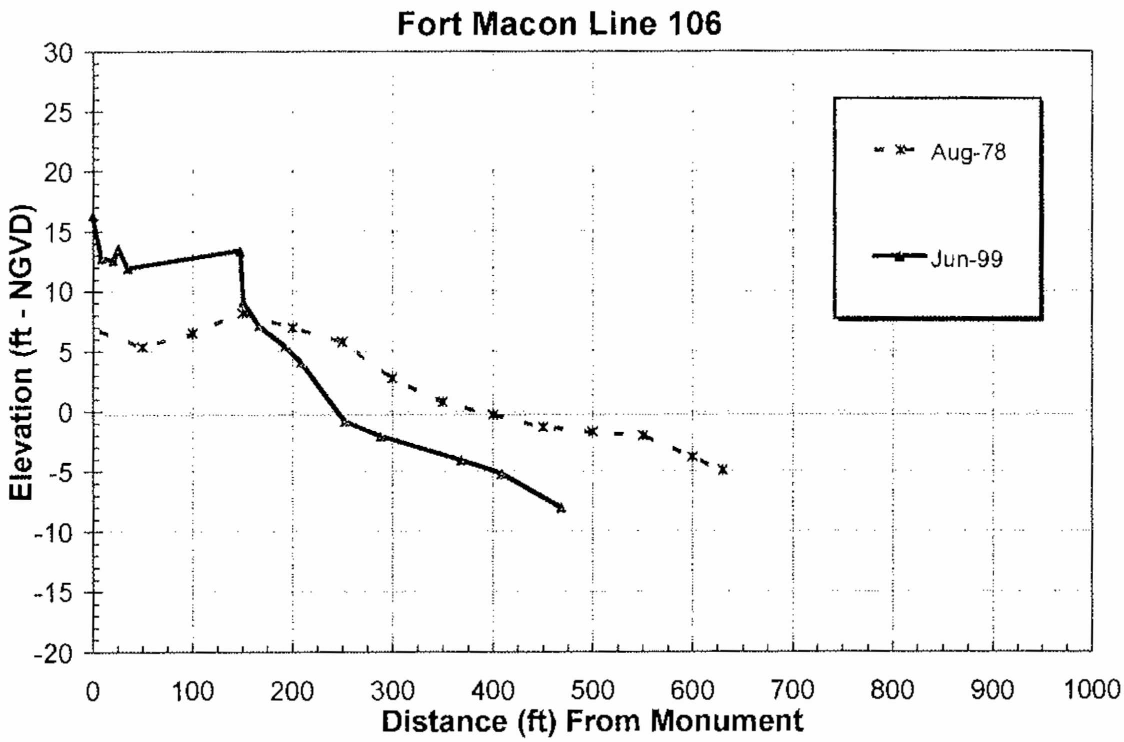

Atlantic Beach Line 103
Aug-78
Jun-99
Elevation (ft - NGVD)
Distance (ft) From Monument
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000



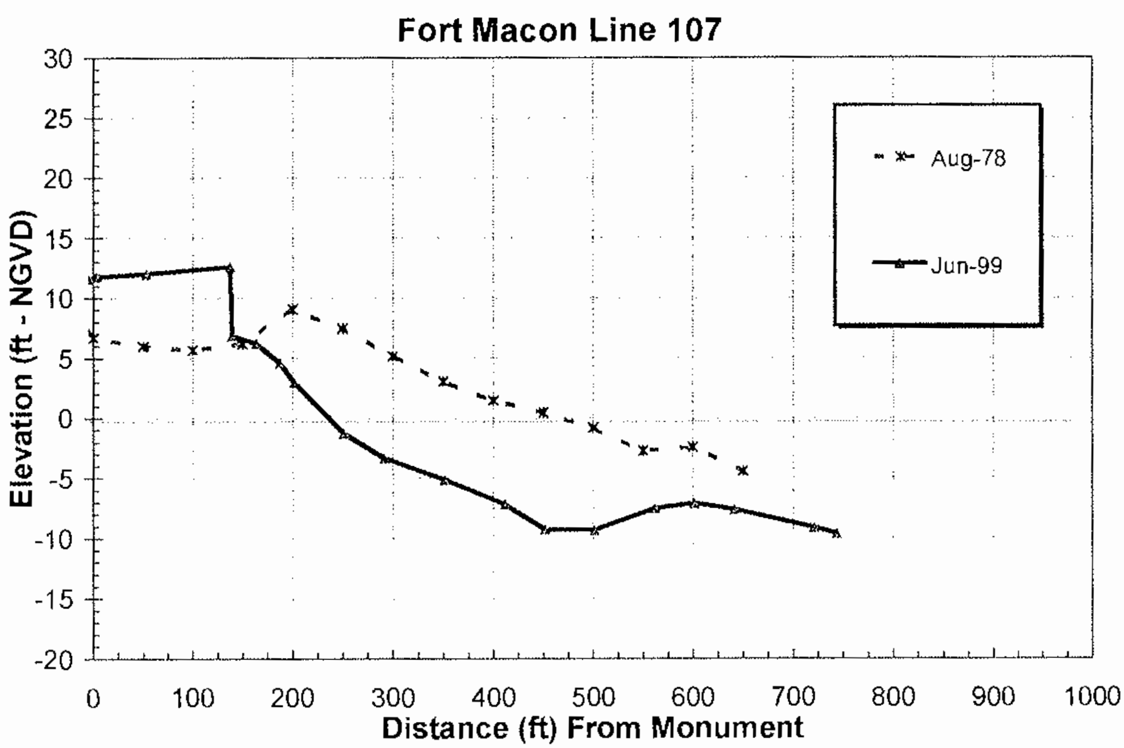
Fort Macon Line 104
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Aug-78
Jun-99



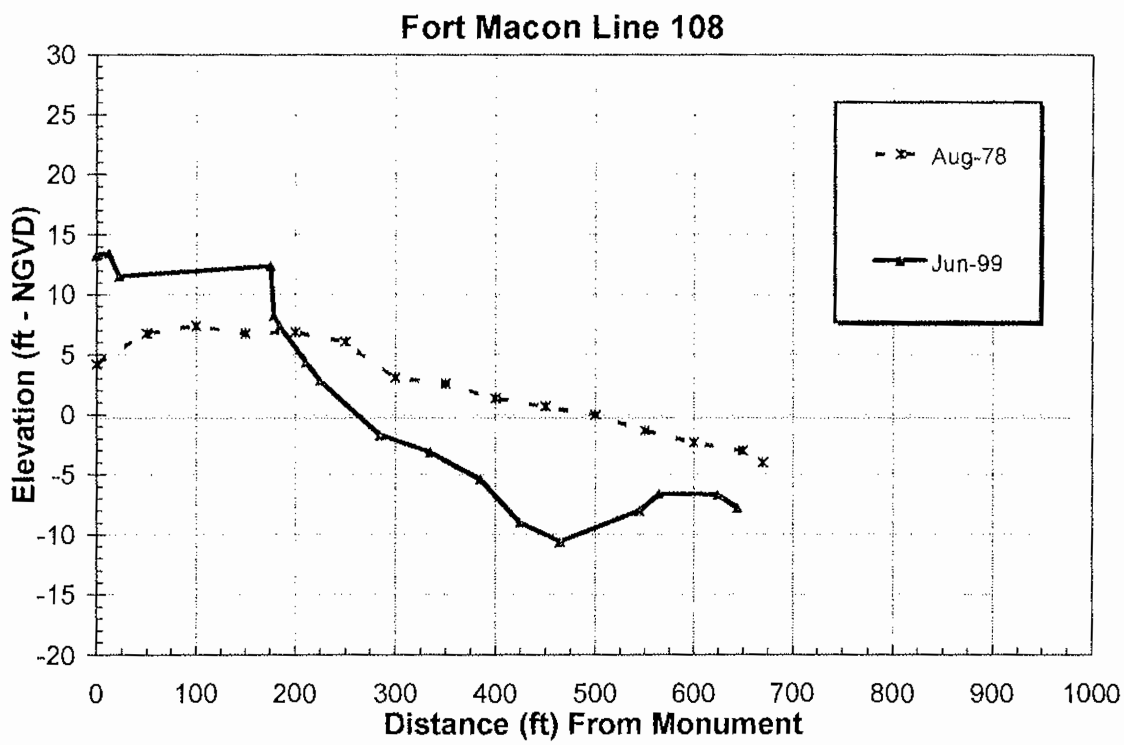
Fort Macon Line 105
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Aug-78
Jun-99

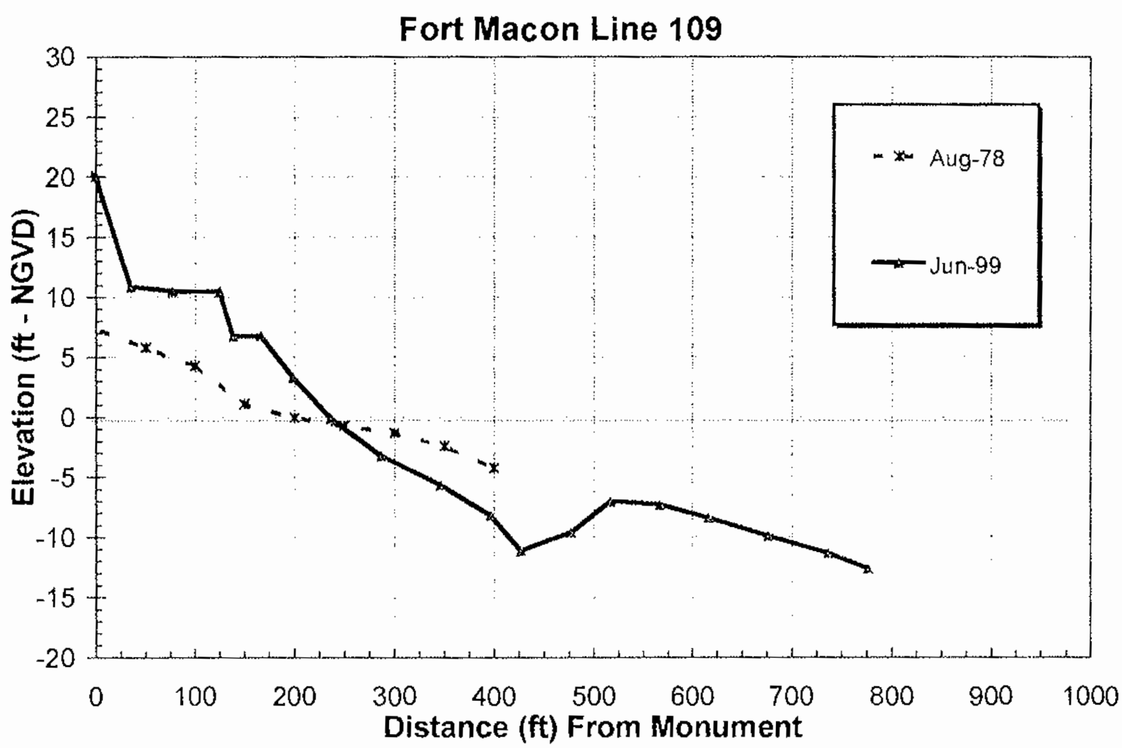


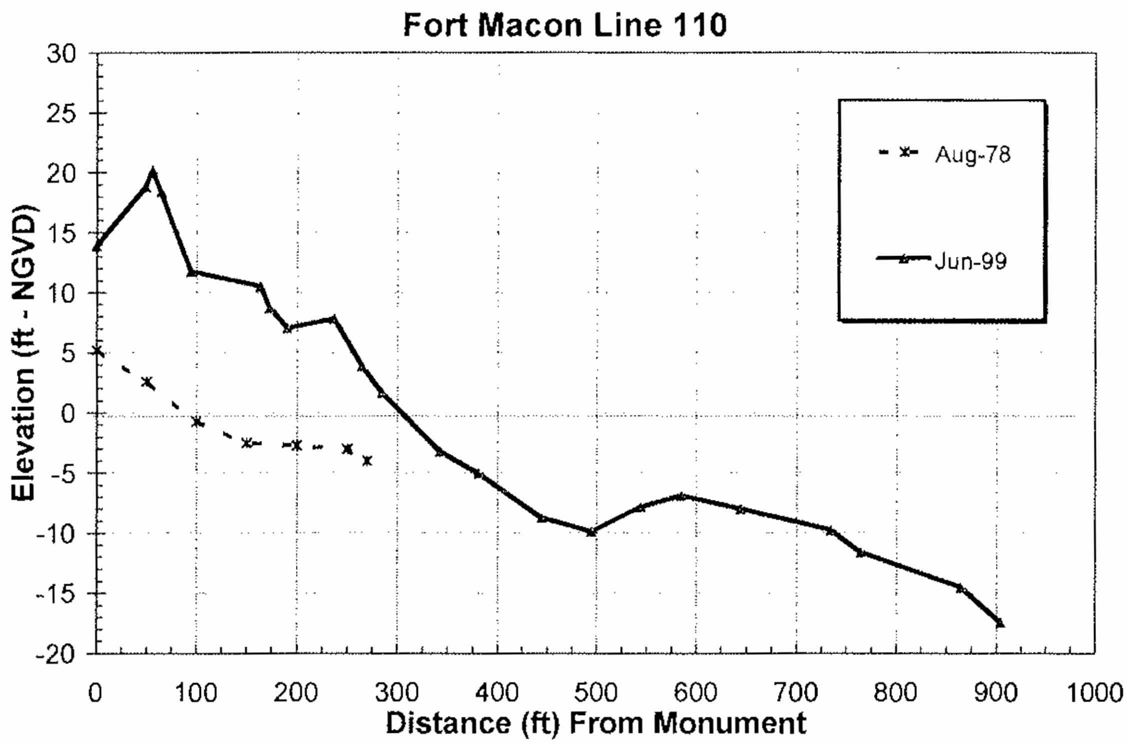
Fort Macon Line 106
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

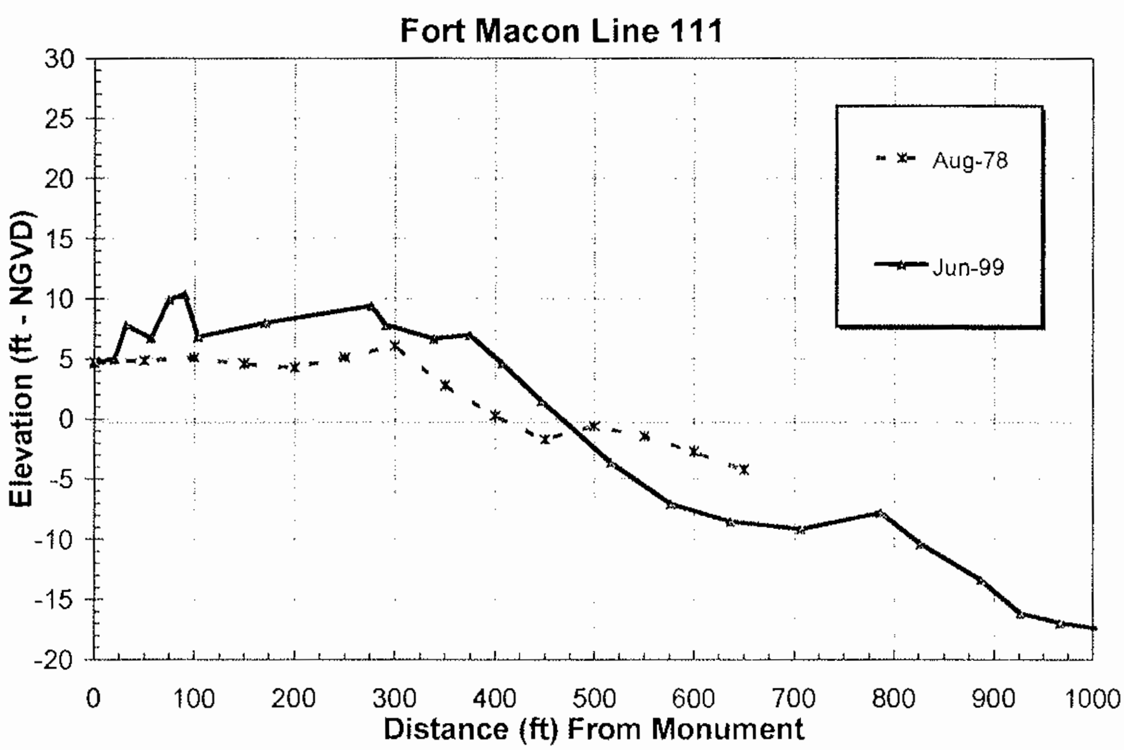


Fort Macon Line 107
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Fort Macon Line 108
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Aug-78
Jun-99


Fort Macon Line 109
Elevation (ft - NGVD)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft) From Monument
Aug-78
Jun-99


Fort Macon Line 110
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000


Fort Macon Line 111
Elevation (ft - NGVD)
Distance (ft) From Monument
Aug-78
Jun-99
30
25
20
15
10
5
0
-5
-10
-15
-20
0
100
200
300
400
500
600
700
800
900
1000

APPENDIX A-1
CORRESPONDENCE

APPENDIX A 2-5
PERMIT APPLICATION
06/06/2001 USDA EA
BIO MONITORING PLAN
USACE COMPILATION

APPENDIX B
MAGNETOMETER
REPORT

APPENDIX C
UNC-IMS STUDY

APPENDIX D
EFH ASSESSMENT

APPENDIX E
GEOTECHNICAL DATA

APPENDIX F
ECONOMICS STUDY

APPENDIX G
LITTORAL PROCESSES

US Army Corps
of Engineers

WILMINGTON DISTRICT
SOUTH ATLANTIC DIVISION

EVALUATION REPORT
AND
FINDING OF NO SIGNIFICANT IMPACT

MOREHEAD CITY HARBOR
SECTION 933

CARTERET COUNTY, NORTH CAROLINA

August 2003

SYLLABUS

The removal of 6,300,000 cubic yards of maintenance material from Brandt Island Upland Disposal Area as well as the maintenance dredging at Morehead City Harbor has created an opportunity for beneficial use of sand for the Carteret County beaches. The beach communities of Pine Knoll Shores, Indian Beach, and Salter Path are experiencing severe storm damage and erosion problems, particularly as a result of Hurricane Fran in September 1996 and Hurricane Floyd in September 1999. During the period from 1996 through 1999, Hurricanes Bertha, Bonnie, Dennis, and Irene have also affected the area. The storm damage and associated erosion from six named storms has resulted in considerable damage to homes and loss of the natural protective berm and dune system since 1996. The erosion of the berm and dune system has also increased and continues to increase the storm damage susceptibility of existing structures and infrastructure. The placement of sand from Brandt Island and Morehead City Harbor on these beaches would reduce the potential for erosion and storm damages.

This report presents two areas of beach placement to take place in conjunction with the Winter 2003/2004 Morehead City Harbor maintenance dredging and Brandt Island pumpout activities. The base disposal area is 100% fully funded by the Federal government and covers approximately 32,000 feet of Atlantic Beach and Fort Macon. If the Section 933 Project is implemented, the Base Disposal Plan will be modified from its 150-ft berm width to a 30-ft berm width; this is referred to as the Base Disposal Plan under the Section 933 project. This base disposal area under the Section 933 project will receive 1,834,000 cubic yards of sand. The area nourished with Federal/Sponsor cost sharing under the authority of Section 933 includes approximately 38,000 feet of shoreline along Pine Knoll Shores, Indian Beach, and Salter Path. The Section 933 project area will receive approximately 4,466,000 cubic yards of sand to construct a 30-ft berm width to an elevation of 7 feet above NGVD.

For the 38,000 feet of Pine Knoll Shores, Indian Beach, and Salter Path, where evaluation is required under Section 933, potential storm damage reduction benefits were analyzed. Expected annual hurricane and storm damages are reduced by 62 percent with the Section 933 project. Evaluating the Section 933 project over a twenty-year period of analysis, the total expected annual benefits (including incidental recreation) are estimated to be $10,655,000, whereas the equivalent expected annual increase in cost for placement of material along the Section 933 project area is $2,178,000. Thus, the net benefits would be $8,477,000 and benefit-cost ratio for the Section 933 project area is 4.9.

Based on the findings in this report, Carteret County is eligible for 65% Federal and 35% non-Federal sponsor cost sharing for the added cost of depositing dredged navigation material on the beaches of Pine Knoll Shores, Indian Beach, and Salter Path, under authority of Section 933 of PL 99-662.

The added cost of placing this quantity of material on the beach rather than in the base disposal plan area is estimated to be $16,354,000, of which $10,630,000 would be paid by the Federal Government and $5,724,000 contributed by non-Federal interest.

EVALUATION REPORT AND FINDING OF NO SIGNIFICANT IMPACT

MOREHEAD CITY HARBOR SECTION 933 CARTERET COUNTY, NORTH CAROLINA

Table of Contents

Item **Page No.**

SECTION 1 - INTRODUCTION

SECTION II – PROBLEM IDENTIFICATION

Table of Contents - continued

Item **Page No.**

SECTION III – ECONOMIC BENEFITS

SECTION IV – ENVIRONMENTAL CONSIDERATIONS IN PROJECT PLANNING

SECTION V – PLAN FORMULATION

SECTION VI – RECOMMENDED PLAN OF IMPROVEMENT

Table of Contents - continued

List of Tables

List of Figures

FINDING OF NO SIGNIFICANT IMPACT
(follows the main report)

List of Appendices

EVALUATION REPORT
AND FINDING OF NO SIGNIFICANT IMPACT

MOREHEAD CITY HARBOR SECTION 933
CARTERET COUNTY, NORTH CAROLINA

SECTION I - INTRODUCTION

The purpose of this study is to investigate the beneficial placement of dredged maintenance material from the authorized pump out of Brandt Island confined dike disposal area, and the maintenance dredging of the Morehead City Harbor navigation project, both of which are scheduled for the Winter of 2003-2004. This study analyzes the deposition of this dredged material along a portion of Bogue Banks beaches beyond the Corps' Base Disposal Plan, referred to as the "Section 933 Study Area" (Figure 1).

The Section 933 Study Area must be assessed for hurricane and storm damage reduction needs. This study also develops a plan of protection for this area based on the economic, engineering, and environmental feasibility, as well as the requests of the local sponsor.

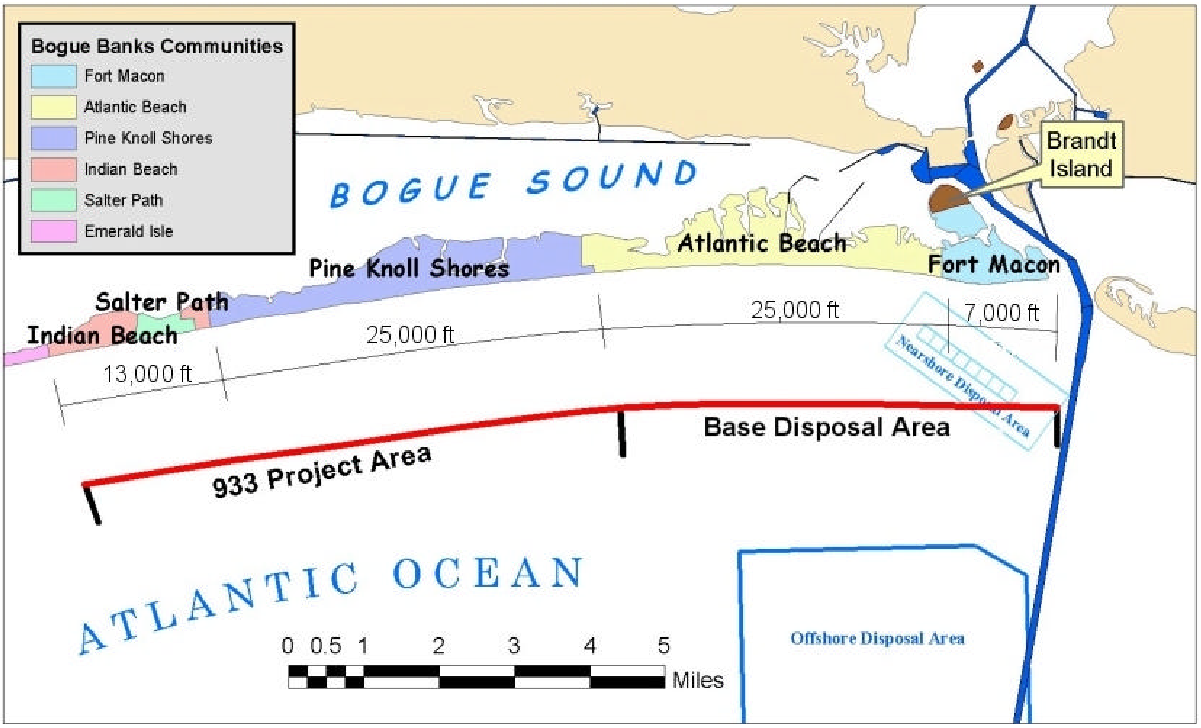


Figure 1. Morehead City Harbor Section 933 Study Area and Base Disposal Plan Area

Carteret County beaches are located on the central North Carolina Coast (Figure 2). The section of beachfront requested to be investigated for the beneficial placement of dredged material for hurricane and storm damage reduction needs includes the resort communities of Pine Knoll Shores, Indian Beach, and Salter Path. This 7.2-mile-long shoreline reach is eroding due to hurricane and storm action. A minimal berm exists along most of the Study Area, resulting in the dune system being frequently inundated during moderate energy events. Numerous structures in this area are highly vulnerable to damage by storm action due to the eroded dune system and loss of natural protection.

Based on analyses conducted during this study, the beneficial placement of dredged material for hurricane and storm damage reduction along the 7.2 miles of Pine Knoll Shores, Indian Beach and Salter Path was determined to be economically justified using a uniform 30-ft berm design width. The sponsor had requested the distribution of the dredged material to be placed in a uniform 30-ft berm design width stretching from Fort Macon to the Indian Beach/Emerald Isle border. Only those areas beyond the Base Disposal Plan are required to be studied and justified as part of the Section 933 project.

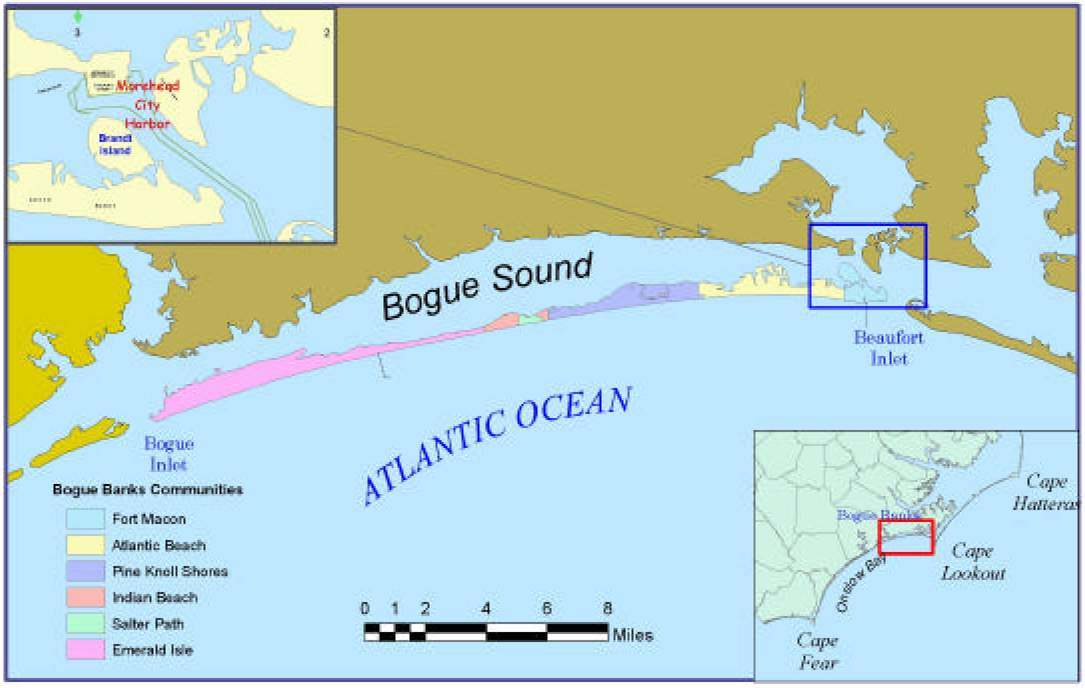


Figure 2. Morehead City Harbor Section 933 Location Map

NON-FEDERAL SPONSOR

In a letter dated February 22, 2001, (see Appendix A, Exhibit 1) the State of North Carolina stated that they supported the interest of Carteret County in a study for a potential Section 933 Project for use of dredge maintenance material from the authorized pump out of the Brandt Island disposal area and dredging of Morehead City Harbor navigation channels, scheduled for 2003-2004, onto Bogue Banks beaches. This letter was produced on behalf of Carteret County that had passed a resolution on January 22, 2001 requesting a Section 933 Project to place this material onto the beaches of the Towns of Pine Knoll Shores and Indian Beach, and the Village of Salter Path (see Appendix A, Exhibit 2).

In their January 6, 2003, letter to the Wilmington District, Carteret County stated their commitment to acting as the cost-sharing sponsor for this Section 933 project (see Appendix A, Exhibit 3).

STUDY AUTHORITY

This study was conducted under the authority of Section 145 of the Water Resources Development Act of 1976, P.L. 94-587, as amended by Section 933 of the Water Resources Development Act of 1986, P.L. 99-662, and other laws, 33 U.S.C. § 426j. Projects carried out under this authority are commonly referred to as "Section 933 projects." The primary study emphasis was directed toward hurricane and storm damage reduction measures at Pine Knoll Shores, Indian Beach and Salter Path. The guidance for this study authority is:

ER1105-2-100, Section II, E-14(h), 22 April 2000:

> "Placement of Dredged Material on Beaches for Hurricane and Storm Damage Reduction. When placement of dredged material (beach quality sand) on a beach is the least costly acceptable means for disposal, then such placement is considered integral to the navigation project and cost shared accordingly. In cases where placement of dredged material on a beach is more costly than the least costly alternative, the Corps may participate in the additional placement costs when: (1) requested by the State; (2) the Secretary of the Army considers it in the public interest; and (3) the added cost of disposal is justified by hurricane and storm damage reduction benefits.
>
> When all local cooperation requirements are met the Corps may cost share the additional 65 percent (Section 933, WRDA 1986, as amended). In cases where the additional costs for placement of the dredged material is not justified, the Corps may still perform the work if the State requests it, and the State or other sponsor contributes 100 percent of the added cost. If the State requests, the Corps may enter into an agreement with a political subdivision of the State to place the sand on its beaches, with the subdivision responsible for the additional costs. The Corps should consider and accommodate to the degree reasonable and practicable a State's or subdivision's schedule for providing its cost share. Each placement event should be supported by a separate decision document. Subsequent decision reports may be supplements to the original Section 933 decision document."

SCOPE OF STUDY

This report presents the results of studies conducted to address the needs for the placement of dredged material for hurricane and storm damage reduction for Carteret County beaches. The study area is shown on Figure 1. Study emphasis was placed on hurricane and storm damage reduction measures for the 7.2-mile-long Study Area as requested by the local sponsor. This area includes the communities of Pine Knoll Shores, Indian Beach and Salter Path. This report is submitted in compliance with Section 933 of WRDA 1986, as amended and Engineer Regulation 1105-2-100 quoted in the "Study Authority" section of this document.

The congressionally authorized Feasibility Study of Bogue Banks (Atlantic Beach, Pine Knoll Shores, Indian Beach, Salter Path and Emerald Isle) will investigate the long term shore protection needs for those beach communities and will be conducted as a separate study and reported later. Carteret County is the non-federal sponsor for this study.

PRIOR STUDIES

There have been several prior studies in the study area and adjacent waters by the Wilmington District. These studies, listed below, include three shoreline studies, two navigation studies and a shoreline mitigation study.

House Document No.555, 87th Congress, "Fort Macon - Atlantic Beach and Vicinity, North Carolina," dated 1961. This report presents the results of an investigation of beach erosion along the Fort Macon - Atlantic Beach shoreline by the Wilmington District.

House Document No. 93-121, "National Shoreline Study," dated 1970. This report, approved by Congress in 1970, presents the results of an investigation of the nations' shorelines as part of a comprehensive study to address shoreline conditions including shoreline ownership, property values, and shoreline changes (eroding, stable, or accreting).

Wilmington District report, "Beaufort Inlet to Bogue Inlet, North Carolina," dated 1965. This report presents the results of an investigation of beach erosion along the Bogue Banks shoreline by the Wilmington District.

House Document No. 92-170/92/1, "Morehead City Harbor, North Carolina," dated 1970. This report presents the results of an investigation to deepen the project to 40-feet Mean Low Water (MLW).

Report of the Chief of Engineers, "Morehead City Harbor, North Carolina," dated 1991. This report presents the results of an investigation to deepen the project to 45-feet MLW.

Wilmington District Section 111 Feasibility Report, "Morehead City Harbor (Pine Knoll Shores), North Carolina," dated 2001. This report presents the results of an investigation of shoreline mitigation for the Morehead City Harbor Navigation Project.

EXISTING FEDERAL PROJECTS

There are no active Federal hurricane and storm damage reduction projects in the study area. There is an active navigation project. The Morehead City Harbor navigation project presently consists of a 47-foot deep (MLW) by 450-foot wide ocean entrance channel through the ocean bar of Beaufort Inlet, which connects with channels and inner harbor which is generally 45 feet deep at MLW (East Leg) and 35 feet deep (West Leg and Northwest Leg). The current project is generally referred to as the 45-foot draft navigation project. A map of the Morehead City Harbor project is shown on Figure 3 and Figure 1 in the EA. Note that the entrance channel is composed of three reaches; namely, Range B (inner channel), the Cutoff, and Range A (ocean bar channel). The primary commodities passing through Morehead City Harbor are fertilizer products, rubber, and wood chips, which are handled by facilities provided by the North Carolina State Port Authority. Lesser amounts of petroleum products, machinery, and paper also pass through the State Port.

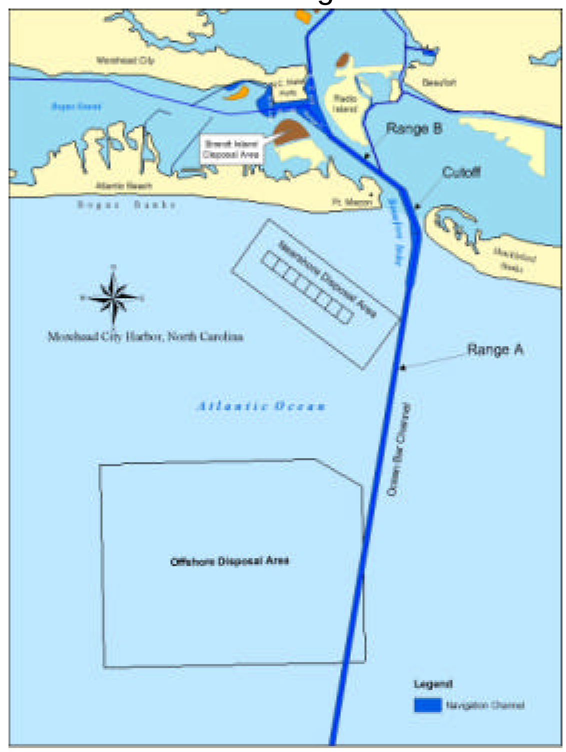


Figure 3. Morehead City Harbor

Historically, the Cutoff and Range A have been maintained by hopper dredge with the dredged material deposited in an offshore dredged material disposal site (ODMDS) located west of the seaward end of the bar channel. During the 1996 maintenance cycle for the bar channel, the disposal location was modified to include an option for near shore placement west of the bar channel in an area centered on the 30-foot MLW depth contour. Subsequent maintenance operations conducted in 1997 and 1999 required that all ocean bar channel material be placed in a near shore disposal site centered on the 25-foot MLW contour west of the channel.

However, operational constraints associated with the operation of hopper dredges has not allowed all of the maintenance material to be placed in the near shore site. The constraints associated with a hopper dredge operation include the inability of the dredge to deposit the material in shallow depths during unfavorable weather and wave conditions and the restricted dredging window (i.e. the time period in which hopper dredges are allowed to operate) imposed on hopper dredge operations due to their propensity to interfere with sea turtles. The dredging window for hopper dredges extends from January through March.

Maintenance of Range B and inner harbor has been performed by pipeline dredge with disposal on Brandt Island, a confined dredged material disposal site located immediately across the harbor from the State Port facility. Due to the limited capacity of this site, and the absence of other suitable upland disposal site in the area, Brandt Island was identified as a temporary holding area for the inner harbor dredged material during the formulation of the 40-foot project in 1976 and the 45-foot project in 1994. In this capacity, maintenance material is to be temporarily stored on Brandt Island for a period of 8 to 10 years after which the material is transferred to a beach disposal site located along the eastern end of Bogue Banks. Previous beach disposal sites have covered sections of both Fort Macon State Park and the Town of Atlantic Beach. Transfer of material from Brandt Island to the beach was accomplished in 1986 and 1994.

FEDERAL STANDARD - BASE DISPOSAL PLAN

Should present plans for sharing sand by Bogue Banks beaches not materialize due to funding problems or other unforeseen reasons, up to 6.3 million cubic yards dredged maintenance material from the inner and outer harbor, as well as the pump out of Brandt Island would be distributed according to the base disposal plan as determined by the Federal Standard (see Appendix B). The base disposal plan represents the least cost alternative for the government, which is engineeringly feasible and environmentally acceptable.

Under the base disposal plan, the outer harbor would be maintained by hopper dredge and the resultant 1.5 million cubic yards of dredged material would be placed in the previously approved near-shore disposal area or the offshore dredged material disposal site (ODMDS) if inclement weather will not allow nearshore placement. The pumpout of Brandt Island and the maintenance dredging of the inner harbor by pipeline dredge would be placed using a design berm width of 150-feet. Up to 4.8 million cubic yards (about 4.0 million from Brandt Island and about 0.8 million from the inner harbor) of beach quality sand may be placed along approximately 32,000 feet of shoreline from Fort Macon State Park to the Atlantic Beach/Pine Knoll Shores border (Figure 1). If the North Carolina State Port Authority does not fund its share of approximately 1.2 million cubic yards of the Brandt Island material, this amount could be reduced to 3.6 million cubic yards.

HISTORICAL BEACH DISPOSAL OF MOREHEAD CITY HARBOR DREDGED MATERIALS

Generally, routine maintenance dredging occurs every two years for Morehead City Inner Harbor and every year for the Outer Harbor. Pump outs of Brandt Island are scheduled every 8-10 years, depending on disposal capacity within the existing confined disposal area. Material removed from the Morehead

City Harbor project, from either Brandt Island or direct transfer onto beaches from maintenance activities, has been deposited on the shoreline of Bogue Banks on four separate occasions (Figure 4).

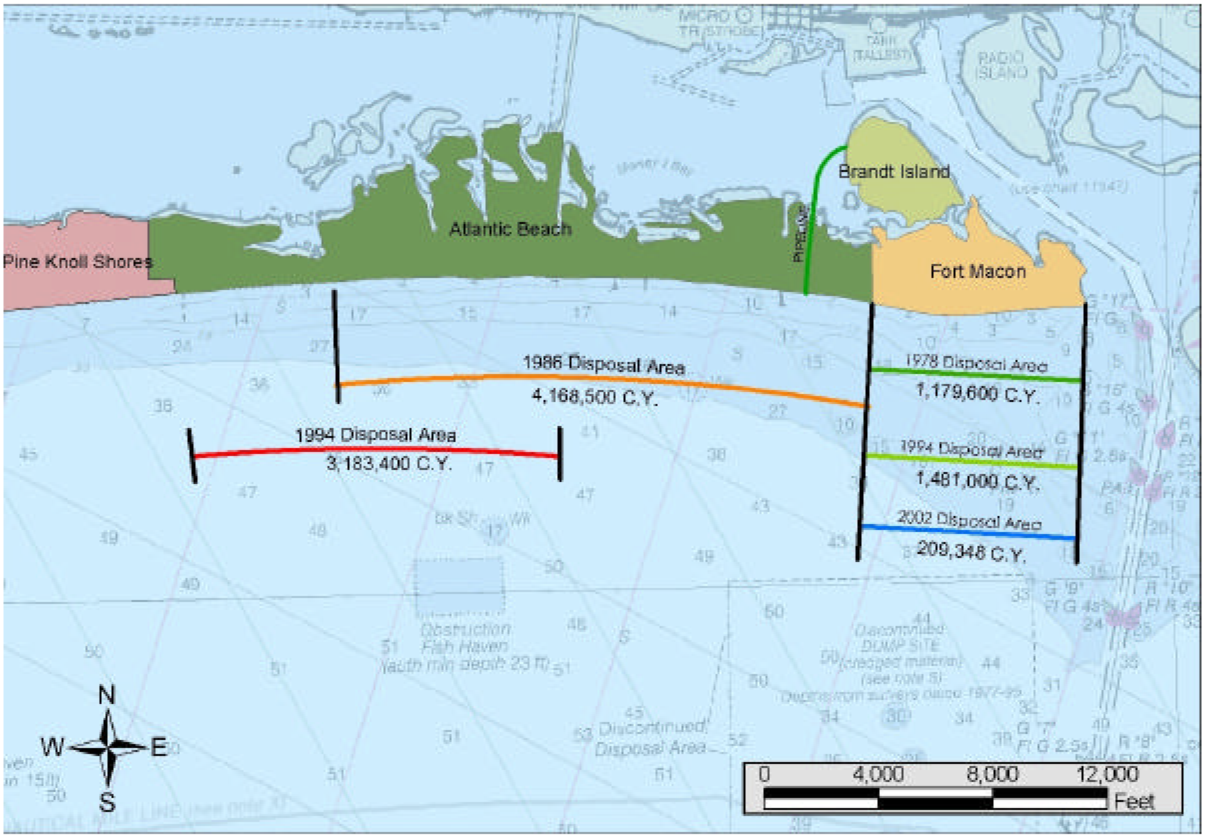


Figure 4. Historic Beach Disposal Operations

In 1978, a total of 1,179,600 CY of material removed for the deepening of the inner harbor and Range B was deposited along the Fort Macon State Park shoreline. In 1986, a total of 4,168,600 CY of dredged material was placed on Atlantic Beach between Corps of Engineers baseline stations 100+00 and 290+00. Of this total, 3,912,900 CY were from Brandt Island, and 255,700 CY of channel and basin maintenance material was transferred directly to the beach disposal site. In 1994 a total of 4,664,400 CY of material was placed on Fort Macon and Atlantic Beach with 3,183,400 CY being deposited between baseline stations 210+00 and 318+00 and the remaining 1,481,000 placed on the shoreline of Fort Macon State Park. Of the total 4,664,000 placed on the beach, 465,700 CY was maintenance material from the inner harbor, 1,725,000 CY was from new work construction, and 2,473,700 CY was from the Brandt Island disposal area. And finally, during the Spring of 2002, a direct transfer of 209,348 CY of maintenance material from the inner harbor was placed on the shoreline of Fort Macon between Corps of Engineers baseline stations 0+00 and 39+00 while the dike on Brandt Island was being reworked and was unavailable for accepting disposal material. The total amount of material available during any given pump out varies depending on the amount of material in Brandt Island and the annual maintenance needs of the inner harbor. There is no foreseeable new work dredging in the immediate future.

LOCALLY FUNDED RENOURISHMENT

This project proposes to place approximately 4.57 million cubic yards of sand over 16.8 miles of Pine Knoll Shores, Indian Beach, Salter Path, and Emerald Isle shoreline. The source of the sand is an ocean borrow site. The project will be completed in three phases over a three-year period. The first phase has been completed with the nourishment of 6.8 miles of beach in Pine Knoll Shores and Indian Beach with approximately 1.7 million cubic yards of sand, which has been taken into account for the pre-Section 933 project conditions. The second phase is expected to place 1.8 million cubic yards of sand on 5.9 miles of Emerald Isle beginning January 13, 2003. And the final phase, if implemented would place 1.0 million cubic yards of sand on 3.5 miles of Emerald Isle in the winter of 2003/2004.

STUDY PARTICIPANTS AND COORDINATION

This Section 933 study will be coordinated with various Federal, State, and local agencies and the public having concerns about the beneficial placement of dredged material for hurricane and storm damage reduction and the environmental impacts of proposed improvements. The Environmental Assessment (EA) was circulated for review and comment along with this Evaluation Report. Comments received during the public review of the EA are addressed in the Finding of No Significant Impact. Required coordination was conducted with all appropriate agencies.

SECTION 933 PROJECT REQUIREMENTS

A Section 933 Project, as described under " Study Authority", allows for the placement of navigation maintenance dredged materials onto beaches other than those that are determined to be part of the Base Disposal Plan. However, a Section 933 Project is subject to the availability of adequate Federal funding as well as the following conditions being met (ER 1165-2-130, *Federal Participation in Shore Protection,* and ER 1105-2-100, *Planning Guidance Notebook*).

a) The State must request that the dredged material be placed on the beach (this may be on the behalf of a political subdivision of the State);

b) The added cost of placing the material on the Section 933 project beaches over the Base Disposal Plan must be justified by the benefits it produces;
c) At least 50 percent of the additional costs must be covered by storm damage reduction benefits;
d) The beach must be open to the public and provide reasonable public access that has been defined as access points approximately every **one-half mile or less**. In addition, sufficient public parking, located within a reasonable walking distance of the access points should be provided. Parking should be sufficient to accommodate the lesser of peak hour demand or the beach capacity for the project area.
e) The placement of the dredged material must satisfy all applicable environmental statutes and regulations;
f) The non-Federal sponsor must pay **35 percent** of the added cost of disposal above the cost of the Base Disposal Plan; and
g) The non-Federal sponsor must provide, without cost to the Federal Government, all lands, easements, rights-of-way, and relocations needed to accomplish the work.

If all of these conditions are not met, the material could still be placed on the proposed beach areas outside of the Base Disposal Plan providing:

a) The State requests that the dredged material be placed on the beach (this may be on behalf of a political subdivision of the State);
b) Protection of the beach is in the public interest, regardless of benefits produced;
c) The placement satisfies all applicable environmental statutes and regulations;
d) The non-Federal-sponsor pays 100 percent of the added cost of disposal above the Base Disposal Plan; and
e) The non-Federal-sponsor provides without cost to the Federal Government, all lands, easements, rights-of-way, and relocation.

AREAS OF CONCERN

The following issues are considered areas of particular concern regarding the proposed project.

- In response to the January 15, 2002, scoping letter, the public and review agencies expressed the following major concerns: fishery resources and habitats, rare butterfly habitat, short- and long-term impacts of the proposed activity, endangered/threatened species, cultural resources, sediment contamination, and other natural resources.

PUBLIC BEACH ACCESS AND PARKING

The Army Corps of Engineers has several requirements that must be met in order to fully cost share in a Section 933 project (see "Section 933 Project Requirements" section on the preceding pages). The Corps' Wilmington District, additionally, has developed more specific public access and parking requirements for participation in Section 933 projects within the District's boundaries of North Carolina (see Appendix E).

The Wilmington District, using aerial photography and traffic surveys from the July 4th holiday, conducted an analysis to determine the peak hour demand for the area. The data was used to determine that the communities currently have adequate parking to meet the Corps' requirements for peak hour demand (see Appendix E).

The additional Section 933 requirements have been addressed by the local sponsor and documented in their Public Transportation and Parking/Access Plan for the proposed project area (see Appendix E – Exhibit 1). The document identifies the number of (8) and location of current public beach access sites and parking spaces (301) available, and outlines the sponsor's plans for future public beach access sites and parking. Additionally, the document addresses the installation of a public transportation system to assist visitors in accessing areas of the beach that have public access, but no public parking.

The sponsor's plan as currently proposed is acceptable to the Corps. Any changes to this plan or any new issues that arise will need to be resolved prior to the signing of the Project Cooperation Agreement.

When the plan is implemented, the sponsor will be eligible for full Federal cost sharing for the majority of the project area. The only exception currently identified includes the westernmost 1900 feet of Indian Beach (between Station 700+00 and Station 681+00) that does not meet the Corps' criteria, and would require 100% non-Federal funding to nourish. The local Sponsor has indicated that they do not intend to pursue this option at this time.

The sponsor will be eligible for cost sharing of 65.0% Federal and 35.0% non-Federal sponsor for the Section 933 project. These values are based on the sponsor's beach access and transportation plan and will be subject to change if more, less, or different access sites are decided upon prior to signing of the Project Cooperation Agreement. Once all access and/or parking sites are obtained, and prior to signing the PCA, the Corps will obtain specific measurements using GIS and or survey data of these sites to make a final determination on project cost sharing.

The local sponsor has developed the Public Transportation and Parking/Access Plan to identify how they will fulfill their commitment to meet the Corps' Section 933 requirements. The adequacy of public access will be revisited before the signing of a Project Cooperation Agreement. At that time, the Corps will verify that all plans have been implemented and that they meet all Section 933 requirements as outlined in this report.

If additional access points and parking are deemed necessary, the Wilmington District and local sponsor will work together on the local sponsor's plan to provide these. Should the local sponsor be required to obtain additional public access areas, these areas should be acquired as easements for the term of years identified in the Project Cooperation Agreement for which the local sponsor is responsible for providing public access for the project. The sponsor will be responsible for ensuring that the Section 933 requirements are met throughout the life of the project. Beach access and parking requirements are presented in Appendix E.

SECTION II - PROBLEM IDENTIFICATION

The purpose of this report section is to identify problems, needs and opportunities in the study area in accordance with the study authority. This report section includes the following: (1) description of the study area; (2) an analysis of public concerns, which presents the concerns of local interests, Federal agencies, and others having interests in the study; (3) a statement of the National Objective, which outlines the criteria for Federal participation in water resources developments; (4) an assessment of Federal interest, which identifies concerns in the study area which the Federal government can address under this objective; and (5) specification of Problems, Needs, and Opportunities.

STUDY AREA

Carteret County is located on the central North Carolina coast. Bogue Banks is a 25.4 miles long south-facing barrier island located on the low-energy limb of the Cape Lookout foreland within Carteret County. It is oriented in an approximate east to west direction between Beaufort and Bogue Inlets, located on the east and west terminuses of the island, respectively. The island is bound to the north by Bogue Sound, a relatively shallow water body through which the Atlantic Intracoastal Waterway passes (Figure 2).

Fort Macon State Park occupies the eastern end of the island. Political subdivisions on the rest of the island include, from east to west: the Town of Atlantic Beach, the Town of Pine Knoll Shores, an unincorporated area known as Salter Path, Town of Indian Beach, and the Town of Emerald Isle. The width of the upland portions of the island (the landmass above mean high water) varies from a minimum of approximately 800 feet to a maximum of over 4,000 feet. The narrowest part of the island, which ranges in width from 800 feet to 1,000 feet, is located along the easternmost 2.8 miles of Emerald Isle. The widest part of the island, which measures over 4,000 feet, is located on the westernmost 5.1 miles of the island, also within the corporate limits of Emerald Isle.

A maritime forest area is located on the sound side of Bogue Banks between the east portion of Indian Beach through Pine Knoll Shores. This reach of the island includes the Theodore Roosevelt Natural Area, which is the only portion of Bogue Banks included in the Coastal Barrier Resources System. In general, the island has been developed in such a manner as to preserve as much of the natural vegetation from the ocean to the sound as possible.

Hurricanes, extratropical events and progressive erosion have always occurred in the study area. Increasing development in Carteret County over the last several years has raised the potential for damages considerably. Development in the study area consists of single family houses, multi-unit apartment and condominium buildings, hotels, motels, and commercial buildings of various sorts, all covering a wide range of values and susceptibility to storm damages. Long-term erosion rates and elevations also vary over the study area.

Because of substantial variations in every factor that will affect storm damages, it is impossible to select any small areas or reaches that could be considered representative of the study area as a whole.

From 1990 to 2000, the population of Carteret County grew about 13% (i.e., 1990 population was 52,407 and 2000 population was 59,383). About 40 percent of the residents live in one of the county's municipalities. With its overwhelming economic emphasis on tourism, retail sales in Carteret County comprise the most important source of jobs and income for the county's economy. In 1993, total farm income for Carteret County was over 18 million dollars, with corn, soybeans, and tobacco the leading commodities. In 1995, the manufacturing sector employed about 10 percent of Carteret County workers.

The North Carolina Office of State Budget and Management estimates Carteret County's 1994 employment at 25,000, with about 35 percent in trade and 21 percent in Government employment. In 1997, per capita income in Carteret County was estimated at $21,624, somewhat higher than the North Carolina per capita income of $20,217.

The 1990's were a decade of rapid growth for the Carteret County beaches. The populations of the towns and Carteret County since 1990 are shown below. The total permanent population for the three principal towns in 2000 is estimated at 3,400. However, peak daily population in the summer can swell to more than 160,000 for the entire county.

TABLE 1

POPULATION STATISTICS
CARTERET COUNTY, NORTH CAROLINA

Town/County	1990 Population	2000 Population
Atlantic Beach	720	789
Pine Knoll Shores	1,360	1,524
Indian Beach	153	95
Morehead City	6,046	7,691
Carteret County	52,407	59,383

Carteret County population projections for 2000 – 2020 are shown below.

TABLE 2

**POPULATION PROJECTIONS
CARTERET COUNTY, NORTH CAROLINA**

County	2005 Population	2010 Population	2020 Population
Carteret	65,633	69,358	76,341

Source: Office of State Planning, State of North Carolina.

In the summer months, a large portion of the homes along Bogue Banks are available as summer rentals to vacationers. Almost 2 million people, including those residing in the Research Triangle area of North Carolina, live within a two-hour drive of these beaches. During the summer months, the population of Carteret County is estimated to exceed 160,000 people. In the off-season months, it drops to 59,000, which includes about 789 permanent residents in Atlantic Beach (2000), 1,524 in Pine Knoll Shores, 95 in Indian Beach and 7,691 in Morehead City.

PUBLIC CONCERNS

Local interests have expressed a need for hurricane and storm damage reduction measures for the 7.2-mile-long shoreline reach, which includes the communities of Pine Knoll Shores, Indian Beach, and Salter Path. In addition, agencies and individuals with interests related to environmental quality have expressed concerns that any plan of improvement be implemented in a manner, which avoids or minimizes environmental impacts. Public concerns are summarized below; detailed discussion of these concerns will be presented in subsequent report sections.

HURRICANE AND STORM DAMAGE REDUCTION

The concerns of local interests, as expressed by their elected representatives, are reflected in the Carteret County resolution and the State's request for a Section 933 evaluation, which is the basis for this study (see Appendix A, Exhibit 2). Hurricane and storm damage have been persistent public concerns in the communities of Pine Knoll Shores, Indian Beach and Salter Path. All three of these areas of Bogue Banks are faced with moderate erosion problems and there is a high potential for hurricane and storm damage to structures in these areas where the protective berm and dune system has been weakened or lost due to recent storm action and long term erosion.

ENVIRONMENTAL QUALITY CONCERNS

In response to the January 15, 2002 scoping letter, the public and review agencies expressed the following major concerns: fishery resources and habitats, rare butterfly habitat, short-and long-term impacts of the proposed activity, endangered/threatened species, cultural resources, sediment contamination, and other natural resources. Specific concerns will be addressed in the Final Report.

CONSISTENCY WITH STATE COASTAL MANAGEMENT PROGRAM

As will be discussed in subsequent report sections, the plan of improvement recommended is considered to be consistent with the State's Coastal Management Program.

THE FEDERAL OBJECTIVE

The Federal Objective in water resources planning is to contribute to the National Economic Development in a manner consistent with protection of the nation's environment. If hurricane and storm damage reduction measures at Pine Knoll Shores, Indian Beach, and Salter Path are economically feasible (benefits exceed costs) and environmentally acceptable, construction of a Federal project for this purpose utilizing the beneficial use of dredged material from the Morehead City Harbor navigation project would contribute to this objective.

FEDERAL INTEREST

In accord with the Federal Objective any plan of improvement to be recommended for Federal implementation must produce benefits that exceed costs. The area must also be open and accessible to the general public on an equal basis. Therefore, detailed studies were directed toward those areas within the 7.2-mile-long reach of shoreline that includes the communities of Pine Knoll Shores, Indian Beach and Salter Path, which will be referred to as the "Section 933 Project Area" (Figure 1). The technically feasible solutions identified in this study consisted of beach berm construction utilizing maintenance dredged material from the Morehead City Harbor navigation project to reduce hurricane and storm damage along the Section 933 project area. These measures will be discussed in detail in the subsequent report section on "Plan Formulation".

PROBLEMS, NEEDS, AND OPPORTUNITIES

The primary public concerns identified in the study area are the loss of land and potential loss of structures due to progressive beach erosion and potential damages to structures due to hurricane and storm action. These concerns are discussed below, and protective solutions are identified. These solutions will be discussed in detail in subsequent report sections.

LONG-TERM EROSION

"Long-term erosion" as used in this report section refers to long-term shore processes. These processes can be documented based on shoreline history, and projected to estimate future conditions. Erosion in this sense differs from erosion during storms, which, although devastating to development, is generally of a temporary nature. Following storms, the coastline tends to reshape itself into its former configuration, as sand displaced from the beach is returned by wave action. The beach shape then conforms to the prevailing wave climate and littoral processes.

However, land losses due to progressive erosion are essentially permanent, as documented by the shoreline history along the Section 933 project area. Analyses of coastal processes conducted during this study indicate that historical erosion trends along the Section 933 project area can be expected to continue if no action is taken to stabilize erosion-prone areas. Past and projected future shoreline positions for the Section 933 project area are discussed below.

Past Shoreline Positions, Section 933 Project Area. Shoreline changes for beach segments from Fort Macon through Indian Beach are shown in Table 3. Figure 5 displays the “representative” reaches identified in Table 3. As shown, the peak erosion has occurred along the Pine Knoll Shores shorelines. Erosion has resulted in the loss of much of the protective berm and results in the dune system and structures located just upland of the shoreline being frequently threatened. Many of the seaward most buildings are highly vulnerable to damages by storm wave action due to the loss of the natural protective berm and dune system. Also, the width and quality of the beach available for recreation have diminished.

Table 3

Shoreline Changes – Project Base Year 2004

		Erosion Rates Change (+ Accretion - Erosion)	Future Shoreline Positions Linear Distance (ft) (+ Accretion - Erosion)	
REPRESENTATIVE REACH	LENGTH (ft)	RATE (ft/yr)	10-yrs 2014	20-yrs 2024
FM-R1	3020	-1.8	-18	-36
FM-R2	4016	-2.1	-21	-42
AB-R1	6063	-2.2	-22	-44
AB-R2	7053	-0.1	-1	-3
AB-R3	6019	+0.9	+9	+18
AB-R4	5998	-0.3	-3	-6
PKS-R1	7037	-2.0	-20	-40
PKS-R2	7008	-3.9	-39	-78
PKS-R3	7020	-3.6	-36	-72
PKS-R4	6006	-2.8	-28	-55
IB-R1	4994	-0.8	-8	-15
IB-R2	6011	+0.3	+3	+7

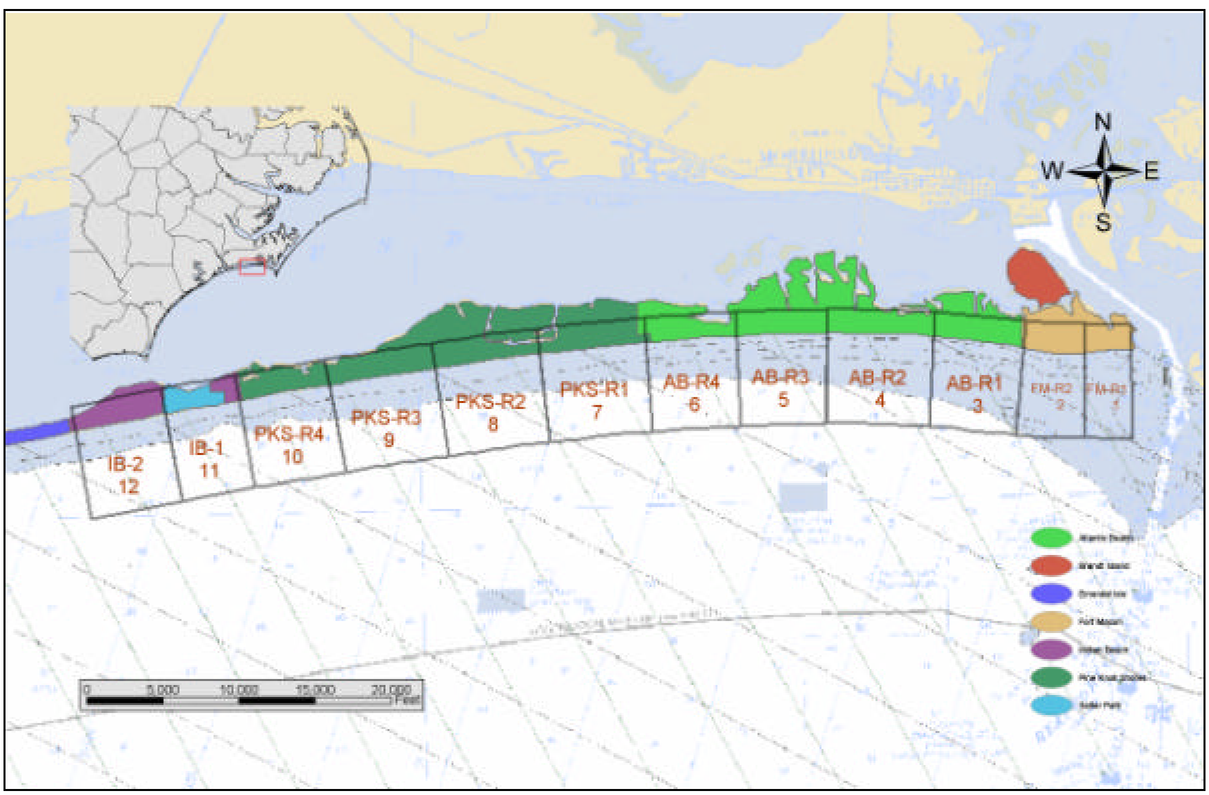


Figure 5. Representative Reach Layout

Estimated Future Shoreline Conditions, Section 933 Project Area. The discussion below presents an estimate of the future shoreline. Again, emphasis is placed on the 7.2-mile-long reach along the shorelines of Pine Knoll Shores, Indian Beach and Salter Path, which is the Section 933 Project Area. This estimated future without-project condition will form the basis for evaluating potential economic benefits for hurricane and storm damage reduction and developing dredged material placement plans to address these needs. For purposes of this discussion, it is assumed that no Federal project will be constructed before 2004. The year 2004 is referred to as the "base year" in subsequent report sections. (It should be noted that a Federal project could be implemented before or after 2004; however, this base year is assumed for purposes of economic analysis.)

Table 3 shows the estimated shoreline positions 10 and 20 years from the base year (2004). These projections were developed based on historic rates of erosion and shoreline adjustments, and do not take into account any erosion-control measures that might be undertaken during the periods of analysis.

By the year 2024, progressive long-term erosion is expected to threaten many structures along the Section 933 project area. The period of analysis for the Section 933 project has been selected to be 20 years. This is based on a 10-year physical life for the Section 933 project and doubling this time period for the period of analysis of the project.

The future shoreline positions discussed above are based on continuation of uniform historic rates of shoreline change. However, considering the value of property along the Section 933 project area (Pine Knoll Shores, Indian Beach, and Salter Path) relative to the cost of erosion control measures, it is likely that local interests will undertake temporary measures to protect against progressive erosion.

At present, the three towns bulldoze the beaches to create artificial dunes in the areas where erosion is most acute. Also, property owners have placed a small beachfill project along their property and have sandbagged for temporary protection. These projects have to be approved by the NC Division of Coastal Management. For beach communities that are actively pursuing a beach nourishment project, these local projects provide temporary protection until the long-term project is constructed. At the present level of activity, these measures are not sufficient to prevent erosion from proceeding landward, as shown in table 3. Therefore, unless more effective beach erosion control measures are undertaken, erosion is expected to progress landward.

Thus, the "most likely future" scenario along the Section 933 project area is that erosion control measures by local and state interests are not expected to provide significant protection against the erosion and flooding associated with hurricane and storm events.

HISTORICAL HURRICANE AND STORM DAMAGE

"Hurricane and storm damages," as used in this report, refer to flooding by wave overwash during hurricanes and extratropical events, as well as short-term erosion, which occurs during these events. When the island is under hurricane and storm attack, the full force of the waves is felt along the immediate ocean shoreline; as the waves break and spill over the ocean edge of the island, development in upland areas is subject to the force of the waves. As noted in the discussion of "beach erosion" problems above, erosion is threatening much of the dune system along the shoreline within the Section 933 project area. These segments of the island could be overtopped by a category 2-storm event. With the smaller storms, such as a category 1-storm event, the principal damages would be associated with the battering and loosening of the pilings, which support beachfront structures, and the loss of decks and other structures. With the larger storms, such as Hurricane Donna in 1960, entire structures can be swept away. Past hurricanes and extratropical events and their damage potential are discussed below.

Past Hurricanes and Extratropical events. Devastating hurricanes and extratropical events periodically strike the study area. Storms occur in cycles with the recent years being fairly active. The following list is intended to present some of the worst storms that have been experienced in the study area. Hurricane season runs from 1 June through 30 November; while the northeaster season extends from 15 October to 10 April. Dollar estimates of the extent of the damages were not available for every storm and sometimes the available estimate covered a wider area than the scope of this study. Where any damage figures are given for storms in previous decades, it should be kept in mind that the damages would of course be far worse if a similar storm occurred today due to the surge in development during recent years.

During the years 1954 and 1955, three extremely severe and devastating storms struck the North Carolina coast. These hurricanes are important because similar storms do have the potential to occur in the study area. Hurricane Hazel, which pounded the coast from 5 to 18 October 1954, was the most destructive storm to strike North Carolina in 50 years. Every fishing pier along 170 miles of coast was destroyed. Between the North Carolina-South Carolina State line and Cape Fear, grass covered dunes, some 20 feet high, and a line of beach houses behind the dunes simply disappeared. Nineteen people were killed and 200 were injured. Damages throughout the State were estimated at $125,309,000, of which $31,190,300 occurred in the coastal and tidal areas. Hurricane Connie caused tremendous beach erosion between 3 and 14 August 1955. The damage throughout the State was thought to be about $50,000,000, but before damages could be fully assessed, Hurricane Diane followed, and between 7 and 21 August, caused about $40,000,000 more in damages.

Recent Hurricane History - Bertha, Fran, Bonnie, Dennis, Floyd, Irene

12 July 1996 - Hurricane Bertha. The center moved over the North Carolina coast near Wilmington on 12 July with sustained winds of approximately 105 mph and gusts reported as high as 144 mph at Topsail Beach. The category 2 hurricane was an early season Cape Verde Hurricane. Damages were estimated to exceed $60 million for homes and structures and over $10 million for agriculture. Corn, tobacco, and other crops received severe damage from the storm. Rainfall totals of over 5 inches were common in eastern North Carolina.

6 September 1996 - Hurricane Fran. The center moved over the Cape Fear area around 0030 on 6 September and was moving northward near 15 knots. When it made landfall, Hurricane Fran was a category three hurricane resulting in significant storm surge flooding on the North Carolina coast and widespread wind damage over North Carolina. At landfall, the minimum central pressure was estimated at 954 mb and the maximum sustained surface winds were estimated at 100 knots. Twenty-one died in North Carolina alone. Rainfall totals exceeding six inches were common near the path of Fran. Extensive flooding spread well inland from the Carolinas. Storm surge on the North Carolina coast destroyed or seriously damaged numerous beachfront houses. Widespread wind damage to trees and roofs, as well as downed power lines, occurred as Fran moved inland over North Carolina. Extensive flooding was responsible for additional damage in the Carolinas. Nearly a half-million tourists and residents were ordered to evacuate the coast in North and South Carolina. Press reports from Reuters News Service stated that 4.5 million people in the Carolinas and Virginia were left without power. The Property Claim Services Division of the American Insurance Services Group reported that Fran caused an estimated $1.6 billion dollars in insured property damage to the United States. This estimate includes $1.275 billion in North Carolina, $20 million in South Carolina, $175 million in Virginia, $50 million in Maryland, $20 million in West Virginia, $40 million in Pennsylvania and $20 million in Ohio. A conservative ratio between total damage and insured property damage, compared to past landfalling hurricanes, is two to one. Therefore, the total U.S. damage estimate is $3.2 billion.

26 August 1998 - Hurricane Bonnie. The center drifted along the coast, with the western part of the eye moving across extreme southeast Brunswick County and over eastern New Hanover County. The center officially came onshore a short distance northeast of Wilmington during the late evening of the 26th and early morning of the 27th. Bonnie then moved slowly over extreme eastern North Carolina, emerging off the Outer Banks near Kitty Hawk early on the 28th. After being downgraded to a tropical storm while over land, Bonnie re-strengthened into a hurricane with 75-mph winds as it moved back into the Atlantic. Early estimates of storm tides are as follows. Brunswick coast: 7 to 9 feet above normal, 2 feet of overwash at Bald Head and eastern end of other islands. New Hanover and Pender County coasts: 9 to 10 feet above normal, 2 to 3 feet overwash at the north end of Carolina Beach. There was less overwash on the south end of Topsail Island.

30 August 1999 - Hurricane Dennis. The hurricane lashed the Carolina coast on the 30th and part of the 31st with sustained tropical storm force winds, gusts to hurricane force, large waves, and high surf. The hurricane turned northeast away from the coast on the morning of the 30th and began to accelerate later that day while moving to the east-northeast. Dennis stalled about 150 miles east of Cape Hatteras on the morning of the 31st and then began to drift westward and weaken. During the first couple of days of September, Dennis continued to weaken and was downgraded to a tropical storm as it drifted slowly to the southwest along the lower Outer Banks. The storm turned to the northwest on the 4th and made landfall over the Outer Banks between Cape Lookout and Ocracoke as a tropical storm. NC 12 was washed out north of Buxton.

16 September 1999 - Hurricane Floyd. The center made landfall near Cape Fear North Carolina as a category two hurricane around 0230 EDT September 16. The hurricane moved over the eastern part of the state and accelerated north-northeast up the coast, weakening to a tropical storm before moving into New England and losing its tropical characteristics early on the 17th. Floyd is responsible for massive inland flooding over portions of the eastern United States, particularly in North Carolina. The death toll from Floyd was 51 and makes this the deadliest United States tropical cyclone since Agnes of 1972. Many ocean front homes were heavily damaged.

18 October 1999 - Hurricane Irene. The center passed just east of the Outer Banks early on the 18th. After passing the Outer Banks, Irene rapidly intensified and reached a peak intensity of 105 mph on the 18th. Irene continued northeast and was absorbed by an extra-tropical low on the 19th.

Hurricane and Storm Damage Potential. The Section 933 project area is heavily developed and the potential for hurricane-wave damage is more likely given the weakened dune system in this area. Unlike long-term erosion, which can be predicted, to some extent, based on past trends and observed shore processes, damages from hurricane-wave attack can occur in any year, and can be predicted only as a mathematical probability. Based on these probabilities, average annual damages were computed for hurricane and storm events, and will be discussed in Section III of this report, "Economic Benefits".

CONDITIONS IF NO FEDERAL ACTION IS TAKEN

Development at Pine Knoll Shores, Indian Beach, and Salter Path is expected to continue, with or without any Federal projects. However, if no Federal action is taken this development will continue to be threatened by hurricanes and storm damage and long-term erosion. Basic assumptions are as follows:

(1) Most development is expected to still be in place by year 2004, the year in which it is assumed that a Section 933 project could be implemented along the Section 933 project area. Local interests are expected to take

short-term actions (bulldozing and sandbagging) to protect their property, however erosion will eventually threaten their structures.

(2) Local measures are not considered likely to provide significant protection against hurricane and storm damage, including wave overwash and flooding.

(3) The Corps of Engineers will continue to pursue the Federal Standard in navigation maintenance dredged material disposal for Morehead City Harbor, which is the most cost effective disposal plan that is environmentally acceptable and consistent with sound engineering practices.

SUMMARY OF PROBLEMS, NEEDS, AND OPPORTUNITIES

The principal water-resources problems identified along the Section 933 project area are progressive beach erosion, due to long-term shore processes, and the threat of hurricane and storm overwash. The need for action to address these problems is particularly acute along the Section 933 project area including the resort communities of Pine Knoll Shores, Indian Beach, and Salter Path.

SECTION III - ECONOMIC BENEFITS

The purpose of this analysis is to estimate the potential economic benefits that could be realized with the reduction of preventable damages due to beach erosion and hurricane and storm action in the Section 933 project area. As discussed previously, the Section 933 project area includes the 7.2-mile-long reach of shoreline, which includes the communities of Pine Knoll Shores, Indian Beach, and Salter Path. This is the area along Bogue Banks beaches where potential benefits are of significant magnitude to merit detailed study of a Section 933 project. Reduction of these damages, along with benefits for enhanced recreational use of the area, constitutes the economic justification for the plans of improvement that will be discussed in subsequent report sections.

METHODOLOGY AND ASSUMPTIONS

The analysis of potential economic benefits, which follows is based on the assumption that no effective action will be taken to reduce hurricane and storm damages along the Section 933 project area. However, efforts by local and state interests will include bulldozing and sandbagging.

The interest rate for the analysis is 5-7/8 percent and a 20-year Period of analysis is used. October 2002 price levels are applied. The "base year" used for the economic analysis is 2004.

The structural database used for this analysis was compiled by field surveying every structure on the oceanfront and second-row in the Study Area, which includes the communities of Fort Macon, Atlantic Beach, Pine Knoll Shores, Indian Beach and Salter Path. Each structure was assigned a reasonable estimate of its depreciated replacement value. Factors such as age, condition, quality of materials, and type and quality of construction enter into this value determination. Tax values were used for the sake of comparison, since the Carteret County tax appraisers also strive to measure replacement value less depreciation.

Estimates of values of contents of commercial structures in the Study Area are based on interviews with business owners and insurance agents familiar with the Carteret County oceanfront, as well as empirical data collected for past studies. Each type of business has a unique content factor applied to its structural value. Motels comprise most of the commercial base and 50 percent of the structural value was used for their content value. For estimating the value of household contents of residential structures in the area, 40 percent of the structural value is used. This is based on site-specific responses from Carteret County officials, insurance agents, realtors, and homeowners familiar with the residential development along this section of oceanfront.

This analysis includes 842 structures that occupy the Study Area and Base Disposal Plan Area. Of this total, there are 470 structures in Atlantic Beach, 258 structures in Pine Knoll Shores, 69 structures in Indian Beach, 44 structures in Salter Path, and 1 structure in Fort Macon State Park. Altogether, they represent a total structural value of about $377 million as shown in table 4.

TABLE 4
Structural Inventory by Town

Town	**Number**	**Oceanfront Structure Value**	**Second Row Structure Value**	**Total Structure Value**
Fort Macon	1	$160,000	$0	$160,000
Atlantic Beach	470	$105,959,000	$31,768,000	$137,727,000
Pine Knoll Shores	258	$119,791,000	$27,688,000	$147,479,000
Indian Beach (Salter Path)	113	$77,258,000	$14,039,000	$91,297,000
TOTAL	842	$303,168,000	$73,495,000	$376,663,000

BENEFITS FOR
HURRICANE AND STORM DAMAGE REDUCTION

Expected annual hurricane and storm damages for these areas were computed using Wilmington District computer programs (see Appendix D). The level of storm damage reduction for this beach fill configuration is determined by simulating hundreds of 20-year life cycles. This is accomplished through the use of the model, GRANDUC, which incorporates risk and uncertainty principles into the analysis. Through a random selection process, a particular 20-year simulation may include several severe storms or perhaps none. All of the 20-year life cycle simulations are run for the existing conditions, then again for a particular plan. Then, the average storm damage reduction potential afforded by a particular design configuration is computed. These damages are then estimated at an expected annual amount. Expected annual hurricane and storm damages for the Section 933 Project Study Area were estimated at $14,543,000 as shown in table 5. The expected annual damage figure includes damages to structures and contents associated with inundation, wave impacts, and storm induced erosion.

TABLE 5
Expected Annual Hurricane and Storm
Benefits for the Section 933 Study Area

TOWN	Expected Annual H&S Damages Existing	 BD Plan	 933 Plan	Expected Annual H&S Benefits 933 Plan
Pine Knoll Shores	$12,008,057	$12,008,057	$4,750,681	$7,257,376
Indian Beach	$2,534,965	$2,534,965	$842,311	$1,692,654
TOTAL	$14,543,022	$14,543,022	$5,592,991	$8,950,031

BENEFITS FOR EMERGENCY COSTS AND OTHER DAMAGE REDUCTION

Emergency costs prevented refer to expected annual expenditures that residents and local and state governments are experiencing under the without project condition that a Federal project would preclude. Other damages prevented include storm damages that are not covered under the National Flood Insurance Program, but represent financial impacts on public and private storm victims that a Federal project could prevent. The categories for this benefit include: (1) bulldozing; (2) sandbagging; (3) emergency costs incurred by the North Carolina Department of Transportation (NCDOT); (4) damages to public property (water and electric utility distribution systems and access walkways); (5) damages to private property such as walkways, driveways, and cleanup costs; and post-storm recovery expenses and storm related expenses such as police patrolling, inspections, and permits. Expected annual emergency costs and other damages for the towns of Pine Knoll Shores, Indian Beach, and Salter Path are estimated at $140,000. The Section 933 Project would reduce this amount to an estimated $18,000. Therefore, the expected annual emergency costs reduction benefits for the Study Area amount to $122,000.

BENEFITS FOR RECREATION

As discussed previously, local interests are expected to bulldoze sand after storm events and place sandbags along the shoreline fronting their structures in an attempt to protect their structures for as long as possible. The local beach nourishment project has provided some additional relief to the beach area. However, the recreational beach that remains by 2004 is expected to be narrow at high tides. Potential recreation benefits for the Study Area were computed by estimating the unit day value of the recreational experience available with and without a Federal project. The term "unit day value" represents the economic value that is assigned to a day of recreational experience (see Appendix D).

A unit day value of $3.96 was assigned for the "without project" condition (see Appendix D). The unit day value will be higher if a Section 933 project is implemented to restore and stabilize the beach strand. With the improved beach width and public access that would accompany a Section 933 project, a unit day value increase of $5.32 for Pine Knoll Shores and $5.11 for Indian Beach and Salter Path is considered more appropriate. This increase of $1.36 for Pine Knoll Shores and $1.15 for Indian Beach and Salter Path per unit day multiplied by estimated annual visitation represents the potential economic benefits for a restored and stabilized beach along the Study Area. Estimated visitation is discussed as follows.

Beach use along the Section 933 project area is estimated at a daily peak of 17,200 persons, based on data from the Towns of Pine Knoll Shores, Indian

Beach, and the Village of Salter Path and the Carteret County Tourist Bureau. This total represents an annual visitation of 776,000 for the Section 933 project area. Therefore, recreational benefits for the Section 933 project area are estimated at an expected annual amount of $1,009,000 (555,000 visitor days x $1.36 increase in unit day value for Pine Knoll Shores plus 221,000 visitor days X $1.15 increase in unit day value for Indian Beach and Salter Path).

SUMMARY OF ECONOMIC BENEFITS

The total expected annual benefits for shore protection along the 7.2-mile-long Section 933 project area that includes the resort towns of Pine Knoll Shores, Indian Beach, and Salter Path, are summarized in table 6. As shown, economic benefits include three categories: (1) Hurricane and Storm Damage Reduction Benefits - Potential benefits in this category are based on damages due to long-term beach erosion and short-term storm erosion and wave overwash during hurricanes and northeasters; (2) Emergency Costs and Other Damage Reduction - Potential benefits in this category are based on storm related expenditures that are not covered by the National Flood Insurance Program; (3) Recreation - Potential benefits in this category are based on increases in the value of the recreation experience for beachgoers with implementation of a Federal project within the Study Area; (4) Benefits During Construction – Those benefits that accrue to the project as it is being constructed.

TABLE 6

EXPECTED ANNUAL BENEFITS
FOR THE SECTION 933 PROJECT AREA
(Pine Knoll Shores, Indian Beach, and Salter Path)

Benefit Category	
Hurricane and Storm Damage Reduction	$8,950,000
Emergency Costs and Other Damages Reduction	122,000
Recreation	1,009,000
Benefits During Construction	574,000
TOTAL	$10,655,000

As shown in Table 6, total expected annual benefits for the Section 933 project area are estimated at $10,655,000. In accord with the National Objective stated previously, the expected annual cost of any Federal improvement recommended must be less than the expected annual benefits. In addition, any plan of improvement to be recommended must be shown to be environmentally acceptable. Environmental resources in the Study Area are discussed in the following report sections.

SECTION IV - ENVIRONMENTAL CONSIDERATIONS IN PROJECT PLANNING

The purposes of this report section are (1) to identify significant environmental resources which might be affected by a Section 933 project along the Section 933 project area; and (2) to identify criteria which should be followed in planning and designing a project to minimize impacts on those resources. Significant, or potentially significant, resources are discussed as follows.

SIGNIFICANT RESOURCES

Generally, the upland areas in the Section 933 project area (i.e., Towns of Pine Knoll Shores and Indian Beach (including Salter Path)) have limited natural values, due to the intensity of development. However, the estuaries, inlets, beaches, and shallow ocean bottom surrounding the Section 933 project area has significant values, as discussed below.

BIOLOGICAL RESOURCES

Marine waters in the vicinity of the beach disposal sites and maintenance dredging of the Morehead City Harbor outer navigation channels, provide habitat for a variety of ocean fish and are important commercial and recreational fishing grounds. Kingfish, spot, bluefish, weakfish, spotted sea trout, flounder, red drum, king mackerel, and Spanish mackerel are actively fished for from boats, the surf, and local piers. Off shore marine waters serve as habitat for the spawning of many estuarine dependent species. These species, according to the National Marine Fisheries Service, "compose approximately 75 percent of commercially and recreationally important catch of fish and invertebrates in North Carolina". The surf zone serves as a nursery area for Florida pompano and juvenile gulf kingfish during the summer. Nearshore waters also accumulate juvenile, ocean spawning, and estuarine dependent fish and invertebrates in the late winter and early spring prior to their transport through Beaufort Inlet and Bogue Inlet to the Bogue Sound estuary.

Although developed areas in the Study Area have limited habitat value, portions of the barrier island beaches (i.e., the inlet shorelines) within the Study Area are important nesting areas. During Migratory periods, piping plover, Wilson's plover, semipalmated plover (*Charadrius semipalmatus*), red knot (*Calidris canutus*), sandwich tern (*Sterna sandvicensis)* Foster's tern (*Sterna forsteri*), Royal tern (*Sterna maxima*), least tern, gull-billed tern (*Sterna nilotica*), common tern, black tern (*Chlidonias niger*), Caspian tern (*Sterna caspia*), herons, egrets, marbled godwit (*Limosa fedoa*), laughing gull (*Larus atricilla*) and cormorant are commonly found in and around the inlets. Overwintering bird species include piping plover, brown pelican, cormorants, Foster's tern, Royal tern, dunlin, and various gull species. Potential project areas were surveyed during this study to determine potential use of these areas by the species mentioned above and the results are presented in the attached Finding of No Significant Impact (FONSI).

A natural dune system is present along the Study Area, however, this dune system is being severely eroded. These dunes are vegetated primarily with grasses, sea oats, and salt meadow hay, which provide habitat for some wildlife species including birds and small mammals. Dunes serve an important function as a barrier to storm tides, protecting barrier island development. Dune vegetation such as sea oats is important as a dune builder and helps to protect against erosion. It is expected that the recommended plan will result in reestablishing and protecting the dune system along the project area.

More detailed descriptions of the landforms and fish and wildlife resources of the study area are presented in the attached FONSI.

ENDANGERED AND THREATENED SPECIES

Coordination with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service has been conducted to identify endangered and threatened species (as well as Federal Species of Concern) that might be present in the vicinity of the Study Area. Species that are currently Federally listed as endangered or threatened (as well as Federal Species of Concern), which may or do occur in the Study Area, and which may be subject to impacts from beach disposal are listed in Table 7.

TABLE 7

THREATENED AND ENDANGERED SPECIES (INCLUDING FEDERAL SPECIES OF CONCERN) POTENTIALLY PRESENT IN CARTERET COUNTY, NORTH CAROLINA

Species Common Names	Scientific Name	Federal Status
Vertebrates		
American alligator	*Alligator mississippiensis*	T(S/A)
Eastern cougar	*Felis concolor couguar*	Endangered*
Green sea turtle	*Chelonia mydas*	Threatened 1
Hawksbill turtle	*Eretmochelys imbricata*	Endangered
Right whale	*Eubaleana glacialis*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Finback whale	*Balaenoptera physalus*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
West Indian Manatee	*Trichechus manatus*	Endangered

Piping Plover	*Charadrius melodus*	Threatened
Roseate tern	*Sterna dougallii*	Endangered
Shortnose sturgeon	*Acipenser brevirostrum*	Endangered
Smalltooth sawfish	*Pristis pectinata*	Endangered
Invertebrates		
a skipper (butterfly)	*Atrytonopsis sp1*	FSC
Arogos skipper	*Atrytone arogos*	FSC

Species Common Names	**Scientific Name**	**Federal Status**
Vascular Plants		
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	Endangered
Seabeach amaranth	*Amaranthus pumilus*	Threatened

[1]Green turtles are listed as threatened, except for breeding populations in Florida and on the Pacific Coast of Mexico, which are listed as endangered.

KEY:

Status	Definition

Endangered - A taxon "in danger of extinction throughout all or a significant portion of its range."

Threatened - A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."

T(S/A) - Threatened due to similarity of appearance (e.g., American alligator)--a species that is threatened due to similarity of appearance with other rare species and is listed for its protection. These species are not biologically endangered or threatened and are not subject to Section 7 consultation.

FSC - A Federal species of concern--a species that may or may not be listed in the future (formerly C2 candidate species or species under consideration for listing for which there is insufficient information to support listing).

Species with 1 asterisk behind them indicate historic record:

* Historic record - the species was last observed in the county more than 50 years ago.

Potential project-related impacts have been addressed for each of these species and are presented in the attached FONSI. It has been determined that the project, as currently proposed, may affect the, piping plover, green sea turtle, hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, loggerhead sea turtle, shortnose sturgeon, and sea-beach amaranth. Methods to minimize impacts to these species are found in the attached EA.

WATER QUALITY

Morehead City Harbor is located at the confluence of the Newport River and Bogue Sound. All tidal waters within Morehead City Harbor are classified as SC and SA. Coastal waters offshore of the project area are classified SB by the State of North Carolina (NCDEM 1989). Class SA waters are defined as suitable

for shellfishing for market purposes and any other usage specified by the "SB" and "SC" classification. Best usage of class SB waters includes swimming, primary recreation, and all Class SC uses including fishing, secondary recreation, fish and wildlife propagation, and other uses requiring lower water quality (NCDEM 1991). The waters in the vicinity of Morehead City Harbor are prohibited shellfish areas.

CULTURAL RESOURCES

The Morehead City Harbor Section 933 study has been reviewed pursuant to Section 106 of the National Historic Preservation Act (16 USC 470 et seq.) and the Abandoned Shipwreck Act (43 USC 2101 et seq.). This review has included consultation with the North Carolina State Historic Preservation Officer and staff of the NC Division of Archives and History Underwater Archaeology Unit and indicates that six archaeological sites have been recorded along the Bogue Banks beaches. Some of these sites consist of transient wreckage that has washed ashore from ships lost nearby in offshore waters.

0001BBB Iron Steamer Pier Wreck Site
Believed to be the Civil War blockade-runner *Pevensey*, an iron-hull side-wheel steamer, lost June 9, 1864. The wreck is located approximately 100 yards offshore on the east side of the pier lying almost parallel to the beach. Portions of a paddle wheel are visible during low tide.

0002BBB Gun Emplacement Site
Granite stones located in the surf zone adjacent to the 6200 block of Ocean Drive at Emerald Isle, believed to be from a World War II coastal shore battery exposed by beach erosion.

0003BBB Salter Path Site
Ship timbers 14" square, approximately 42 feet and 18 feet long with 1.25" diameter iron fasteners located roughly 1200 feet east of the beach access road near Squatters Campground.

0004BBB Cupola Site
Portions of a ship hull approximately 30' long and 14' wide fastened with iron pins, yellow pine planking on oak frames. This site is located in the surf zone near 18th Street, Emerald Isle. (Tag Numbers 134, 135)

0005BBB Emerald Isle Pier Wreck

Ship timber 40' long, 12" x 18" square, iron fasteners and one attached frame. This site is located near Emerald Isle Fishing Pier. (Tag Numbers 155, 156)

0006BBB Ocean Reef Site
Ship wreckage covering an area of approximately 100' by 35' near the Ocean Reef Condos (marked by a warning sign on the beach). This site consists of extensive debris with iron fasteners.

AESTHETIC RESOURCES

The Carteret County beach communities of Pine Knoll Shores, Indian Beach, and Salter Path that are located in the Section 933 project area, provide a vacation area for millions of visitors each year. The beaches within the Section 933 project area are used extensively for recreation. This includes sunbathing, swimming, surf fishing, jogging, bird watching and sightseeing. Public access with parking or public transportation will be available along the Section 933 project area as outlined in Appendix E – Exhibit 1.

ENVIRONMENTAL CRITERIA AND CONSTRAINTS

No environmental constraints were identified which would preclude implementation of a Section 933 project at Pine Knoll Shores, Indian Beach, and Salter Path. However, any plan of improvement should be designed and implemented, to the extent practicable, to avoid impacts on the threatened species known to occur along the Section 933 project area (see Table 7).

Generally, any plan of improvement should be designed to avoid adverse impacts on water quality and biological resources. Also, the timing of project construction should be adjusted as practicable to avoid periods of high biological productivity. Methods to minimize impacts to these periods of high biological productivity are found in the attached EA.

As noted above, the aesthetic qualities of the beach strand at Pine Knoll Shores, Indian Beach, and Salter Path will probably continue to be degraded as erosion encroaches on development. Therefore, there is an opportunity to enhance this aspect of the island's aesthetic quality by restoration of the beachfront.

SECTION V - PLAN FORMULATION

This report section describes the procedures by which the Recommended Plan of improvement was developed and ultimately selected. The Recommended Plan, which may also be referred to as the Section 933 Project, includes approximately 7.2 miles of beachfront, and is the maximum project area that has been identified within the Study Area. The non-Federal sponsor prefers a project that covers the maximum project area.

PLAN FORMULATION RATIONALE

A Section 933 project would consist of a beach berm project to control erosion and reduce wave overwash during storms. Beneficial use of dredged material for a Section 933 project for hurricane and storm damage reduction is limited to the volume of dredge maintenance material required to be removed from the navigation project due to channel shoaling and is also limited to operation and maintenance funds available for maintaining the project. Furthermore since dredged volumes are tied to the navigation project, the typical plan optimization (identification of the NED Plan based on maximum net average annual benefits) is not required. Therefore only one plan need be evaluated to determine economic feasibility.

ALTERNATIVE PLANS

As explained above, only one plan need be evaluated in determining economic feasibility. The Recommended Plan, therefore, was the only plan considered in great detail. Although the Recommended Plan was the only plan analyzed in detail, there were several plans initially assessed which would have provided protection for a number of different combinations of areas within the Study Area and the Base Disposal Plan Area. These plans were used as tools to assist in the initial determination of the one plan to evaluate in more detail. The recommended project area was evaluated since: (1) this area has had consistent development and erosion has weakened the protective dune; (2) there are no significant environmental constraints associated with these reaches; and (3) The non-Federal sponsor prefers a project that covers the maximum project area.

SECTION 933 RECOMMENDED PLAN

The Recommended Plan would consist of constructing a sand berm along the oceanfront at an elevation of 7 feet above NGVD, which mimics the natural berm elevation in the Study Area. The design berm ties into the existing dune system at + 7 ft NGVD, extends 30-ft seaward, and transitions at a 1V:25H slope to the Mean Tide Level (MTL). The offshore portion of the profile then parallels the preplacement profile slope out to closure depth.

The construction profile will greatly differ from the design profile. Since it is not economically feasible to groom the offshore portion of the profile to mimic design profile conditions, it is common construction practice to place an equivalent volume of material in the upper part of the profile as shown in Figure 6. Natural wave conditions will restore the profile shape to equilibrium conditions, resulting in the design profile berm width. The increase in berm width during construction varies according to profile conditions. The average construction berm width for the project increased to 107 ft as compared to the 30-ft design berm width. Average volumetric requirements for the recommended plan were approximately 90 cubic yards per foot.

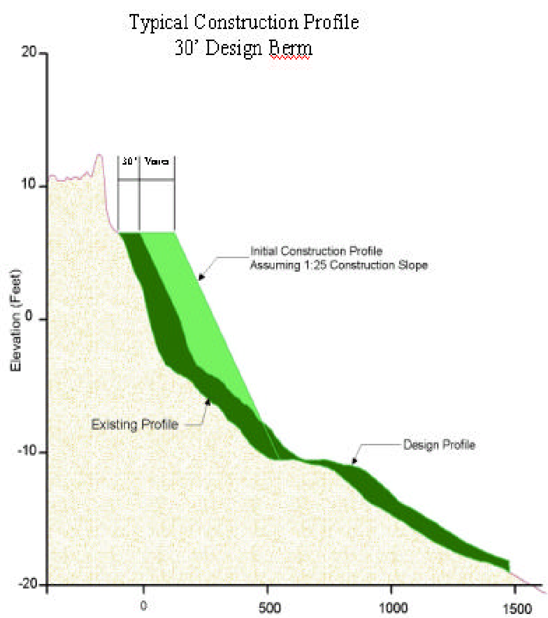


Figure 6. Design and Construction Profile Conditions.

It should be noted that existing dune conditions in the Project Area typically exceeded 15 ft NGVD. Such conditions exceed typical dune systems commonly incorporated into storm damage reduction projects. Therefore, dunes were not considered as an alternative. The 30-foot design berm width along the entire study area (7.2 miles) is expected to provide increased protection against long-term erosion.

The Recommended Plan includes a transition zone at the west end of the main fill. Since the fill will cause the shoreline to protrude seaward, the west end of the fill will erode rapidly unless measures are taken to terminate the fill with a gradual transition. The transition zone at the west end of the fill is 1,000 feet long. The transition fill will taper into the existing system. The east end of the main fill will tie into the base disposal main fill.

The Recommended Plan would be constructed by hydraulic dredges (pipeline and hopper with pump out capability) using the navigation project areas shown on Figure 3. The material would be pumped from the navigation project areas to the beach and shaped by earth moving equipment. The beachfill would be constructed at an elevation of +7-feet NGVD, the elevation of the existing beach berm along the project reaches. A benefits and costs discussions for the Recommended Plan follows.

BENEFITS AND COSTS FOR THE RECOMMENDED PLAN

Benefits for the Recommended Plan as well as the Base Disposal Plan, the disposal plan that would be used in the without project condition as determined by the Federal Standard, are shown below in Table 8.

TABLE 8

EXPECTED ANNUAL BENEFITS FOR RECOMMENDED PLAN
(Based on 5-7/8 percent interest rate, 20-year Period of analysis)
(October 2002 price levels)

Benefit Category	
Hurricane and Storm Damage Reduction	$8,950,000
Emergency	$ 122,000
Recreation	$ 1,009,000
Benefits During Construction	$ 574,000
Expected Annual Total Benefits	$10,655,000

BENEFITS FOREGONE

Benefits foregone were evaluated for those reaches that are located within the Base Disposal Plan (Atlantic Beach and Fort Macon) that would not receive the entire dredge disposal due to the proposed Section 933 project. There are no benefits foregone related to emergency costs or recreation, only hurricane and storm damage reduction. The total expected annual benefits forgone are estimated at $705,000. This amount is added to the cost side of the Section 933 Project to account for the lower level of protection that the Base Disposal Plan would have offered Atlantic Beach and Fort Macon.

COSTS FOR RECOMMENDED PLAN

First costs for the Recommended Plan and the Base Disposal Plan are shown in Table 9. The costs between the two plans vary proportionately to the volume of the fill and the distance the fill is located from the navigation project areas. Expected annual costs of the recommended Section 933 Project are shown in table 10 and presented in Appendix H.

TABLE 9
FIRST COST SUMMARY

Description	Sand Placement Location	Costs
TOTAL SECTION 933 PROJECT + MODIFIED DISPOSAL PLAN:		
Mobilization & Demobilization		$2,850,000
Pumpout Brandt Island & Inner Harbor	Fort Macon & Atlantic Beach	$3,706,654
Pumpout Brandt Island, Inner Harbor, & Entrance Channel	AB, PKS, & IB	$24,654,870
Embankment Replacement		$500,000
Beach Tilling		$137,600
Planning Engineering & Design		$375,000
Construction Management		$100,000
SUBTOTAL before Contingencies		**$32,324,124**
Contingencies (10%)		$3,211,876
TOTAL Section 933 Project + Modified Disposal Plan		**$35,536,000**
BASE DISPOSAL PLAN:		
Mobilization & Demobilization		$1,750,000
Pumpout Brandt Island & Inner Harbor	Atlantic Beach and Fort Macon	$10,737,600
Mobilization & Demobilization		$250,000
Dredge Entrance Channel	Near Shore Disposal Area	$3,900,000
Embankment Replacement		$500,000
Beach Tilling		$130,400
Planning Engineering & Design		$120,000
Construction Management		$50,000
SUBTOTAL before Contingencies		**$17,438,000**
Contingencies (10%)		$1,744,000
TOTAL Base Disposal Plan		**$19,182,000**
SECTION 933 PROJECT COSTS		**$16,354,000**

Note: The percentage of the Section 933 Project costs ($16,354,000) to the total Section 933 Project plus the Modified Disposal Plan ($35,536,000) is 46.0 percent.

TABLE 10

EXPECTED ANNUAL COSTS FOR RECOMMENDED PLAN
(Based on 5-7/8 percent interest rate, 20-year Period of analysis)
(October 2002 price levels)

Total Project Summary	**Total 933 Project**	**Base Disposal Plan**	**Difference to be Justified**
Total Initial Construction:	$36,927,000	$20,573,000	$16,354,000
Interest During Construction	$708,000	$0	$708,000
Total Investment Cost	$37,644,000	$20,573,000	$17,062,000
Expected Annual Cost:			
I&A-20 years			$1,473,000
Annual Benefits Forgone			$705,000
Total Expected Annual Cost			$2,178,000

SUMMARY OF BENEFITS AND COSTS, SECTION 933 PLANS

Table 11 summarizes benefits and costs for the Recommended Plan. As shown in this table, the Recommended Plan would produce benefits greater than costs. This plan would provide effective protection for long-term shore erosion.

TABLE 11

EXPECTED ANNUAL BENEFITS AND COSTS OF THE RECOMMENDED PLAN

Expected Annual Total Benefits	$10,655,000
Expected Annual Total Costs	$2,178,000
Benefit-to-Cost Ratio	4.9

RATIONALE FOR DESIGNATION OF RECOMMENDED PLAN AND PLAN SELECTION

The Recommended Plan would control progressive erosion and minimize permanent land losses. The plan would reduce damages to structures caused by short-term, storm-induced erosion. The plan is considered to be environmentally acceptable. As discussed previously, the National Objective for Federal water resources projects is to contribute to the National Economic Development.

SECTION VI - RECOMMENDED PLAN OF IMPROVEMENT

The purpose of this report section is to centralize information concerning the Recommended Plan of Improvement for the Section 933 Project. The Recommended Plan is discussed in terms of (1) Plan Features, (2) Construction, (3) Plan Accomplishments, (4) Plan Impacts, (5) Public Views and (6) Plan Implementation.

PLAN FEATURES

The Recommended Plan of Improvement includes a 30-ft wide berm placed at 7-ft NGVD. Project dimensions are shown on Figure 7. The project will extend along the reaches shown on Figure 1. The total length of the main fill will be approximately 38,000 feet, which includes the 1,000-foot transition zone on the west end of the main fill.

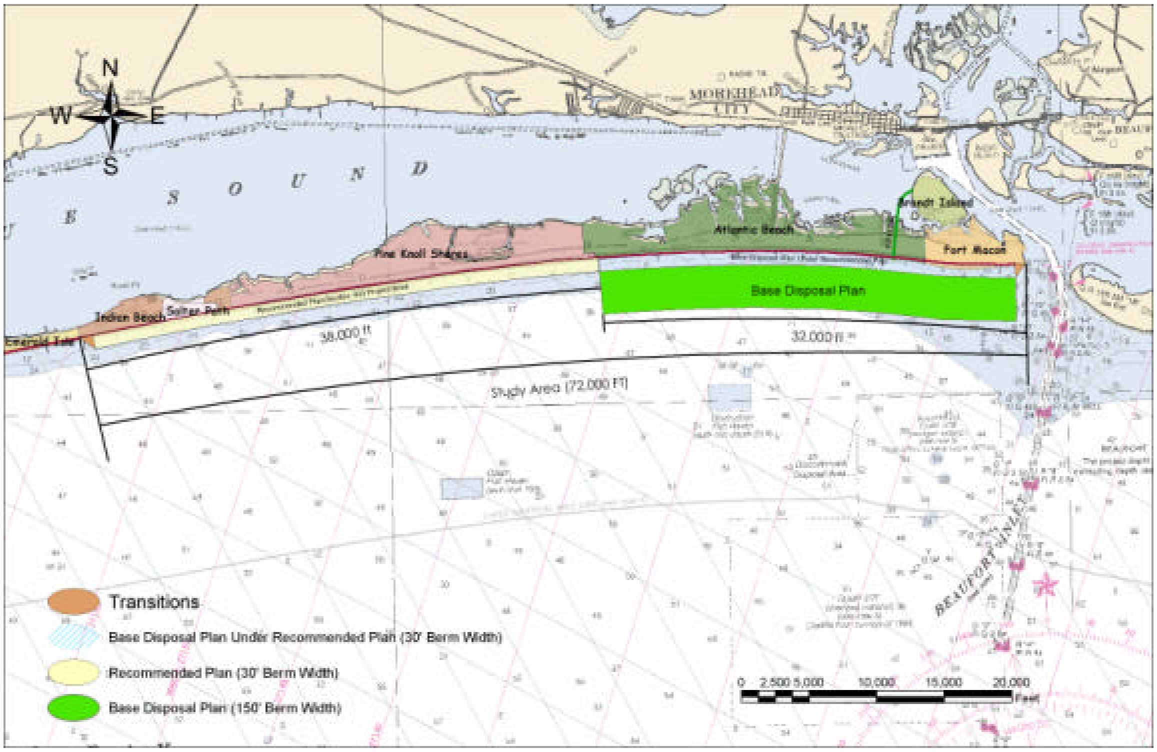


Figure 7. MHC Section 933 Recommended and Base Disposal Plans

PROJECT CONSTRUCTION AND OPERATION

Project construction will make use of approximately 4,466,000 cubic yards of sand for the Recommended Plan. The material will be pumped to the beach by pipeline dredge and/or hopper dredge with pump out capability and shaped on the beach by earth moving equipment.

NAVIGATION PROJECT AREAS AND FILL MATERIAL

Navigation project areas to be dredged and the material to be used for beachfill are located as shown on Figure 3. Based on grain size analysis of samples taken in these areas from the previous placements of material from Brandt Island and Morehead City Harbor maintenance onto Bogue Banks, it is reasonably confident that the navigation project areas contain good quality beach sand, which will be verified prior to placement on the beaches (see Appendix G for additional details on the geotechnical analysis).

Brandt Island, the inner harbor and the entrance channel will be the major sources of sand for the construction of the Section 933 project. The volume of material remaining on the beach immediately following placement will be reworked (sorted) by wave action into a distribution of material sizes from the berm crest seaward to closure depth that will closely mimic the native material distribution. This sorting process will take several months to occur and will result in the removal of the remaining excess material from the design template.

Generally, the material removed by this sorting action will be the finer fraction of the sandy material, which will be transported to offshore depths greater than 27 feet below NGVD.

OPERATION AND MAINTENANCE

There are no operation and maintenance requirements associated with the Section 933 project. All benefits to the Section 933 Project will accrue without operation and maintenance.

GEOTECHNICAL PROCESS

Morehead City Harbor dredge material has traditionally been placed in Brandt Island or on the beach at Atlantic Beach and Fort Macon. The material in Brandt Island was sampled and grain size tests were performed in the mid-1980's prior to the initial pump out in 1986. The quality of the material was determined to be suitable for beach disposal. Brandt Island was pumped out again in 1994 with the material being disposed of on the beach.

The subsurface investigation will include drilling the shoals in Morehead City Harbor and taking beach grab samples, and grain size testing the material collected from these samples. Twenty-one, 10-foot vibracore borings in the Harbor area and the connecting channels with the worst shoals were drilled on March 26, 2003. The borings were performed with the snagboat *SNELL* using a 3 7/8 inch diameter Alpine vibracore drill machine. The tubes were sampled for representative material and at a minimum of one sample for every two feet of recovered length. Each tube is expected to have approximately 3 soil samples for a total of approximately 60 samples. No borings will be performed on Brandt Island as part of this project. It is assumed that the material in Brandt Island is the same as the inner Harbor material tested for this project, since the Inner Harbor material from previous dredging is stored in Brandt Island. Grab samples will be collected from twenty-five profile lines perpendicular to Fort Macon, Atlantic Beach, Pine Knoll Shores, Indian Beach, Emerald Isle, and Bogue Inlet Area for a total of 150 samples. These samples will be tested for grain size, silt content, shell content in accordance with ASTM D 422 using a minimum of 12 sieves. Samples will be classified in accordance with the Unified Soils Classification system.

All the samples collected from the Harbor Shoal material and the beach grab samples will be analyzed to determine the material suitability for beach placement. Based on material removed from the Inner Harbor and Brandt Island in the past, it is expected that the material designated for beach placement as part of this project will be suitable.

REAL ESTATE REQUIREMENTS

Real estate requirements for the Recommended Plan of Improvement include lands, easements, rights-of-way and relocations, and disposal/borrow areas, which are referred to as LERRD's. Existing easements are in places that were acquired by the sponsor for a local, non-federally funded project. The easements incorporated the standard language in the Government Perpetual Storm Damage Reduction Easement. It is anticipated that all work will be completed within the limits of the existing easements and/or seaward of these easements. In order for Real Estate to be certified for this project, the project sponsor will be required to supply CESAS-RE with a map and copies of their existing easements. Per discussion with The North Carolina Department of Administration, the State of North Carolina does not require a permit to place sands below the mean high water line. However, the Local Sponsor will need to furnish the State of North Carolina Department of Administration with a letter of intent to place sand below the Mean High Water Line.

Other things that are to be considered are access to the beach during construction, additional pipeline routes, and temporary work area easements. Access to the beach will be by public access points that are located along the beach area. A previously acquired perpetual pipeline easement will be used for the placement of the pipeline. Should additional pipeline routes be identified, the project sponsor will be responsible for acquisition. Additional details of the Real Estate Requirements are discussed in Appendix F.

PLAN ACCOMPLISHMENTS

The Recommended Plan reduces expected annual damages to structures due to hurricane-wave action and storm induced erosion. As shown in Table 5, existing expected annual damages for hurricane and storm damage are estimated at $14,543,000 without a Section 933 project in place in the Study Area. With the Recommended Plan in place expected annual hurricane and storm damages are reduced to about $5,593,000. Thus, as stated above, the Recommended Plan would reduce hurricane and storm damages by an expected annual amount of $8,950,000 for the 7.2-mile-long Section 933 project area, or about 62 percent.

Although the plan will substantially reduce damages due to hurricane-wave overwash, it should be noted that the Recommended Plan of Improvement provides for storm protection only in terms of protecting development from the action of ocean storm surge and wave action.

BENEFITS

Total expected annual benefits for the Recommended Plan are estimated at $10,655,000 based on October 2002 price levels. An itemized listing of expected annual benefits was presented in Table 6. If the plan is to be recommended for implementation, expected annual costs must be less than this amount. Project costs are discussed below.

PROJECT COSTS

Determination of the economic costs of the Recommended Plan consists of two basic steps. First, project first costs are computed. First costs include expenditures for project design and construction and related costs of supervision and administration. First costs also include the lands, easements, and rights of way for project construction.

Second, interest during construction is added to the project first cost. Interest during construction is computed from the start of PED through the construction period. The project first cost plus interest during construction represents the total investment required to place the project into operation.

These costs consist of interest and amortization of the investment. The expected annual costs provide a basis for comparing project costs to project benefits. A summary of the computations involved in each of these two steps is presented below.

Project First Costs - The total first cost of construction for the Recommended Plan is estimated at $16,354,000, based on October 2002 price levels. An itemized listing of first costs is presented in Table 9.

Interest During Construction - Interest during construction, computed over PED and the construction period, is established at $708,000 for the Section 933 Project Area. The total investment required to place the project into operation would be $17,062,000 for the Section 933 Project Area.

Expected Annual Costs - Expected annual costs include interest and amortization of the investment over an assumed project life of 20 years. As shown in Table 10, expected annual costs for the Selected Plan of Improvement are estimated at $2,178,000 for the Section 933 Project Area.

Benefit-Cost Ratio - The Recommended Plan produces expected annual benefits estimated at $10,655,000 for the Section 933 Project Area. Expected annual costs for the Recommended Plan are estimated at $2,178,000 for the Section 933 Project Area. Thus benefits divided by costs results in a benefit-cost ratio of 4.9 for the Section 933 Project Area. Since project benefits exceed costs, the Recommended Plan is considered economically feasible.

ENVIRONMENTAL IMPACTS

The Recommended Plan of Improvement is considered to be environmentally acceptable, although some environmental impacts are anticipated. Significant resources likely to be affected by the Recommended Plan include biological resources, water quality, aesthetic values, and threatened species. The proposed action will not cause any significant impacts to the environment (see attached EA). No effect on cultural resources is anticipated. Anticipated impacts on each resource are discussed below.

IMPACTS ON BIOLOGICAL RESOURCES

Biological resources will be affected by dredging of material from Brandt Island and the Morehead City Harbor navigation channels for project construction and by placement of this material on the beach. The sediments taken from Brandt Island and the Morehead City Harbor navigation channels is believed to be suitable for placement on the beaches of Bogue Banks. As indicated in the attached EA, Brandt Island has been previously pumped out in FY 1986 and FY 1994 and the resultant dredge material placed on the beaches of Bogue Banks. Expected impacts on biological resources due to dredging and fill placement are discussed on the following pages.

Navigation Project Area Dredging - No significant impact on biological resources is expected due to piping of dredged material from the navigation project areas (including Brandt Island) to the beachfill areas. The pipeline route will extend from the navigation project areas and Brandt Island to the beach and then will follow the shoreline.

There will be some loss of dune vegetation where the pipeline crosses the dune to the beach. Plants growing adjacent to the seaward side of the dunes will be buried by the discharge of dredged material. Dune vegetation disturbed by the pipeline crossing to the beach will be restored to pre-project grade and replanted following project completion.

Negative impacts associated with pipeline routes will be minor and temporary.

Beachfill Construction - The major impacts associated with this type of operation include:

A. Increased turbidity in the surf zone;

B. Effects on the benthic communities;

During disposal operations, there will be an increase in the turbidity of the surf zone in the immediate area of sand disposition. This increase may cause the temporary displacement of various species of sport fish, causing a negative impact to surf fishing in the area of deposition.

A considerable body of information is available on the effects of dredging on benthic communities and specific environmental consequences of beach disposal. However, there are some uncertainties on the degree of impacts on certain resources over the long term. A more detailed discussion is found within the FONSI.

ENDANGERED AND THREATENED SPECIES

As noted previously, species which could be present in the project area during the proposed action are the finback whale, humpback whale, right whale, sei whale, sperm whale, West Indian manatee, piping plover, roseate tern, green sea turtle, hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, loggerhead sea turtle, shortnose sturgeon, and sea-beach amaranth. Some of these species may be affected by construction of the Recommended Plan of Improvement. The greatest potential for impacts to the endangered and threatened sea turtle species found within the project area is for beach disposal from 1 May to 15 November of any year, and hopper dredging from April 1 to December 31. Potential project impacts to these species are discussed below and more detailed information is found in the FONSI.

Loggerhead, Kemp's Ridley, and Green Sea Turtles - All of these turtles are known to nest in North Carolina and could nest in the project area. For this reason, they may be affected by the project construction.

In order to minimize impacts on nesting sea turtles, beach disposal sand should match natural sand as closely as possible. Before any dredged maintenance material is pumped from Brandt Island and/or Morehead City Harbor maintenance, onto Bogue Banks beaches, we will assure that the material is suitable for beach disposal. The type of material used for beachfill should not affect sea turtles. Also, beach tilling will be accomplished for the purpose of loosening the sand fill set, which hardens and makes nesting by sea turtles difficult.

Sea turtle monitoring and nest relocation will be required during construction if disposal occurs during the sea turtle nesting season (1 May to 15 November). Sea turtles also occur in the entrance channel proposed for dredging and may be affected (by take) since hopper dredges may be used for maintenance dredging and pump out for beach disposal along the Project Area. To minimize takes by a hopper dredge, work will be restricted from 1 January to 31 March.

As noted above, a monitoring and nest relocation program will be implemented when beach disposal occurs during the nesting season. However, even with this program in place, the possibility of accidental egg loss during nest relocation exists. Therefore, it has been determined that the project may adversely affect the loggerhead, Kemp's ridley, and green sea turtles.

During the period of sea turtle nesting and hatching (1 May through 15 November), all lighting associated with project construction shall be minimized to the maximum extent practicable while maintaining compliance with all safety requirements. Reduced wattage and special fixtures or screens to reduce illumination of adjacent beach and near shore waters shall be used if practical.

Lighting on offshore equipment shall also be minimized to the maximum extent practicable while meeting Coast Guard requirements. Shielded low pressure sodium vapor lights are highly recommended for all lights on the beach or on offshore equipment.

Piping Plover - Because beach disposal may temporarily impact foraging habitat and disrupt nesting that may be attempted along the eroded beach front, it has been determined that the project may affect the piping plover.

Marine Mammals - Marine mammals occur in offshore sites proposed for dredging. It is expected that these species can be detected by use of observers and avoided, therefore a no effect determination is proposed.

Seabeach Amaranth - While beach disposal will restore much of the habitat lost to erosion, disposal on a portion of the beaches in the growing season during project construction may slow population recovery over the short term. Therefore, the project may affect seabeach amaranth.

IMPACTS ON WATER QUALITY

The proposed project will result in elevated turbidity and suspended solids compared to the existing non-storm conditions of the surf zone in the immediate area of beachfill. Due to the low percentage of silt and clay in Brandt Island and the Morehead City Harbor navigation channels (averaging less than 10 percent), this impact is not expected to be greater than the natural increases in turbidity and suspended material during storm events. Discharge of sediment that is predominantly sand would be required for beach disposal. Such discharge would occur within the 3-mile limit and therefore would be subject to regulation under Section 404(b)(1) of the Clean Water Act of 1977, as amended and will require a Section 401 (P.L. 95-217) State of North Carolina Water Quality Certificate.

It is expected that dredged disposal on the beach would result in turbidity and suspended solids concentrations that are elevated over normal background levels in the navigation project areas during dredge excavation and in the surf zone in the immediate area of beach disposal operation. No other water quality parameters are anticipated to be impacted significantly during dredge channel maintenance, pumpout of Brandt Island, and beach disposal.

The degree of water quality impacts associated with navigation maintenance dredging activities and beach disposal has been evaluated during this study and presented in the attached FONSI. Investigations indicated that suitable material would be used for beach disposal; therefore water quality impacts would not be significant.

IMPACTS ON AESTHETIC RESOURCES

Aesthetic impacts of project construction are expected to be both positive and negative. The aesthetics of the beach would temporarily be degraded during beach disposal due to the presence of heavy equipment and pipeline on the beach and elevated turbidity in the surf zone. Noise and exhaust created by the operation of the dredge and other equipment will result in minor increases in noise and air pollution. However, upon completion of the project, the aesthetics and recreational use of the beach should be enhanced due to the wider beach.

IMPACTS ON CULTURAL RESOURCES

The Wilmington District, in consultation with the NC Division of Archives and History Underwater Archaeology Unit, have considered both the potential impact of the project and the nature of the known resources, and have determined that the information does not support a recommendation for an archaeological survey of the entire beach area. However, it is possible during the course of construction that vessel remains will be encountered. Therefore, the Underwater Archaeology Unit has requested that Wilmington District personnel, contractors, and others be aware that the possibility exists that this work may unearth a beached shipwreck. In the event that such occurs, work should move to another area and the Underwater Archaeology Unit should be contacted immediately at telephone number (910) 458-9042. A staff member will be sent to assess the wreckage and, if practical, undertake appropriate documentation.

CUMULATIVE IMPACTS

A cumulative analysis of the impacts of existing, proposed and potential projects involving beach disposal, is found in Attachment E of the Draft Evaluation Report and Environmental Assessment, Morehead City Harbor, Section 933, Carteret County, North Carolina, dated May 2003. General impacts of beach disposal on other North Carolina beaches are considered to be similar to those described herein. The degree of cumulative impact would increase proportionally with the total length of beach impacted. This analysis quantifies these impacts in terms of the percent of North Carolina beaches affected on an annual and total basis by sand disposal for maintenance of Federal navigation channels, and existing, proposed or potential beach disposal projects. Cumulative impacts of the proposed action appear negligible.

SUMMARY OF ENVIRONMENTAL IMPACTS

Adverse environmental impacts associated with the proposed action include (1) Destruction and displacement of intertidal and benthic fauna during construction; (2) temporary increases in turbidity and suspended solids during construction and disposal operations; and (3) it has been determined that the project, as currently proposed, may affect the piping plover, green sea turtle, loggerhead sea turtle, hawksbill sea turtle, leatherback sea turtle, Kemp's ridley sea turtle, and seabeach amaranth. A program of monitoring and nest relocation will be implemented to mitigate adverse impacts on the sea turtles when fill placement overlaps the sea turtle nesting season. Additionally, the Corps will continue to monitor seabeach amaranth during the growing season (1 July to September 30).

MITIGATION REQUIREMENTS

The term "mitigation requirements," as used herein refers to actions necessary to reduce or compensate for adverse environmental impacts of the project. Overall environmental impacts are expected to be minor, due to the scope, location, and timing of project activities. However, project construction may occur during the nesting season of the loggerhead sea turtle, green sea turtle, and Kemp's ridley sea turtle (1 May through 15 November). A beach monitoring and nest relocation program will be implemented to mitigate impacts on these species as discussed in the FONSI.

PUBLIC VIEWS

The Recommended Plan is considered acceptable to local interests. Required coordination related to the environmental permits and entitlements necessary for project construction is discussed in detail in the Environmental Assessment. Local views and the views of the State of North Carolina are summarized below. Additional views were received during public and agency coordination of the Evaluation Report and Environmental Assessment.

VIEWS OF THE LOCAL SPONSOR

The Recommended Plan of Improvement is considered to be acceptable to, and supported by, the local sponsor, Carteret County (see Appendix A, Exhibit 3.)

VIEWS OF THE STATE OF NORTH CAROLINA

The State of North Carolina, Department of Environment and Natural Resources, Division of Water Resources, supports the Recommended Plan of Improvement.

SUMMARY OF PLAN EFFECTS

Table 12 provides a summary of project effects. Effects are evaluated in the following categories: (1) National Economic Development (NED), which reflects the plan's economic justification; (2) Environmental Quality, which evaluates the plan's environmental acceptability; (3) Regional Economic Development; and (4) Other Social Effects, including health and safety.

Effects in these four categories encompass significant effects on the human environment as required by the National Environmental Policy Act of 1969, as amended. They also encompass social well being as required by Section 122 of the Flood Control Act of 1970. For purposes of comparison, the effects of the Selected Plan are evaluated against the "without project" or "no action" condition.

TABLE 12

SUMMARY OF PLAN EFFECTS OF SECTION 933 PROJECT AREA

	RECOMMENDED PLAN	"NO ACTION"
1. NATIONAL ECONOMIC DEVELOPMENT		
Beneficial Contribution		
Expected Annual Benefits:		
Hurricane Storm Damage Reduction	$8,950,000	None
Emergency Costs and Other Damage Reduction	$ 122,000	None
Recreation	$ 1,009,000	None
Benefits During Construction	$ 574,000	None
Total Expected Annual Benefits	$10,655,000	
Adverse Contributions		
Expected Annual Costs:		
Interest & Amortization	$ 1,473,000	Continuation of hurricane and storm damages along with damages due to progressive beach erosion.
Annual Benefits Foregone	$ 705,000	
Total Exp. Annual Costs 933 Project Area	$ 2,178,000	

2. ENVIRONMENTAL QUALITY

<u>Beneficial Contribution</u>	None	None
<u>Adverse Contribution</u>		
a. Water Quality and Aquatic Resources	*Increased turbidity during construction	None
b. Vegetation and Wetlands	*Minimal impact	None
c. Wildlife Habitat	*Destruction and displacement of intertidal and benthic fauna during construction; effect will be temporary, but will recur over life of project.	None
d. Aesthetic Value	*Minimal impact	Continued loss of aesthetic values of oceanfront as erosion intrudes upon development.
e. Air and Noise Pollution	*Increased air and noise pollution during construction	None
f. Threatened and Endangered	*Possible adverse impacts on loggerhead sea turtle, green sea turtle, Kemps ridley sea turtle, and leatherback sea turtle. When fill placement occurs during the sea turtle nesting season, a nest monitoring and relocation program will be implemented.	None
g. Cultural Resources	None	None

TABLE 12 (continued)

SUMMARY OF PLAN EFFECTS OF SECTION 933 PROJECT AREA

	RECOMMENDED PLAN	"NO ACTION"
3. REGIONAL ECONOMIC DEVELOPMENT		
Beneficial Contribution		
Increased Income and Employment	*Minimal portion of project cost returned to local economy	None
Adverse Contributions		
Increased Income and Employment	None	*Potential loss of tourism income due to beach erosion
4. OTHER SOCIAL EFFECTS		
Beneficial Contributions		
Enhancement of community social well being, health and safety	*Reduction of hurricane and storm hazard along with shoreline stabilization is expected to have favorable impact on social well being and safety; net effect not quantified	None
Adverse Contributions		
Enhancement of community social well being, health and safety	*Minor and temporary inconvenience due to construction activities	*Continued threat of erosion along with hurricane and storm damages

*Effect specified in Section 122 of PL 91-611

PROJECT SCHEDULE

The schedule for the Section 933 Project through initial construction is shown below. This schedule assumes expeditious review and approval of the project through all steps, including ASA(CW) approval and funding. Actual project implementation would follow as shown on the proposed schedule.

Date	Milestone
February 10, 2003	Initiate Plans and Specs
March 31, 2003	CESAW provides report to CESAD and HQUSACE for review and approval
April 30, 2003	HQUSACE approves Section 933 Report
May 9, 2003	CESAW sends PCA, Financial Plan, Letters of Support from Carteret County and State of North Carolina to HQUSACE
May 9, 2003	HQUSACE provides Report to ASA(CW) 6-weeks before submitting the PCA for approval
June 2, 2003	HQUSACE approves PCA Package
June 16, 2003	HQUSACE provides PCA to ASA(CW) for approval
June 30, 2003	ASA(CW) approves PCA
July 7, 2003	Carteret County and CESAW sign PCA
July 14, 2003	Carteret County provides cash contribution
July 14, 2003	Carteret County and State of North Carolina provide all Lands, Easements, Rights-of-Way, Etc (Including evidence of legal authority to grant Right-of-Entry) and CESASRE certifies Real Estate for Project
July 25, 2003	Complete Plans and Specs
August 1, 2003	CESAW sends out Solicitation for Bids - "Advertise"
September 4, 2003	Bids are Opened by CESAW
September 26, 2003	Contract Award
October 31, 2003	CESAW gives "Notice to Proceed"
November 15, 2003	Begin Dredging
April 30, 2005	Complete Dredging

DIVISION OF PLAN RESPONSIBILITIES

Federal policy concerning cost sharing for water resources projects requires that project costs be allocated to the various purposes served by the project; these costs are then apportioned between the Federal Government and the non-Federal sponsor according to percentages specified in Federal guidelines. As shown in Table 13, all project costs are allocated to the purposes of "Section 933 - Beneficial Use of Dredged Material for Hurricane and Storm Damage Reduction." Under current Federal policy, costs allocated to this category are shared with the Federal Government paying 65 percent and the non-Federal sponsor paying 35 percent for project construction. Private-use shores are cost shared at 100 percent by the non-Federal sponsor. Based on the findings in this report (see Appendix E), Carteret County is eligible for 65.0% Federal and 35.0% non-Federal sponsor cost sharing for the added cost of depositing dredged navigation material on the requested sections of the beaches of Pine Knoll Shores, Indian Beach, and Salter Path, under authority of Section 933 of PL 99-662.

TABLE 13

COST ALLOCATION AND APPORTIONMENT

PROJECT CONSTRUCTION

SECTION 933 PROJECT AREA

Project Purpose	Project First Cost	Apportionment (%) Non-Federal	Apportionment (%) Federal	Apportionment ($) Non-Federal	Apportionment ($) Federal
Section 933	$16,354,000	35.0%	65.0%	$5,724,000	$10,630,000

As shown above, the non-Federal and Federal shares of initial project construction are estimated at $5,724,000 and $10,630,000 respectively for the Section 933 project.

SECTION VII - CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

I have given consideration to all significant aspects in the overall public interest, including engineering feasibility and economic, social, and environmental effects. The Recommended Plan of Improvement described in this report provides an economical feasible solution for the beneficial use of dredged material for hurricane and storm damage reduction for the Section 933 project area, which includes Pine Knoll Shores, Indian Beach, and Salter Path.

RECOMMENDATIONS

This study has addressed the beneficial use of dredged material from the Morehead City Harbor navigation project to meet the needs for hurricane and storm damage protection for the 7.2-mile shoreline reach which includes the communities of Pine Knoll Shores, Indian Beach, and Salter Path in Carteret County, as requested by the non-Federal sponsor, Carteret County and also as requested by the State of North Carolina.

I recommend that the Recommended Plan of Improvement described herein as the "Section 933 Project," and selected herein for the purposes of beneficial use of dredged material from the Morehead City Harbor navigation project for hurricane and storm damage reduction for the Pine Knoll Shores, Indian Beach, and Salter Path Project Area, be approved for implementation as a Federal Section 933 project, with such modifications as in the discretion of the Chief of Engineers may be advisable; at a first cost presently estimated at $16,354,000, and an expected annual costs presently estimated at $2,178,000. When compared to expected annual benefits of $10,655,000, the Recommended Plan yields a benefit-to-cost ratio of 4.9. The recommended plan consists of a 7-foot NGVD, 30-foot wide, beach berm with a main fill length of 38,000 feet including a transition length of 1,000 feet at the west end of the project. The east end of the Project will tie in to the Base Disposal Area along the Atlantic Beach shoreline. Recommendations of this plan is made, provided that, except as otherwise provided in these recommendations, the exact amount of non-Federal contributions shall be determined by the Chief of Engineers prior to project implementation in accordance with the following requirements to which non-Federal interests must agree prior to implementation.

a. Contribute 35 percent of total project costs for public shorelines and 100 percent for private shorelines.

b. Provide all lands, easements, and rights-of-way, and suitable borrow and dredged or excavated material disposal areas that the Government determines the Non-Federal sponsor must provide for the construction of the Project, and shall perform or ensure performance of all relocations that the Government determines to be necessary for the construction of the Project.

c. Do not use Federal funds to meet the non-Federal sponsors share of total project costs unless the Federal granting agency verifies in writing that the expenditure of such funds is authorized;

d. Assure continued conditions of public ownership and use of the shore upon which the amount of Federal participation is based during the life of the Project, in accordance with existing law and based on shore ownership and use existing at the time of construction;

e. Provide and maintain its current access roads, parking areas, and other public use facilities open and available to all on equal terms;

f. Be responsible for monitoring the nesting of sea turtles within the Project limits when construction occurs during the 1 May to 15 November nesting season;

g. Assure that dredged material placed under this Project is not removed or the configuration altered or the material is placed on privately owned land, nor shall the Non-Federal sponsor allow any third party to do so;

h. Hold and save the Government free from all damages arising from the construction, operation, maintenance, repair, replacement, and rehabilitation of the Project and any Project-related betterments, except for damages due to the fault or negligence of the Government or its contractors;

i. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

j. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended, 42 U.S.C. 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for the construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the Non-Federal sponsor with prior specific written direction, in which case the Non-Federal sponsor shall perform such investigations in accordance with such written direction;

k. Assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be necessary for the initial construction, operation, or maintenance of the project;

l. Agree that the Non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, and repair the project in a manner that will not cause liability to arise under CERCLA;

m. If applicable, comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way, required for the initial construction, operation, and maintenance of the project, including those necessary for relocations, borrow materials, and dredged or excavated material disposal, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

n. Comply with all applicable Federal and State laws and regulations, including, but not limited to, Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d), and Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army, and Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), requiring non-Federal preparation and implementation of flood plain management plan;.

o. Provide costs of that portion of total historic preservation mitigation and data recovery costs attributable to the Project that are in excess of 1 percent of the total amount authorized to be appropriated for the Project; and

p. Recognize and support the requirements of Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended, and Section 103 of the Water Resources Development Act of 1986, Public Law 99-662, as amended, which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element.

The local sponsor has indicated that they have available the necessary funds to provide the non-Federal share of project costs. I am confident that the local sponsor will provide their share.

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works operation and maintenance program nor the perspective of higher review levels within the Executive Branch.

W. Eugene Tickner, P.E.
Deputy District Engineer,
Programs and Project Management

Charles R. Alexander, Jr.
Colonel, U.S. Army
District Engineer

US Army Corps
of Engineers

WILMINGTON DISTRICT
SOUTH ATLANTIC DIVISION

FINDING OF NO SIGNIFICANT IMPACT

MOREHEAD CITY HARBOR
SECTION 933

CARTERET COUNTY, NORTH CAROLINA

AUGUST 2003

FINDING OF NO SIGNIFICANT IMPACT
MOREHEAD CITY HARBOR, SECTION 933
Carteret County, North Carolina

The responsible lead agency is the U.S. Army Engineer District, Wilmington.

ABSTRACT: The Draft Evaluation Report and Environmental Assessment (EA) was circulated to Federal and State agencies and the public on May 2, 2003. The EA described the proposed Section 933 project as the placement of up to 6.3 million cubic yards of material dredged from the pumpout of Brandt Island and the maintenance dredging of Morehead City Harbor on about 13 miles of Bogue Banks, from Fort Macon State Park to Indian Beach (including Salter Path). We estimated that the Section 933 project would take up to 16 months to complete (start November 16, 2003 and be completed by March 2005).

As a result of discussions and a June 24, 2003 meeting with the State and Federal agencies, the proposed Section 933 project has been modified. We still propose to place up to 6.3 million cubic yards of material dredged from the pumpout of Brandt Island and the maintenance dredging of Morehead City Harbor onto Bogue Banks, from Fort Macon State Park to Indian Beach (including Salter Path), a distance of about 13 miles. However, the time required to complete this proposed Section 933 project has been reduced, from up to 16 months to about 6 months (start the pipeline dredging on November 1, 2003 and may be completed by April 30, 2004). The contract solicitation will indicate this November 1, 2003 to April 30, 2004 period. However, if the contractor experiences mechanical problems with the pipeline dredge or booster pumps, we may have to extend the contract past April 30, 2004. This means that if the contractor experiences 13 days down time (from November 1, 2003 to April 30, 2004), he would be given 13 days in May to recover the down time. Under no circumstance, would the contractor be given an unequal amount of time (i.e., down 13 days and given 31 days to recover in May).

All pumping of material to the beach will be completed no later than May 31, 2004. Placement and removal of equipment (pipe, booster pumps, etc.) may be staged on the beach several weeks before November 1, 2003 and removed from the beach after May 31, 2004. If we have to work on the beach strand after May 1, 2004, we will initiate sea turtle monitoring and relocate any nests within the project area (as well as abide by the environmental commitments 1 and 2 found in Section 9.0 of the FONSI). Under no circumstances would we place material on Bogue Banks past the May 31, 2004 deadline. The hopper dredging would not change (start January 1, 2004 and be completed by March 31, 2004).

Carteret County has agreed to continue monitoring the Phase 1 area (Pine Knoll Shores to Indian Beach (including Salter Path)) beyond November 2003, if adequate recovery of mole crabs and coquina clams does not occur. If required the monitoring would be extended to November 2004. Please note if the Section 933 project is not funded, Carteret County **will not** extend the monitoring until November 2004.

If the Section 933 project is not funded, then the pumpout of Brandt Island and the maintenance dredging of Morehead City Harbor will be undertaken in accordance with the base disposal plan as described in the EA. After review and consideration of the comments received on the EA, the Finding of No Significant Impact (FONSI) was signed.

SEND YOUR COMMENTS TO THE DISTRICT ENGINEER AT THE ADDRESS BELOW.

For further information concerning this FONSI, please contact Mr. Hugh Heine, Environmental Resources Section, at the address below, by telephone at (910) 251-4070, or by e-mail at hugh.heine@usace.army.mil.

DISTRICT ENGINEER
U.S. Army Engineer District, Wilmington
P.O. Box 1890
Wilmington, North Carolina 28402-1890

FINAL EVALUATION REPORT AND FINDING OF NO SIGNIFICANT IMPACT MOREHEAD CITY HAROBR SECTION 933 CARTERET COUNTY, NORTH CAROLINA AUGUST 2003

TABLE OF CONTENTS

APPENDICES

FINAL EVALUATION REPORT AND
FINDING OF NO SIGNIFICANT IMPACT
MOREHEAD CITY HARBOR, SECTION 933
Carteret County, North Carolina

1.00 INTRODUCTION

1.01 Description and Location. Morehead City Harbor is a deep-draft, federal navigation project located in the town of Morehead City, North Carolina, approximately 2.5 miles from the Atlantic Ocean through Beaufort Inlet (Figure 1 found in the EA). Morehead City Harbor is divided into two main parts: the outer harbor, which is made up of Range A (including extension and widener) and the Cutoff; and the inner harbor, which is made up of Ranges B and C, Northeast Leg, West Leg, East Leg (including extension), and Turning Basin (including extension).

On average, the Morehead City Harbor inner harbor navigation channels are maintained every two years by hydraulic pipeline with dredged material being placed either in the Brandt Island Upland Diked Disposal Area (hereafter referred to as Brandt Island) or the beaches on Bogue Banks. The Morehead City outer harbor navigation channels are usually maintained annually by hopper dredge and the resultant material is placed either in the United States Environmental Protection Agency (USEPA) designated Morehead City Ocean Dredged Material Disposal Site (ODMDS) or the previously approved nearshore area. The frequency of maintenance dredging in Morehead City Harbor is subject to the availability of funds.

Approval was obtained for deepening of the inner harbor navigation channels (including Range B and the Cutoff) from the existing 40 feet (plus 2 feet overdepth) to 45 feet (plus 2 feet overdepth) mean low water (mlw). Range A (Ocean Bar Channel) was also approved to be deepened from an existing depth of 42 feet (plus 2 feet overdepth) to 47 feet (plus 2 feet overdepth) mlw to account for wave action. Regularly scheduled maintenance dredging, deepening of the navigation channels and pumpout of Brandt Island were completed in Fiscal Year (FY) 1994.

Brandt Island is a 96-acre island, which has been used as a disposal area since about 1955. Brandt Island is owned and used as a sand-recycling site by the North Carolina State Ports Authority (NCSPA) and dedicated for the purpose of dredged material disposal. Brandt Island has a present capacity of about 3 million cubic yards, which can be increased by about 1 million cubic yards by reworking the dikes every four to five years. Every 8 to 10 years maintenance material is pumped out of Brandt Island and placed on the ocean beaches of Bogue Banks. In FY 1986 and FY 1994 approximately 3.9 million and 2.5 million cubic yards of dredged material were pumped out of Brandt Island and placed on Bogue Banks from Fort Macon State Park to Atlantic Beach, respectively.

1.02 Purpose and Need. The purpose of the 933 project is to utilize beach quality sand dredged from the adjacent Federal navigation channels and from Brandt Island in order to stabilize eroding beaches on Bogue Banks.

2.00 DESCRIPTION OF THE PROPOSED ACTION AND AUTHORIZATION.

Historically, dredged material has been considered a waste material. Prior to the National Environmental Policy Act (NEPA) of 1969 and the Federal Water Pollution Control Act of 1972, its treatment often consisted of unconfined disposal into waters and wetlands adjacent to navigation channels. More recently, it has been deposited within diked disposal islands or transported to an ODMDS located offshore. However, dredged material is now recognized as a valuable resource that can be beneficially used in various ways depending upon its physical and chemical characteristics and its location. Sand is especially valuable for beach replenishment. Consequently, it is no longer an acceptable practice to remove sand from the active littoral system by ocean disposal when other cost-efficient and environmentally acceptable options are available. The North Carolina Coastal Management Program now requires that clean, beach-quality sand dredged from navigation channels in the coastal area not be removed permanently from the active nearshore, beach, or inlet shoal system, unless no practicable alternative exists (NC Administrative Code T15A: 07M.1102). This policy is not without controversy since intertidal macroinvertebrate populations, shorebirds, and nesting sea turtles utilize beach habitat and can be subject to adverse impacts from placement of dredged material during warmer months of the year.

Beach-quality sand dredged during maintenance of Morehead City Harbor and the pumpout of Brandt Island will be made available for placement on area beaches, to the extent feasible. Planning for the placement of this sand is being coordinated through Carteret County, the towns of Atlantic Beach, Pine Knoll Shores and Indian Beach (including Salter Path), and Fort Macon State Park. These communities have expressed interest in acquiring as much sand as possible from the proposed action and are currently working with Federal and State governments to obtain funding assistance for sand placement, through the authority of Section 933 of the Water Resources Development Act of 1986, as amended.

Placement of sand on the Bogue Banks beaches under Section 933 is designed to begin at the toe of the existing dune (elevation + 7.0 ft NGVD) and extend to the mean high water mark seaward by means of a low berm (Figure 6 of the main report).

As a result of discussions and a June 24, 2003 meeting with the State and Federal agencies, the proposed Section 933 project has been modified. We still propose to place up to 6.3 million cubic yards of material dredged from the pumpout of Brandt Island and the maintenance dredging of Morehead City Harbor onto Bogue Banks, from Fort Macon State Park to Indian Beach (including Salter Path), a distance of about 13 miles. However, the time required to complete this proposed Section 933 project has been reduced, from up to 16 months to about 6 months (start the pipeline dredging on November 1, 2003 and may be completed by April 30, 2004). The contract solicitation will indicate this November 1, 2003 to April 30, 2004 period. However, if the contractor experiences mechanical problems with the pipeline dredge or booster pumps, we may have to extend the contract past April 30, 2004. This means that if the contractor experiences 13 days down time (from November 1, 2003 to April 30, 2004), he would be given 13 days in May to recover the down time. Under no circumstance, would the contractor be given an unequal amount of time (i.e., down 13 days and given 31 days to recover in May).

All pumping of material to the beach will be completed no later than May 31, 2004. Placement and removal of equipment (pipe, booster pumps, etc.) may be staged on the beach several weeks before November 1, 2003 and removed from the beach after May 31, 2004. If we have to work on the beach strand after May 1, 2004, we will initiate sea turtle monitoring and relocate any nests within the project area (as well as abide by the environmental commitments 1 and 2 found in Section 9.0 of the FONSI). Under no circumstances would we place material on Bogue Banks past the May 31, 2004 deadline. The hopper dredging would not change (start January 1, 2004 and be completed by March 31, 2004).

Carteret County has agreed to continue monitoring the Phase 1 area (Pine Knoll Shores to Indian Beach (including Salter Path)) beyond November 2003, if adequate recovery of mole crabs and coquina clams does not occur. If required the monitoring would be extended to November 2004. Please note if the Section 933 project is not funded, Carteret County **will not** extend the monitoring until November 2004.

Basically, two components of the project's economics would be affected by reducing construction time from 16 months as assumed in the report to 6 months; they are Benefits During Construction (BDC) and Interest During Construction (IDC). The IDC, which is not an annual cost but a contributing line item to first cost that is later annualized, goes from $708,000 to $309,000. The impact of this change on the cost side and the BCR is negligible. Reducing the construction period by 10 months has a much larger effect on BDC, which is computed as an annual benefit. BDC would go from $574,000 shown in the report to about $217,000. The net effect of this $357,000 decrease in the total expected annual benefits in the report, $10,655,000, yields a slight decrease in the BCR from 4.9 to 4.7. The economics of the project remain very robust.

Should present plans for sharing sand by Bogue Banks beaches not materialize due to funding problems or other unforeseen reasons, dredged maintenance material from the inner and the outer harbor, as well as the pump out of Brandt Island would be distributed according to the base disposal plan. The base disposal plan represents the least cost alternative for the government, which is engineeringly feasible and environmentally acceptable.

Under this base disposal plan, the outer harbor would be maintained by hopper dredge and the resultant excavated material (up to 1.5 million cubic yards) would be placed in the previously approved nearshore area, or in the ODMDS if sea conditions were too rough nearshore. The pumpout of Brandt Island and the maintenance dredging of inner harbor by pipeline dredge would be placed from Fort Macon State Park to Atlantic Beach. Up to 4.8 million cubic yards (i.e., approximately 4.0 million from Brandt Island and about 0.8 million from the inner harbor) of beach quality sand may be placed along 32,000 feet of shoreline from Fort Macon State Park to Atlantic Beach.

Under either the 933 or base plan, the beachfill impacts are measured as the distance from the existing dune tie-in at +7 feet NGVD to Mean High Water (+2.21 feet NGVD). After a period of sorting, the beachfill slope will flatten as indicated in Figure 6 of the main report. Because of the sorting process, the proposed construction berm width will be 2 to 3 times as wide as the design berm widths indicated in Table 1-1 (found in the EA). The 933 design berm widths and the base berm widths would remain unchanged, however, if dredge material quantities are reduced the placement of dredge material may be shortened.

The hopper dredge(s) would start maintaining the Morehead City outer harbor channels and pump the material ashore to Indian Beach and/or Pine Knoll Shores. The hopper dredge(s) would work only from 1 January to 31 March of any year, when turtles are not likely to be present.

The proposed project is being undertaken under the authority of Section 933 of the Water Resources Development Act of 1986 (Public Law 99-662), as amended. Section 933 authorizes 65 percent federal and 35 percent non-federal sharing of the extra costs of depositing dredged material from federal navigation improvements and maintenance on beaches. Sand placed through the use of this authority must provide benefits at least equal to the cost of placement, but future nourishment of the beach is not a project requirement; i.e., the beach does not become a federal shore protection project with a continuing maintenance obligation.

3.00 INCORPORATION BY REFERENCE

U. S. Army Corps of Engineers, Wilmington District. Draft Evaluation Report and Environmental Assessment, Morehead City Harbor, Section 933, Carteret County, North Carolina. May 2003.

4.00 PUBLIC AND AGENCY COORDINATION

On May 2, 2003, the Draft Evaluation Report and Environmental Assessment (EA) referenced previously, was mailed to Federal and State agencies and the interested public for a 30-day review and comment period. The list of recipients is provided in the above-referenced EA.

On July 10, 2003, the Draft Unsigned Finding of No Significant Impact (FONSI) was e-mailed to those individuals and agencies, which commented on the EA for a 7-day review and comment period.

5.00 COMMENTS RECEIVED AND RESPONSES

Comments were received from the following:

5.01 U.S. Environmental Protection Agency (USEPA)
5.02 U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS)
5.03 U.S. Department of Health and Human Services, Centers for Disease Control & Prevention (CDC)
5.04 U.S. National Marine Fisheries Service (NMFS), Endangered Species
5.05 U.S. National Marine Fisheries Service (NMFS), EFH Comments
5.06 U.S. Department of the Interior, Fish and Wildlife Service (USFWS), Endangered Species
5.07 U.S. Department of the Interior, Fish and Wildlife Service (USFWS), NEPA Review on the EA
5.08 North Carolina Department of Administration
5.09 North Carolina Department of Environment and Natural Resources (NCDNR)
5.10 -Division of Marine Fisheries, memo from Preston P. Pate, Director
5.11 -Division of Marine Fisheries, e-mail from Mike Street to Melba McGee
5.12 -Division of Marine Fisheries, memo from Mike Marshall to Melba McGee
5.13 -Division of Coastal Management, memo from Ted Tyndall to Guy Pearce
5.14 North Carolina Wildlife Resources Commission
5.15 Shellfish Sanitation and Recreational Water Quality Section
5.16 NC Division of Coastal Management, memo to Melba McGee from Guy Pearce
5.17 Checklist from Wilmington Regional Office, NCDENR
Public Letters Addressed to Ms. Chrys Baggett, State Clearinghouse, NC Department of Administration
5.18 Dr. Charles H. Peterson, UNC Chapel Hill, Environmental Defense (identical letter addressed to the Corps, mentioned below 5.20)

5.19 Bogue Banks Environmental Stewardship Corporation
5.20 Environmental Defense
5.21 North Carolina Coastal Federation (NCCF)
5.22 Dr. Andrew Coburn, Duke University
5.23 Dr. Douglas J. Wakeman, Meredith College
5.24 Mr. T. B. Doe III

All comments received on the EA were considered in making the decision to sign the FONSI. Pertinent comments from each reviewer are summarized and addressed below. Copies of the letters received are included in Appendix 2. In many instances, our response to a comment is indicated as "noted". Noted, means that the comment was evaluated and was considered before making the decision to sign the FONSI.

In order to reduce repetition, responses are made once to a comment and a particular issue. If the issue appears again, in another letter or in the same letter, the reader is referred to the initial comment. Detailed responses are not given to comments, which repeat information found in the Draft Evaluation Report.

As indicated in Section 4.0 of the FONSI, on July 10, 2003 we e-mailed copies of the Draft Unsigned FONSI to those agencies and individuals commenting on the EA dated May 2, 2003 for a 7-day review. No formal responses will be made on these new comments, but we have made revisions as appropriate to the FONSI.

5.01 USEPA; letter dated May 13, 2003.

Comment 1: Pursuant to Section 309 of the Clean Air Act, EPA, Region 4 has reviewed the subject document, an evaluation of the environmental consequences of placing dredged material from the Morehead City Harbor and the Brandt Island Upland Diked Disposal Area onto the Bogue Banks Beaches, viz., Atlantic Beach, Pine Knoll Shores, and Indian Beach. The subject beaches (13 miles in extent) will receive up to 6.3 million cubic yards of material from the two noted project sites. A berm system 30-feet wide at +7 NGVD will be constructed on a 1:25 slope in this one-time operation.

Response: Noted.

Comment 2: EPA has previously commented to the District on the overall advisability of pumping sand onto an eroding shore face. Generally, we have not had significant concerns about beach nourishment when it provides a disposal site for a proximate, already authorized navigation project. However, the more operative factor was whether or not biologically sensitive resources would be adversely affected through the use of this disposal option. In this particular case the value of the impacted natural resources which will be inundated do not appear compelling and/or at long-term risk. On the other hand, the declining width of the recreational beach, the storm protection potential afforded adjacent shore front property owners, and the acceptable expense of this disposal option appear to counter balance any unavoidable effects accruing from this proposal.

Response: Noted.

Comment 3: As a result, we have no substantive objections with the FONSI determination that an environmental impact statement is not necessary to evaluate the project. Thank you for the opportunity to comment. If we can be of further assistance, Dr. Gerald Miller (404-562-9626) will serve as initial point of contact.

Response: Noted.

5.02 NRCS; letter dated May 15, 2003.

Comment: The NRCS does not have any comments at this time.

Response: Noted.

5.03 CDC, letter dated May 19, 2003.

Comment 1: We appreciate the opportunity to review the Draft Evaluation Report and Environmental Assessment (EA) for Morehead City Harbor, Section 933, Carteret County, North Carolina. We are responding on behalf of the U.S. Public Health Service, Department of Health and Human Services (DHHS).

Response: Noted.

Comment 2: This project will have beneficial effects when completed and we are in overall agreement with its implementation. We believe this EA has adequately addressed the potential human health and safety concerns with one exception. Although we agree with the Corps that the probability of contamination may be low, we still believe that Morehead City inner harbor sediments should be sampled prior to dredging. The cost of running a few samples to verify that there are no human health concerns from potentially contaminated sediments is minimal in relation to the estimated overall project cost of $16,354,000. We also noted that in response to your January 15, 2002 scoping letter, that the public and other review agencies had also raised a similar concern.

Response: As indicated in Section 6.12 of the EA, "The USACE standard tiered approach for analyzing the potential for encountering contaminated sediments in the navigational channels and Brandt Island were used to assess these areas for HTW. According to this analysis, before any chemical or physical testing of sediments is conducted, **a reason to believe that the sediments may be contaminated must be established (emphasis added by the writer)**. The sources of the sediments in the selected areas (i.e., Brandt Island and the existing navigation channels) are generally sand derived from sediment transport and deposition by ocean currents that are not conducive to settling of contaminants. The probability of the sites being contaminated by pollutants is also low since the sediment in existing navigational channels and placement areas have not been used as an industrial site, dump, or contaminant disposal area." As indicated in Section 4.02 of the EA, the waters in the vicinity of the Morehead City Harbor inner harbor channels have been classified as prohibited shellfish areas by the NC Shellfish Sanitation and Recreational Water Quality Section. If maintenance material is excavated from these closed shellfishing areas (i.e., Morehead City Harbor inner harbor channels) between May 1 and October 31 and placed on Bogue Banks, NC Shellfish Sanitation and Recreational Water Quality Section has requested us to post a swimming advisory and a press release will be made. Additionally, the Wilmington District will notify the Shellfish Sanitation and Recreational Water Quality Section prior to dredging from a closed shellfishing area with placement on a recreational swimming area (see Section 6.14 of the EA).

Comment 3: Thank you for the opportunity to review and comment on this document. Please send us a copy of the final document when it becomes available.

Response: We will provide you with a copy of the final document.

5.04 NMFS, letter dated June 13, 2003, regarding the formal Section 7 consultation under the Endangered Species Act of 1973, as amended.

Comment 1: This correspondence is in reply to the May 2, 2003, letter and accompanying information from the U.S. Army Corps of Engineers (COE), Wilmington District. The COE has requested section 7 consultation from the National Marine Fisheries Service (NOAA Fisheries), pursuant to the Endangered Species Act of 1973 (ESA). The project is the placement of beach quality material from the pumpout of Brandt Island and the maintenance dredging of Morehead City Harbor navigation channels on Bogue Banks. The NOAA Fisheries' consultation number for this project is I/SER/2003/00567; please refer to this number in future correspondence on this project. The COE is proposing to use the beach quality sand collected from the maintenance dredging of Morehead City Harbor and the pumpout of the Brandt Island Upland Diked Disposal Area for beach renourishment on Bogue Banks. The proposed Section 933 (Water Resources Development Act of 1986) project would place this sand along about 70,000 feet (13 miles) of beach from Fort Macon State Park to Indian Beach if the requirements of Section 933 are satisfied. If Section 933 requirements are not satisfied placement will occur only along the base disposal plan area (Fort Macon State Park to Atlantic Beach, a distance of about 6 miles).

Response: Agree.

Comment 2: ESA-listed species under the purview of NOAA Fisheries which potentially occur in the project area include the *green (Chelonia* mydas), loggerhead (Caretta caretta), Kemp's ridley *(Lepidochelys kempii),* leatherback *(Dermochelys coriacea),* and hawksbill *(Eretmochelys imbricata)* sea turtles, and the shortnose sturgeon *(Acipenser brevirostris). A* number of endangered large whale species are known to occur off North Carolina, but are not expected to occur in the project area. No critical habitat has been designated or proposed for listed species within the project area.

Response: Agree.

Comment 3: The maintenance dredging of the inner harbor and the pumpout of Brandt Island would be performed with a pipeline dredge, while the outer harbor maintenance dredging would be done by a hopper dredge. Pipeline dredging is not known to take sea turtles. When the hopper dredge is used, the project would be authorized under the regional biological opinion (RBO) on hopper dredging by NOAA Fisheries (September 25, 1997, biological opinion to U.S. Army Corps of Engineers, South Atlantic Division, on the continued hopper dredging of channels and borrow areas in the southeastern United States). All terms and conditions included in the RBO will be adhered to by the COE (e.g., observer and reporting requirements, dredging windows), which was reiterated by Mr. Hugh Heine in a May 20, 2003, phone call to NOAA Fisheries. Any incidental take of sea turtles resulting from the operation of hopper dredges by the COE's South Atlantic Division is authorized under the Incidental Take Statement (ITS) of that biological opinion, and such take would be counted toward the total allowable take in that ITS. Year to date, 6 loggerheads have been taken under the ITS for the South Atlantic coast hopper dredging RBO. The total take limit for the year is 35 loggerhead, 7 green, 7 Kemp's ridley, and 2 hawksbill sea turtles, as well as 5 shortnose sturgeon.

Response: We will abide by the terms and conditions found within the NMFS regional biological opinion (RBO). The 1997 NMFS RBO has no hopper dredging window, however the Corps of Engineer, South Atlantic Division (SAD) and the Wilmington District Protocols indicate that for Morehead City Harbor, hopper dredging can only be conducted from 1 January to March 31 of any year. We will comply with the SAD and Wilmington District Protocols.

Comment 4: As stated above, pipeline dredging is not known to take sea turtles, and hopper dredging would be covered under the hopper dredging RBO. The placement of dredged material onto the Bogue Bank beaches would not have a direct impact on sea turtles in water, and would not have a substantial impact on sea turtle foraging habitat. Nesting-related impacts from beach renourishment fall under the purview of the U.S. Fish and Wildlife Service, which must be consulted regarding this aspect of the project. Turbidity resulting from the dredging and the spoil placement would be temporary and minimal. Shortnose sturgeon are not known to occur in the project area. NOAA Fisheries, therefore, believes that the proposed action is not likely to adversely affect any listed species under our purview.

Response: Agree.

Comment 5: This letter concludes the COE's consultation responsibilities under section 7 of the ESA. for the proposed actions for federally-listed species, and their critical habitat, under NOAA Fisheries' purview. A new consultation should be initiated if there is a take, new information reveals impacts of the proposed actions that may affect listed species or their critical habitat, a new species is listed, the identified action is subsequently modified, or critical habitat is designated that may be affected by the proposed activity.

Response: If any of these conditions are met, we will reconsult with NMFS.

Comment 6: The action agency is also reminded that, in addition to its protected species/critical habitat consultation requirements with NOAA Fisheries' Protected Resources Division pursuant to section 7 of the ESA, prior to proceeding with the proposed action the action agency must also consult with NOAA Fisheries' Habitat Conservation Division (HCD) pursuant to the Magnuson-Stevens Fishery Conservation and Management Act's requirements for essential fish habitat (EFH) consultation (16 U.S.C. 1855 (b)(2) and 50 CPR 600.905-.930, subpart K). The action agency should also ensure that the applicant understands the ESA and EFH processes; that ESA and EFH consultations are separate, distinct, and guided by different statutes, goals, and time lines for responding to the action agency; and that the action agency will (and the applicant may) receive separate consultation correspondence on NOAA Fisheries letterhead from HCD regarding their concerns and/or finalizing EFH consultation. Consultation is not complete until EFH and ESA concerns have been addressed.

Response: See responses to NMFS letter (5.05) dated June 5, 2003, regarding EFH below.

Comment 7: If you have any questions about EFH consultation for this project, please contact Mr. Ron Sechler, HCD, at (252) 728-5090. If you have any questions about this ESA, consultation, please contact Dennis Klemm, fishery biologist, at the number above or by e-mail at Dennis.Klemm @noaa.gov.

Response: Thank you for your comments.

5.05 NMFS, letter dated June 5, 2003, regarding the EFH review of the EA.

Comment 1: The National Marine Fisheries Service (NOAA Fisheries) has reviewed Public Notice CESAW-TS-PE-03-16-002 (Notice of Availability) and the Draft Environmental Assessment (EA) and Evaluation Report, dated May 2, 2003, for proposed work on Bogue Banks in Carteret County, North Carolina. The U.S. Army Corps of Engineers (COE) proposes to place dredged material from maintenance of the inner and outer harbor navigation channels, and stored at the Brandt Island upland disposal site, on oceanfront beaches of Fort Macon, Atlantic Beach, Pine Knoll Shores, and Indian Beach. Disposal of 1.8 million cubic yards of material is currently authorized for periodic placement along 6 miles of beach at Fort Macon and Atlantic Beach. The proposed Section 933 beneficial use of dredged materials project would extend this disposal area an additional 7.2 miles and authorize placement of 4.5 million cubic yards of material on beaches at Pine Knoll Shores and Indian Beach, which includes Salter Path. A total of approximately 6.3 million cubic yards of material would be placed along a total of 13.2 miles of oceanfront beach on Bogue Banks. A hydraulic pipeline dredge would be used to construct the project and work would begin on November 16, 2003, and continue through April 30, 2005, a total of 16 months.

Response: As indicated in Section 2.0 of the FONSI, we have modified the proposed Section 933 project. As a result of discussions and a June 24, 2003 meeting with the State and Federal agencies, the proposed Section 933 project has been modified. We still propose to place up to 6.3 million cubic yards of material dredged from the pumpout of Brandt Island and the maintenance dredging of Morehead City Harbor onto Bogue Banks, from Fort Macon State Park to Indian Beach (including Salter Path), a distance of about 13 miles. However, the time required to complete this proposed Section 933 project has been reduced, from up to 16 months to about 6 months (start the pipeline dredging on November 1, 2003 and may be completed by April 30, 2004). The contract solicitation will indicate this November 1, 2003 to April 30, 2004 period. However, if the contractor experiences mechanical problems with the pipeline dredge or booster pumps, we may have to extend the contract past April 30, 2004. All pumping of material to the beach will be completed no later than May 31, 2004. Placement and removal of equipment (pipe, booster pumps, etc.) may be staged on the beach several weeks before November 1, 2003 and removed from the beach after May 31, 2004. If we have to work on the beach strand after May 1, 2004, we will initiate sea turtle monitoring and relocate any nests within the project area (as well as abide by the environmental commitments 1 and 2 found in Section 9.0 of the FONSI).

Under no circumstances would we place material on Bogue Banks past the May 31, 2004 deadline. The hopper dredging would not change (start January 1, 2004 and be completed by March 31, 2004).

Comment 2: NOAA Fisheries understands that the project would allow the beneficial use of dredged material and that other beach re-nourishment activities would not be authorized under this authority. We are concerned, however, that adverse impacts to fishery resources for which we have stewardship responsibility, may result. The project would involve disposal of dredged material in marine intertidal and ocean surf zone areas that are designated as Essential Fish Habitat (EFH) for Federally managed species. We note that an EFH Assessment is provided on Pages 36-40 in the EA and, by letter dated May 2, 2003, from the COE, NOAA Fisheries was notified that via transmittal of the EA, the Wilmington District was initiating coordination procedures for EFH as required by the 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA)(PL 94-265).

Response: Noted.

Comment 3: Based on our review of the EFH assessment, we find that EFH and associated managed species found in the project area are adequately described. However, we do not agree with the determination that project related impacts to Federally managed species would be minimal when viewed in connection with other similar and authorized projects in this area. The project would be located in an area identified by the South Atlantic Fishery Management Council (SAFMC) as EFH for red drum, brown shrimp, pink shrimp, and white shrimp. In addition, EFH for king mackerel and Spanish mackerel, is located just offshore of the immediate project area. Categories of EFH for various life history stages of these species include the marine water and ocean surf zone. In addition, tidal inlets such as Beaufort and Bogue inlets, located on the eastern and westernmost ends of the project area, respectively, are designated as Habitat Areas of Particular Concern (HAPC) for shrimp and red drum. EFH for summer flounder and bluefish, which are under jurisdiction of the Mid-Atlantic Fishery Management Council (MAFMC) also occur in the project area. Categories of EFH for these species include marine water column, intertidal areas, and marine bottoms. Other species of commercial, recreational, and ecological importance found in the project area include Atlantic croaker, spot, Atlantic menhaden, striped mullet, and Florida pompano. These species serve as prey for species such as king mackerel, Spanish mackerel, cobia, and others that are managed by the SAFMC, and for highly migratory species (e.g., billfishes and sharks) that are managed by NOAA Fisheries. In addition, pursuant to Section 906(e)(1) of the water Resources Development Act of 1986 (PL 99-602) NOAA Fisheries regards fishery resources impacted by this project and their associated habitats as aquatic resources of "national economic importance".

Response: The USACE desires to protect the fish and shellfish resources of the project area. Section 5.05, Essential Fish Habitat of the EA discusses the impacts of the project on Hardbottoms, State-designated Areas of Importance for Managed Species, Marine Water Column, Cape Lookout Sandy Shoals, Mud Bottoms, Larval Entrainment and Other Habitat Areas of Particular Concern. We summarize the EFH section by indicating, that "the proposed action is not expected to cause any significant impacts to Essential Fish Habitat of EFH species. Impacts are expected to be minor on an individual and cumulative effects basis." Since we have modified the project description (see response to Comment 1, above), we believe that the proposed action will not cause any significant impacts to Essential Fish Habitat of EFH species.

Comment 4: NOAA Fisheries is concerned that the EA does not adequately consider cumulative impacts to fishery resources that may result from multiple beach nourishment projects on Bogue Banks. The communities of Pine Knoll Shores, Indian Beach and Emerald Isle are currently authorized, via the three phased Bogue Bank Beach Nourishment Project (BBBNP), to place sand along 16.8-miles of beach on Bogue Banks. Beaches at Pine Knoll Shores and Indian Beach were recently impacted by a project that is similar to that being proposed, and similar work is planned for Emerald Isle in 2004. Environmental monitoring of these privately constructed projects indicate that populations of macro-invertebrates and several fish species that inhabit the surf zone of these beaches have not fully recovered. Construction of the proposed Section 933 project, as scheduled, would eliminate any recovery of these species, which has taken place at Pine Knoll Shores and Indian Beach. Populations of mole crabs *(Emerita talpoida)* and coquina clams *(Donax variabilis),* which normally occur in the ocean surf zone EFH, are important components of the aquatic food chain that supports regionally and nationally significant fishery resources. Elimination of these important food sources twice within a three-year period could result in significant ecological impacts due to loss of forage organisms for other species; however, we acknowledge that detection of such impacts would be difficult.

Response: See response to EFH Recommendations 4 (Comment 12), below.

Comment 5: Based on the preceding, NOAA Fisheries does not support the determination, as stated in the EA, that continuous dredging and disposal of dredged material on Bogue Banks for 16 months would only minimally impact fishery resources including Federally managed species. Work associated with the BBBNP was restricted to winter months (November 16 to the end of March or April of any year) and the COE Regulatory Division agreed that a seasonal restriction on dredging and disposal of dredged material on the beachfront was appropriate for protection of fishery resources. Consequently, NOAA Fisheries believes the same seasonal work restriction is needed in connection with the proposed Section 933 project.

Response: See response to EFH Recommendations 2 (Comment 10), below.

Comment 6: In connection with the preceding, we further note that Phase I of the BBBNP was constructed between December 2001, and April 2002, and Phase II was constructed between January and March of 2003. Maintenance dredging of navigation channels in and around Morehead City harbor resulted in placement of another 200,000+ cubic yards of material on the Fort Macon shoreline in 2002. The proposed Section 933 project would place up to 6.3 million cubic yards of material on Bogue Banks in 2003, 2004 and, 2005, and Phase III of the BBBNP would immediately follow in the winter of 2004 - 2005. During this four-year period, surf zone EFH would be repeatedly impacted and recovery of the macro-invertebrate forage base that supports Federally managed fishes could be negligible over a wide area of Bogue Banks.

Response: See response to EFH Recommendations 1 (Comment 9) and EFH Recommendations #4 (Comment 12), below.

Comment 7: The EA also provides no convincing evidence that the project would significantly reduce shoreline erosion and storm damage. The analyses of storm related erosion and damage, both with and without the project, does not adequately consider existing conditions created by Phases I and II of the BBBNP which has widened the beaches at Pine Knoll Shores and Indian Beach. This change has reduced the vulnerability of these locations to storm damage and the EA should be revised to include existing conditions in the "without the project" alternative analysis. Reevaluation of the "without the project" alternative to include the BBBNP could preclude the need for the proposed Section 933 project. In any case, NOAA Fisheries does not believe that the Section 933 project is the least environmentally damaging practical alternative since the cumulative impact to fishery resources over a relatively short period of time may be substantial and is undetermined.

Response: See response to EFH Recommendations 1 (Comment 9), below.

Comment 8: The compatibility of sediments between those found at the Brandt island disposal site and those on Bogue Banks beaches is not adequately addressed in the EA. The 6.3 million cubic yards of material located at Brandt Island have not been tested for characteristics known to be of ecological importance (e.g., grain size/percent fines and carbonate/shell content). The EA assumes that this material is representative of the material historically found in the navigation channels and concludes that no further analysis is warranted. NOAA Fisheries is concerned that sediments removed from the navigation channels may contain significantly different percentages of shell, silt, and clay than those found Bogue Banks beaches. This is important since significant differences in sediment compositions could adversely affect the recovery of surf zone fish and invertebrate species. Based on (1) previous observations which revealed material previously pumped from Brandt Island to Fort Macon was darker and contained large amounts of shell; (2) previously stated concerns regarding the sediment compatibility at Bogue Banks; and (3) the absence of site specific sediment analysis for the Brandt Island material, we find no convincing basis for assertion, as contained in the EA, that the material is compatible and can be used without ecological or environmental impacts. Therefore, NOAA Fisheries recommends completion of a comprehensive evaluation of sediment size and composition prior to implementation of the proposed Section 933 project.

Response: See response to EFH Recommendations 3 (Comment 11), below.

Comment 9: In view of the preceding, NOAA Fisheries recommends against construction of the project unless the following conditions are incorporated into the project plan.

EFH Conservation Recommendations

1. The "without the project" conditions in the EA should be modified to include shoreline changes associated with the BBBNP. The BBBNP represents a significant change in the "without the project" conditions and these changes should be considered in the overall analyses of the need and timing of the proposed action.

Response: Appendix C of the Draft Evaluation Report and Environmental Assessment, Morehead City Harbor Section 933, Carteret County, North Carolina, dated May 2, 2003 contains the 30 page Coastal Analysis, which describes how the proposed project was developed. The Coastal Analysis Appendix discusses the existing conditions, beach profile characteristics, shoreline change rates, coastal processes, storm surge modeling, etc. On page C-23, within the "Beachfill Evolution" section we state "Beachfill or beach disposal planform evolution was evaluated for both recent local nourishment activities and potential study alternatives." On page C-24, within the "Beachfill Evolution" section we also describe the local nourishment project and study alternatives. Additionally, section 1.02 of the EA describes the BBBNP and is included in the Corps Cumulative Impact Analysis found in Attachment E of the EA.

As indicated in Section 1.02 of the EA and the Coastal Analysis Appendix found in the Draft Evaluation Report (page Appendix C-24), "phase 1 of the local nourishment project resulted in the placement of approximately 1.73 million cubic yards of material on Pine Knoll Shores to Indian Beach, a distance of 39,202 feet. The berm-only project averaged less than 45 cubic yards per foot, which is a very small beachfill." Table 1-1 in the EA provides maximum quantities (cubic yards per foot) for both the Section 933 and the base disposal plan. The average maximum sediment disposal rate (cubic yard per foot) is 88 for Fort Macon, 49 for Atlantic Beach, 124 for Pine Knoll Shores, and 105 for Indian Beach (including Salter Path). The local nourishment project did not preclude the urgency to conduct the proposed Section 933 project (see Coastal Analysis Appendix found in the Draft Evaluation Report). Therefore, the BBBNP was considered in the overall analysis of the need and timing of the proposed action.

Comment 10: EFH Recommendations 2**.** In order to avoid and minimize adverse impacts to surf zone EFH and associated fishery resources during peak periods of biological activity, project construction should be limited to the period between November 16 and March 1 of any year.

Response: As indicated in Section 2.0 of the FONSI and in response to comment 1, above, we have agreed to limit beach disposal from November 1, 2003 to April 30, 2004 (or no later than May 31, 2004, if the contractor experiences equipment problems). By constructing the proposed Section 933 project within the revised window, we believe that the work will avoid and minimize impacts to EFH and associated fishery resources.

Comment 11: EFH Recommendations 3. Prior to the placement of fill material on Bogue Banks, it should be evaluated and found to be compatible and suitable with regard to fishery habitat and other ecological and environmental factors.

Response: We agree. As you are aware, the majority of dredge material from the Morehead City Harbor inner channels are pumped to Brandt Island. In March 2003, we sampled the inner harbor channels and have completed the compatibility analysis on the material of the inner channels and compared that to the existing beach at Fort Macon, Atlantic Beach, Pine Knoll Shores, and Indian Beach (see Table 1, below). These results indicate that the dredge material from Brandt Island and the Morehead City Harbor inner channels are compatible with native materials found on Bogue Banks.

Table 1

Bogue Banks
Compatibility Analysis Results

Borrow Area

	Samples	% Silt	% Shell	Mean	Standard Deviation
Morehead City Inner Harbor	12	1.6	5.4	2.24	.43

Native Beach

	Samples	% Silt	% Shell	Mean	Standard Deviation	Overfill Ratio
Fort Macon	43	1.6	10.9	2.23	.80	1.11
Atlantic Beach	82	3.4	8.8	2.45	.79	1.28
Pine Knoll Shores	105	3.6	8.9	2.41	.81	1.46
Indian Beach	36	3.2	10.9	2.28	.93	1.20
East Emerald Isle	51	2.6	6.3	2.30	.74	1.63
West Emerald Isle	68	2.4	4.9	2.37	.68	1.20
Bogue Inlet Area	51	1.9	4.0	2.40	.52	1.02

NOTE: Mean and Standard Deviation are expressed in terms of ϕ.

Comment 12: EFH Recommendations 4. To avoid and minimize cumulative adverse impacts, scheduling of the project should be revised so that any section of beach nourished in connection with the BBBNP after December 2001, should allow for a minimum three-year recovery period for fish and macro-invertebrate populations.

Response: As indicated in our response to EFH Recommendations #3, above, the material placed on Bogue Banks from Brandt Island is compatible. Literature dating back to the early 1970's along the southeast coast indicate that opportunistic infauna species (ex. *Emerita* and polychaetes) found in the nourished areas are subject to direct mortality from burial, however, recovery often occurs between 1 to 3 years depending on sediment compatibility and the relationship of nourishment placement to recruitment timeframes (Hayden and Dolan, 1974; Saloman, 1984; Nelson, 1989; Van Dolah et al., 1992; Van Dolah et al., 1993; Hackney et al. 1996; P.C. Jutte et al., 1999). Therefore, a minimum three-year recovery period is not required.

Comment 13: EFH Recommendations 5**.** Avoidance and minimization of adverse impacts is always preferable to restoration after impacts occur; however, since placement of incompatible sediments on the ocean beachfront and surf zone is a reoccurring concern, the COE should develop a beach nourishment reclamation plan to address this possibility. The plan could include measures such as removal of incompatible material and replacement with compatible material and/or an increase in monitoring the magnitude and longevity of ecological impacts.

Response: As indicated in our response to NMFS Comment 11, EFH Recommendation 3, above the material from Brandt Island is compatible. The proposed Section 933 action is a civil works project and therefore Corps' inspectors will be assigned to monitor the hydraulic dredge, pipeline route, booster pumps (if required), and placement sites on the beach. These inspectors review the ongoing work for safety, as well as making sure that the contractor complies with all conditions (found in the plans and specifications) of the contract. We will include the following paragraph in the proposed Section 933 specifications, "*Materials: The dredging shall be accomplished so that the most suitable material available for beach disposal is placed within the prescribed section. Suitable materials shall be comprised of materials by ASTM D 2487 as SP, SP-SM, and SW. This material shall be predominantly of sand grain size with no more than 10% silt, shell, and clay material present. Should the dredge encounter materials not suitable for placement on the beach, the Contractor will be directed by the Contracting Officer to move to a more satisfactory location within Brandt Island or the navigation channels.*" If problems occur during construction anywhere along the pipeline route or if the contractor is not abiding by the conditions of the contract (i.e., pumping material to the beach that is not suitable), these Corps inspectors would immediately notify the Contracting Officer (CO) located at the District office and the CO would direct the contractor to move the dredge to a more suitable site in Brandt island or the navigation channels.

Comment 14: NOAA Fisheries is unable to concur with a Finding of No Significant Impact for this project and preparation of an Environmental Impact Statement (EIS) is recommended. An adequate EIS would provide for a comprehensive assessment of the site specific and cumulative impacts of Bogue Banks Section 933 project and other related activities and projects on Bogue Banks. Furthermore, the potential for significant and adverse long-term impacts to nationally important living marine resources is such that NOAA Fisheries may elect to recommend that the project not be implemented and, depending on the content and conclusions reached in the Final EA or EIS, refer this project to the Council on Environmental Quality under Section 1504 of the Council's Regulations for implementing the Procedural Provisions of the National Environmental Policy Act.

Response: In summary, we have reviewed all the comments received on the EA. Based upon our review of these comments and investigations required to respond to NMFS and the other comments, we believe that the EA/FONSI is an appropriate document for the proposed action and it fully complies with NEPA. We believe that the proposed action will not adversely impact "the nationally important living marine resources" for the following reasons: 1. The dredge material found within Brandt Island and the Morehead City Harbor channels is compatible (see response to Comment 11: EFH Recommendations 3 within the NMFS letter 5.05, dated June 5, 2003), 2. Requirements for Section 7 of the Endangered Species Act of 1973, as amended have been met. The project is covered under a USFWS Biological Opinion dated July 22, 2003 and a NMFS Regional Biological Opinion dated 1997. All reasonable and prudent measures, as well as all terms and conditions of the USFWS Biological Opinion dated July 22, 2003 (see Appendix 2) and the NMFS Regional Biological Opinion dated 1997 (see letter dated June 13, 2003 from NMFS found in Appendix 2) will be complied with, 3. Literature dating back to the early 1970's along the southeast coast indicate that opportunistic infauna species (ex. *Emerita* and polychaetes) found in the nourished areas are subject to direct mortality from burial, however, recovery often occurs between 1 to 3 years depending on sediment compatibility and the relationship of nourishment placement to recruitment timeframes (Hayden and Dolan, 1974; Saloman, 1984; Nelson, 1989; Van Dolah et al., 1992; Van Dolah et al., 1993; Hackney et al. 1996; P.C. Jutte et al., 1999). Therefore, a minimum three-year recovery period is not required, 4. The revised construction window is from November 1, 2003 to April 30, 2004 (to May 31, 2004, if required), 5. Carteret County has agreed to continue monitoring the Phase 1 area (Pine Knoll Shores to Indian Beach (including Salter Path)) beyond November 2003, if adequate recovery of mole crabs and coquina clams does not occur. If required the monitoring would be extended to November 2004. Please note if the Section 933 project is not funded, Carteret County **will not** extend the monitoring until November 2004.

Comment 15: Section 305(b)(4)(B) of the MSFCMA and NGAA Fisheries' implementing regulation at 50 CFR Section 600.920(k) require your office to provide a written response to this letter within 30 days of its receipt. If it is not possible to provide a substantive response within 30 days, then in accordance with our "findings" with your Regulatory Functions Branch, an interim response should be provided to NOAA Fisheries. A detailed response then must be provided prior to final approval of the action. Your detailed response must include a description of measures proposed by your agency to avoid, mitigate, or offset the adverse impacts of the activity. If your response is inconsistent with our EFH Conservation Recommendations, you must provide a substantive discussion justifying the reasons for not following the recommendations.

Response: By letter dated June 27, 2003, we provided your office with our written responses to the five EFH Recommendations. By letter dated July 16, 2003 (see Appendix 2), NMFS provided their comments to our letter dated June 27, 2003, which responded to the EFH Recommendations. The NMFS still had unresolved issues regarding recovery of mole crabs/coquina clams and developing a feasibility plan for beach restoration in the event that incompatible material is placed on the beach. As indicated during our meeting on June 24, 2003, a representative from Carteret County stated that they would continue monitoring the Phase 1 area (Pine Knoll Shores to Indian Beach (including Salter Path)) beyond November 2003, if adequate recovery of mole crabs and coquina clams does not occur. If required, the monitoring would be extended to November 2004. Please note if the Section 933 project is not funded, Carteret County will not extend the monitoring until November 2004. Since the material pumped to Bogue Banks from Brandt Island and the Morehead City Harbor inner channels is compatible (see Table 1, above), the Corps will not develop a feasibility plan for beach restoration in the event that incompatible material is placed on the beach. Therefore, it is our position that impacts of the project on the environment will be within acceptable levels.

Comment 16: Finally, these comments do not satisfy your consultation responsibilities under Section 7 of the Endangered Species Act of 1973, as amended. If any activity(s) "may effect" listed species and habitats under the purview of NOAA Fisheries, consultation should be initiated with our Protected Resources Division at the letterhead address.

Response: See NMFS letter (5.04) dated June 13, 2003, above, which indicates that if the Corps abides by all of the terms and conditions of the 1997 RBO, the proposed Section 933 project will not likely adversely affect any listed species under NMFS purview.

Comment 17: Thank you for the opportunity to provide these comments. Related questions or comments should be directed to the attention of Mr. Ronald S. Sechler at our Beaufort Office, 101 Pivers Island Road, Beaufort, North Carolina, or at (252) 728-5090.

Response: We appreciate your comments on this matter.

5.06 USFWS; letter dated June 6, 2003, regarding formal Section 7 consultation under the Endangered Species Act of 1973, as amended.

Comment 1: This letter acknowledges the U.S. Fish and Wildlife Service's (Service) May 5, 2003 receipt of your May 3, 2003 letter requesting initiation of formal section 7 consultation under the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 et seq.). The consultation concerns the possible effects of your proposed Morehead City Harbor Section 933 Project on Federally-listed species, including the roseate tern *(Sterna dougallh),* piping plover *(Charadrius melodus),* West Indian manatee *(Trichechus manatus),* seabeach amaranth *(Amaranthus pumilus),* and green *(Chelonia mydas),* hawksbill *(Eretmochelys imbricata),* Kemp's ridley *(Lepidochelys kempii),* leatherback *(Dermochelys coriacea),* and loggerhead *(Caretta caretta)* sea turtles.

Response: Noted.

Comment 2: All information required of you to initiate consultation was either included with your letter or is otherwise accessible for our consideration and reference. The proposed action, as detailed in your draft Environmental Assessment and Evaluation Report, dated May 2003, consists of placing approximately 6.3 million cubic yards of dredged material stored in the Brandt Island disposal site and sediments from maintenance dredging of the inner and outer harbor navigation channels of Morehead City and Beaufort Inlet along approximately 13.2 miles of oceanfront beaches of Bogue Banks (including Fort Macon, Atlantic Beach, Pine Knoll Shores, Salter Path, and Indian Beach), Carteret County, North Carolina (hereafter referred to as Morehead City Harbor Section 933 Project). The proposed project is a one-time action scheduled to begin

November 16, 2003 and continue for up to 16 months (estimated completion date April 30, 2005). However, the pump-out of Brandt Island and disposal of these sediments on the oceanfront beaches of Bogue Banks is expected to occur, as it has in the past, every 8 to 10 years.

Response: See our modified project description found in Section 2.0 of the FONSI and in response to Comment 1 within the NMFS letter (5.05) dated June 5, 2003, above.

Comment 3: The Service prepared a biological opinion, dated December 7, 1989, for the proposed dredging of Morehead City Harbor and subsequent disposal of dredged sediments in a Morehead City Ocean Dredged Material Disposal Site, an upland diked dredge disposal area on Brandt Island, or pumped directly onto the oceanfront beach at Atlantic Beach. In our biological opinion we concurred with your findings that the proposed action would have no effect on the piping plover, roseate tern, and hawksbill and Kemp's ridley sea turtles, and that the proposed action may affect loggerhead and green sea turtles. Our biological opinion concluded that the proposed action was not likely to jeopardize the continued existence of loggerhead and green sea turtles.

Response: Agree.

Comment 4: An amendment to the biological opinion, dated April 19, 1993, was prepared in response to updated project plans of the original dredge and disposal action. The project modifications included the disposal of additional dredged sediment material on oceanfront beaches from Fort Macon State Park to Pine Knoll Shores and a different pipeline route than reviewed in the original project. The amended biological opinion concluded that the proposed project modifications were not likely to jeopardize the continued existence of loggerhead and green sea turtles. The amended biological opinion also included a conference opinion for the proposed Federally-threatened seabeach amaranth in which we concluded that the proposed action would not likely jeopardize the continued existence of this species.

Response: Agree.

Comment 5: In your Biological Assessment, dated May 2003, you determined that the updated project plans for the proposed Morehead City Harbor Section 933 Project are not likely to adversely affect the roseate tern or the West Indian manatee. Moreover, you determined that the proposed activities may affect the piping plover, seabeach amaranth, and green, hawksbill, Kemp's ridley, leatherback, and loggerhead sea turtles. We concur with your determination that the proposed action may affect the hawksbill, Kemp's ridley, and leatherback sea turtles; however, we conclude that the proposed action is not likely to adversely affect these species. In addition, based on the information provided and other information available, we concur with your determination that the proposed action is not likely to adversely affect the roseate tern. With regard to the West Indian manatee, however, the Service would concur with your determination that the proposed action is not likely to adversely affect this species if the measures detailed in the *Precautionary Measures For Activities In North Carolina Waters Which May Be Used By The West Indian Manatee* (attached) are implemented.

Response: We will abide by conditions and restrictions found within the *Precautionary Measures For Activities In North Carolina Waters Which May Be Used By The West Indian Manatee*.

Comment 6: Because the proposed action is different in timing and scope from the project reviewed in the original biological opinion and amendment, and new information is available on the piping plover, seabeach amaranth, and green and loggerhead sea turtles, we are initiating formal consultation for these species. Section 7 allows the Service up to 90 calendar days to conclude formal consultation with your agency and an additional 45 calendar days to prepare our biological opinion (unless we mutually agree to an extension). However, we expect to provide you our second amendment to the biological opinion by late-July. Based on the information provided and other information available, we anticipate the second amendment to conclude that the proposed action is not likely to jeopardize the continued existence of the piping plover, seabeach amaranth, and green and loggerhead sea turtles. The second amendment will primarily update the incidental take statement and the reasonable and prudent measures with their implementing terms and conditions based on information obtained since the last project review and first amendment to the biological opinion.

Response: Agree.

Comment 7: We have assigned log number 03-S243 to this consultation. Please refer to that number in future correspondence on this consultation. If you have any questions or concerns about this consultation or the consultation process in general, please feel free to contact me or Mr. David Rabon of my staff at (919) 856-4520 extensions 11 or 16, respectively.

Response: We appreciate your comments on this matter.

5.07 USFWS; letter dated June 6, 2003, regarding the NEPA review of the EA.

Comment 1: The Service issued a draft Fish and Wildlife Coordination Act (FWCA) report on the Federal shore protection project for Bogue Banks in November 2002 (available on our website at http://nc-es.fws. ov/pubs/fwcafbogue.html). This project is distinct from the Section 933 project and is a storm damage reduction project along the entire 26-mile length of Bogue Banks. In this report the Service summarized the fish and wildlife resources in the Bogue Banks area, which includes the project area for the proposed Section 933 project. The Service incorporates this report by reference, particularly its list of conservation measures for avoiding, minimizing and mitigating potential adverse environmental impacts resulting from the placement of fill material via dredging equipment on oceanfront beaches.

Response: As indicated in Section 2.0 of the FONSI, the Section 933 project is a one-time placement of up to 6.3 million cubic yards of dredge maintenance material from Brandt Island and the Morehead City Harbor navigations channels onto Bogue Banks, from Fort Macon State Park to Indian Beach (a distance of about 13.2 miles). Section 1.2 of the FONSI states that the purpose and need of the proposed Section 933 project is to "utilize beach quality sand dredged from the adjacent Federal navigation channels and from Brandt Island in order to stabilize eroding beaches on Bogue Banks."

The conservation measures found within the FWCA report dated November 2002 deal with the long-term (i.e., 50 years project life) 24-mile long, Bogue Banks Shore Protection Feasibility Study. Many of the 22 conservation measures found within the FWCA are not applicable to the proposed action, since these measures are not within the project scope of the Section 933. For example, conservation measures 3, 4, 13, and 15 deals predominantly with borrow areas (i.e., the 43 dredge disposal islands in Bogue Sound and offshore borrow areas). The Section 933 will not impact these 43-dredge disposal islands in Bogue Sound and there are no off-shore borrow areas in the Section 933 project. Conservation measures 1, 2, and 7 deal predominantly with the construction of and planting of dunes (the Section 933 is not constructing any dunes, see Section 1.03 of the EA). Conservation measures 8, 10, 12, and 14 deal predominantly with phased construction of the 24-mile project area, renourishment intervals, avoiding CBRA zones and conservation lands (the Section 933 is a one-time action and will not impact CBRA zones and/or conservation lands). Conservation measures 16, 17, 18, 19, 20, and 21 deals predominantly with mitigation for adverse impacts to the environment (there is no mitigation proposed for the Section 933).

The remaining conservation measures found within the FWCA are addressed in the FONSI. Conservation measures 5, 6, and 11 deals with construction windows (see response to the NMFS and USFWS letters (5.04 and 5.06, respectively) dealing with endangered species, above and the NCWRC letter (5.14), below). Conservation measure 9 deals with sand compatibility (see Table 1, above). Conservation measure 22 deals predominantly with long-term monitoring of the long-term study (see revised project description in Sections 2.0 and 9.0 of the FONSI).

Comment 2: The Service supports projects that (1) are ecologically sound; (2) are the least environmentally damaging alternative; (3) have avoided and minimized damage or loss of fish and wildlife resources and uses; (4) have adopted all important recommended conservation measures to compensate for unavoidable damage or loss to fish and wildlife resources; and (5) are clearly a water dependent activity with a demonstrated public need if there are wetland or shallow water habitats in the project area (January 23, 1981, Federal Register v. 46, n. 15, p. 7659). The Service does not believe that this project, as currently proposed, gives equal consideration to fish and wildlife resources and may generate adverse impacts to aquatic resources of national importance. In addition, we do not think this project meets the 404(b)(1) guidelines for the Clean Water Act.

Response: The proposed Section 933 project is:

1. ecologically sound (see Sections 5.00 and 6.00 of the EA and response to NMFS letter (5.05) dated June 5, 2003, comment # 14, above),

2. is the least environmental damaging (see revised section 2.0 of the FONSI and response to NMFS letter (5.05) dated June 5, 2003, comment # 14),

3. has avoided and minimized damage or loss of fish and wildlife resources and uses (see revised Section 2.00 of the FONSI and response to NMFS letter (5.05) dated June 5, 2003, comment #12),

4. see response to Comment 1, above, and

5. is clearly a water dependent activity with a demonstrated public need (see Section 1.02 of the EA, Appendix D of the EA (Economic Analysis), and the Section III - Economic Benefits of the Draft Evaluation Report). We also believe that the EA does give equal consideration to both fish and wildlife resources (see Sections 4.00 and 5.00 of the EA). Moreover, the project does meet the 404(b)(1) guidelines for the Clean Water Act (see Attachment A of the EA).

Comment 3: Environmental Acceptability. The project documents do not adequately consider the locally constructed Bogue Banks Beach Restoration Project (BBBRP). The Evaluation Report and EA cite recent storm damages and erosion as the need for the project, and reduction in storm damages and erosional losses as the beneficial use of the dredged material. However, the Evaluation Report states that "the most likely future" scenario along the Section 933 project area is that erosion control measures by local and state interests are not expected to provide significant protection against the erosion and flooding associated with hurricane and storm events" (p. 19).

The Service strongly disagrees with this finding. The Section 933 project evaluation determined that a 30-foot wide addition to the beach would significantly reduce storm damages, for a total of $8.95 million in annual benefits in Pine Knoll Shores and Indian Beach. The BBBRP had a design width of over 30 feet throughout these communities, however. To make a determination that the locally constricted beach wider than what the Corps has determined will significantly reduce storm damages and erosional losses (30 feet) as insignificant is not sound.

Response: The proposed Section 933 project considered the locally funded beach nourishment project in place and part of the "without project" condition. Benefits for the Section 933 project are beyond those provided by the locally funded beach nourishment project. Neither projects (i.e., the proposed Section 933 or the locally funded beach nourishment project) were optimized for hurricane and storm reduction or provides for periodic nourishment.

Comment 4: Secondly, the material to be pumped from Brandt Island (an estimated 4 mcy) has not been tested for sedimentary characteristics known to be ecologically significant to fish and wildlife resources (i.e., carbonate content, color, grain size). The Corps assumes that material presently within the navigational channels of the inner harbor are representative of the dredged materials currently residing in Brandt Island. The EA does not include the sedimentary analyses of this material (which the Service understands is presently underway) and makes the assumption that it is suitable for beach placement.

Response: See response to Comment 11: EFH Recommendations 3 within the NMFS letter (5.05) dated June 5, 2003, above.

Comment 5: The Service does not concur with either of these assumptions. Material previously pumped from Brandt Island to Fort Macon contained dark gray and highly shelly material that created tall scarps that are still sometimes visible at the park (Figure 1 of the USFWS letter). This material is similar to the ecologically incompatible material used in the BBBRP. It is not reasonable to assume that all of the material presently within Brandt Island is ecologically compatible with the native beaches of Bogue Banks. The Service strongly recommends sampling the sediments currently within Brandt Island to determine the compatibility of this material for beach placement.

Response: See response to comment 4, above.

Comment 6: Moreover, sediments that settle within navigation channels may be significantly finer than beach sands and contain high percentages of silt and clay. The Evaluation Report and EA assume that only beach quality sand will be present in the deepwater channels of the inner harbor. That assumption is premature. Since geotechnical data are presently being compiled for the sediments in the inner harbor channels, the Service recommends that any evaluation of the suitability of the material for beach placement be delayed until the data are available.

Response: See response to comment 4, above.

Comment 7: The least environmentally damaging alternative would utilize sediments that are ecologically compatible with Bogue Banks beaches. A recent study by the Service determined that native sediments of North Carolina beaches contain less than 12.8 % gravel (sediments larger than 2 millimeters (mm)), less than 4.1 % fines (sediments smaller than 1/16 mm), and an average of 7.4 % carbonate or shelly material. Site specific data available for Bogue Banks indicate that the native sediments for the sandy beach ecosystem contain 4.9 %, gravel, 0.6 % fines, and 13.3 shell material. The limited data utilized to assess sediment compatibility for the Section 933 project indicate that the proportion of fines may be 6 % to 12 % (p. EA-15, EA-16). The absence of sedimentary data for the Brandt Island fill material preclude a determination that the material is similar to existing material and suitable for fish and wildlife resources. Previous experiences with ecologically incompatible sediments at both Fort Macon and the BBBRP project area do not support a reasonable assumption that the Section 933 project will only place beach compatible material on the beaches of Bogue Banks.

Response: By e-mail dated June 30, 2003, Mr. John Ellis, USFWS in the Raleigh Field Office indicated that there are two "options" suggested by USFWS for sediments found in Brandt Island. Option 1 is defined as sediment that has the following characteristics: Carbonate (shell) content – 12.4 %; gravel content – 4.9 %; fines content – 0.6% by weight; organic matter content – less than or equal to that of native beach material; Dominant grain size – medium to fine grained sand. Option 2 is defined as sediment that has the following characteristics: Carbonate - up to 25.13% by weight; Gravel – up to 16.84% by weight; Fines – up to 7.72% by weight; Organic Matter Content – less than or equal to that of the native beach; Dominant Grain Size – should be medium to fine grained sand. The Corps is not required to comply with these criteria, but according to the compatibility analysis found in response to Comment 11: EFH Recommendations 3 within the NMFS letter (5.05) dated June 5, 2003, the material from Brandt Island is within the parameters of Option 2. The dredged material placed on Bogue Banks is compatible (see response to Comment 11: EFH Recommendations 3 within the NMFS letter (5.05) dated June 5, 2003, above).

Comment 8: Ecological Impacts. The local communities of Pine Knoll Shores, Indian Beach and Emerald Isle currently have a Regulatory Permit for the three phase Bogue Banks Beach Restoration Project along 16.8 miles of beach on Bogue Banks. Pine Knoll Shores and Indian Beach were constructed in 2001-02 (Phase I). Eastern

Emerald Isle was constructed from January to March 2003 (Phase II). The third phase of this project is scheduled for western Emerald Isle during the winter of 2004-05. These oceanfront beaches were impacted by a dredge and fill project with dimensions similar to those proposed by the Section 933 project.

Response: We disagree. As indicated in Section 1.02 of the EA and the Coastal Analysis Appendix found in the Draft Evaluation Report (page Appendix C-24), states "phase 1 of the local nourishment project resulted in the placement of approximately 1.73 million cubic yards of material on Pine Knoll Shores to Indian Beach, a distance of 39,202 feet. The berm-only project averaged less than 45 cubic yards per foot, which is a very small beachfill." Table 1-1 in the EA provides maximum quantities (cubic yards per foot) for both the Section 933 and the base disposal plan. The average maximum sediment disposal rate (cubic yard per foot) for the proposed Section 933 is 88 for Fort Macon, 49 for Atlantic Beach, 124 for Pine Knoll Shores, and 105 for Indian Beach (including Salter Path).

Comment 9: The available data indicate that the sandy beach ecosystem in the BBBRP area has not recovered, and the Section 933 project would eliminate any recovery gains made by the system in the last year. Furthermore, the Section 933 project would bury the closest recruitment population for macroinvertebrates at Atlantic Beach. The macroinvertebrate population, dominated by coquina clams (*Donax variabilis*) and mole crabs (*Emerita talpoida*), is the prey base for regionally and nationally significant waterbirds, shorebirds, and fishery species. The Service believes that burial of the macroinvertebrate prey population twice within a three year period will generate significant ecological impacts, delaying the recovery of the food source for longer than would occur if the Section 933 project were constructed after the prey base within the BBBRP area was fully recovered.

Response: We disagree. The results from the monitoring performed by Coastal Science Associates (CSA), Inc. see (CSAi 2002 B), and (CSAi 2003), as a requirement of the Department of the Army permit #200000362 for Phase I of the local beach nourishment project and the data provided by Dr. C.H. Peterson et al does not agree with your conclusion (see response to Comments 2 and 3 of the Dr. C.H. Peterson letter (5.18) dated May 28, 2003, below and response to Comment 14 of the NMFS letter (5.05) dated June 5, 2003).

Comment 10: Furthermore, the cumulative impacts of multiple dredge and fill projects on Bogue Banks within a short period of time will be significant. The Service does not concur with the Corps' finding that cumulative impacts will be insignificant. Phase I of the BBBRP was constructed from December 2001 through April 2002. Phase II of the 13BBRP was constructed from January to March 2003. Maintenance dredge disposal of navigational channels in and around the Morehead City harbor placed 209,348 cubic yards of material at Fort Macon during early 2002. The Section 933 project proposed to place 6.3 mcy of material on Bogue Banks in 2003, 2004 and 2005. Phase III of the BBBRP is currently scheduled for the winter months of 2004 and 2005.

Response: See response to comment 12 within the NMFS letter (5.05) dated June 5, 2003, above.

Comment 11: The cumulative impacts of five large scale dredge and fill projects on the same barrier island within less than 4 years will be significant. Less than one mile of oceanfront beach on the island would remain undisturbed by fill placement in western Emerald Isle near Bogue Inlet. That less than one mile area would be indirectly impacted by the proposed Bogue Inlet Relocation Project during the same time period (as Bogue Inlet is proposed for relocation and/or mining for Phase III of the BBBRP). Migratory populations of waterbirds, shorebirds and fishery resources are not likely to have reliable sources of food along virtually the entire 26-mile long barrier island for a number of years.

Response: See response to comment 9, above, comment 2 within the Dr. C. H. Peterson letter (5.18) dated May 28, 2003, below, and comment 8 within the NCWRC letter (5.14) dated May 27, 2003, below.

Comment 12: Although the islands to the east and southwest of Bogue Banks are in conservation, several studies indicate that migratory birds have high site fidelity to migratory staging, stopover and overwintering sites that are smaller in areal extent (e.g., 10 kilometers (6.2 miles)) than Bogue Banks is long (e.g,, 41.8 km (26 mile) (Dinsmore et al. (1998); Pfister et al. (1998); Johnson and Baldassarre (1988)). The Section 933 project documentation concludes that habitat disturbance from beach fill projects is not likely to have population level impacts on avifauna Dinsmore et al. (1998, p. 171)), however, concluded that "habitat loss or alteration [on the Outer Banks of North Carolina] could adversely affect the Atlantic Flyway population of several [bird] species (e.g., Sanderlings) as well as the threatened Piping Plover." The draft EA does not adequately address the continuous perturbation of the Bogue Banks sandy beach ecosystem and the impacts it will have on migratory birds. Chronic disturbance of valuable foraging habitat may be more important than occasional disturbances and may affect shorebird survival rates (Pfister et al. (1992, 1998); West et al. (2002)). The Service disagrees with the Corps' finding that the proposed project will not significantly impact migratory bird populations and recommends that an Environmental Impact Statement be prepared to fully evaluate this concern.

Response: See response to Comment 9, above, Comment 8 within the NCWRC letter (5.14) dated May 27, 2003,below and Comment 2 within the Dr. C. H. Peterson letter (5.18) dated May 28, 2003, below. Additionally, see response to Comment 13, below regarding the need for an EIS.

Comment 13: As currently proposed, the Section 933 project anticipates a year-round construction schedule that would start November 16, 2003 and proceed for up to 16 months through April 30, 2005. The Corps proposes a Finding of No Significant Impact (FONSI) for this construction schedule, even though the generally accepted environmental window for dredge and fill projects in North Carolina occurs during the winter months from November 16 to the end of March or April annually. The Corps has determined that the year-round construction schedule and the use of hopper dredges may adversely impact federally-protected species such as sea turtles, piping plover *(Charadrius melodus)* and seabeach amaranth *(Amaranthus pumilus).* The Service contends that a FONSI is inconsistent with any shoreline stabilization or dredge disposal project (on beaches) scheduled for the summer months, which are the peak biological productivity period for coastal North Carolina.

Response: The construction window for the proposed Section 933 project has been revised (see Section 2.0 of the FONSI). We have reviewed all the comments received on the EA. Based our review of these comments and investigations required to respond to the comments, we believe that the EA/FONSI is an appropriate document for the proposed action and it fully complies with NEPA. Moreover, requirements for Section 7 of the Endangered Species Act of 1973, as amended have been met. The project is covered under a USFWS Biological Opinion dated July 22, 2003 and a NMFS Regional Biological Opinion dated 1997. All reasonable and prudent measures, as well as all terms and conditions of the USFWS Biological Opinion dated July 22, 2003 (See Appendix 2) and the NMFS Regional Biological Opinion dated 1997 (see letter dated June 13, 2003 from NMFS found in Appendix 2) will be complied with. Therefore, the proposed action will not adversely effect sea turtles, piping plovers, and seabeach amaranth within the project area.

Comment 14: 404(b)(1) Guidelines. Environmental impacts should first be avoided, then minimized. Any unavoidable environmental impacts should then be compensated with mitigation. The draft EA has determined that the proposed Section 933 project has avoided and minimized environmental impacts. The Service does not concur with this finding.

Response: See response to comment 2, above.

Comment 15: If the project proceeds, the Service has identified the following conservation measures to avoid and minimize environmental impacts from a Section 933 project at Pine Knoll Shores and Indian Beach: 1) Avoid periods of peak biological activity, limiting construction to the environmentally acceptable window of November 16 to March 1 annually.

Response: See response to comment 10 in the NMFS letter (5.05) dated June 5, 2003 above.

Comment 16: Conservation Measure 2) Use fill material that has been adequately evaluated and is ecologically compatible with the native beach material on Bogue Banks.

Response: See response to Comment 11: EFH Recommendations 3 within the NMFS letter (5.05) dated June 5, 2003, above.

Comment 17: Conservation Measure 3) Update the without project condition and existing conditions of the project area to include the locally constructed Bogue Banks Beach Restoration Project.

Response: See response to comment 9 found within the NMFS letter (5.05) dated June 5, 2003, above.

Comment 18: Conservation Measure 4) Avoid pumping out Brandt Island during colonial waterbird and shorebird nesting seasons, when these species are likely to be nesting on Brandt Island,

Response: See response to Comments 11 and 12 within the NCWRC letter (5.14) dated May 27, 2003, below.

Comment 19: Conservation Measure 5) Avoid destruction of habitat for the as yet unidentified skipper (*Atrytonopsis* new species 1) Brandt Island, which may be endemic to the greater project area, until ecological studies of the species are completed.

Response: See response to comment 13 within the NCWRC letter (5.14) dated May 27, 2003, below.

Comment 20: Conservation Measure 6) Avoid complete elimination of nesting waterbird and shorebird habitat on Brandt Island by configuring the remaining dikes and spoil material to include a bare sand island less than 15 feet in elevation and separated from vegetated areas by a minimum of 100 yards of deep water.

Response: See response to comment 12 within the NCWRC letter (5.14) dated May 27, 2003, below.

Comment 21: The Service has also identified several potential measures for compensatory mitigation for unavoidable ecological impacts: 1) Maintain a semi-permanent bare ground nesting island within the Brandt Island complex for shorebird and waterbird nesting, separated from vegetated areas by at least 100 yards of deep water to minimize predation of nests.

Response: See response to comment 12 within the NCWRC letter (5.14) dated May 27, 2003, below.

Comment 22: Compensatory Mitigation 2) Enhance shorebird and waterbird nesting and foraging habitat in the area by working with the local sponsors to implement leash laws, bird nesting areas (denoted by signage and post and rope fencing), prohibiting beach driving in certain areas, and banning kites and fireworks. West Point near Bogue Inlet is a potential location for such mitigation.

Response: See response to comment 14 within the NCWRC letter (5.14) dated May 27, 2003, below.

Comment 23: Compensatory Mitigation 3) Implement year-round bird monitoring in the project area to determine the longevity of ecological impacts to nesting and foraging waterbirds and shorebirds,

Response: See response to comment 15 within the NCWRC letter (5.14) dated May 27, 2003, below.

Comment 24: Compensatory Mitigation 4) Implement a survey and monitoring program for the unnamed skipper to aid in the identification, description and conservation of this potentially new species.

Response: See response to comment 13 within the NCWRC letter (5.14) dated May 27, 2003, below.

Comment 25: Compensatory Mitigation 5) Enhance the recovery of macroinvertebrate species in the fill placement areas by harvesting and transplanting dominant species or stocking the new fill material with cultured populations.

Response: See response to comment 9 within the NCWRC letter (5.14) dated May 27, 2003, below.

Comment 26: Compensatory Mitigation 6) Design a remediation plan for inadvertent placement of incompatible fill materials on the beach. Remediation measures may include removal of incompatible material, replacement with compatible material, and increased scientific monitoring of the magnitude and longevity of ecological impacts. The Service believes that incorporation of these conservation measures to avoid, minimize and mitigate for ecological impacts would satisfy the 404(b)(1) guidelines. At present the draft EA does not include conservation measures to sufficiently avoid and minimize impacts.

Response: See response to Comment 13 within the NMFS letter (5.05) dated June 5, 2003, above.

Comment 27: In conclusion, the Service does not believe that the proposed Section 933 project for Bogue Banks, as presently designed, gives equal consideration to fish and wildlife resources. The project as proposed does not meet the criteria of the Service's Mitigation Policy. A Finding of No Significant Impact is not warranted and the Service requests an Environmental Impact Statement be prepared. The ecological impacts of the project are likely to be significant, particularly if the current perturbations to the Bogue Banks sandy beach ecosystem and the migratory populations that it supports are continued. In accordance with the procedural requirements of the 1992 404(q) Memorandum of Agreement, Part IV.3(a), we are advising you that the proposed work may result in substantial and unacceptable impacts to aquatic resources of national importance.

Response: See response to comment 14 within the NMFS letter (5.05) dated June 5, 2003, above. The procedural requirements contained in 1992 404 (q) MOA, part IV, 3(a) strictly deals with Regulatory issues (i.e., individual Section 404 permit issues) and not civil works projects. The proposed 933 project is a civil works action and is consistent with Section 404 requirements.

By letter dated July 21, 2003, the USFWS commented on the Draft Unsigned FONSI. USFWS comments that were not addressed above dealt largely with the Bogue Banks Long-term Shore Protection study, beach access, Section 7 consultation, construction window, monitoring of the project by the Corps' inspector, sand compatibility issues, unsuitable material found within the navigation channels, developing a feasibility plan for beach restoration in the event that incompatible material is placed on the beach, and the Corps considering waterbird nesting habitat on the proposed 61-acre Environmental Sustainable Confined Disposal Facility (ESCDF) near Pelletier Creek, off Bogue Sound, in Morehead City.

Monitoring data from the locally funded beach nourishment project will be used to prepare an environmental impact statement (EIS) for the proposed the Bogue Banks Long-term Shore Protection study. Beach access issues are addressed in the NCCF (5.21) and Duke University (5.22) letters, below. We have revised the sections in the FONSI dealing with Section 7 consultation. During the construction of the Section 933 project, if the contractor experiences mechanical difficulties or delays from November 1, 2003 to April 30, 2004, he would be given an equal amount of time during May 2004. This means that if the contractor experiences 13 days down time (from November 1, 2003 to April 30, 2004), he would be given 13 days in May to recover the down time. Under no circumstance, would the contractor be given an unequal amount of time (i.e., down 13 days and given 31 days to recover in May). The Corps inspector assigned to the Section 933 will ensure that suitable material is placed on Bogue Banks. The Corps inspector does not have the authority to direct the contractor to relocate but will notify the Contracting Officer in Wilmington, if problems arise. Sand compatibility issues have been already been addressed in the NMFS letter (5.05) dated June 5, 2003, above. Additionally, regarding unsuitable material within the navigation channels, see response to Comment 13 within the NMFS letter (5.05) dated June 5, 2003. The Corps will not remove unsuitable material from Bogue Banks, since the material from the inner harbor is compatible (see Table 1). Lastly, the ecologically sustainable confined disposal facility (ESCDF), which is under consideration for development in Bogue Sound near Peletier Creek is anticipated to provide several categories of environmental enhancement benefits. Components of the plan will continue to be coordinated with other agencies prior to its finalization, so that habitat value can be included for the resources of greatest concern. However, no commitments can be made to the proposed Section 933 project with regard to the proposed ESCDF, because it would be a part of the Atlantic Intracoastal Waterway (AIWW) project. Its funds, management, and commitments would all be linked to the AIWW project, and it cannot bear commitments on behalf of other Federal projects.

5.08 North Carolina Department of Administration, Ms. Chrys Baggett, Environmental Policy Act Coordinator; letter dated June 9, 2003. (Transmitting the following intergovernmental review comments and recommendations.)

Comment 1: The above referenced environmental impact information has been submitted to the State Clearinghouse under the provisions of the National Environmental Policy Act. According to Q.S. 113A-10, when a state agency is required to prepare an environmental document under the provisions of federal law, the environmental document meets the provisions of the State Environmental Policy Act: Attached to this letter for your consideration are the comments made by agencies/organizations tip this office in the course of this review.

Response: Noted.

Comment 2: If any further environmental review documents are prepared for this project, they should be forwarded to this office for intergovernmental review. Should you have any questions, please do not hesitate to call.

Response: Noted.

5.09 NCDENR; memorandum to Ms. Chrys Baggett, NC State Clearinghouse, from Ms. Melba McGee, Environmental Review Coordinator, dated June 6, 2003, (which transmitted the following NCDENR Division letters to the State Clearinghouse).

Comment 1: The Department of Environment and Natural Resources has completed its review of the proposed draft evaluation report. The purpose of this report is to investigate the placement of dredged maintenance material along a portion of Bogue Banks beaches.

Response: Noted.

Comment 2: The primary concern with the beach disposal is the potential for indirect impacts to mole crabs, coquina clams, sea turtles and shore birds due to potential reductions on food resources. The department is equally concerned with the effects of year round disposal on fish and birds, the quality of the disposal material, its effect on sand temperature, meeting recommended moratorium deadlines and monitoring. The department does not believe the Environmental Assessment provided a thorough discussion of these points and believes division's concerns should be thoroughly addressed prior to this project moving forward. It is our recommendation that the Corps of Engineers would benefit more by preparing an Environmental Impact Statement. The Environmental Impact Statement would give a more accurate picture of the direct impacts and evaluate whether the dredge disposal would have insignificant impacts on the beach ecosystem.

Response: See responses to memo's from NCDMF, NCWRC, and the letter from Dr. Charles H. Peterson, below, as well as the revised project description found in Section 2.0 of the FONSI. Additionally, we have reviewed all the comments received on the EA.

Based upon our review of these comments and investigations required to respond to NCDENR and other comments, we believe that the EA/FONSI is an appropriate document for the proposed action and it fully complies with NEPA.

Comment 3: Thank you for the opportunity to respond. The Corps is encouraged to notify our reviewing divisions with any problems or questions they may have in resolving their concerns. Final approval will depend on the impacts of this project being adequately addressed.

Response: Noted.

5.10 NCDENR; memorandum to Ms. Melba McGee, Environmental Coordinator, dated May 27, 2003, from Preston P. Pate, Jr., Director, Division of Marine Fisheries.

Comment: I have reviewed the following comments provided by the District Manager and/or Bio-Supervisor and concur with their recommendations.

Response: Noted.

5.11 NCDENR; E-mail to Ms. Melba McGee, Environmental Coordinator, dated June 6, 2003, from Mike Street, Division of Marine Fisheries.

Comment: Melba -- Mike Marshall and I have discussed the subject project. We agree that there are several issues of sufficient importance that they cannot be adequately addressed in a revised Environmental Assessment. Of special concern are cumulative impacts of this proposed one-time project and all the other proposed (reasonably foreseeable) and ongoing beach nourishment projects along Bogus Banks, including work in both Beaufort and Bogue Inlets. It is simply unrealistic scientifically to continue to examine these many projects independently when the effects of these projects are not independent. Therefore, the Division of Marine Fisheries urges that an Environmental Impact Statement be prepared for the subject project. Street.

Response: We understand that the local beach nourishment project (Department of the Army Permit #200000362) is important to consider in light of the proposed Section 933 project, that's why the local project was thoroughly described in Section 1.02 of the EA. The Cumulative Impact Assessment (CIA) found in Attachment E of the EA, takes into account the three phases of the local beach nourishment project on Bogue Banks, as well as the potential delay of Phase 3 until the NCDCM and U.S. Army Corps of Engineers, Wilmington District, Regulatory Division issues the required permits for the proposed Bogue Inlet Channel Relocation Project. The CIA considers known past, present and the reasonably foreseeable future sand placement on the statewide scale and the project vicinity (i.e., Bogue Banks) scale over a 50-year period from 1965 to 2015.

We have reviewed all the comments received on the EA and have revised the project description found in Section 2.0 of the FONSI. Based upon our review of these comments and investigations required to respond to NCDMF and the other comments, we believe that the EA/FONSI is an appropriate document for the proposed action and it fully complies with NEPA.

5.12 <u>NCDENR; memorandum to Ms. Melba McGee, Environmental Coordinator, dated May 19, 2003, from Mike Marshall, Division of Marine Fisheries</u>.

Comment 1: The NC Division of Marine Fisheries (DMF) has reviewed the subject environmental assessment (EA) under authority of G. S. 113-131 and according to the
Policies of the North Carolina Marine Fisheries Commission for Beach Dredge and Fill Projects, and we offer the following comments.

Response: Noted.

Comment 2: The subject EA discusses the impacts of lengthening the authorized beach disposal area for the Morehead City Harbor navigation project from 7 miles to 13 miles. The increased area will include western Pine Knoll Shores and Indian Beach along with the authorized areas of Fort Macon, Atlantic Beach and eastern Pine Knoll Shores. Continuous pipeline construction is proposed beginning November 16, 2003 and construction is possible after May 1, 2004 in western Pine Knoll Shores and Indian Beach.

Response: See our modified project description found in Section 2.0 of the FONSI and in response to Comment 1 within the NMFS letter (5.05) dated June 5, 2003, above.

Comment 3: Construction on a year round basis will result in impacts to local recreational and commercial fishing activities. Public trust uses of the surf zone and intertidal beach will also be affected during intensive use periods if construction extends into the summer months. These impacts should be examined in the EA.

Response: As indicated in our response to comment 2, above, we will no longer work year round on the beach and therefore the proposed action will not adversely impact local recreational and commercial fishing activities. See response to Comment 14 of the NMFS letter (5.05) dated June 5, 2003, above.

Comment 4: The EA does not address the effects of year round pumping on beach prey species. The anticipated rate of 200 feet per day could have significant impacts on populations of mole crabs and coquina clams if allowed during the months when these species inhabit the intertidal beach. These impacts need to be discussed.

Response: As indicated in our response to Comment 3, above, the proposed Section 933 project will no longer be accomplished year round. Therefore, we believe that beach prey species will not adversely be impacted. Also see response to Comment 2, within the Dr. C. H. Peterson letter (5.18) dated May 28, 2003, below

Comment 5: The EA rejects our earlier recommendation to monitor the impacts of the project and to coordinate that monitoring with the Bogue Banks monitoring plan. This course of action presents several problems that will affect our comments on further requests for large scale beach nourishment utilizing offshore borrow sites. The Morehead City Harbor Dredging and 933-beach disposal will progressively altered by pumping spoil onto sampling stations designed to evaluate the impacts of the Bogue Banks project. By May 1, 2004, at least three control stations and three monitoring stations will have been altered and two years of monitoring data, will not be collected or will be compromised for those sites. Those six sites are 40% of the sites to be sampled and 50% of the control sites. Monitoring of the Bogue Banks project has taken on higher significance due to the high shell content of much of the nourishment material. This material may require extended time for the beach to recover from making extended sampling critical. The impacts of the current project on this sampling should be addressed in the EA.

Response: Regarding monitoring, see response to comment 14 within the NMFS letter (5.05) dated June 5, 2003, above and the Environmental Commitments found in Section 9.0, below.

The schedule of monitoring for the “Bogue Banks Beach Restoration Project” (Department of the Army Permit #200000362) submitted by the Coastal Science Associates, Inc. indicates that Phase I sampling (Pine Knoll Shores to Indian Beach (including Salter Path)) will consist of two spring and fall post dredging analyses which **will end in November 2003 (emphasis added by the writer)**. The Bogue Banks Section 933 project will extend from Fort Macon to Indian Beach and is scheduled to begin construction on November 1, 2003. The Section 933 project will not impact the monitoring stations until after the Phase I monitoring has already been completed with two years post-disposal data collection. The three control sites located in Atlantic Beach, as part of the monitoring plan, will be impacted by the Section 933 project approximately in January of 2004 based on a dredging rate of 200 ft/day and a distance of about 10,140 ft from the start of disposal to the first control site. However, three additional control sites are located on the southern end of Emerald Isle which can continue to be used for the Phase II monitoring. These Emerald Isle control sites will be impacted by the final Phase III project, but Phase III construction has been delayed to the winter months of 2004 and 2005 and is contingent on the issuance of the required permits from NCDCM and USACE regulatory division for the proposed Bogue Inlet Channel Relocation Project.

While the locally preferred Section 933 will impact the three control locations in Atlantic Beach, the no action or base disposal plan, which already has agency approval and the required environmental clearances, would be implemented on November 1, 2003 if the 933 is not approved. The no action or base disposal plan would also impact these control locations in Atlantic Beach, but also not until the November 2003 sampling is complete. Portions of both Phase I and Phase II of the permitted local project contained material that did not match the existing beach conditions and concern of a longer infaunal recovery rate was evident. Monitoring by the IMS-UNC of Phase I of the Bogue Banks beach restoration project has compared the beach fill in Pine Knoll Shores and Indian Beach to control beaches in Emerald Isle. Post nourishment sampling has occurred at the ends of March, May, July and September. Prior to the proposed Section 933 project, two years of post disposal monitoring will have been recorded. The first post disposal monitoring documented a statistically significant decline in productivity of most animals with few signs of recovery after 5 to 8 months (Draft Fish and Wildlife Coordination Act Report Bogue Banks Shore Protection Project Carteret County, NC). Based on the historical literature, this type of impact is to be expected. Recent data collected March 2004, about one year later (one recruitment season) appear to indicate the recovery of several organisms after reduced numbers in March 2002, immediately following disposal activities, with some organisms exhibiting faster recovery rates than others. The primary recruitment period for macro invertebrate species on Bogue Banks is from May-September (Hackney, 1996; Diaz, 1980; Reilly and Bellis, 1978), therefore, it is expected that recovery will persist as sampling is conducted through September. Literature indicates that longer recovery rates can be expected with less compatible nourishment material (Hackney et al., 1996).

Monitoring performed by Coastal Science Associates, Inc., as a requirement of the Department of the Army permit #200000362, indicates a decline in the phylum's Mollusca and Arthropoda with large increases in the phylum Annelida. This appears to be consistent with previous beach nourishment studies in South Carolina (Van Dolah et al., 1994; P.C. Jutte et al., 1999). However, variability among and within transects makes this data difficult to interpret. The data were non-normally distributed and no non-parametric statistical tests for significance were performed, therefore, these data lack statistical validity. However, when subtracting control results normalizes the abundance data, the trend of declining mollusks and arthropods is reduced. When the data are normalized by subtracting the control results the impact is reduced to a 9% and 20% reduction, respectively. According to the Coastal Science Associates, Inc., (CSAi June 2002 B) first year post-disposal conclusions indicate that it is difficult to sort project impacts from the natural range of species diversity and abundance.

Comment 6: The possibility that a prolonged recovery period may be necessary for the Bogus Banks project indicates that further recovery time may be created by the additional nourishment in Pine Knoll Shores and Indian Beach. However, the initial recovery period may be reduced if the additional material is of better quality. Both of these possibilities should be examined in the EA.

Response: See our discussion on recovery times in our response to Comment 5, above as well as our response to Comments 2 and 3 in the Dr. Charles R. Peterson letter (5.18) dated May 28, 2003 (see below). See response to Comment 11: EFH Recommendations 3 within the NMFS letter (5.05) dated June 5, 2003, above, regarding compatibility.

Comment 7: Thank you for the opportunity to review and comment on the EA. DMF finds the EA inadequate unless it is amended as indicated.

Response: We have reviewed all the comments received on the EA and have modified the project description found in Section 2.0 of the FONSI. Based upon our review of these comments and investigations required to respond to NCDMF and other comments, we believe that the EA/FONSI is an appropriate document for the proposed action and it fully complies with NEPA.

5.13 NCDENR; memorandum to Guy Pearce, Consistency Coordinator, dated June 6, 2003, from M. Ted Tyndall, NC Division of Coastal Management.

Comment 1: The project is located on Bogue Banks in the communities of Atlantic Beach, Pine Knoll Shores, and Indian Beach (which includes Salter Path) and includes Fort Macon State Park. This office offers the following comments and recommendation on the subject project.

Response: Noted.

Comment 2: Brandt Island was previously pumped out back in 1986 and 1994. The material was placed onto the beaches of Atlantic Beach and Fort Macon. These projects were found consistent with the Coastal Management Program in late 1985 and amended in March of 1986. Then in early 1993; the DCM made a determination that the "base disposal area" covering some 6 miles of Atlantic Beach and Fort Macon remained consistent with the Coastal Management Program. Similarly, the area to be nourished under the authority of Section 933 includes over 7 miles of Pine Knoll Shores, Indian Beach and Salter Path, This is the same area that was authorized for beach nourishment under CAMA Major Permit #124-01 and most of which was completed.

Response: Noted.

Comment 3: Based on our review, this office would offer the following comments regarding the Draft Evaluation and Environmental Assessment. 1) On page EA-3, there is a statement that "beach-quality dredged material" must not have more than 10 percent fine sediment. This statement read in conjunction with the preceding statement on that page about the Coastal Management Program requiring beach-quality sand dredged from navigation channels not being permanently removed from the system is somewhat misleading. Currently, the Division of Coastal Management does not have any rules that reference a specific sand/silt percentage for beach deposition.

Response: We will remove any reference to the Division of Coastal Management having a specific sand/silt percentage for beach deposition in the FONSI.

Comment 4: 2) The document states that the towns of Atlantic Beach and Pine Knoll Shores will be responsible for surveying the first line of stable natural vegetation along the beach strand within their jurisdiction. By CRC rule, this line is the vegetation line that existed before commencement of the 1986 and 1994 projects. The division requests copies of these maps, preferably done as overlays on ortho aerial photographs.

Response: Noted. We have notified the towns of Atlantic Beach and Pine Knoll Shores of this requirement.

Comment 5: 3) The Division of Coastal Management would echo sentiments made by Jody Merritt, the Park Superintendent, in his February 2, 2002 letter regarding the importance of sand being placed on the recreation beach at the Fort. The Division of Coastal Management concurs that the beach access point near the western end of the Park should be a high priority for sand deposition. The sand pumped in front of the Port back in 2002 stopped short of this area leaving a very narrow useable beach at high tide.

Response: Noted. We plan to accommodate Fort Macon's request.

Comment 6: 4) The office would also request that if a consistency statement is issued that all commitments made in the EA, including those listed on page EA-52, be listed as conditions of that consistency,

Response: We agree to your request and have added to the commitments found in Section 9.0 of the FONSI. We plan to add the following commitment: Only beach compatible material will be placed on Bogue Banks from either the pumpout of Brandt Island or the maintenance dredging of the Morehead City Harbor navigation channels. We will include the following paragraph in the proposed Section 933 specifications, "*Materials: The dredging shall be accomplished so that the most suitable material available for beach disposal is placed within the prescribed section. Suitable materials shall be comprised of materials by ASTM D 2487 as SP, SP-SM, and SW. This material shall be predominantly of sand grain size with no more than 10% silt, shell, and clay material present. Should the dredge encounter materials not suitable for placement on the beach, the Contractor will be directed by the Contracting Officer to move to a more satisfactory location within Brandt Island or the navigation channels.*"

Comment 7: Based on our review, it appears that the proposal is consistent with the North Carolina Coastal Management Program.

Response: Noted.

5.14 NCWRC, memorandum to Ms. Melba McGee, Environmental Coordinator dated May 27, 2003, from Shannon Deaton, Section Manager, Habitat Conservation Section.

Comment 1: Biologists with the North Carolina Wildlife Resources Commission (Commission) reviewed the Environmental Assessment (EA) with regard to impacts of the project on fish and wildlife resources. Our comments are provided in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and the North Carolina Environmental Policy Act (G.S. 113A-1 et seq., as amended; 1 NCAC-25).

Response: Noted.

Comment 2: The United States Army Corps of Engineers (Corps) is proposing disposal of dredge material on Bogue Banks to replenish the eroding beaches and reduce the potential for storm damage. The Corps currently disposes of dredged material from the Brandt Island disposal site and Morehead City Harbor navigation channels along a 32,000' base disposal area extending from Fort Macon to Atlantic Beach. Under provisions of Section 933 of the Water Resources Development Act, the Corps, with cost-sharing support from Carteret County, is proposing extending the disposal area by 38,000' on beach along the towns of Pine Knoll Shores, Indian Beach, and Salter Path. If the Section 933 project is implemented, the existing base disposal area will receive 1.8 million cubic yards of material with a design berm width reduced from 150' to 30'. The Section 933 project area would receive approximately 4.5 million cubic yards of material to construct a design berm with a width of 30 feet and elevation of 7 feet. Project construction with pipeline and hopper dredges may begin November 16, 2003 and continue uninterrupted for up to 16 months. Hopper dredging would only be used in the Morehead City outer harbor from January 1 to March 31 of any year to minimize the potential take of sea turtles.

Response: See the revised project description found in Section 2.0 of the FONSI. The revised construction window is from November 1, 2003 to April 30, 2004 (to May 31, 2004, if required) and no pumping of material on the beach after May 31, 2004. No change is proposed for the hopper dredges (January 1, 2004 to March 31, 2004).

Comment 3: The proposed Section 933 project is inconsistent with our *Policies and Guidelines for Conservation of Wetlands and Aquatic Habitats*. The Commission recognizes that beach renourishment is sometimes necessary to counteract erosion that threatens developed coastal areas. However, renourishment should be conducted in a manner that minimizes direct, adverse impacts on wildlife resources and their habitat. Avoidance of critical nesting or foraging periods used to minimize impacts on wildlife resources and beach or dune construction activities during these critical periods should only be conducted when human health and safety are in eminent danger. Beach renourishment conducted from 2001 to 2002 along the Section 933 project area has largely precluded the urgency to conduct additional beach disposal during recommended moratoriums.

Response: We agree that the proposed Section 933 should be conducted in a manner that minimizes the direct adverse impacts to wildlife resources and their habitat. That is why we have revised the project description found in Section 2.0 of the FONSI. No year round dredging is proposed and the pumping of beach quality material on the beach will not extend past May 31, 2004. The majority (up to 86%) of the proposed Section 933 would be completed before the peak intertidal macrofauna recruitment time periods on Bogue Banks, from May to September (Hackney et al., 1996; Diaz, 1980; Reilly and Bellis, 1978).

Additionally, the environmental commitments found in Section 9.0 of the FONSI, will also minimize the impacts to wildlife resources and their habitat.

As indicated in Section 1.02 of the EA and the Coastal Analysis Appendix found in the Draft Evaluation Report (page Appendix C-24), states "phase 1 of the local nourishment project resulted in the placement of approximately 1.73 million cubic yards of material on Pine Knoll Shores to Indian Beach, a distance of 39,202 feet. The berm-only project averaged less than 45 cubic yards per foot, which is a very small beachfill." Table 1-1 in the EA provides maximum quantities (cubic yards per foot) for both the Section 933 and the base disposal plan. The average maximum sediment disposal rate (cubic yard per foot) is 88 for

Fort Macon, 49 for Atlantic Beach, 124 for Pine Knoll Shores, and 105 for Indian Beach (including Salter Path). The local nourishment project did not preclude the urgency to conduct the proposed Section 933 project (see Coastal Analysis Appendix found in the EA.

Comment 4: The Commission has the following additional comments and concerns regarding impacts of the proposed project on fish and wildlife resources and recommended mitigation strategies for those impacts:

Sea Turtle and Shorebird Impacts. The Commission disagrees with the inference that beaches on Bogue Banks are suitable for only loggerhead (*Caretta caretta*) turtles. In fact, during the 2000 nesting season, there was a confirmed green (*Chelonia mydas*) turtle nest on Bogue Banks and habitat there is also suitable for leatherback (*Dermochelys coriacea*) turtles. Given that nesting by both leatherbacks and green turtles has sharply increased in the last 10 years in the Southeastern United States, and North Carolina represents the northern limit of nesting for both of these species, increased nesting in the state in the near future would not be unexpected. Therefore, Bogue Banks must be considered suitable nesting habitat for loggerheads, as well as greens and leatherbacks.

Response: There is no inference in the EA that the beaches at Bogue Banks are **only** suitable for loggerhead sea turtles. However, our discussions with Matthew H. Godfrey and Nicole A. Mihnovets indicate that the majority of nesting sea turtles at Bogue Banks are loggerheads. We also agree that green, as well as leatherbacks may nest on Bogue Banks since we indicated in our Biological Assessment (Attachment D of the EA) that, "It has been determined that the project, as currently proposed, may affect the piping plover, **green sea turtle, loggerhead sea turtle, hawksbill sea turtle, leatherback sea turtle, Kemp's ridley sea turtle (emphasis added by the writer)**, and seabeach amaranth."

Comment 5: Restricting hopper dredging between January and March is appropriate because water temperatures are cool and sea turtle abundance is likely to be lowest. However, as experienced with other similar projects, anticipated schedules are sometimes delayed, which places sea turtles at substantial risk. Therefore, the Commission feels that contingency sea turtle protection plans need to be prepared including anticipatory trawling to remove any turtles in the project area.

Response: By letter dated, June 13, 2003, National Marine Fisheries Service (NMFS) has informed us that if the hopper dredges comply with the 1997 Regional Biological Opinion (RBO) for the Continued Hopper Dredging of Channels and Borrow Areas in the Southeastern United States that we would not adversely effect sea turtles. The 1997 NMFS RBO has no hopper dredging window, however the Corps of Engineer, South Atlantic Division and the Wilmington District Protocols indicate that for Morehead City Harbor, hopper dredging can only be conducted from 1 January to March 31 of any year. See response to comment 3 within the NMFS letter (5.04) dated June 13, 2003, above.

Comment 6: In addition to in-water measures, if renourishment occurs during the sea turtle nesting season, sufficient time must be provided on a daily basis to allow volunteers/monitors to locate at-risk nests for subsequent relocation. The Commission recommends a no-work window until 10 am each day during the nesting season to ensure sufficient time to get any nests off the beach, and also to locate any turtles that nest late into the night and do not return to the ocean until around sunrise. Effective communication between the monitors and the dredge workers is essential to these mitigation efforts.

Response: We disagree. We believe that the established sea turtle nest monitoring and relocation protocol provides adequate protection of these species. Moreover, requirements for Section 7 of the Endangered Species Act of 1973, as amended have been met. The project is covered under a USFWS Biological Opinion dated July 22, 2003 and a NMFS Regional Biological Opinion dated 1997. All reasonable and prudent measures, as well as all terms and conditions of the USFWS Biological Opinion dated July 22, 2003 (see Appendix 2) and the NMFS Regional Biological Opinion dated 1997 (see letter dated June 13, 2003 from NMFS found in Appendix 2) will be complied with. Therefore the proposed action will not adversely effect sea turtle nesting within the project area. Additionally, the daily active beach construction zone averages about 200 feet. That means the bulldozers and the spreader (i.e., the end of the discharge pipe) will be actively working within the daily 200-foot section of beach. It is unlikely that a sea turtle would attempt to nest in the 200-foot long construction zone that has that much activity (i.e., lights for the safety of the workers, bulldozers, flowing water, etc.). The remainder of the beach would be available for sea turtle nesting purposes. Also, this proposal would dramatically increase costs and create an unacceptable delay in the completion of the proposed Section 933.

Comment 7: The Commission is encouraged by the prospect that the material proposed for placement on the beaches might be more suitable material than that placed by previous renourishment work on Bogue Banks. However, recent work also resulted in the placement of incompatible materials on the beach despite extensive pre-project sediment quality testing of the source areas. Therefore, the Commission feels that, in additional to thorough testing of the dredge and pumpout areas, a inviolate protocol for monitoring, communicating, and responding to any unforeseen placements of incompatible material on the beach should be implemented for any Section 933 project on Bogue Banks.

Response: See response to Comment 11: EFH Recommendations 3 within the NMFS letter (5.05) dated June 5, 2003, above regarding compatibility.

The proposed Section 933 action is a civil works project and therefore Corps' inspectors will be assigned to monitor the hydraulic dredge, pipeline route, booster pumps (if required), and placement sites on the beach. These inspectors review the ongoing work for safety, as well as making sure that the contractor complies with all conditions (found in the plans and specifications) of the contract. We will include the following paragraph in the proposed Section 933 specifications, "*Materials: The dredging shall be accomplished so that the most suitable material available for beach disposal is placed within the prescribed section. Suitable materials shall be comprised of materials by ASTM D 2487 as SP, SP-SM, and SW. This material shall be predominantly of sand grain size with no more than 10% silt, shell, and clay material present. Should the dredge encounter materials not suitable for placement on the beach, the Contractor will be directed by the Contracting Officer to move to a more satisfactory location within Brandt Island or the navigation channels.*" If problems occur during construction anywhere along the pipeline route or if the contractor is not abiding by the conditions of the contract (i.e., pumping material to the beach that is not suitable), these Corps inspectors would immediately notify the Contracting Officer (CO) located at the District office and the CO would direct the contractor to move the dredge to a more suitable site in Brandt island or the navigation channels.

Comment 8: Several factors would counteract the perceived benefit of additional disposal of more compatible material so soon after the previous renourishment project. The EA states, "migratory shorebirds may use the project area for foraging and roosting habitat, but would not be adversely affected by the proposed action." While the beachfront of Bogue Banks does not support much nesting habitat because of the extensive development, some nesting by Wilson's plovers (*Charadrius wilsonia*), willets (*Catoptrophorus semipalmatus*) and American oystercatchers (*Haematopus palliatus*) may still occur on wider beach stretches and migratory shorebirds such as sanderlings (*Calidris alba*) and ruddy turnstones (*Arenaria intrepres*) do forage and roost in the project area. Any depletion of the prey base could certainly have a negative affect on these latter bird species. The pumping of sand onto the beach covers and depletes invertebrate resources and successive burial, as would be the case for Indian Beach and Pine Knoll Shores, greatly delays recovery. Further, renourishment during the months of March through May is particularly destructive since this is the primary recruitment period for most beach macroinvertebrates. The EA also mentions a recent year-round study of shorebird use in Brunswick County, North Carolina (USACE 2002). Although this report indicated that beach nourishment had "no measurable impact on bird use during the first year of monitoring.", it was also concluded that "…the power for all statistical comparisons regarding the effects of renourishment was generally low, indicating that additional surveys or data will be required prior to confident conclusions."

Response: The primary recruitment period for macro invertebrate species on Bogue Banks is from May-September (Hackney, 1996; Diaz, 1980; Reilly and Bellis, 1978), not March through May. See our response to comment 2 in Dr. Charles H. Peterson letter (5.18) dated May 28, 2003, below regarding depletion of the prey base (i.e., beach macroinvertebrates) for shorebirds. The recent year-round study of shorebird use in Brunswick County (USACE 2002) quoted in the EA and in your comment was the first year report of the study. The second year report has been completed and is located at http://www.saw.usace.army.mil/wilmington-harbor/main.htm under Monitoring Reports. The results of the second year report (USACE 2003), Section 5.0 Summary, page 18 states "Despite the potential for community changes at renourished beaches, in this study, beach renourishment was not found to alter the overall abundance or species richness of waterbirds and shorebirds. A clear renourishment effect was not evident for individual species either, including willet and sanderling, which are heavily dependent on beach habitat. Moreover, examination of weekly survey data revealed no consistent short-term changes in abundance or species richness in the weeks following beach renourishment". These results should be applicable to Bogue Banks.

Comment 9: Since renourishment would deplete beach macro invertebrate populations, particularly if conducted during the primary recruitment period, the Commission recommends implementation of a restocking program for coquina clams and/or mole crabs to accelerate recovery from any Section 933 project. This program could either involve collection at the project site before spoil placement or possibly the use of cultured sources of these invertebrates.

Response: See response to Comment 8, above regarding depletion of the prey base (i.e., beach macroinvertebrates) for shorebirds. As indicated in Section 9.0 of the FONSI, to the maximum extent practicable and during the warmer months, we will try to reduce direct impacts to intertidal macrofauna by relocation to completed portions of the beach.

Comment 10: In addition to impacts on macro invertebrate resources and waterbirds, the new spoil material may adversely effect sea turtle nesting. For example, the disposal may alter the thermal environment during incubation, and hence alter the sex ratios of the hatchlings produced by eggs laid there in future years. Similarly, turtle nests moved from the work area may experience different temperatures in their relocated positions. If such measures are implemented, the Commission recommends that dataloggers be purchased to not only monitor sand temperatures both pre and post project, but also nest temperatures of relocated nests. The Commission has some dataloggers for Atlantic Beach to Bogue Inlet, but more (approximately 20) are needed to monitor sand temperatures of the beach in Fort Macon and also nest temperatures of any nests that are relocated because of a Section 933 project.

Response: See response to Comment 6, above regarding the project adversely effecting sea turtle nesting. As indicated, requirements for Section 7 of the Endangered Species Act of 1973, as amended have been met. On May 9, 2003, the Wilmington District provided funds via USFWS to NCWRC for the purchase of Hobo H8 dataloggers, a Munsell soil color chart, and a soil compaction meter for the monitoring of sand temperatures in Atlantic Beach. On July 31, 2003, we again provided additional funds via USFWS to NCWRC for the purchase of dataloggers to monitor sand temperatures both pre and post project and for nest temperatures of relocated nests.

Comment 11: Brandt Island Habitat: Brandt Island is a site of extraordinary nesting numbers of North Carolina's highest priority migratory bird species. In particular, as many as 576 pairs of common terns (*Sterna hirundo*) have nested on the site with as many as 182 pairs of black skimmers (*Rynchops niger*), 175 pairs of state threatened gull-billed terns (*Sterna nilotica*) and 90 pairs of least terns (*Sterna albifrons*). In comparison, the entire nesting population of these four species in North Carolina based on the last statewide census is as follows:

common tern = 1131 nests
black skimmer = 594 nests
gull-billed tern = 258 nests
least tern = 1742

Clearly, Brandt Island is very important to these four colonial nesting species, although habitat quality there is declining because of tall vegetation and increased predator populations. However, other priority species such as Wilson's plovers and American oystercatchers nest on the site each year regardless of the mammalian predators that have managed to populate the area.

Response: We agree that Brandt Island has provided valuable habitat for waterbirds, but according to the NC Colonial Waterbird Program Data Base developed and maintained by NCWRC, the last time 576 nests of common terns and 182 nests of black skimmers occurred on Brandt Island was in 1983 and 1977, respectively. This same database indicates that in 1983 the total nests on Brandt Island was 855 and in 1988 there was a total of 9 nests (Black skimmer-2 nests, Common tern-5 nests, and Gull-billed tern-2 nests). Results since then indicate that Brandt Island has been surveyed, but the numbers of nests and/or types of waterbirds are not mentioned in the NC Colonial Waterbird Program Data Base.

Comment 12: While pumpout of Brandt Island during the nesting season is strongly discouraged, if it does occur, measures should be taken to mitigate for the disturbance. Given the ephemeral nature of waterbird nesting habitat there, we feel it is imperative that pumpout activities be done in a way consistent with the continued use of this site by nesting waterbirds. This will entail a simple modification of the pumpout activities so that a small isolated island is retained with the remaining 5-10 acres in a dome (less than 15 feet above mean high tide) of primarily sand and shell that is void of heavy grass or shrubs. The island should be separated from remaining disposal areas with at least 100 yards of deep water. Whether or not the Section 933 project is implemented, the base plan could also implement the pumpout activities to isolate the nesting island.

Response: Brandt Island is owned and used as a sand recycling site by the North Carolina State Ports Authority (NCSPA) and is dedicated for the purpose of dredged material disposal. In 1986 and 1994, Brandt Island was pumped out and the resultant material was placed on Bogue Banks. The Corps' most current survey of the approximately 96-acre Brandt Island indicates that top of dike averages about 40 feet above mean sea level. The height has increased the effects of wind blown sand, which destroys nests, and the islands' size enables predators to survive year round. Additionally, as you indicated in Comment 11, the habitat quality is declining due to tall vegetation and predation.

As indicated in the EA, the pumpout of Brandt Island will be initiated on November 1, 2003, whether or not the Section 933 is funded. If the proposed action extends into the waterbird nesting season (1 April to August 31 of any year), we will work with representatives of NCWRC to reduce impacts to nesting waterbirds. Over the years, the Corps has worked with NCWRC, Audubon Society and other agencies to protect and restore waterbird habitat. Wainwright Island, Battery Island, Ferry Slip Island, and Pelican Island are examples of the Corps' commitment to this principle.

We cannot agree to create a 5 to 10 acre dome of sand separated by 100 yards of deep water on Brandt Island. By creating this island, the dredge material capacity of Brandt Island would be severely reduced for Morehead City Harbor. By reducing the capacity of Brandt Island, this could possibly mean more frequent pumpouts to Bogue Banks. Lastly, we do not own the island and cannot make any commitments on NCSPA's property.

However, the Corps is proposing to construct the 61-acre Environmental Sustainable Confined Disposal Facility (ESCDF) near Pelletier Creek, off Bogue Sound, in Morehead City. About 21 acres of the ESCDF would be upland and we could consider using a portion of the area for colonial waterbird habitat. Of course, that decision would be contingent upon the topographic area, elevation, etc., of the proposed ESCDF.

Comment 13: Since Brandt Island serves as habitat for an undescribed skipper, the Commission believes that surveys and subsequent monitoring for this species are appropriate. Information is needed about this species to assess the impacts of the proposed Brandt Island pumpout, and possibly the subsequent mitigation efforts to create more suitable shorebird habitat.

Response: On June 16, 2003, representatives of Corps, USFWS, NC Natural Heritage Program and NCSPA met on Brandt Island to discuss this matter. The purpose of this meeting was to observe and discuss habitat management options that may be viable on Brandt Island and surrounding islands for the host plant Seaside Little Bluestem (*Schizachyrium littorale*) and the "Banks Skipper" (*Atrytonopsis* sp.). The U.S. Fish & Wildlife will be requesting a meeting of stakeholders to discuss long-term habitat management strategies. At a minimum, this meeting would include the USACE, USFWS, Natural Heritage, NCSPA, NC Parks and Coastal Management. Both the USACE and the NCSPA stated they were willing to "come to the table and discuss potentials" for addressing the USFWS concerns regarding habitat management of the host plant and "Banks Skipper". We may meet in September 2003, to discuss these issues.

Comment 14: Additional Shorebird Mitigation. There are some opportunities to protect the West Point near Bogue Inlet as mitigation for foraging area losses, and perhaps nesting habitat losses, attributable to the Section 933 project and Brandt Island pumpout. These measures include year-round posting of mud/sand flats, a year-round leash law for dogs, no driving on the spit and a ban on fireworks and kites. The Commission believes that the magnitude of the proposed project warrants these mitigation efforts.

Response: The project does not warrant mitigation beyond that indicated in the EA. We believe from our review of the existing data (see response to comment 2 in Dr. Charles H. Peterson letter (5.18) dated May 28, 2003), that the proposed action will not adversely effect foraging area habitat for shorebirds. Additionally, if the Section 933 is funded, the majority (perhaps up to 86%) of the proposed Section 933 would be completed by April 1, 2004 (see response to Comment 3, above). If the Section 933 project is not funded, the base disposal plan may be completed at or before April 1, 2004, which should not adversely impact nesting habitat.

Comment 15: The Commission believes year-round bird monitoring on the beach as well as Brant Island should be implemented.

Response: A recent year round study in Brunswick County, NC documents in detail shorebird use there (USACE 2002). This report indicated that beach nourishment had no measurable impact to bird use during the first year of monitoring. The second year report has been completed and is located at http://www.saw.usace.army.mil/wilmington-harbor/main.htm under Monitoring Reports. The results of the second year report (USACE 2003), Section 5.0 Summary, page 18 states "Despite the potential for community changes at renourished beaches, in this study, beach renourishment was not found to alter the overall abundance or species richness of waterbirds and shorebirds. A clear renourishment effect was not evident for individual species either, including willet and sanderling, which are heavily dependent on beach habitat. Moreover, examination of weekly survey data revealed no consistent short-term changes in abundance or species richness in the weeks following beach renourishment". These results should be applicable to Bogue Banks.

Comment 16: Based on the preceding concerns, the Commission feels that a Finding of No Significant Impact for the proposed project is not appropriate and that an Environmental Impact Statement should be prepared. The Commission appreciates the opportunity to comment on the impacts of the project on fish and wildlife resources.

Response: We have reviewed all the comments received on the EA and have modified the project description found in Section 2.0 of the FONSI. Based upon our review of comments and investigations required to respond to your and other comments, we believe that the EA/FONSI is an appropriate document for the proposed action and it fully complies with NEPA.

By memorandum dated July 16, 2003, NCWRC commented on the Draft Unsigned FONSI. NCWRC had the same issues indicated in their earlier letter dated May 27, 2003 (i.e., construction window, cumulative impacts, recovery of macro invertebrates, impacts to shorebirds, etc.) These issues are addressed above. NCWRC wanted the Corps to consider waterbird nesting habitat on the proposed 61-acre Environmental Sustainable Confined Disposal Facility (ESCDF) near Pelletier Creek, off Bogue Sound, in Morehead City.

The ecologically sustainable confined disposal facility (ESCDF), which is under consideration for development in Bogue Sound near Peletier Creek is anticipated to provide several categories of environmental enhancement benefits. Components of the plan will continue to be coordinated with other agencies prior to its finalization, so that habitat value can be included for the resources of greatest concern. However, no commitments can be made to the proposed Section 933 project with regard to the proposed ESCDF, because it would be a part of the Atlantic Intracoastal Waterway (AIWW) project. Its funds, management, and commitments would all be linked to the AIWW project, and it cannot bear commitments on behalf of other Federal projects. As indicated during our inter agency meeting on June 24, 2003, a representative from Carteret County stated that they would continue monitoring the Phase 1 area (Pine Knoll Shores to Indian Beach (including Salter Path)) beyond November 2003, if adequate recovery of mole crabs and coquina clams does not occur. If required the monitoring would be extended to November 2004. Please note if the Section 933 project is not funded, Carteret County will not extend the monitoring until November 2004.

5.15 Memorandum to Jim McRight, Public Water Supply from Patti Fowler, Shellfish Sanitation and Recreational Water Quality Section dated May 20, 2003.

Comment: The Shellfish Sanitation and Recreational Water Quality Section would have no objection to the above mentioned project provided that beach disposal occurs only between November 1 and April 30, when recreational usage is low end that clean sand Is used and not dredged sand from closed shellfishing areas. If beach disposal was to occur at times other than stated above or if sand from a closed shellfishing area is to be used, a swimming advisory may be posted and a press release may be made. Please notify this office when such disposal occurs.

Response: As indicated in Section 9.0 of the FONSI, entitled Environmental Commitments, number 6 states "Within Morehead City Harbor, some of the navigational channels are closed to shellfish harvesting. By Memorandum dated January 31, 2002, from the North Carolina Department of Environment and Natural Resources, Division of Environmental Health, Shellfish Sanitation and Recreational Water Quality Section (see Attachment B of the main report), if maintenance material is excavated from these closed shellfishing areas between May 1 and October 31 and placed on Bogue Banks a swimming advisory will be posted and a press release made. The Wilmington District will notify the Shellfish Sanitation and Recreational Water Quality Section prior to dredging from a closed shellfishing area with placement on a recreational swimming area."

5.16 Memorandum to Ms. Melba McGee, Environmental Coordinator from Guy C. Pearce, Consistency Coordinator dated June 5, 2003.

Comment: The subject project is currently under a consistency review by the Division. Our office will make comments on the proposed project during consistency determination. If you have any questions, or wish to discuss this matter further, please contact me at (919) 733-2293, ext.249. Thank you.

Response: Thank you for your help in this matter.

5.17 Checklist from the Wilmington Regional Office, NCDENR dated May 23, 2003.

Comment: The Sedimentation Pollution Control Act of 1973 must be properly addressed for any land disturbing activity. An erosion & sedimentation control plan will be required if one or more acres to be disturbed. Plan filed with proper Regional Office (Land Quality Section) at least 30 days before beginning activity. A fee of $40 for the first acre or any part of an acre.

Response: The District will file the required erosion & sedimentation control plan with the proper Regional Office (Land Quality Section) at least 30 days before beginning activity.

5.18 Letter to Chrys Baggett from Dr. Charles H. Peterson, Professor of Marine Sciences, University of North Carolina at Chapel Hill, letter dated May 28, 2003.

Comment 1: I write in response to my review of the EA for the deposition of dredged materials on 13 miles of the Bogue Banks beaches as part of a proposed 933 project. I serve as a member of the NC Environmental Management Commission, the Chair of the Water Quality Committee, a member of the Inter-commission Team on Coastal Habitat Protection Plan for fisheries, a member of the Science Panel on Coastal Hazards for the NC Coastal Resources Commission, and a two-term former member of the NC Marine Fisheries Commission. I also am professor of marine ecology at UNC, with extensive experience on sand beach ecology. Thus I have both management and scientific experience and expertise.

Response: Noted.

Comment 2: The EA is so grossly inadequate in its failure to treat cumulative impacts as to be in full violation of NEPA at the federal level and its state counterpart. Specifically, the beaches of Pine Knoll Shores, Salter Path, and part of Indian Beach were already nourished in winter 2001-2. The benthic biological communities of the beach and the shorebirds that utilize them as vital prey have not yet recovered from that event that occurred over one and a half years ago. I have data on this absence of recovery that I am happy to share and have shared with federal and state agencies from an ongoing monitoring project that we are conducting under Sea Grant funding. This EA violates NEPA and the state counterpart in the area of cumulative impacts in two ways. First, there is no mention and analysis of the cumulative impacts issue. So there is a procedural violation. Second, the available information known to the USACE and to DENR from our research on the last nourishment is not used to construct a credible evaluation of how a second perturbation will affect the beach ecosystem and its ecosystem services to fish and wildlife before recovery from the first one has even occurred. The spatial issue of cumulative impacts also needs attention because the majority of the western end of Bogue Banks has also been nourished and our data show that this project has had a huge impact on the benthic invertebrates and vertebrate consumers as of the present date. Many of these species would normally help in recovery of eastern Bogus Banks through migration but cannot because they are depleted in the potential source area. Both temporal and spatial aspects of cumulative effects are utterly ignored in this EA.

Response: Attachment E found in the EA contains the Corps' Cumulative Impact Assessment (CIA), which follows the 11-step process outlined by the Council on Environmental Quality (CEQ) in their 1997 publication Considering Cumulative Effect Under the National Environmental Policy Act. Additionally Section 5.14 of the EA summarizes the CIA and refers to the cumulative analysis of existing, proposed, and potential project involving the placement of sand material on the beach and directs the reader to Attachment E of Draft Evaluation Report. The CIA also addresses the three-phase local beach nourishment project. Moreover the CIA considers known past, present and the reasonably foreseeable future, sand placement on a statewide and project vicinity (i.e., Bogue Banks) scale over a 50-year period of analysis from 1965 to 2015. The EA complies with all NEPA requirements.

The Corps has requested and reviewed the data collected by Dr. Charles Peterson and Associates at IMS-UNC. The data lacks statistical analyses and is therefore difficult to interpret scientifically. Without an evaluation of the data under statistical scrutiny, it is not possible to separate variability among and within transects and spatial and temporal variability. Therefore, it is difficult to make any sound scientific conclusions about disposal impacts on macro invertebrate populations. However, what can be interpreted based on the data presented is presence or absence of organisms in the different site locations.

The data are collected in two month increments throughout one recruitment season immediately following Phase I impacts at Pine Knoll Shores (November 2001-April 2002) with the addition of March 2003 data and the figures are grouped into with and without Bear Island as a control. Those figures that included Bear Island as a control were not included in the analysis since no beach scraping or other manipulation has ever occurred on this island. To better understand pre- and post-project impacts on Bogue Banks, the Corps believes that the control transects should be located on the same beach which has been subject to similar historical dynamics.

The Corps has evaluated the data with respect to recruitment periods in order to provide a more representative assessment of post-disposal organism presence. The recruitment period for macro invertebrate populations on Bogue Banks, North Carolina is from May-September with peak recruitment occurring from July-September (Hackney et al., 1996; Diaz, 1980; Reilly and Bellis, 1978). As indicated in the literature, based on these recruitment periods and the data that has been collected by Peterson thus far, there has only been one complete recruitment period within the 1.5-year timeframe. Literature dating back to the early 1970's along the southeast coast indicate that opportunistic infauna species (ex. *Emerita* and polychaetes) found in the nourished areas are subject to direct mortality from burial, however, recovery often occurs between 1 to 3 years depending on sediment compatibility and the relationship of nourishment placement to recruitment timeframes (Hayden and Dolan, 1974; Saloman, 1984; Nelson, 1989; Van Dolah et al., 1992; Van Dolah et al., 1993; Hackney et al. 1996; P.C. Jutte et al., 1999).

Sediment compatibility will affect species differently depending on the grain size and sorting characteristics. *Emerita* may be negatively impacted by the introduction of finer grained sand while polychaete populations may increase (Hackney et al, 1996). The increase in fast growing opportunistic species such as polychaetes is often evident immediately following nourishment (Coastal Science Associates, Inc.; C.H. Peterson, IMS-UNC; P.C Jutte et al., 1999). Species that require a longer growing season may require a longer recovery period. The material placed on Bogue Banks during the permitted “Bogue Banks Beach Restoration Project” contained high shell content and was cited by the North Carolina Division of Coastal Management for “incompatibility”. Though the material placed on the beach differs from the existing conditions of Bogue Banks, there does appear to be a presence of organisms in the nourished area after one recruitment season indicating signs of partial recovery (C.H. Peterson, IMS-UNC; Coastal Science Associates, Inc.). Review of the vibricore samples taken by the U.S. Army Corps of Engineers from the Morehead City inner harbor indicate that the material dredged from the inner harbor channels is compatible with the native beach material (see response to Comment 11 EFH Recommendations 3 within the NMFS letter (5.05) dated June 5, 2003, above). Potentially, the placement of material that is more representative of the native beach conditions onto Bogue Banks would improve the recovery time of the macrobenthic community and potentially improve the current “incompatible” conditions (C.H. Peterson Personal communication).

Though the biological communities exhibited decreased abundances immediately following nourishment and have not yet fully recovered, when including data for one complete recruitment season, these data appear to indicate at least partial recovery in both *Donax* and *Emerita. Donax* appear to be impacted immediately following disposal when compared to the control locations. Though numbers are low, it is important to mention that *Donax* were present throughout the recruitment period and by March 2003 are similar in numbers to the control transects. The data appear to indicate that *Donax* are recovering to near control levels after one recruitment season; however, the recovery process is slower than other organisms. *Emerita* also appear to be impacted immediately following disposal with lower numbers per transect compared to the control. However, during and after the recruitment period, *Emerita* numbers in the disposal transects surpassed the control. Finally, the new data from March 2003 indicate equal numbers of *Emerita* in both nourished and control areas. Amphipods exhibited reduced numbers after disposal, and after one year numbers per transect were still low. However, control numbers show evidence of a six-fold decrease from March 2002 to March 2003 possibly indicating that other factors may be effecting amphipod numbers. Ghost crab burrow counts are reduced in the nourished transects consistently throughout the year; however, they are present throughout all sampling months. The shorebird data indicate similar trends to the macro invertebrate data in that there appears to be reduced numbers immediately after disposal. Though numbers of feeding shorebirds are still reduced by about half of the control numbers in May 2003, it appears that feeding shorebirds are in the process of recovering after considerable reductions immediately following the project in March of 2002. Based on the review of Peterson’s data collected on Bogue Banks, several organisms appear to be recovering after reduced numbers in March 2002 immediately following disposal activities with some organisms exhibiting faster recovery rates than others.

Additional monitoring performed by Coastal Science Associates, Inc., as a requirement of the Department of the Army permit #200000362, indicates a decline in the phylum’s Mollusca and Arthropoda with large increases in the phylum Annelida. This appears to be consistent with previous beach nourishment studies in South Carolina (Van Dolah et al., 1994; P.C. Jutte et al., 1999). However, variability among and within transects makes this data difficult to interpret. The data were non-normally distributed and no non-parametric statistical tests for significance were performed, therefore, these data lack statistical validity. However, when subtracting control results normalizes the abundance data, the trend of declining mollusks and arthropods is reduced. When the data are normalized by subtracting the control results the impact is reduced to a 9% and 20% reduction respectively. According to the Coastal Science Associates, Inc., (CSA June 2002) first year post-disposal conclusions indicate that it is difficult to sort project impacts from the natural range of species diversity and abundance.

After review of the data presented by Dr. Charles H. Peterson and associates at IMS-UNC and Coastal Science Associates, Inc., the Corps agrees that impacts from the permitted project are evident; however the length of time for recovery of the benthic invertebrates and vertebrate consumers are not outside of what was expected according to the historical literature. Partial recovery after 1 year indicates that organisms are in the process of recovering to pre-project conditions.

Comment 3: In addition to ignoring cumulative impacts of multiple beach nourishment projects within a 2+year period, the EA fails to evaluate the known impacts of previous beach nourishments on Bogue Banks. Bogue Banks has relatively little long-shore transport and perhaps for that reason has slow recolonization and recovery rates of beach invertebrates. Transport and immigration of beach invertebrates is not achieved over long distances under low longshore transport conditions. The failure to recover promptly creates important impacts on fisheries habitat in direct contradiction to the NC Fisheries Reform Act of 1987 and its focus on enhancing fisheries habitat through the CHPP process. This impact is especially serious for Florida pompano, Gulf kingfish, and flounders, all of which use the surf zone and, beach invertebrate prey as primary nursery. The EA claim of perhaps as short as two months until recovery is unrealistic in light of known durations of impact from previous Bogue Banks nourishments.

Response: See response to comment 2 (above), regarding cumulative impacts. The Corps is not aware of any literature indicating slow recolonization and recovery rates of beach invertebrates as a result of little long-shore transport on Bogue Banks. In addition, long-shore transport is not the only method of transport for recolonization. Short-term wave action and wind driven currents will also play a large role in transport and immigration of beach invertebrates. Though it is understood that immediately following disposal there is a potential for loss of intertidal macrofauna, it appears that the presence of organisms on Bogue Banks begins within months after disposal ceases and the recovery process continues through year one post nourishment impacts. According to Reilly and Bellis (1978), recovery should occur within one or two recruitment seasons following the project. After one complete recruitment season, the data that have been collected by Peterson and Coastal Science Associates, Inc. on Bogue Banks indicate organisms recovering with an increasing number of recruitment time frames. It can be expected that as this population of macro invertebrates continues to increase, the impacts on surf zone fish species, which use this prey base, will be minimized. Ross and Lancaster (2002) found site fidelity exhibited by Florida Pompano and Gulf Kingfish indicating that disturbances could impact behavior or survival of juvenile fishes in the surf zone. According to the New York District's Biological Monitoring Program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section Beach Erosion Control Project (USACE 1999), analysis of the first post-nourishment year of monitoring did not reveal any long-term impacts to surf zone finfish distribution and abundance patterns.

Comment 4: Finally, the plan for 16 months of continuous project activity through the biologically productive warm months violates the tenets of minimization and avoidance in environmental management. Such a plan is certain to pose higher impacts on habitat usage and recruitment of surf fish and shorebirds. There is no justification except financial and the only reason it is cheaper is that no mitigation is proposed. All the costs to public trust resources are externalized so as to create a false economy. If summertime activity is desired, then proper habitat mitigation should be included. Project activity in summertime will also have a large economic impact on the hotel, hospitality, and tourism business on Bogue Banks, an impact not addressed in the EA and not compensated for in the plan.

Response: We have revised the project description for the proposed Section 933 found in Section 2.0 of the FONSI. The revised construction window is from November 1, 2003 to April 30, 2004 (to May 31, 2004, if required). Economic issues are addressed in Appendix D of the Draft Evaluation Report and in our responses to Dr. Douglas J. Wakeman's letter (5.23) dated June 2, 2003 and NCCF's letter (5.21) dated June 2, 2003.

5.19 Bogue Banks Environmental Stewardship Corporation (BBESC), letter dated May 16, 2003.

Comment 1: Please have someone on your staff review the attached comment to the United States Army Corps of Engineers (USACE). The Port of Morehead City, N.C., Beaufort Inlet, ***EVALUATIONAND ENVIRONMENTAL ASSESSMENT REPORT***. I am submitting this comment on behalf of our membership to the Wilmington District, United States Army Corps of Engineers.

Response: Noted.

Comment 2: Permitting and funding of this project are essential to preserve one of North Carolina's oldest and most precious natural resources: Bogue Banks. If you have questions, please contact me at 252-747-2911 or at home 252-522-4229.

Response: Noted.

Comments on the USACE 933 Project, dated May 12, 2003

Comment 3: Introductory Remarks:

The *BBESC* was incorporated in June of 2001. The membership consists of 281 homeowners along Bogue Banks. The goal of our organization is simple:

> *We are seeking a similar sand management system used by the* ***United States Army Corps of Engineers*** *(USACE) to maintain Wilmington Harbor and Cape Canaveral Harbor in Florida to be put into practice at Morehead City Harbor. Sand presently being removed from the littoral system by USA CE in maintenance of Beaufort Inlet and dumped at sea must be put on adjacent beaches*

In a meeting requested by the *BBESC* and held in Raleigh in August of 2002, representatives from the *Department of Environment and Natural Resources,* including the *Department of Water Resources* and the *Department of Coastal Management (DCM),* along with representatives from the USACE Wilmington District, Mr. Aiken was requested to consider a maintenance project for Beaufort Inlet that would combine outer and inner harbor sediment disposal practices in which spoils could be distributed along adjacent beaches west to Indian Beach. The *Morehead City Harbor/Beaufort Inlet Proposed 933 Project* is the answer for which we had hoped.

Response: Noted. See response to comment 5, below.

Comment 4: Brief History of Accelerated Erosion Rates at Pine Knoll Shores since 1993: The dry beach at Pine Knoll Shores actually accreted from 1987 to 1992. My home was built in 1987 with a 100' setback. My neighbor built in 1992. His footprint is five feet in front of mine. The *1993 Morehead City Harbor Project* deepened Beaufort Inlet from 40' to 47' and broadened the inlet 100' to 450'. In 1994, Hurricane Gordon brushed the eastern coast of North Carolina in November. Although the effects on the eastern end of the island were minimal, the primary vegetation line from Pine Knoll Shores to Emerald Isle was devastated. Pine Knoll Shores and Emerald Isle have never recovered from Hurricane Gordon, and each successive hurricane has wreaked havoc with 1000 year old sand ridges, Maritime forests, and turtle sanctuaries. **(Please see the attached newspaper account.) Newspaper article is found in Appendix 2.**

In the *Morehead Improvement Design Memorandum & Environmental Assessment* in March of 1992, the USACE describes the berm design as:

> "...a feeder berm which purpose is to keep the material within the littoral system ... This berm is not intended to replenish the beach ... The existing disposal method ... removes the sand from the littoral system entirely..."

In 1994, at the Request of the N.C. Department of Coastal Management (DCM), the USACE ceased disposal of dredged material on the Offshore Dredged Material Disposal Site (ODMDS) "when weather permitted" and disposed of the sand on a newly created near shore berm in expectation the sand would return to the active littoral system. DCM has observed sand on the nearshore berm has **not** returned to the active littoral system over the last 10 years. DCM has notified the USACE on two occasions this disposal practice is not consistent with the North Carolina Coastal Zone Management Plan. In October of 2002, "disposal of sand outside the active littoral system" was forbidden by North Carolina statue.

Response: We disagree with the statement "sand on the nearshore berm has not returned to the active littoral system." We also disagree with the implication that the nearshore disposal of Morehead City Harbor Project dredged material is inconsistent with the North Carolina Coastal Management Plan. The purpose of the nearshore disposal area is to return sand dredged from the ebb shoal of Beaufort Inlet to the same inlet shoal system. The Wilmington District has determined that the nearshore disposal area is consistent with the approved North Carolina Coastal Management Program to the maximum extent practicable. The North Carolina Department of Coastal Management (DCM) has reviewed this determination and concurred. DCM has requested updates on the Morehead City Harbor Project and the status of monitoring of the nearshore disposal area.

Comment 5: There is no definitive sediment transport study for Bogue Banks and according to the June 2001 USACE 111 Study we do not have time to assign blame for the accelerated erosion rates since 1993:

... The overall net loss of littoral sediment from the beaches adjacent to Beaufort Inlet between 1936 *and* 1994 is 19,205,5000 *cubic yards ...Beaufort Inlet, in particular, and Morehead City Harbor in general, has trapped littoral material at a higher rate each time the project has been deepened... The offshore profiles six miles west of Beaufort Inlet and all of Shackleford Banks appear to be getting steeper, closer to shore. These offshore changes appear to be directly related to the deflation or deepening of the ebb tide delta of Beaufort Inlet, which is a direct impact of the dredging operations. Unfortunately, the*

shoreline data does not demonstrate an impact at this time. However, the continuing deepening of the offshore profile is a major concern that needs to be addressed. -Section 111 June 2001

Our organization believes this *933 Project Proposal* is the USACE good faith effort to incorporate disposal practices consistent with the *May 2000 Wilmington Harbor Environmental Assessment,* which articulates the geological correlation principle between sediment removal and beach erosion.

"...the impact of sediment removal... tends to be diffused throughout the impacted area. Since this diffusion process can extend over miles of shoreline, the erosive impact of the sediment removed from the navigation channel and its deposition outside the active littoral zone is difficult to detect in the short term... Years of research by USACE and practical knowledge gained from the operation of the numerous coastal navigation projects dictate this material must be conserved... the removal of a *cubic yard of littoral sediment from a tidal entrance or inlet with deposition outside the active littoral zone of the beach will ultimately cause a cubic and deficit somewhere within the sand sharing system... The impact of the removal of littoral sediment from the active littoral zone through channel maintenance is identified as a major cause of man-induced erosion.*

Response: The purpose of the proposed Section 933 project is to utilize beach quality sand dredged from the adjacent Federal navigation channels and from Brandt Island in order to stabilize eroding beaches on Bogue Banks. We also understand that the North Carolina Coastal Management Program now requires that clean, beach-quality sand dredged from navigation channels in the coastal area not be removed permanently from the active nearshore, beach, or inlet shoal system, unless no practicable alternative exists (NC Administrative Code T15A: 07M.1102). Moreover, as indicated in the June 2001 USACE 111 Study, the continuing deepening of the offshore profile does not demonstrate an impact on the shoreline.

Comment 6: The years of research by USACE and practical knowledge gained there from are confirmed in Dr. Orin Pilkey's 1975 novel, ***Living With an Island****:*

> *The cause of erosion on Bogue Banks (Atlantic Beach/Ft. Macon Park) is not altogether certain. ... A significant part, however, is very likely due to hopper dredging. Hopper dredging consists of removing the sand from channels and dumping it at sea, entirely out of the shoreline system. Thus, sand that would naturally drift across and replenish the beach is lost and erosion rates increase. This is a major problem nationwide.*

Response: As indicated in your comment 5, above there is no definitive sediment transport study for Bogue Banks. Moreover, as indicated in the June 2001 USACE 111 Study, the continuing deepening of the offshore profile does not demonstrate an impact on the shoreline.

Comment 7: Environmental Concerns: During the permitting process, various government agencies and environmental groups will raise the following environmental concerns.

1. Shell content.
2. Microbial life recovery
3. "Fish Feed" life recovery
4. Coquina, mole crab, destruction
5. Various avarian concerns

There has never been an incident of sand bypassing/beach nourishment in which microbial life did not recover. Turtle sanctuaries are reinvigorated, maritime forests flourish, and 1000-year-old sand ridges become a new line of primary vegetation. The east end of Bogue Banks is testimony to a beach that recovers its natural vegetation and wildlife following renourishment.

Response: Please review responses to comment letters from USFWS, NCWRC, and NMFS, above on shell content of the material placed on Bogue Banks, macroinvertebrate recovery, construction windows, and impacts to shorebirds.

Comment 8: Conclusion: Section 209 of PL 91-611 (WRDA 1970) states**:**

It is the intent of Congress that the objectives of enhancing regional economic development, the quality of the total environment, including its protection and improvement, the well-being of the people of the United States, and the national economic development are the objectives to be included in federally financed water resource projects, and in the evaluation of benefits and cost attributable thereto

.

In the cost benefit equation the environmental concerns raised during previous renourishment projects must be weighed against the benefits derived from beach nourishment during initial storm surges. A recent article published by the North Carolina Sea Grant program concluded:

The benefits (of beach renourishment) are actually more dramatic than implied... All of the threatened buildings listed for the three communities were located outside the nourishment project limits or in transition areas at the ends of the projects where the dunes were not constructed. Hurricanes Floyd and Dennis threatened or destroyed 968 buildings outside the three Corps designed nourishment projects' manmade dunes. Remarkably, not even one building behind the project dunes was threatened by erosion - that's ZERO. (Wrightsville, Kure, and Carolina Beach). Failure to permit or fund the project will eventually result in catastrophic loss of property. A chilling review of the USACE *Final Section 111 Feasibility Report: Morehead City Harbor: June, 2001,* by Olsen Associates articulates the consequences**.**

Indeed, from a coastal engineering or geology standpoint, it is well known that removal of littoral material in excess of natural conditions results in (erosion) of the shorelines within the littoral system. The significant deflation of the offshore beach profiles documented in the study... must ultimately translate to destabilization of the beach and shoreline... the beach profile cannot continue to steepen without resulting in a landward translation of the shoreline. The condition is analogous to the foundation of a house: i.e., a structure's foundation cannot continue to be undermined without ultimate destabilization of that structure.

Response: As indicated in the Draft Evaluation report, Appendix C, Coastal Analysis, Appendix D, Economic Analysis, and in the EA, the proposed Section 933 project is economically justified, would provide erosion protection, and the impacts to the human environment are not significant.

5.20 Environmental Defense, letter dated June 2, 2003.

Comment 1: First and foremost, we believe that a full Environmental Impact Statement (EIS), rather than an Environmental Assessment (EA), is warranted. Clearly, there will be environmental impacts from this project; in light of the significant impacts from recent beach nourishment projects on Bogue Banks a more thorough analysis is needed.

Response: We have reviewed all the comments received on the EA and have revised the project description found in Section 2.0 of the FONSI. Based upon our review of these comments and investigations required to respond to your comments, we believe that the EA/FONSI is an appropriate document for the proposed action and it fully complies with NEPA.

Comment 2: Cumulative Impacts: The cumulative impacts analysis is non-existent with regard to biological resources and includes no data. It is merely a comparison of the percentage of area being impacted by this project versus sand deposition activities throughout the state. No attempt is made to address differences in habitat quality which might occur along the ocean beaches. Dr. Charles H. (Pete) Peterson has conducted several studies examining the recovery rates of intertidal infauna on Bogue Banks, and his findings are not nearly as optimistic as the conclusion stated in the EA. A full EIS which incorporates these data and evaluates the impact of the project on the recovery rates of intertidal infauna is necessary. Lack of recovery of these infaunal species has the potential to significantly affect shorebird populations.

Response: See response to comment #2 in Dr. Charles H. Peterson letter (5.18) dated May 28, 2003, above and Comment 1 above, regarding the need for an EIS.

Comment 3: Monitoring: There is no pre- or post-project monitoring plan. There is only a commitment to monitor and relocate sea turtle nests should construction occur during the nesting season. It should be clear from the sand placement activities which occurred on Emerald Isle and Pine Knoll Shores the past two winters that biological monitoring at the placement site and the mine site must be a required component of any beach nourishment project. The EA states that because the project is "one time only", it is not "appropriate for adaptive management". The sand placement activities at Emerald Isle and Pine Knoll Shores are also part of a one time only project. Without monitoring and data collection, there is no justification for the assertion that recovery of biological communities will be rapid and complete.

Response: See response to comment 5 within the NCDENR memo to Melba McGee, from Mike Marshall, NCDMF, (5.12) dated May 19, 2003, above.

Comment 4: Sediment Analysis: The sediment analysis for source material from Brandt Island was performed over 10 years ago and must be updated, particularly in light of the poor quality of material placed on the beaches at Pine Knoll Shores and Emerald Isle during the past two seasons. The borrow site for those sand placement events was supposedly thoroughly sampled and analyzed, yet failed to reveal the presence of tires and cobble-sized material. In addition, an analysis of the potential biological impacts of placing presumably finer grained materials on top of the very coarse material already on the beach needs to be performed. Finally, the composition of the material at Brandt Island could alter the frequency and duration of the turbidity plume and therefore, impacts to surf zone fish species their prey.

Response: See response to Comment 11: EFH Recommendations 3 within the NMFS letter (5.05) dated June 5, 2003, above.

Comment 5: Again, we must emphasize that the certain impacts from this project warrant the development of a full EIS with a comprehensive analysis of cumulative impacts. Until such time as an EIS is prepared and the concerns expressed above are addressed, we cannot support this project. Thank you for your consideration and for the opportunity to comment on projects which impact our coastal public trust resources.

Response: See response to the comment 1, above.

By letter dated July 17, 2003, Environmental Defense had concerns about the lack of time (only 7 days) to review the Draft Unsigned FONSI, sediment analysis, monitoring, cumulative impacts analysis, and our response to Dr. Peterson's letter (5.18), above. Concerns regarding sediment analysis, monitoring, and cumulative impacts analysis are addressed above. Additionally, we have revised our responses to Dr. Peterson's letter (5.18), above.

The 7-day review period for the Draft Unsigned FONSI was determined to be sufficient in order to provide assurances to federal and state agencies that the commitments made during the June 24, 2003 meeting were addressed in the Draft Unsigned FONSI.

5.21 NCCF letter dated June 2, 2003.

Comment 1: The North Carolina Coastal Federation staff has reviewed the document entitled *Draft Evaluation Report and Environmental Assessment, Morehead City Harbor, Section 933, Carteret County, North Carolina.* The following represents our comments on the document and the project.

Response: Noted.

Comment 2: If there is one lesson we have learned from our experience in reviewing and critiquing beach renourishment projects over the past four years, it is that haste makes waste. Whenever the applicants and/or the Corps of Engineers have sought expedited, or cursory review of projects, including the local beach renourishment projects on Bogue Banks, the Sea Turtle Restoration Project on Oak Island, and the Mason Inlet Relocation Project, the projects have been laden with unexpected environmental problems. In the interest of time, the Corps chose not to proceed with an EIS in either the Bogue Banks and Mason Inlet projects. In the Oak Island Sea Turtle Restoration Project, the Corps failed to adequately characterize the sediment at the Yellow Banks disposal area, and boulders were pumped onto the beach. More boulders are uncovered on the Oak Island beach with each high tide even today, several years after project completion.

Response: The USACE desires to protect the fish and shellfish resources of the project area. The proposed Section 933 action is a civil works project and therefore Corps' inspectors will be assigned to monitor the hydraulic dredge, pipeline route, booster pumps (if required), and placement sites on the beach. These inspectors review the ongoing work for safety, as well as making sure that the contractor complies with all conditions (found in the plans and specifications) of the contract. We will include the following paragraph in the proposed Section 933 specifications, "*Materials: The dredging shall be accomplished so that the most suitable material available for beach disposal is placed within the prescribed section. Suitable materials shall be comprised of materials by ASTM D 2487 as SP, SP-SM, and SW. This material shall be predominantly of sand grain size with no more than 10% silt, shell, and clay material present. Should the dredge encounter materials not suitable for placement on the beach, the Contractor will be directed by the Contracting Officer to move to a more satisfactory location within Brandt Island or the navigation channels.*" If problems occur during construction anywhere along the pipeline route or if the contractor is not abiding by the conditions of the contract (i.e., pumping material to the beach that is not suitable), these Corps inspectors would immediately notify the Contracting Officer (CO) located at the District office and the CO would direct the contractor to move the dredge to a more suitable site in Brandt island or the navigation channels.

Comment 3: We strongly recommend that, an environmental impact statement (EIS) be prepared for this 933project. Recommendations that an EIS be conducted were made to the Corps by federal and state resource agencies during the scooping period. If the Corps is not willing to recognize the appropriateness and necessity of an EIS for this project, we will recommend that the Division of Coastal Management find the project inconsistent with state policies due to the potential environmental impacts described in this letter.

Response: We have reviewed all the comments received on the EA and have revised the project description found in Section 2.0 of the FONSI. Based upon our review of these comments and investigations required to respond to NCCF and the other comments, we believe that the EA/FONSI is an appropriate document for the proposed action and it fully complies with NEPA.

Comment 4: Alternatives. The alternatives analysis should include an alternative that spreads the pump out of Brandt Island over several seasons. The Environmental Policy Act requires the Corps to evaluate an alternative that would avoid environmental impacts, in addition to the no action alternative. In this case the no action alternative is identical to the existing authority to dispose of dredged material on the beaches of Fort Macon and Atlantic Beach. The Corps must also analyze a less damaging practicable alternative that would avoid, rather than minimize, environmental impacts by honoring the moratorium for shorebirds as established by the NC Wildlife Resources Commission and for fisheries as established by the NC Marine Fisheries Commission. These moratoria would limit the period for beach disposal of sediment to November 16 until March 31. While it is clear that this alternative would require the redeployment of pipelines and other equipment in future years, it is an alternative that requires further analysis and public review. We request that the Corps include an analysis of this alternative in its EIS.

Response: See the revised project description found in Section 2.0 of the FONSI. The revised construction window is from November 1, 2003 to April 30, 2004 (to May 31, 2004, if required). Section 1.03 of the EA, states "Should present plans for sharing sand by Bogue Banks beaches not materialize due to funding problems or other unforeseen reasons, dredged maintenance material from the inner and the outer harbor, as well as the pump out of Brandt Island would be distributed according to the base disposal plan. The base disposal plan represents the least cost alternative for the government, which is engineeringly feasible and environmentally acceptable".

Comment 5: Project Timetable. The Draft 933 Environmental Assessment proposes to pump out Brandt Island and place sediment material on the beach from Fort Macon State Park to Indian Beach for 16 consecutive months. The NC Wildlife Resources Commission and the NC Marine Fisheries Commission have established moratoria on beach fill activities that would limit construction to the period from November 16 to March 31. These moratoria were developed to protect the food sources for migrating shorebirds and fish in the surf zone during periods of peak biological activity. The Draft EA is inconsistent with state policies inasmuch as it proposes to violate these moratoria.

Response: See response to comment #3 in NCWRC letter (5.14) dated May 27, 2003, above.

Comment 6: Economic Impact. The Draft 933 EA has determined that the benefits of this project outweigh the costs by a factor of 4.9 to 1. The singular argument made by the Corps in its EA for conducting nonstop beach fill activities for 16 consecutive months is the increased redeployment cost of pipelines and other equipment in future years if the project was required to honor the NC Wildlife Resources Commission and NC Marine Fisheries Commission moratoria policy on the placement of fill on the beach during periods, of high biological activity. Given the high benefit to cost ratio established in the economic impact analysis, the cost of redeploying pipeline and other equipment is a reasonable and practicable expense. The cost of mobilization and deployment is estimated to be $2:85 million. If the cost of redeploying pipeline and other equipment were added to the costs of the project, the benefit to cost ratio would still be approximately 4 to 1. Given this generous benefit to cost ratio, there is no compelling economic argument not to honor the moratoria.

Response: See response to comment 4, above.

Comment 7: The Draft 933 EA estimates the benefits of the 933 project using storm damage reduction savings and recreational benefits to day users, among other criteria. During 2001-2002, a locally funded beach renourishment project was conducted on the same beaches (Pine Knoll Shores, Salter Path and Indian Beach) that are under consideration in the Draft 933 EA. The locally funded project was reviewed and permitted by the Corps of Engineers Wilmington District. The longevity of the locally funded project was ten years. The locally funded project also projected storm damage reduction savings and benefits to day users, among other criteria. The Draft 933 EA also has a projected life of ten years. Both projects propose to save the same oceanfront and second row structures from storm damage and long-term erosion. The Draft 933 EA is in effect-double counting benefits that have already accrued to the protection of structures and recreation on Pine Knoll Shores, Salter Path and Indian Beach. *Since* the Corps of Engineers reviewed and approved the: locally funded economic impact analysis, these benefits should serve as a baseline *upon* which the additional benefits of the 933 project can be calculated. The question is how much additional` benefit will these same said structures and beachgoers receive over and above the benefits provided by the locally funded beach fill project? If, the locally funded project did not meets its objectives, then what is the revised lifespan of the locally funded project and what is the revised baseline, i.e. costs and benefits, of the locally funded project?

Response: The proposed 933 project considered the locally financed project in place and as part of the without project condition. Benefits were computed for the 933 project as compared to the without project condition, which included all proposed locally financed nourishment.

Comment 8: The Corps should also explain why it uses a *20-year* period *for* its cost benefit analysis when the project is only expected to last 10 years. The use of a 20-year period is particularly important inasmuch as the Corps is also evaluating a 50-year *civil* works project *for* the entirety of Bogue Banks that is expected to be built prior to the end of the 10-year life of the proposed 933 project. We question whether the proposed 933 project has any economic benefits that have not already been realized by the locally funded project, or that will be realized by the 50-year civil works project.

Response: The period of analysis of 20 years was selected to take into account the expected life of the nourishment of 10 years and any immediate impacts in the period after the fill is expected to be gone. Both the with and without project conditions were evaluated over the same period of analysis. The Bogue Banks long-term project will consider all previous nourishments as part of the without-project condition.

Comment 9: Environmental Impacts/Cumulative Impacts. The Draft 933 EA fails to seriously consider the environmental impacts and the cumulative impacts of the proposed 933 project on biological resources *on* Pine Knoll Shores, Salter Path and Indian Beach. The locally funded project has had a devastating effect on macro faunal invertebrates on these beaches as documented by Peterson et al. The Draft EA fails to consider any biological monitoring data from scientists such as Peterson or from the local project's biologist. The Draft 933 EA examines the impact of beach fill projects in the abstract, rather than evaluating the wealth of current data that is available for these beaches. The question that should have, been addressed in the Draft 933 EA and which must be examined in the EIS is what is the cumulative biological impact of burying invertebrates on beaches that have not fully recovered? In addition, fill material that is widely regarded as incompatible was placed on a significant portion of Emerald Isle: The question this Draft EA failed to consider is what is the cumulative impact on birds, fish, and invertebrates of conducting another beach fill project before the beach ecosystem has had time to reestablish itself? As the Draft 933 EA notes, the recovery rates for beach ecosystems is generally from 1 to 3 years. The timeframe is shorter when beach material is compatible and longer when beach material is not compatible. These are questions that will require close examination of existing research as well as field studies that are appropriate to the EIS.

Response: See response to Comment 12 within the NMFS letter (5.05) dated June 5, 2003, above regarding environmental and cumulative impacts. Regarding "the monitoring data from scientists such as Peterson or the local project's biologist" as well as cumulative impacts on birds, fish, etc. and recovery times, please review comment 2 within the Dr. C. H. Peterson letter (5.18) dated May 28, 2003, above.

Comment 10: Sediment Compatibility. The draft environmental document is the appropriate vehicle to *publicly* share data collected on a given project. In the Draft 933 EA, the Corps shares its belief (ER-43) and provides assurance (ER-44) that the sediment will be compatible with the natural beach and for sea turtle nesting. The Draft 933 EA indicates that data will be collected on sand compatibility along portions of the proposed project area, but this data is not contained in the Draft EA-and *is* not available for public review. All relevant data must be included in draft environmental documents. The public has a right to comment on data, not beliefs and assurances, particularly given the Corps' past acceptance of incompatible material on Bogue Banks, Oak Island and from Mason Inlet.

Response: See response to Comment 11 within the NMFS letter (5.05) dated June 5, 2003, above.

Comment 11: Public Access and Parking. The Corps' guidelines require public access in order for the federal government to share in the costs of a storm damage reduction project:" These guidelines for public access and parking indicate "public use means use by all on equal terms." The public access and parking plan in the Draft 933 EA presents a stark disparity between public access and parking sites along the project area. It is remarkable that the areas that provide the greatest public access, Fort Macon State Park, are slated to receive the same volume of sand as areas with the least amount of public access.

Response: The Corps does not formulate project for recreation. It is only an incidental benefit.

Comment 12: The Corps conducted its public access survey using aerial photography taken between 11:15 AM and 11:40 AM on July 4, 2002. The Town of Pine Knoll Shores had only one public access site open on that date, which was opened during a June 28 ribbon cutting. On the day of the Corps' survey, Pine Knoll Shores was essentially a privately accessed beach. It is not feasible to evaluate public access on a privately accessed beach. We also question how the time between 11:15 and 11:40 on a single day constitutes peak hour demand. I personally have traveled to the state beach access at Salter Path on numerous occasions to find the lot full and cars parked illegally on Highway 54.

Response: The Corps has traditionally considered the 4th of July as the peak visitor day for beaches. We obtained traffic count data from the NC Department of Transportation over the two bridges onto the island for the 4th of July over several years and found that the peak usage occurred around this time and date.

Comment 13: The survey methodology is seriously flawed, as are the results. We strongly recommend that the Corp follow through on the revised parking survey methodology as described in Appendix E-5 to revisit the parking issue this summer. The revised parking survey should also be conducted on multiple peak days, and at a variety of times and locations on those days.

Response: See Appendix E-5, "Parking Analysis Methodology", 3rd paragraph. The document was reviewed by an independent technical review team, as well as USACE District, Division, and Headquarters and it was determined that the analysis adequately analyzed the demand and is consistent with guidance. Future recreation studies will continue to improve through the use of criteria such as those suggested above.

Comment 14: The access plan for Pine Knoll Shores is a violation of Corps guidelines governing public use. The Corps guidelines for public use states:

Lack of *sufficient parking facilities* for *the general* public *(including non-resident users), located reasonably near and accessible to the project beaches or lack* of *public pedestrian* *rights-of-way to the beaches at suitable intervals* would *constitute de* facto *restriction on public* access *and* use *of such beaches, thereby precluding eligibility for Federal assistance. EP 1165-2-1 Chapter 14-1(b)(2)*

Response: The sponsor's plan presented in the document provides additional public beach access and parking (or transportation to access). We believe it is a significant increase over their initial public access and parking scenario and is consistent with Corps guidance. The Plan was reviewed by an independent technical review team, as well as USACE District, Division, and Headquarters and it was determined that the sponsor's commitments will provide adequate access and parking per our regulations.

Comment 15: The use of public transportation by the Town of Pine Knoll Shores to transport visitors from existing beach parking areas to planned beach access areas meets neither the letter or the spirit of the public use definition in Corps guidelines. Historically, Corps guidelines have allowed public transportation, but only "to reduce automobile pollutants by encouraging public transportation." Nowhere has Pine Knoll Shores stated that its " motivation is in reducing automobile pollutants and the public access plan would not reduce automobile pollutants anyway.

Response: Corps guidance on the use of public transportation allows flexibility in applications to include reasons such as: reducing pollutants, available space, roadways, natural area avoidance, etc. The document was reviewed by an independent technical review team, as well as USACE District, Division, and Headquarters and it was determined that the sponsor's commitments for public transportation will provide adequate access per our regulations, and are consistent with Corps policy.

Comment 16: The Corps has offered no corroborating data from any comparable beach community to justify that this experiment will provide any benefit to day users of the beaches at Pine Knoll Shores. Why would a day user park near the beach and then take a shuttle to another access area? Is the public expected to carry cellular phones, in order to reach the public transportation carrier during the off season? Unless the Corp can provide data and justification that this transportation system has worked in a town setting similar to Pine Knoll Shores, we strongly recommend that the project be scrapped.

Response: We do plan to monitor use and make adjustments as necessary. See Appendix E-12, "Monitoring/Adaptation of Transportation Plan"

Comment 17: In our view, the primary purpose of the public transportation plan is to gain a higher percentage of federal cost share funds. It is not clear to us that the Town of Pine Knoll Shores has exhausted all practical options in providing appropriate parking at each proposed access site. There are gated private parking lots within walking distance to the beach that could be purchased or condemned that could accommodate ten or more parking spaces.

Response: Providing adequate public transportation is expensive and logistically difficult therefore we believe that the Town of Pine Knoll Shores will continue to evaluate beach access and parking as an alternative to public transportation.

Comment 18: The public transportation plan does not provide a realistic alternative for the public to access what will continue to be privately accessible beaches.

By accepting their flawed concept of public transportation to reach multiple beach accesses in Pine Knoll Shores, the Corps has violated public faith in the notion that Federal funds will only be used to provide storm damage reduction benefits to beaches that the public can access on an equal basis.

Response: See response to comment #14, above.

Comment 19: We recommend that the Corps provide the Town of Pine Knoll Shores until November 1, 2004 to meet the public parking criteria that requires a minimum of ten parking places and handicapped access for each beach access within the town limits. If the town cannot meet the public access requirement by that date, the Corps should require the town to pay 100 percent of the cost of placing beach fill on areas that do not conform to the Corps guidelines.

Response: Pine Knoll Shores continues to evaluate its options, and the Corps will ensure that access and parking requirements are met for those sections of beach which are Federally cost shared.

Comment 20: State Easements. North Carolina law requires an easement for performing work that involves alterations to state lands. The beach up to the high tide land is state property in North Carolina. Any land disturbing activity requires an easement from the Department of Administration and approval of the Council of State. The Corps should describe how it plans to obtain an easement to alter state lands.

Response: There will be no alteration of state lands as part of the Section 933. All work for the Section 933 will be performed in areas in which the Towns of Pine Knoll Shores and Indian Beach/Salter Path have obtained perpetual easements.

Comment 21: Turbidity in the Construction Areas. The Draft EA states "Turbidities outside of the construction or mixing zone would not exceed the state standard of 25 NTU's in all saltwater classes." The EA has not indicated how the Section 401 Water Quality Unit defines and delineates the area of construction. The EA also does not indicate when a portion of the beach ceases to be a construction area in time or spatial terms. Research by Peterson, et al, has shown that turbidity continued for months after the completion of beach construction at Emerald Isle. The EIS should evaluate Peterson's data and model the turbidity that will be generated during the proposed project.

Response: As a part of the Wilmington Harbor Deepening project, sand was placed on the beaches of Brunswick County, NC. This project involved extensive monitoring, including turbidity, which was performed by our contractor, Versar Inc. The first year report is available at http://www.saw.usace.army.mil/wilmington-harbor/main.htm under <u>Monitoring Reports</u>. The second year report should be available later this summer.

A summary of the turbidity monitoring from the first year report is as follows: "Water quality monitoring at the two Oak Island fishing piers revealed that beach replenishment operations did not create large increases in turbidity over background conditions. While turbidity spikes where observed when the pipeline was near both piers, similarly high turbidity values were recorded during periods when the beach replenishment operations were miles from the monitoring sites or when dredging operations where temporarily shut down. These large non-dredged related turbidity events were most likely caused by periodic storm surges and heavy surf conditions. Turbidity plume mapping revealed that the turbidity created by the pipeline discharge hugged the shoreline following the long-shore currents. On-shore wind events contributed to keeping turbidity plume close to shore and in most cases the plumes were not discernable from turbidity created by the breaking waves in the surf zone a few 100 meters away from the end of the pipeline. Elevated suspended sediment loads outside of the surf zone were rarely observed." Even though the percent fines in the Morehead City project will be less than Wilmington Harbor Project, we anticipate results will be similar.

Modeling is difficult to perform for this type of action because of numerous variables. The extent of the turbidity plume would vary depending of the amount of fines in the nourishment material; dredge pumping rate which can vary depending of size of dredge, pumping distance, and need or not for booster pumps; wind, wave, and current velocity and direction, etc.

The Water Quality Unit does not define the construction area. The Corps generally maintains a 1,000 foot wide fenced construction/safety zone (about 500 feet either side of the end of the pipeline) to preclude potential injury to the public from construction equipment.

Regarding the research by Peterson, we understand this information has not been published and to date this information has not been provided to the Corps.

NCCF had concerns about the lack of time (only 7 days) to review the Draft Unsigned FONSI. Please see our response to the one-week review found at the end of the Environmental Defense letter (5.20), above.

5.22 Andrew Coburn, Associate Director, Program for the Study of Developed Shorelines, Nicholas School of the Environment and Earth Sciences, Duke University, e-mail dated June 3, 2003.

Comment 1: This document contains comments and questions pertaining to the ***Draft Evaluation Report and Environmental Assessment: Morehead City Harbor Section 933*** and is being submitted to the US Army Corps of Engineers Wilmington District by the Duke University Program for the Study of Developed Shorelines.

Comments on Appendix E: Beach Access/Parking Analysis and Requirements

Appendix E contains a significant number of errors, issues and discrepancies that need to be resolved. The quality of data used to determine current and projected public access and public parking needs is inaccurate; the analyses that rely on this data are flawed; population growth rates used to estimate the future peak hour usage are incorrect and huge discrepancies regarding beach usage remain unresolved. It is also clear that the study area fails to meet Federal Policies and Authorities regarding the geographic distribution of public access and public parking. Specific comments and questions follow:

Determinations of public access, public use and public parking needs and demands are based on one 25-minute observation along a shoreline that is classified as private in Engineering Regulations 1105-2-100 or 1165-2-130.

What procedures are typically employed by Wilmington District to evaluate public beach use and public parking demands?

Response: The procedures used to evaluate demand can be found in Appendix E of the Draft Evaluation Report, under “Beach Capacity vs. Peak Hour Demand”.

Comment 2: How can the Corps justify its decision to spend tens of millions of taxpayer dollars on this project when it fails to meet the cost-share criteria outlined in Engineering Regulations 1105-2-100 or 1165-2-130?

Response: The requirements necessary to obtain the full 65%/35% Federal/Non-Federal cost sharing were outlined in Section 1 of the Main Report as well as Appendix E under Access and Parking. The Corps has determined that the non-Federal sponsor’s commitments will meet these requirements.

Comment 3: The EA makes projections based on the amount of public access and parking currently available in the study area, which does not meet the federal cost share guidelines. How can the Corps make an accurate estimate of future peak hour demand when the area fails to provide either adequate public access or public parking, as defined in Engineering Regulations 1105-2-100 or 1165-2-130?

Response: See response to comment #14 to NCCF letter (5.21) dated June 2, 2003.

Comment 4: In a letter dated May 16, 2003 Colonel Charles Alexander states, “…the US Army Corps of Engineers, Wilmington District intends to ensure the requirements as indicated in US Army Corps of Engineers Engineering Regulations 1105-2-100 and 1165-2-130 are adhered to for this and all shoreline protection projects.” However, neither existing Department of the Army public access nor public parking requirements contained in Engineering Regulations 1105-2-100 and 1165-2-130 are being adhered to in the project area. Please explain the discrepancy between Colonel Alexander’s stated position and the fact that minimum public access and parking requirements as indicated in US Army Corps of Engineers Engineering Regulations 1105-2-100 and 1165-2-130 are not being adhered to.

Response: See response to comment #14 to NCCF letter (5.21) dated June 2, 2003.

Comment 5: According to ER 1165-2-130, “In the event public access points are not within one-half mile of each other, either an item of local cooperation specifying such a requirement and public use throughout the project life must be included in project recommendations or the cost sharing must be based on private use.” According to Appendix E, public access points are not available, nor are they projected to be available, every one half mile in the project area. Since the project area fails to meet existing policies and authorities concerning public access and parking, and since no item of local cooperation specifying such a requirement is provided, why isn’t the project being cost-shared based on private use?

Response: As explained in previous responses, Appendix E-8, 1st paragraph states that the sponsor’s current access and parking plan meets the Corps’ parking and access criteria and therefore are cost shared at the full 65%/35% as detailed under “Cost Sharing Percentage”.

Comment 6: According to ER 1165-2-130, public transportation facilities may substitute for or complement parking facilities in some instances in which state and local plans call for a reduction in automobile pollutants. Please provide a compilation of all state and local plans that call for a reduction in automobile pollutants in the project area.

Response: See response to comment #14 to NCCF letter (5.21) dated June 2, 2003.

Comment 7: In the absence of such documentation, please provide the specific rules under which the Wilmington District has the authority to allow a public transportation system to serve as a substitute for meeting explicit public access and parking policies and authorities as contained in ER 1165-2-130 and 1105-2-100.

Response: See response to comment #15 to NCCF letter (5.21) dated June 2, 2003.

Comment 8: How many Section 933 projects have allowed public transportation in lieu of providing adequate parking, and where are they located?

Response: There are several projects which fall in areas which have existing public transportation available prior to the project being put in place, however, we were unable to find any examples of projects that have implemented a public transportation system specifically to meet parking and access requirements.

Comment 9: On Page E-1, an assumption is made that visitors require 100 square feet of beach per visit. Upon what data is this assumption based?

Response: This is a conservative number based on previous Corps studies. Many of the studies used 150 square feet or more as their assumption. This would have reduced the number of potential visitors, thereby reducing the potential capacity of the beach, and the associated parking requirements.

Comment 10: The estimation of peak hour usage/demand is based upon a 25-minute snapshot of beach visitation taken between 11:15 and 11:40 am on July 4, 2002, and the EA assumes that almost the same number of people were under tents and umbrellas than were visible on the beach. What was the weather in the study area between 11:15 and 11:40 am on July 4, 2002?

Response: Sunny with a little haze present.

Comment 11: Is it reasonable to assume that the number of people under a tent or umbrella would be equal to the number of people visible on the beach?

Response: The number was 34% more individuals for Pine Knoll Shores and 48% more individuals under tents/umbrellas for Indian Beach. This was deemed reasonable and conservative. The more individuals we assume to be on the beach, the more parking is required. We would error on the side of ensuring adequate parking by making this assumption.

Comment 12: Upon what data is the assumption that an average of 2 people were under each tent and 1.5 people were under each umbrella based?

Response: The contractor providing the aerial photography and calculations suggested numbers based on their experience.

Comment 13: How can peak hour usage/demand be estimated with any degree of accuracy using one 25-minute aerial observation taken on one day of the year?

Response: The Corps has traditionally considered the 4th of July as the peak visitor day for beaches. We obtained traffic count data from the NC Department of Transportation over the two bridges onto the island for several years of 4th of July traffic and found that the peak usage occurred around this time.

Comment 14: On page E-2, the EA states that July 4 is assumed to be the peak day of the year for visitors on beaches. Upon what data is this assumption based?

Response: See response to comment #13, above.

Comment 15: What evidence is available to show that peak beach usage occurs between 11:15 and 11:40 am?

Response: See response to comment #13, above.

Comment 16: On page E-2, the EA states that a higher number of visitors may have been present if July 4 had fallen on a weekend, and that the actual numbers were increased by 14.2% based on the volume of traffic crossing the two bridges onto Bogue Banks on Friday, July 5. Page E-2 states that the assessment completed on July 4 is not accurate. Why wasn't the assessment undertaken on Saturday July 6 or Sunday July 7?

Response: The weather on Saturday, July 6th was not conducive to aerial photography and an additional flight on Sunday, July 7th was flown and found to have a lower number of visitors. Therefore the greater number from the 4th of July flight was used.

Comment 17: Since Friday is not typically considered a weekend, why were traffic counts for Friday July 5th used instead of traffic counts for Saturday July 6 and/or Sunday July 7?

Response: From the NC Department of Transportation data, we found that July 5th had the greatest traffic volume of any of the days mentioned.

Comment 18: What was the actual volume of traffic on each bridge on July 5th?

Response: Appendix E-2, 1st paragraph addresses traffic volume.

Comment 19: During what time period was the traffic count conducted on July 5?

Response: Every hour over the 24 hour time period.

Comment 20: What percentage of traffic crossing these bridges used the beaches in the study area?

Response: The Corps assumptions are stated on Appendix E-2, 1st paragraph of the Draft Evaluation Report.

Comment 21: What was the actual traffic volume on each bridge on July 4?

Response: See response to Comment #18, above.

Comment 22: During what time period was the traffic count conducted on July 4?

Response: See response to Comment #19, above.

Comment 23: How, exactly, was the figure of 14.2% obtained?

Response: See response to comment #20, above.

Comment 24: On page E-2, the peak hour demand in the project area is projected to be 2,835 in the year 2014. This figure is based upon an average North Carolina annual growth rate of 1.8% between 2000 and 2010. It is implausible to assume that daily visitors to the project area are, and will be, distributed equally throughout the entire state. A more accurate analysis should assume that the majority of daily visitors to the project area is, and will remain, from North Carolina's coastal region. Therefore, population growth rates specific to North Carolina's coastal municipalities, as contained in 15A NCAC 07B .0701, should have been used to predict future beach and parking demand. Why were CRC-approved population growth rates for coastal NC not used in this study?

Response: Division of Coastal Management has stated that the growth rates referred to in this section are not spelled out, but rather are made up of Census data from the past 10 years which is also where the NC Demographics Office gathers it's data.

Comment 25: On page E-2, the EA states that only 30% (59 out of 171) of all available parking spaces in the project area were filled during the peak usage time period between 11:15 and 11:40 am on July 4, 2002. Such a low demand for parking during the stated peak period of demand appears inconsistent with the definition of "peak demand." Could this indicate that the peak demand did not actually occur during the time of observation?

Response: The observed numbers were adjusted to account for differences in peak demand. See Appendix E-2, 1st paragraph of the Draft Evaluation Report.

Comment 26: How does the Wilmington District resolve or explain this discrepancy?

Response: See response to comment #25.

Comment 27: On Page E-3, the Corps estimates that each car contains 2 persons. The communities in the study region actively promote themselves as "family beaches" which means there is a strong likelihood that each car contained more than 2 persons. Upon what data is the assumption that each car contains only two individuals based?

Response: The data was determined looking at the number of visitors on the beach at Fort Macon and the number of vehicles in the lot. The assumption is that there is little likelihood that the individuals on the beach are coming from any houses since it is a considerable distance from any private housing. Therefore the number of individuals on the beach was divided by the number of vehicles in the lot and resulted in an average of 2 persons per vehicle. Other studies have used 2.5 and 3.0 persons per vehicle.

Comment 28: The peak hour parking demand projections on page E-3 use the 1.8% growth rate for the entire state of NC. Why wasn't this calculation based on coastal growth rate projections contained in 15A NCAC 07B .0701?

Response: See comment #24.

Comment 29: On Page E-4 the EA states, "…it is important to keep in mind that meeting peak hour capacity does not alleviate the sponsor's obligation to provide parking within one quarter mile of each access site." Does the sponsor provide parking within one-quarter mile of each access site?

Response: The sponsor's plan provides parking and public transportation to meet the Corp's parking and access criteria.

Comment 30: On Page E-4, the EA states that the percentage of "day-users" in PKS is 3.5% and is significantly lower than the average for beach studies. What is the average percentage of "day-users" for Corps beach studies?

Response: See Appendix E-2, Paragraph 4 and Appendix E-4, paragraph 5 of the Draft Evaluation Report.

Comment 31: How does the Corps resolve or describe this significant discrepancy?

Response: The discrepancy was discussed on Appendix E-4, under the "*Note" in the Draft Evaluation Report.

Comment 32: Why shouldn't this significant difference affect the validity of the EA?

Response: This is addressed on Appendix E-5, under Parking Analysis Methodology, paragraph #3, in the Draft Evaluation Report.

Comment 33: The Corps, under NOTE on Page E-4, admits that the calculations in the document are inaccurate due to a number of factors including a discrepancy in the estimated peak day, day-visitor beach population in Pine Knoll Shores. According to the Pine Knoll Shores' 1996 Land Use Plan, the town estimated its peak day, day-visitor population to be in excess of 50,000 persons. The EA, however, determined the peak hour, day-visitor beach population demand in PKS to be 50 persons. Even if this hourly demand is multiplied by 24, the peak day, day-visitor beach population in PKS, according to the EA, is 1,200. How does the Corps explain the enormous discrepancy in peak day, day-visitor populations between its calculations and the estimates provided by the PKS police department?

Response: We did not develop the PKS data and therefore cannot speak to its validity. Various studies using different methodologies often produce widely different results.

Comment 34: What reason can the Corps provide for not using the peak day, day-visitor population data contained in the Pine Knoll Shores 1996 Land Use Plan?

Response: The Corps did not find Pine Knoll Shore's findings to be reproducible.

Comment 35: On page E-5, under Parking Analysis Methodology, the proposed project is compared to a recently completed, locally funded project with no federal public access/parking policies and authorities in which the local communities still have not met pre-project public access promises made to secure state funding. How can the Corps compare a federally funded project to a locally funded project with no federal public access/parking policies and authorities?

Response: The locally funded project was in place when we prepared the analyses of the 933 project. Visitation for that project was reflected in the existing conditions. The locally funded project has met the State required parking.

Comment 36: On page E-5, under Parking Analysis Methodology, the EA states that parking is a component of the recreation analysis. Assuming the EA is accurate and significantly fewer people are using the beach on a daily basis, how will this affect future analyses of recreational benefits?

Response: We expect to conduct additional recreation studies before doing future beach recreational analyses.

Comment 37: The conditions and stipulations contained under Access and Parking Requirements on Page E-5 are ambiguous and confusing. According to ER 1165-2-130 and 1105-2-100, adequate parking must be within ¼ mile of each access. On Page E-6, the Corps is allowing parking to be equally distributed within 2-mile stretches. The criteria presented for the selection of two miles is irrelevant. The issue is the geographic distribution of public parking and public access, not the minimum length of a Corps beach nourishment project. The fact remains that the study area does not meet existing federal policies and authorities pertaining to public access and parking. What authority does the Corps' Wilmington District have to disregard existing federal policies and authorities regarding the geographic distribution of public access and public parking?

Response: We have no authority to disregard federal policies or authorities and we do not. See response to comment #14 to NCCF letter (5.21) dated June 2, 2003.

Comment 38: On Page E-6, section 4 B is extremely confusing. The passage reads, in part, "In order to meet the spirit of the regulations to provide public access to those beaches receiving Federal funding for a Section 933 project, it was decided that the sponsor should provide this minimum." From this wording, it appears that the regulations have not been met. What does the "spirit" of the regulations mean, how does this differ from actually meeting the regulations?

Response: Because Corps regulations do not specifically spell out the number of spaces required per access, we developed criteria based on what we interpreted to be the intent of the regulations. The current parking was found to meet peak hour demands, however, it was decided that a minimum number of parking spaces per access and a distribution needed to be established in addition to meeting peak hour demand.

Comment 39: If the regulations have not been met, why isn't the Corps enforcing them?

Response: They have been met and we are enforcing them. See response to comment #14 to NCCF letter (5.21) dated June 2, 2003.

Comment 40: In Section 5 on Page E-6: How will the sponsor be held responsible for providing the required number of parking spaces?

Response: Through the Project Cooperation Agreement

Comment 41: What is the period of analysis of the project?

Response: 20 years

Comment 42: What is meant by "on an equal basis?"

Response: Everyone will have access whether they live on the beach, live on the island, live off the island, or even in another state.

Comment 43: What is meant by "Failure to do so would result in sections of the project reverting to private beach status…?"

Response: This means that the section would no longer be in compliance with Corps criteria and therefore is deemed to be a "private" beach.

Comment 44: What is the timeframe being discussed?

Response: The life of the Section 933 fill is expected to be 10 years..

Comment 45: What criteria will be used to determine whether a section of the project does not meet "Corps parking criteria" and what parking criteria is being referred to here?

Response: The criteria as outlined in Section 1 of the Main Report and "Access and Parking Requirements" of Appendix E-5.

Comment 46: In Item 6 on page E-6: What authority does the Corps Wilmington District have to allow public transportation to substitute for adequate public parking as defined in to ER 1165-2-130 and 1105-2-100?

Response: See response to comment #15 to NCCF letter (5.21) dated June 2, 2003.

Comment 47: What enforcement mechanism will be used by the Corps to ensure that a public transportation system is provided year-round?

Response: See response to comment #40.

Comment 48: What happens if the local sponsor fails to follow through on its commitment?

Response: See response to comment #40.

Comment 49: Under Existing and Proposed Parking and Access Sites on Page E-7: What authority does the Wilmington District have to allow public transportation to substitute for adequate public parking as defined in to ER 1165-2-130 and 1105-2-100?

Response: See response to comment #15 to NCCF letter (5.21) dated June 2, 2003.

Comment 50: Under Existing and Proposed Parking and Access Sites on Page E-7, the EA states that there is an 82% decrease in demand during the off-peak season. How was this figure calculated?

Response: By comparing peak visitation as determined by weighted annual visitation (Appendix D-20, Table 10, in the Draft Evaluation Report) during peak and off-peak season.

Comment 51: On Page E-8, an exception to existing public access requirements was given to a section of Indian Beach based on "environmental conditions." What are the specific environmental conditions that prompted the exception, and what authority does the Wilmington District have to make such an exception?

Response: The location of the access area was adjusted by less than .1 mile to avoid impacting a vegetated State Park property.

Duke University Program for the Study of Developed Shorelines had the following major issues with the Draft Unsigned FONSI: the lack of time (only 7-days) to review the Draft Unsigned FONSI, that an EIS is required for the proposed action, impacts to beach macrofauna and essential fisheries habitats, cumulative impacts, mitigation plan for removal of incompatible sand placed as a result of the proposed action on Bogue Banks, no post project biological monitoring, and issues on base conditions, economics, public access, parking, and storm impacts.

See response to Environmental Defense letter (5.20), above on the 7-day review of the Draft Unsigned FONSI, letters to NMFS, USFWS, NCWRC, NCDMF letters above discussing impacts to beach macrofauna and essential fisheries habitats, cumulative impacts, and mitigation plan for removal of incompatible sand placed as a result of the proposed action on Bogue Banks. As indicated during our meeting on June 24, 2003, a representative from Carteret County stated that they would continue monitoring the Phase 1 area (Pine Knoll Shores to Indian Beach (including Salter Path)) beyond November 2003, if adequate recovery of mole crabs and coquina clams does not occur. If required the monitoring would be extended to November 2004. Please note if the Section 933 project is not funded, Carteret County will not extend the monitoring until November 2004.

Additionally issues on base conditions, economics, public access, and parking, are already discussed above in your original letter. Storm impacts are discussed in the Coastal Appendix of the EA.

5.23 Dr. Douglas J. Wakeman, Professor of Economics, Meredith College, letter dated June 2, 2003.

General Comment: I have read the "Draft Evaluation Report and Environmental Assessment, Morehead City Harbor, Section 933, Carteret County, North Carolina, May 2003" and offer the following comments regarding the conclusions drawn with regard to the economic benefits and costs of the project.

In general, it is my professional opinion that the document fails to provide an economically valid or reliable basis for conclusions regarding the benefits of the project, and that therefore the economic conclusions drawn must be regarded as, at best, speculative. This opinion is based upon the following considerations:

Response: See our responses to the 8 comments below.

Comment 1. Failure to fully assess the in-progress locally-financed project: if I recall correctly, the project currently underway in this area with local financing was purported to provide 8-10 years of storm protection. If it IS performing as promised, then much of the storm protection claimed for the 933 project is attributable to the existing project, and should not be counted again as benefits for the 933 project. If the current project IS NOT performing as promised by USACE and the local sponsors, then it remains to be shown (1) why that (almost immediate) failure has occurred, and, (2) how/why the design of the 933 project differs in such ways that the failure will not be repeated. Otherwise, the economic analyst has no choice to presume that the 933 project will also fail almost immediately, thereby eliminating most of the claimed future benefits.

Response: The proposed 933 project considered the locally financed project in place and as part of the without project condition. Benefits were computed for the 933 project as compared to the without project condition, which included all proposed locally-financed nourishment.

Comment 2. Inadequate analysis of severe storm events: the discussion (and presumably, analysis) of major storm events is limited to categories 1 and 2. This omission is presumably justified by the fact that neither the existing beach nor the augmented beach provide much protection against the larger, more damaging storms, and therefore the augmentation would provide no benefit to analyze. What's missing is the possibility that a Category 4 or 5 storm could destroy many of the structures as well as much of the augmented beach, leaving no protection at all against future storms of any category, and thereby reducing the benefits of the project to essentially zero, thereafter. [Obviously, this line of reasoning contradicts the notion expressed in the document that short-term storm-damage to beaches quickly re-equilibrates to pre-existing conditions and contours; but if that reasoning is correct, how is it that we're still trying to "correct" damage that occurred in 1996?]

Response: The project analysis accounted for the probable occurrence of all expected storms, including category 4 and 5 hurricanes. The loss of beach in an extreme storm would reduce storm damages as compared to the loss of structures and infrastructure.

Comment 3. Inappropriate period for analysis: one searches in vain for any serious, substantive justification for analyzing a 10-year project over a 20-year period. One supposes that it might be argued that simply by delaying until 2015-2024 the damage that otherwise would have occurred during 2005-2014 there is a gain in present value. (That's true, but it's also true that the gain would be small.) If that is the reason for the 20-year observation period, it should be made explicit, and data presented so that the reader may verify that this indeed is what has been done. If there is some other reason for the 20-year observation period, then that should be presented. Otherwise, it must be concluded that the doubling of the observation period is both arbitrary and capricious, and that estimated benefits are therefore too large by a factor of 2.

Response: The period of analysis of 20 years was selected to take into account the expected life of the nourishment of 10 years and any immediate impacts in the period after the fill is expected to be gone. Both the with and without project conditions were evaluated over the same period of analysis. At an interest rate of 5 7/8 percent, a dollar of damage in year 10 has a present worth of only 56 cents as compared to a dollar of damage in the base year.

Comment 4. **Inadequate analysis of recreational benefits**: the valuation of recreational benefits is highly speculative, for several reasons: (a) the unit day-value lacked theoretical justification when it was first adopted some 40 years ago, and is now quite hopelessly obsolete; estimates based on this method are presumed to be completely lacking in economic validity; (b) the number of people using the beach can be estimated far more reliably than by aerial photographs; given the simplicity (and low cost) of simply sending an observer to the beach to count the people on the beach at various times on various days, the use of the far-less-direct aerial observance is simply not good science; (c) similarly, the estimates of room occupancy, conjoined with the assumption that every dweller in every room goes to the beach, perhaps contains an upward bias. Taking these deficiencies together, one is forced to conclude that the analysis of recreational benefits (as presented) is seriously biased and unreliable, and should not play any role in evaluating the 933 project. [One also notes that the language in the enabling statute refers explicitly to storm damage, but makes no mention of recreational value. A compelling legal case could be made that recreational value has no legal standing in a 933 analysis.]

Response: The proposed 933 project provides net economic benefits based solely on expected reductions in storm damages. The limitations in the unit-day value methods are known, but Principles and Guidelines allow it to be used under certain conditions, which this project meets. We understand that beach use on an annual basis varies greatly from day to day and season to season, but wanted to obtain some aerial photographs on July 4 to give us some information on the magnitude of beach use. The photographs, combined with motel occupancy data and traffic counts at the two bridges, help us estimate expected recreation use with and without the proposed 933 project. We will continue to gather additional recreation data on Bogue Banks as part of our ongoing studies in the region.

Comment 5. Contents value: the assumption that contents of commercial structures are valued at 50% of the structures' value is another empirical issue that could easily be verified by actual survey of actual commercial structures, rather than relying on local expert opinion. To rely on opinion when data can so easily be gathered is simply not acceptable procedure.

Response: We believe that the values we used were reasonable and properly determined, and tested the sensitivity of using lower content values, with little change in benefits.

Comment 6. Excess burden of taxation: although USACE procedures do not require it, sound economic analysis of economic benefits and costs requires consideration of the benefit reductions caused by the behavioral alterations caused by the use of taxation to finance projects. As per OMB suggestion, the analyst should increase cost estimates by about 25% to account for this effect; this adjustment results in a substantial reduction on net benefits.

Response: This concept is not reflected in either the Water Resources Council's Principles and Standards or the Corps' Principles and Guidelines. OMB has not asked the Corps to include this type of adjustment in their communications with us. There are also arguments that the discount rate should be lower to remove the expectation of inflation from the rates paid on US treasury bills, which would increase project net benefits.

Comment 7. Linear loss of land value: it is assumed that land's loss of value is linear with the loss of area (i.e., that every 1% reduction in area produces a 1% loss of value); further, it is asserted that this assumption is "reasonable and non-subjective." It may be indeed be reasonable, but it is absolutely subjective, insofar as many other relationships are both possible and reasonable. For instance, it is also reasonable to believe that small changes in area are largely unnoticed by the market as long as the lot remains (re) buildable, followed by a very large loss of value for the potentially very small loss of land that takes away the ability to build and/or rebuild. Which is correct? Once again, as we say in economics, that's an empirical question, to be answered not by theory but by statistical research. Otherwise, the choice is wholly subjective, and results based thereupon must be regarded as speculation.

Response: The guidance provides that we use near-shore land values rather than ocean front values in our land losses and benefits. Since the nearshore land is lost as the ocean erodes the shoreline, computing this on an as accrued basis seemed most reasonable. Other methods would provide similar results.

Comment 8: Taking all of these issues into account, it appears that the analysis as presented provides no sound economic basis for a conclusion regard the net economic benefits of the Morehead City 933 project. It is my belief that if all of these issues were fully and appropriately addressed, that the resulting net economic benefits would be far lower than as presented in the document, and quite possibly negative. Sound public policy demands that no action be taken pending correction of these deficiencies.

Response: We believe that the analyses performed are appropriate to the question being decided (Whether the Federal Government should participate in placing material from Brandt Island along a greater length of Bogue Banks?). The added cost is greatly exceeded by the expected additional benefits.

5.24 Mr. T. B. Doe, III, letter dated May 8, 2003.

Comment 1: This is in reference to your above titled May 2, 2003 document. Be advised that page 2, second paragraph, sentence three is in error. The notice specifically states, "...the proposed project is consistent with .... the land use plan for............. Towns of Atlantic Beach........." In fact, the proposed 933 project is in direct violation of the approved 1993 Town of Atlantic Beach Land Use Plan. Specifically, the Atlantic Beach Land Use Plan makes three references to the long standing disposal of Beaufort Inlet and Harbor spoils on Atlantic Beach.

• Page 1-71, (i) Excessive Erosion Areas.

"Numerous spoil projects performed by the U. S. Army Corps of Engineers as a result of dredging projects around the State Port have preserved the Atlantic Beach ocean shoreline. The sand utilized for the spoil was obtained from dredging projects in Beaufort Inlet and Bogue Sound."

• Page IV-6, Ocean Hazard Areas: (b)

"Atlantic Beach supports the deposit of dredge spoil by the U.S. Army Corps of Engineers on the beach and relocation as the preferred erosion control measures for ocean hazard areas."

Page IV-7, Ocean Hazard Areas: (e)

"Atlantic Beach will support the limited adjustment of the CAMA setback line in association with ongoing deposit of sand from dredge spoil projects and the establishment of new permanent dune and vegetation lines. However, it is understood that this policy will not impact permit decisions regarding CAMA setback line in ocean hazard areas unless the Coastal Resources Commission modifies the State use standards for this AEC."

These three sections of the document clearly tie into the ongoing placement of inner harbor spoils on Atlantic Beach. Transfer of more than 70% of the spoils required to continue this plan, elsewhere, to supply sand for the 933 project, clearly violates Atlantic Beach's Land Use Plan. A 933 plan that builds itself by taking the sand supporting Atlantic Beach's Land Use Plan must be rejected as not "consistent to the maximum extent.....".

Response: We disagree. We were unable to find any reference in the above mentioned land use plans, that the proposed Section 933 project would be inconsistent with the Atlantic Beach Land Use Plan if a certain percentage (i.e., 70% or any other percentage, see Mr. Doe's above comment) of maintenance material taken from the pumpout of Brandt Island or Morehead City Harbor navigation channels is not placed and retained on Atlantic Beach.

The last time that the Corps pumped out Brandt Island was in FY 1994. Approximately 2.5 million cubic yards of dredged material was pumped out of Brandt Island and placed on Bogue Banks from Fort Macon State Park to Pine Knoll Shores. By letter dated April 22, 1993, the NC Department of Environment, Health, and Natural Resources, Division of Coastal Management determined that the project was consistent with the enforceable policies and standards of the North Carolina Coastal Management Program (see US Army Corps of Engineers, Wilmington District. Finding of No Significant Impact, Disposal of Dredged Material on the Ocean Beach of Bogue Banks from the Combined Maintenance Dredging and Deepening of Morehead City Harbor Inner Harbor Navigation Channels, Bulkhead Channel, U.S. Navy LST Ramp, and Pumpout of Brandt Island Upland Diked Disposal Site, Carteret County, North Carolina. April 1993). By letter dated March 4, 1993 (enclosed in this FONSI dated April 1993), Mr. Bruce C. Payne, Town Planner for Atlantic Beach did not indicate that the placement of dredge maintenance material onto Bogue Banks from Fort Macon State Park to Pine Knoll Shores was inconsistent with the Town's Land Use Plan. Moreover, Mr. Payne's letter did not mention anything about the alleged requirement of 70% (or any other percentage) of the dredge material pumped onto Bogue Banks should be placed on Atlantic Beach.

By letter dated July 18, 2003 (copy found in Appendix 2), the North Carolina Department of Environment an Natural Resources, Division of Coastal Management agreed with the Wilmington Districts' determination that the proposed activity is consistent with the North Carolina Coastal Management Program to the maximum extent practicable providing that the five conditions mentioned in this letter were satisfied. The Wilmington District will comply with these conditions.

6.00 THREATENED AND ENDANGERED SPECIES

The EA includes a determination that the proposed Section 933 project will not adversely affect or threaten the continued existence of threatened and endangered species and is in compliance with Section 7 of the Endangered Species Act of 1973, as amended. The EA was provided to USFWS and NMFS on May 2, 2003.

Requirements for Section 7 of the Endangered Species Act of 1973, as amended have been met. The project is covered under a USFWS Biological Opinion dated July 22, 2003 and a NMFS Regional Biological Opinion dated 1997. All reasonable and prudent measures, as well as all terms and conditions of the USFWS Biological Opinion dated July 22, 2003 (see Appendix 2) and the NMFS Regional Biological Opinion dated 1997 (see letter dated June 13, 2003 from NMFS found in Appendix 2) will be complied with.

7.00 COMPLIANCE WITH ENVIRONMENTAL REQUIREMENTS.

7.01 Water Quality. A Section 404 (b)(1) evaluation was completed and is found in the referenced EA. A Section 401 Water Quality Certificate from the NC Division of Water Quality is required before the Section 933 work proceeds.

7.02 Air Quality. The project is in compliance with Section 176 (c) of the Clean Air Act, as amended (CAA). The Wilmington Regional Office of the North Carolina Department of Environment and Natural Resources has air quality jurisdiction for the project area. The ambient air quality for Carteret County has been determined to be in compliance with the National Ambient Air Quality Standards, and this county is designated as an attainment area (Personal Communication, 11 March 02, Brad Newland, Engineer, NC Division of Air Quality). The direct and indirect emissions from the project fall below the prescribed de minimus levels; therefore, this project is not anticipated to create any adverse effect on the air quality of this attainment area.

7.03 Cultural Resources. The US Army Corps of Engineers, Wilmington District, in consultation with the NC Division of Archives and History Underwater Archaeology Unit, have considered both the potential impact of the project and the nature of the known resources, and have determined that the information does not support a recommendation for an archaeological survey of the entire beach area. However, it is possible during the course of construction that vessel remains will be encountered. Therefore, the Underwater Archaeology Unit has requested that Wilmington District personnel, contractors, and others be aware that the possibility exists that this work may unearth a beached shipwreck. In the event that such occurs, work should move to another area and the Underwater Archaeology Unit should be contacted immediately. A staff member will be sent to assess the wreckage and, if practical, undertake appropriate documentation.

7.04 Executive Order 11988 (Flood Plain Management). Dredged maintenance material will be placed in the flood plain. The proposed action is not anticipated to induce development of the floodplain, or to otherwise adversely affect any floodplain, since the existing oceanfront property is already developed. The proposed action is in compliance with the requirements of Executive Order 11988.

7.05 Executive Order 11990 (Protection of Wetlands). The work will not require filling any wetlands. The proposed work will not produce any significant hydrologic or salinity changes affecting any wetlands. The proposed action is in compliance with Executive Order 11990.

7.06 Executive Order 11593 (Protection and Enhancement of the Cultural Environment). The proposed plan has been evaluated under Executive Order 11593, and it is not an undertaking affecting potential National Register sites.

7.07 Executive Order 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low Income Communities and Low Income Populations). The Proposed Action is not expected to disproportionately impact minority communities or low-income populations.

7.08 Executive Order 13405 (Protection of Children From Environmental Health Risks). This order mandates Federal agencies identify and assess environmental health and safety risks that may disproportionately affect children as a result of the implementation of federal policies, programs, activities, and standards (63 Federal Register 19883-19888). The Proposed Action would not impact schools or housing areas. The beaches at Bogue Banks are considered a gathering place for children. However, the actual beach construction zone would be fenced off and monitored by the contractor. No unauthorized individuals will be allowed within the work zone. Therefore, there would be no short- or long-term impacts on the health and safety of children.

7.09 Executive Order 13186 (Protection of Migratory Birds). This Executive Order mandates agencies to protect and conserve migratory birds and their habitats. The proposed action will not have a measurable negative affect on migratory bird populations. In fact the proposed action would restore and increase the riparian habitat along Bogue Banks beaches for migratory birds.
Migratory birds may also use Brandt Island for foraging, nesting, and roosting habitat. If the proposed action extends into the waterbird nesting season (1 April to August 31 of any year), we will work with representatives of NCWRC to reduce impacts to nesting waterbirds.

7.10 North Carolina Coastal Management Program

The project will take place in the designated coastal zone of the State of North Carolina. Pursuant to the federal Coastal Zone Management Act (CZMA) of 1972, as amended (P.L. 92-583), federal activities are required to be consistent to the maximum extent practicable with the federally approved coastal management program of the state in which their activities would be occurring. We believe that the Section 933 project is consistent with the North Carolina Coastal Management Program for the following reasons: 1. The dredge material found within Brandt Island and the Morehead City Harbor channels is compatible (See response to Comment 11: EFH Recommendations 3 within the NMFS letter (5.05) dated June 5, 2003, above), 2. Both the USFWS and NMFS indicated that the proposed action will not adversely affect endangered species, 3. Literature dating back to the early 1970's along the southeast coast indicate that opportunistic infauna species (ex. *Emerita* and polychaetes) found in the nourished areas are subject to direct mortality from burial, however, recovery often occurs between 1 to 3 years depending on sediment compatibility and the relationship of nourishment placement to recruitment timeframes (Hayden and Dolan, 1974; Saloman, 1984; Nelson, 1989; Van Dolah et al., 1992; Van Dolah et al., 1993; Hackney et al. 1996; P.C. Jutte et al., 1999). Therefore, a minimum three-year recovery period is not required. 4. The revised construction window is from November 1, 2003 to April 30, 2004 (to May 31, 2004, if required), and 5. Carteret County has agreed to continue monitoring the Phase 1 area (Pine Knoll Shores to Indian Beach (including Salter Path)) beyond November 2003, if adequate recovery of mole crabs and coquina clams does not occur. If required the monitoring would be extended to November 2004. Please note if the Section 933 project is not funded, Carteret County **will not** extend the monitoring until November 2004. .

By letter dated July 18, 2003 (copy found in Appendix 2), the North Carolina Department of Environment an Natural Resources, Division of Coastal Management agreed with the Wilmington Districts' determination that the proposed activity is consistent with the North Carolina Coastal Management Program to the maximum extent practicable providing that the five conditions mentioned in this letter were satisfied. The Wilmington District will comply with these conditions.

8.00 ENVIRONMENTAL IMPACTS

No unacceptable adverse effects on water resources (surface and groundwater), aquatic resources, terrestrial resources, wetlands and flood plains, threatened and endangered species, cultural resources, aesthetic and recreational resources, and socioeconomic resources are expected to occur as a result of the proposed project. The majority of the comments received during the coordination of the project indicate that the document adequately addresses the resources in the project area and the potential project-related impacts to those resources.

9.00 ENVIRONMENTAL COMMITMENTS

The following commitments will be followed:

1. A sea turtle nest-monitoring program will be implemented during construction if dredging and disposal occur during sea turtle nesting season on the beach from November 1 to November 15, 2003 and May 1 to May 31, 2004. If work takes place from November 1 to November 15, 2003 and from May 1 to May 31, 2004, the Wilmington District will be responsible for monitoring the construction area and will relocate any sea turtle nests. During the period of sea turtle nesting and hatching (November 1 to November 15, 2003 and May 1 to May 31, 2004), all lighting associated with project construction shall be minimized to the maximum extent practicable while maintaining compliance with all safety requirements. Reduced wattage and special fixtures or screens to reduce illumination of adjacent beach and near shore waters shall be used if practical. Lighting on offshore equipment shall also be minimized to the maximum extent practical while meeting Coast Guard requirements. Shielded low-pressure sodium vapor lights are highly recommended for all lights on the beach or on offshore equipment.

2. Monitor the beaches on Bogue Banks (from Fort Macon State Park to Indian Beach (including Salter Path) for escarpment formation following the placement of dredged material during construction and prior to the first turtle-nesting season (May 1, 2004), and will level the escarpment (if the escarpment exceeds 18 inches in height and 100 feet in length for a period of 48 hours). All beaches that have received dredged material will be tilled to a depth of 36-inches, prior to May 1, 2004. In order to avoid sea turtle nests, no tilling or leveling of escarpments will take place after May 1, 2004.

3. Should a hydraulic pipeline dredge be used offshore, the pipeline from the navigation channels to the disposal beach will be submerged until it reaches nearshore waters. The pipeline would be marked to let commercial and recreational boaters know of its presence along the bottom. Work barges and other appurtenances associated with a pipeline dredge operating in open water would be moored so as to minimize interference with boat traffic in the area.

4. There will be some loss of dune vegetation where the pipeline crosses the dune to the beach. Plants growing adjacent to the seaward side of the dunes will be buried by the discharge of dredged material. Dune vegetation disturbed by the pipeline crossing to the beach will be restored to pre-project grade and replanted following project completion. Planting stocks shall consist of sea oats and American beachgrass. The vegetative cover shall extend from the landward to the seaward toe of the dune. American beachgrass will be the predominant plant with sea oats as a supplemental plant. Planting would be accomplished during the season best suited for the particular plant.

5. Within Morehead City Harbor, some of the navigational channels are closed to shellfish harvesting. By Memorandum dated January 31, 2002, from the North Carolina Department of Environment and Natural Resources, Division of Environmental Health, Shellfish Sanitation and Recreational Water Quality Section (see Attachment B), if maintenance material is excavated from these closed shellfishing areas between May 1 and October 31 and placed on Bogue Banks a swimming advisory will be posted and a press release made. The Wilmington District will notify the Shellfish Sanitation and Recreational Water Quality Section prior to dredging from a closed shellfishing area with placement on a recreational swimming area.

6. Only beach compatible material will be placed on Bogue Banks from either the pumpout of Brandt Island or the maintenance dredging of the Morehead City Harbor navigation channels. We will include the following paragraph in the proposed Section 933 specifications, "*Materials: The dredging shall be accomplished so that the most suitable material available for beach disposal is placed within the prescribed section. Suitable materials shall be comprised of materials by ASTM D 2487 as SP, SP-SM, and SW. This material shall be predominantly of sand grain size with no more than 10% silt, shell, and clay material present. Should the dredge*

encounter materials not suitable for placement on the beach, the Contractor will be directed by the Contracting Officer to move to a more satisfactory location within Brandt Island or the navigation channels."

7. To the maximum extent practicable and during the warmer months, we will try to reduce direct impacts to intertidal macrofauna (mole crabs and coquina clams) by relocation to completed portions of the beach.

8. As indicated during our inter agency meeting on June 24, 2003, a representative from Carteret County stated that they would continue monitoring the Phase 1 area (Pine Knoll Shores to Indian Beach (including Salter Path)) beyond November 2003, if adequate recovery of mole crabs and coquina clams does not occur. If required the monitoring would be extended to November 2004. Please note if the Section 933 project is not funded, Carteret County **will not** extend the monitoring until November 2004.

10.00 FINDING OF NO SIGNIFICANT IMPACT

No unacceptable adverse effects on water and aquatic resources, terrestrial resources, wetlands and floodplains, threatened and endangered species, cultural resources, recreational resources, recreational fishing, or socioeconomic resources are expected to occur as a result of the proposed project. Based on the EA, referenced previously, the recommended plan will not significantly affect the quality of human environment; therefore, this action will not be subject of an environmental impact statement.

Date: 8/15/03

Charles R. Alexander, Jr.
Colonel, U. S. Army
District Engineer

Literature Cited

Coastal Science Associates, Inc. (CSAi). 2001. *Bogue Banks Beach Nourishment, Second Pre-Dredge Environmental Monitoring Study, June 2001*. Columbia, SC. 38 p. + appendices.

__________________________ (CSAi). 2002 A. *Bogue Banks Beach Nourishment, Second Pre-Dredge Environmental Monitoring Study, November 2001*. Columbia, SC. 32 p. + appendices.

__________________________ (CSAi). 2002 B. *Bogue Banks Beach Nourishment, Second Post-Dredge Environmental Monitoring Study, June 2002*. Columbia, SC. 51 p. + appendices.

__________________________ (CSAi). 2003. *Bogue Banks Beach Nourishment, Second Post-Dredging Environmental Monitoring Study, November 2002*. Columbia, SC. 49 p. + appendices.

Diaz, H. 1980. The Mole Crab *Emerita Talpoida* (Say): A Case of Changing Life History Pattern. *Ecological Monographs*, 50(4). Pp. 437-456.

Donoghue, C.R. 1999. The Influence of Swash Processes on *Donax variabilis* and *Emerita talpoida*. A dissertation presented to the graduate faculty of the University of Virginia in candidacy for the degree of doctor of Philosophy.

Hackney, C.T., M.H. Posey, S.W. Ross, and A.R. Norris. 1996. A Review and Synthesis of Data on Surf Zone Fishes and Invertebrates in the South Atlantic Bight and the Potential Impacts from Beach Nourishment. Report to the Wilmington District, U.S. Army Corps of Engineer. Wilmington, North Carolina. 109 pp.

Hayden, B. and R. Dolan. 1974. Impact of Beach Nourihsment on Distribution of *Emerita Talpoida*, the Common Mole Crab. 1974. *Journal of the Waterways Harbors and Coastal Engineering Division*.

Jutte, P.C., R.F. Van Dolah, and M.V. Levisen. 1999. An Environmental Monitoring Study of the Myrtle Beach Renourishment Project: Intertidal Benthic Community Assessment. Phase I – Cherry Grove to North Myrtle Beach. Final Report. South Carolina Department of Natural Resources Marine Resources Division, Charleston, South Carolina.

Leonard, L., K.L. Dixon, and O.H. Pilkey. 1990. A comparison of beach renourishment on the U.S. Atlantic, Pacific and Gulf coasts. *J. Coastal Res.*, Special Issue 6: 127-140.

Lynch, A.E. 1994. Macroinfaunal recolonization of Folly Beach, South Carolina, after beach nourishment. M.S., Marine Biology, University of Charleston, S.C., Charleston, South Carolina.

Nelson, W.G. 1989. An overview of the effects of beach nourishment on the sand beach fauna. In: Beach Preservation Technology '88: Problems and Advancements in Beach Nourishment, ed. L.S. Tait. Florida Shore and Beach Preservation Association, Tallahassee, Fl., USA. Pp 295-310.

Personnel Communication, Rick Spadoni, Senior Vice President, Coastal Planning and Engineering, Boca Raton, FL, November 27, 2002.

Personnel Communication, Charles H. Peterson. Institute of Marine Science – University of North Carolina at Chapel Hill, June 18, 2003.

Personnel Communication, Dr. Bart Baca, Program Director, Nova Southeastern University, Ft. Lauderdale, FL, November 27, 2002.

Pilkey, O.H. 1992. Another view of beachfill performance. *Shore and Beach*. 60(2): 20-25.

Rees, E.I.S., A. Nicholaidou, and P. Laskaridou. 1977. The effects of storms on the dynamics of shallow water associations. In Biology of benthic organisms, edited B.F. Keegan, P.O Ceidigh and B.P.J.S. Oxford: Pergamon Press.

Reilly, F.J. Jr. and V.J. Bellis. 1978. A Study of the Ecological Impact of Beach Nourishment with Dredged Materials on the Intertidal Zone. East Carolina University Institute for Coastal and Marine Resources, Technical Report No. 4, Greenville, North Carolina. 107 pp.

Saloman, C.H. and S.P. Naughton. 1984. Beach Restoration with Offshore Dredged Sand: Effects on Nearshore Macrofauna. U.S. Dept. of Commerce, National Oceanic and Atmospheric Association, NOAA Tech. Memorandum NMFS-SEFC-133. 20 pp.

U. S. Army Corps of Engineers, New York District. 1999. The New York District's Biological Monitoring Program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section Beach Erosion Control Project, Phases II-III, During Construction and 1st Year Post-Construction Studies.

U.S. Army Corps of Engineers, Wilmington District. 2002. Waterbird and shorebird use of beaches in Brunswick County, North Carolina, December 2000-November 2001. prepared by CZR, Incorporated for the Wilmington District under Contract DACW54-97-d-0028, March 2002. 46 pp plus appendices.

U.S. Army Corps of Engineers, Wilmington District. 2003. Waterbird and shorebird use of beaches in Brunswick County, North Carolina, December 2001-November 2002. prepared by CZR, Incorporated for the Wilmington District under Contract DACW54-97-d-0028, March 2002. 21 pp plus appendices.

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levisen, W.A. Roumillat. 1992. A physical and biological monitoring study of the Hilton Head beach nourishment project. Marine Resources Research Institute, South Carolina Marine Resources Division, Charleston, S.C. 159 pp.

Van Dolah, R.F., R.M. Martore, M.V. Levisen. 1993. Physical and biological monitoring study of the Hilton Head beach nourishment project. Supplemental report submitted to the Town of Hilton Head Island by the South Carolina Marine Resources Research Institute, South Carolina Marine Resources Division, Charleston, South Carolina. 10 pp.

Van Dolah, R.F., R.M. Martore, A.E. Lynch, P.H. Wendt, M.V. Levison, D.J. Whitaker, and W.D. Anderson. 1994. Final Report. Environmental evaluation of the Folly Beach nourishment project. South Carolina Department of Natural Resources, Marine Resources Division, Charleston SC. Prepared for the United States Army Corps of Engineers, Charleston District, Charleston, SC.

APPENDIX 1

Final Evaluation of Section 404(b) (1) Guidelines 40 CFR 230

MOREHEAD CITY HARBOR SECTION 933
CARTERET COUNTY, NORTH CAROLINA

Final Evaluation of Section 404 (b) (1) Guidelines 40 CFR 230

This evaluation covers the placement of all fill material into waters and wetlands of the United States required for construction of the Morehead City Harbor Section 933, Carteret County, North Carolina.

Section 404 Public Notice No. CESAW-TS-PE-03-16-0002

		Preliminary 1/	Final 2/
1.	Review of Compliance (230.10(a)-(d)) A review of the NEPA Document indicates that:		
a.	The discharge represents the least environmentally damaging practicable alternative and if in a special aquatic site, the activity associated with the discharge must have direct access or proximity to, or be located in the aquatic ecosystem to fulfill its basic purpose (if no, see section 2 and NEPA document);	YES ☐ NO☐	YES☒ NO☐
b.	The activity does not: 1) violate applicable State water quality standards or effluent standards prohibited under Section 307 of the CWA; 2) jeopardize the existence of federally listed endangered or threatened species or their habitat; and 3) violate requirements of any federally designated marine sanctuary (if no, see section 2b and check responses from resource and water quality certifying agencies);	YES☐ NO☐*	YES☒ NO☐
c.	The activity will not cause or contribute to significant degradation of waters of the U.S. including adverse effects on human health, life stages of organisms dependent on the aquatic ecosystem, ecosystem diversity, productivity and stability, and recreational, aesthetic, and economic values (if no, see section 2);	YES☐ NO☐	YES☒ NO☐
d	Appropriate and practicable steps have been taken to minimize potential adverse impacts of the discharge on the aquatic ecosystem (if no, see section 5).	YES☐ NO☐*	YES☒ NO☐

Proceed to Section 2
*, 1, 2/ See page 6.

2. Technical Evaluation Factors (Subparts C-F)

a. Physical and Chemical Characteristics of the Aquatic Ecosystem (Subpart C)

Factor	N/A	Not Significant	Significant
(1) Substrate impacts.		X	
(2) Suspended particulates/turbidity impacts		X	
(3) Water column impacts.		X	
(4) Alteration of current patterns and water circulation.		X	
(5) Alteration of normal water fluctuations/hydroperiod.		X	
(6) Alteration of salinity gradients.	NA		

b. Biological Characteristics of the Aquatic Ecosystem (Subpart D)

Factor	N/A	Not Significant	Significant
(1) Effect on threatened/endangered species and their habitat.		X	
(2) Effect on the aquatic food web.		X	
(3) Effect on other wildlife (mammals birds, reptiles, and amphibians).		X	

c Special Aquatic Sites (Subpart E)

Factor	N/A	Not Significant	Significant
(1) Sanctuaries and refuges.	NA		
(2) Wetlands.	NA		
(3) Mud flats.	NA		
(4) Vegetated shallows.	NA		
(5) Coral reefs.	NA		
(6) Riffle and pool complexes.	NA		

d. Human Use Characteristics (Subpart F)

Factor	N/A	Not Significant	Significant
(1) Effects on municipal and private water supplies.	NA		
(2) Recreational and commercial fisheries impacts		X	
(3) Effects on water-related recreation.		X	
(4) Aesthetic impacts.		X	
(5) Effects on parks, national and historical monuments, national seashores, wilderness areas, research sites, and similar preserves.		X	

Remarks: Where a check is placed under the significant category, preparer add explanation below.

Proceed to Section 3

*See page 6.

3. <u>Evaluation of Dredged or Fill Material (Subpart G) 3/</u>

a. The following information has been considered in evaluating the biological availability of possible contaminants in dredged or fill material. (Check only those appropriate.)

(1) Physical characteristics .... ☒
(2) Hydrography in relation to known or anticipated sources of contaminants .... ☒
(3) Results from previous testing of the material or similar material in the vicinity of the project .... ☒
(4) Known, significant sources of persistent pesticides from land runoff or percolation .... ☐
(5) Spill records for petroleum products or designated (Section 311 of CWA) hazardous substances .... ☐
(6) Other public records of significant introduction of contaminants from industries, municipalities, or other sources .... ☐
(7) Known existence of substantial material deposits of substances which could be released in harmful quantities to the aquatic environment by man-induced discharge activities .... ☐

(8) Other sources (specify). .... ☐

List appropriate references.

Reference: Finding of No Significant Impact, <u>Morehead City Harbor Section 933, Carteret County, North Carolina</u>, dated August 2003.

b. An evaluation of the appropriate information in 3a above indicates that there is reason to believe the proposed dredge or fill material is not a carrier of contaminants, or that levels of contaminants are sub-stantively similar at extraction and disposal sites and not likely to result in degradation of the disposal site.** YES ☒ NO☐*

<u>Proceed to Section 4</u>
*, 3/, see page 6.

4. Disposal Site Determinations (230.11(f)).

a. The following factors as appropriate, have been considered in evaluating the disposal site.

(1) Depth of water at disposal site. ☒

(2) Current velocity, direction, and variability at disposal site ☒

(3) Degree of turbulence. ☒

(4) Water column stratification ☒

(5) Discharge vessel speed and direction ☒

(6) Rate of discharge. ☒

(7) Dredged material characteristics (constituents, amount and type of material, settling velocities). ☒

(8) Number of discharges per unit of time. ☒

(9) Other factors affecting rates and patterns of mixing (specify)

List appropriate references.

Reference: Finding of No Significant Impact, Morehead City Harbor Section 933, Carteret Count, NC.

b. An evaluation of the appropriate factors in 4a above indicates that the disposal site and/or size of mixing zone are acceptable. YES ☒ NO ☐*

5. Actions to Minimize Adverse Effects (Subpart H).

All appropriate and practicable steps have been taken, through application of recommendations of 230.70-230.77, to ensure minimal adverse effects of the proposed discharge. List actions taken. YES ☒ NO ☐*

See Environmental Assessment and Finding of No Significant Impact.

Return to section 1 for final stage of compliance review. See also note 3/, page 3.
*See page 6.

6. Factual Determinations (230.11).

A review of appropriate information as identified in items 2-5 above indicates that there is minimal potential for short- or long-term environmental effects of the proposed discharge as related to:

a. Physical substrate at the disposal site (review sections 2a, 3, 4, and 5). YES ☒ NO ☐*

b. Water circulation, fluctuation, and salinity (review sections 2a, 3, 4, and 5). YES ☒ NO ☐*

c. Suspended particulates/turbidity (review sections 2a, 3, 4, and 5). YES ☒ NO ☐*

d Contaminant availability (review sections 2a, 3, and 4). YES ☒ NO ☐*

e. Aquatic ecosystem structure and function (review sections 2b and c, 3, and 5). YES ☒ NO ☐*

f. Disposal site (review sections 2, 4, and 5). YES ☒ NO ☐*

g. Cumulative impact on the aquatic ecosystem. YES ☒ NO ☐*

h. Secondary impacts on the aquatic ecosystem. YES ☒ NO ☐*

7. Findings.

a. The proposed disposal site for discharge of dredged or fill material complies with the Section 404(b)(1) guidelines. . . . . ☒

b. The proposed disposal site for discharge of dredged or fill material complies with the Section 404(b)(1) guidelines with the inclusion of the following conditions:. . . . . ☐

c. The proposed disposal site for discharge of dredged or fill material does not comply with the Section 404(b)(1) guidelines for the following reasons(s):

(1) There is a less damaging practicable alternative . . . . ☐

(2) The proposed discharge will result in significant degradation of the aquatic ecosystem . . . . ☐

*See page 6.

(3) The proposed discharge does not include all practicable and appropriate measures to minimize potential harm to the aquatic ecosystem. ☐

8.

Charles R. Alexander, Jr.
Colonel, U.S. Army
District Engineer

Date: 8/15/03

*A negative, significant, or unknown response indicates that the permit application may not be in compliance with the Section 404(b)(1) Guidelines.

1/ Negative responses to three or more of the compliance criteria at this stage indicate that the proposed projects may not be evaluated using this "short form procedure." Care should be used in assessing pertinent portions of the technical information of items 2 a-d, before completing the final review of compliance.

2/ Negative response to one of the compliance criteria at this stage indicates that the proposed project does not comply with the guidelines. If the economics of navigation and anchorage of Section 404(b)(2) are to be evaluated in the decision-making process, the "short form evaluation process is inappropriate."

3/ If the dredged or fill material cannot be excluded from individual testing, the "short-form" evaluation process is inappropriate.

APPENDIX 2

Letters Received During the 30-Day Review and Comment Period

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

MAY 13 2003

District Engineer
Wilmington District, Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402-1890
Attention: Mr. Hugh Heine (CESAW-TS-PE)

Subject: **Environmental Assessment (EA) and Finding Of No Significant Impact (FONSI) for Morehead City Harbor (Section 933), Carteret County, NC (dtd. May, 2003)**

Dear Sir:

Pursuant to Section 309 of the Clean Air Act, EPA, Region 4 has reviewed the subject document, an evaluation of the environmental consequences of placing dredged material from the Morehead City Harbor and the Brandt Island Upland Diked Disposal Area onto the Bogue Banks Beaches, viz., Atlantic Beach, Pine Knoll Shores, and Indian Beach. The subject beaches (13 miles in extent) will receive up to 6.3 million cubic yards of material from the two noted project sites. A berm system 30-feet wide at +7 NGVD will be constructed on a 1:25 slope in this one-time operation.

EPA has previously commented to the District on the overall advisability of pumping sand onto an eroding shore face. Generally, we have not had significant concerns about beach nourishment when it provides a disposal site for a proximate, already authorized navigation project. However, the more operative factor was whether or not biologically sensitive resources would be adversely affected through the use of this disposal option. In this particular case the value of the impacted natural resources which will be inundated do not appear compelling and/or at long-term risk. On the other hand, the declining width of the recreational beach, the storm protection potential afforded adjacent shore front property owners, and the acceptable expense of this disposal option appear to counter balance any unavoidable effects accruing from this proposal.

As a result, we have no substantive objections with the FONSI determination that an environmental impact statement is not necessary to evaluate the project. Thank you for the opportunity to comment. If we can be of further assistance, Dr. Gerald Miller (404-562-9626) will serve as initial point of contact.

Sincerely,

HMueller

Heinz J. Mueller, Chief
Office of Environmental Assessment

United States Department of Agriculture

NRCS
Natural Resources Conservation Service
4405 Bland Road, Suite 205
Raleigh, NC 27609

State Conservationist
Telephone No.: (919) 873-2101
Fax No.: (919) 873-2156
Email: mary.combs@nc.usda.gov

May 15, 2003

Mr. Hugh Heine
CESAW-TS-PE
Environmental Resources Section
U. S. Army Engineer District, Wilmington
P. O. Box 1890
Wilmington, NC 28402-1890

Dear Mr. Heine:

Thank you for the opportunity to provide comments on Draft Evaluation Report and Environmental Assessment, Morehead City Harbor Section 933, Carteret County, North Carolina.

The Natural Resources Conservation Service does not have any comments at this time. If you should have any questions, please contact Mike Hinton at (919) 873-2134.

Sincerely,

Mary K. Combs
State Conservationist

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
and Prevention (CDC)
Atlanta GA 30333

May 19,2003

W. Coleman Long
Chief Planning and Environmental Branch
Wilmington District
US Army Corps of Engineers
PO Box 1890
Wilmington, North Carolina 28402-1890

Dear Mr. Long:

We appreciate the opportunity to review the Draft Evaluation Report and Environmental Assessment (EA) for Morehead City Harbor, Section 933, Carteret County, North Carolina. We are responding on behalf of the U.S. Public Health Service, Department of Health and Human Services (DHHS).

This project will have beneficial effects when completed and we are in overall agreement with its implementation. We believe this EA has adequately addressed the potential human health and safety concerns with one exception. Although we agree with the Corps that the probability of contamination may be low, we still believe that Morehead City inner harbor sediments should be sampled prior to dredging. The cost of running a few samples to verify that there are no human health concerns from potentially contaminated sediments is minimal in relation to the estimated overall project cost of $16,354,000. We also noted that in response to your January 15, 2002 scoping letter, that the public and other review agencies had also raised a similar concern.

Thank you for the opportunity to review and comment on this document. Please send us a copy of the final document when it becomes available.

Sincerely yours,

Paul Joe

Paul Joe, DO, MPH
Medical Officer
National Center for Environmental Health (F16)
Centers for Disease Control & Prevention

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive North
St. Petersburg, FL 33702
(727) 570-5312; Fax 570-5517
http://caldera.sero.nmfs.gov

JUN 13 2003

F/SER3:DK

Mr. W. Coleman Long
Chief, Planning and Environmental Branch
Wilmington District Corps of Engineers
Department of the Army
P.O. Box 1890
Wilmington, NC 28402-1890

Dear Mr. Long:

This correspondence is in reply to the May 2, 2003, letter and accompanying information from the U.S. Army Corps of Engineers (COE), Wilmington District. The COE has requested section 7 consultation from the National Marine Fisheries Service (NOAA Fisheries), pursuant to the Endangered Species Act of 1973 (ESA). The project is the placement of beach quality material from the pumpout of Brandt Island and the maintenance dredging of Morehead City Harbor navigation channels on Bogue Banks. The NOAA Fisheries' consultation number for this project is I/SER/2003/00567; please refer to this number in future correspondence on this project.

The COE is proposing to use the beach quality sand collected from the maintenance dredging of Morehead City Harbor and the pumpout of the Brandt Island Upland Diked Disposal Area for beach renourishment on Bogue Banks. The proposed Section 933 (Water Resources Development Act of 1986) project would place this sand along about 70,000 feet (13 miles) of beach from Fort Macon State Park to Indian Beach if the requirements of Section 933 are satisfied. If Section 933 requirements are not satisfied placement will occur only along the base disposal plan area (Fort Macon State Park to Atlantic Beach, a distance of about 6 miles).

ESA-listed species under the purview of NOAA Fisheries which potentially occur in the project area include the green (*Chelonia mydas*), loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), and hawksbill (*Eretmochelys imbricata*) sea turtles, and the shortnose sturgeon (*Acipenser brevirostris*). A number of endangered large whale species are known to occur off North Carolina, but are not expected to occur in the project area. No critical habitat has been designated or proposed for listed species within the project area.

The maintenance dredging of the inner harbor and the pumpout of Brandt Island would be performed with a pipeline dredge, while the outer harbor maintenance dredging would be done by a hopper dredge. Pipeline dredging is not known to take sea turtles. When the hopper dredge is used, the project would be authorized under the regional biological opinion (RBO) on hopper dredging by NOAA Fisheries (September 25, 1997, biological opinion to U.S. Army Corps of Engineers, South Atlantic Division, on the continued hopper dredging of channels and borrow areas in the southeastern United States). All terms and conditions included in the RBO will be adhered to by the COE (e.g., observer and reporting requirements, dredging windows), which was reiterated by Mr. Hugh Heine in a May 20, 2003, phone call to NOAA Fisheries. Any incidental take of sea turtles resulting from the operation of hopper dredges by the COE's South Atlantic Division is authorized under the Incidental Take Statement (ITS) of that biological opinion, and such take would be counted toward the total allowable take in that ITS. Year to date, 6 loggerheads have been taken under the ITS for the South Atlantic coast hopper dredging RBO. The total take limit for the year is 35 loggerhead, 7 green, 7 Kemp's ridley, and 2 hawksbill sea turtles, as well as 5 shortnose sturgeon.

As stated above, pipeline dredging is not known to take sea turtles, and hopper dredging would be covered under the hopper dredging RBO. The placement of dredged material onto the Bogue Bank beaches would not have a direct impact on sea turtles in water, and would not have a substantial impact on sea turtle foraging habitat. Nesting-related impacts from beach renourishment fall under the purview of the U.S. Fish and Wildlife Service, which must be consulted regarding this aspect of the project. Turbidity resulting from the dredging and the spoil placement would be temporary and minimal. Shortnose sturgeon are not known to occur in the project area. NOAA Fisheries, therefore, believes that the proposed action is not likely to adversely affect any listed species under our purview.

This letter concludes the COE's consultation responsibilities under section 7 of the ESA for the proposed actions for federally-listed species, and their critical habitat, under NOAA Fisheries' purview. A new consultation should be initiated if there is a take, new information reveals impacts of the proposed actions that may affect listed species or their critical habitat, a new species is listed, the identified action is subsequently modified, or critical habitat is designated that may be affected by the proposed activity.

The action agency is also reminded that, in addition to its protected species/critical habitat consultation requirements with NOAA Fisheries' Protected Resources Division pursuant to section 7 of the ESA, prior to proceeding with the proposed action the action agency must also consult with NOAA Fisheries' Habitat Conservation Division (HCD) pursuant to the Magnuson-Stevens Fishery Conservation and Management Act's requirements for essential fish habitat (EFH) consultation (16 U.S.C. 1855 (b)(2) and 50 CFR 600.905-.930, subpart K). The action agency should also ensure that the applicant understands the ESA and EFH processes; that ESA and EFH consultations are separate, distinct, and guided by different statutes, goals, and time lines for responding to the action agency; and that the action agency will (and the applicant may) receive separate consultation correspondence on NOAA Fisheries letterhead from HCD regarding their concerns and/or finalizing EFH consultation. Consultation is not complete until EFH and ESA concerns have been addressed.

If you have any questions about EFH consultation for this project, please contact Mr. Ron Sechler, HCD, at (252) 728-5090. If you have any questions about this ESA consultation, please contact Dennis Klemm, fishery biologist, at the number above or by e-mail at Dennis.Klemm@noaa.gov.

Sincerely,

Roy E. Crabtree, Ph.D.
Regional Administrator

cc: F/PR3
F/SER41-R. Sechler
COE- SAD, Atlanta - Daniel Small

File: 1514-22 f.1 NC
O:\section 7\informal\Morehead City Harbor.wpd

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive North
St. Petersburg, Florida 33702

June 5, 2003

Colonel Charles R. Alexander, Jr.
District Engineer, Wilmington District
Department of the Army, Corps of Engineers
Regulatory Division
P. O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Coleman Long

Dear Colonel Alexander:

The National Marine Fisheries Service (NOAA Fisheries) has reviewed Public Notice CESAW-TS-PE-03-16-002 (Notice of Availability) and the Draft Environmental Assessment (EA) and Evaluation Report, dated May 2, 2003, for proposed work on Bogue Banks in Carteret County, North Carolina. The U.S. Army Corps of Engineers (COE) proposes to place dredged material from maintenance of the inner and outer harbor navigation channels, and stored at the Brandt Island upland disposal site, on oceanfront beaches of Fort Macon, Atlantic Beach, Pine Knoll Shores, and Indian Beach. Disposal of 1.8 million cubic yards of material is currently authorized for periodic placement along 6 miles of beach at Fort Macon and Atlantic Beach. The proposed Section 933 beneficial use of dredged materials project would extend this disposal area an additional 7.2 miles and authorize placement of 4.5 million cubic yards of material on beaches at Pine Knoll Shores and Indian Beach, which includes Salter Path. A total of approximately 6.3 million cubic yards of material would be placed along a total of 13.2 miles of oceanfront beach on Bogue Banks. A hydraulic pipeline dredge would be used to construct the project and work would begin on November 16, 2003, and continue through April 30, 2005, a total of 16 months.

NOAA Fisheries understands that the project would allow the beneficial use of dredged material and that other beach re-nourishment activities would not be authorized under this authority. We are concerned, however, that adverse impacts to fishery resources for which we have stewardship responsibility, may result. The project would involve disposal of dredged material in marine intertidal and ocean surf zone areas that are designated as Essential Fish Habitat (EFH) for Federally managed species. We note that an EFH Assessment is provided on Pages 36-40 in the EA and, by letter dated May 2, 2003, from the COE, NOAA Fisheries was notified that via transmittal of the EA, the Wilmington District was initiating coordination procedures for EFH as required by the 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA)(PL 94-265).

Based on our review of the EFH assessment, we find that EFH and associated managed species found in the project area are adequately described. However, we do not agree with the determination that project related impacts to Federally managed species would be minimal when viewed in connection with other similar and authorized projects in this area. The project would be located in an area identified by the South Atlantic Fishery Management Council (SAFMC) as EFH for red drum, brown shrimp, pink shrimp, and white shrimp. In addition, EFH for king mackerel and Spanish mackerel, is located just offshore of the immediate project area. Categories of EFH for various life history stages of these species include the marine water and ocean surf zone. In addition, tidal inlets such as Beaufort and Bogue inlets, located on the eastern and westernmost ends of the project area, respectively, are designated as Habitat Areas of Particular Concern (HAPC) for shrimp and red drum. EFH for summer flounder and bluefish, which are under jurisdiction of the Mid-Atlantic Fishery Management Council (MAFMC) also occur in the project area. Categories of EFH for these species include marine water column, intertidal areas, and marine bottoms. Other species of commercial, recreational, and ecological importance found in the project area include Atlantic croaker, spot, Atlantic menhaden, striped mullet, and Florida pompano. These species serve as prey for species such as king mackerel, Spanish mackerel, cobia, and others that are managed by the SAFMC, and for highly migratory species (e.g., billfishes and sharks) that are managed by NOAA Fisheries. In addition, pursuant to Section 906(e)(1) of the water Resources Development Act of 1986 (PL 99-602) NOAA Fisheries regards fishery resources impacted by this project and their associated habitats as aquatic resources of "national economic importance".

NOAA Fisheries is concerned that the EA does not adequately consider cumulative impacts to fishery resources that may result from multiple beach nourishment projects on Bogue Banks. The communities of Pine Knoll Shores, Indian Beach and Emerald Isle are currently authorized, via the three phased Bogue Bank Beach Nourishment Project (BBBNP), to place sand along 16.8-miles of beach on Bogue Banks. Beaches at Pine Knoll Shores and Indian Beach were recently impacted by a project that is similar to that being proposed, and similar work is planned for Emerald Isle in 2004. Environmental monitoring of these privately constructed projects indicate that populations of macro-invertebrates and several fish species that inhabit the surf zone of these beaches have not fully recovered. Construction of the proposed Section 933 project, as scheduled, would eliminate any recovery of these species which has taken place at Pine Knoll Shores and Indian Beach. Populations of mole crabs (*Emerita talpoida*) and coquina clams (*Donax variabilis*), which normally occurin the ocean surf zone EFH, are an important components of the aquatic food chain that supports regionally and nationally significant fishery resources. Elimination of these important food sources twice within a three year period could result in significant ecological impacts due to loss of forage organisms for other species; however, we acknowledge that detection of such impacts would be difficult.

Based on the preceding, NOAA Fisheries does not support the determination, as stated in the EA, that continuous dredging and disposal of dredged material on Bogue Banks for 16 months would only minimally impact fishery resources including Federally managed species. Work associated with the BBBNP was restricted to winter months (November 16 to the end of March or April of any year) and the COE Regulatory Division agreed that a seasonal restriction on dredging and disposal of dredged material on the beachfront was appropriate for protection of fishery resources. Consequently, NOAA Fisheries believes the same seasonal work restriction is needed in connection with the proposed Section 933 project.

In connection with the preceding, we further note that Phase I of the BBBNP was constructed between December 2001, and April 2002, and Phase II was constructed between January and March of 2003. Maintenance dredging of navigation channels in and around Morehead City harbor resulted in placement of another 200,000+ cubic yards of material on the Fort Macon shoreline in 2002. The proposed Section 933 project would place up to 6.3 million cubic yards of material on Bogue Banks in 2003, 2004 and, 2005, and Phase III of the BBBNP would immediately follow in the winter of 2004 - 2005. During this four year period, surf zone EFH would be repeatedly impacted and recovery of the macro-invertebrate forage base that supports Federally managed fishes could be negligible over a wide area of Bogue Banks.

The EA also provides no convincing evidence that the project would significantly reduce shoreline erosion and storm damage. The analyses of storm related erosion and damage, both with and without the project, does not adequately consider existing conditions created by Phases I and II of the BBBNP which has widened the beaches at Pine Knoll Shores and Indian Beach. This change has reduced the vulnerability of these locations to storm damage and the EA should be revised to include existing conditions in the "without the project" alternative analysis. Reevaluation of the "without the project"alternative to include the BBBNP could preclude the need for the proposed Section 933 project. In any case, NOAA Fisheries does not believe that the Section 933 project is the least environmentally damaging practical alternative since the cumulative impact to fishery resources over a relatively short period of time may be substantial and is undetermined.

The compatibility of sediments between those found at the Brandt island disposal site and those on Bogue Banks beaches is not adequately addressed in the EA. The 6.3 million cubic yards of material located at Brandt Island have not been tested for characteristics known to be of ecological importance (e.g., grain size/percent fines and carbonate/shell content). The EA assumes that this material is representative of the material historically found in the navigation channels and concludes that no further analysis is warranted. NOAA Fisheries is concerned that sediments removed from the navigation channels may contain significantly different percentages of shell, silt, and clay than those found Bogue Banks beaches. This is important since significant differences in sediment compositions could adversely affect the recovery of surf zone fish and invertebrate species. Based on (1) previous observations which revealed material previously pumped from Brandt Island to Fort Macon was darker and contained large amounts of shell; (2) previously stated concerns regarding the sediment compatibility at Bogue Banks; and (3) the absence of site specific sediment analysis for the Brandt Island material, we find no convincing basis for assertion, as contained in the EA, that the material is compatible and can be used without ecological or environmental impacts. Therefore, NOAA Fisheries recommends completion of a comprehensive evaluation of sediment size and composition prior to implementation of the proposed Section 933 project.

In view of the preceding, NOAA Fisheries recommends against construction of the project unless the following conditions are incorporated into the project plan.

EFH Conservation Recommendations

1. The "without the project" conditions in the EA should be modified to include shoreline changes associated with the BBBNP. The BBBNP represents a significant change in the

"without the project" conditions and these changes should be considered in the overall analyses of the need and timing of the proposed action.

2. In order to avoid and minimize adverse impacts to surf zone EFH and associated fishery resources during peak periods of biological activity, project construction should be limited to the period between November 16 and March 1 of any year.

3. Prior to the placement of fill material on Bogue Banks, it should be evaluated and found to be compatible and suitable with regard to fishery habitat and other ecological and environmental factors.

4. To avoid and minimize cumulative adverse impacts, scheduling of the project should be revised so that any section of beach nourished in connection with the BBBNP after December 2001, should allow for a minimum three year recovery period for fish and macro-invertebrate populations.

5. Avoidance and minimization of adverse impacts is always preferable to restoration after impacts occur; however, since placement of incompatible sediments on the ocean beachfront and surf zone is a reoccurring concern, the COE should develop a beach nourishment reclamation plan to address this possibility. The plan could include measures such as removal of incompatible material and replacement with compatible material and/or an increase in monitoring the magnitude and longevity of ecological impacts.

NOAA Fisheries is unable to concur with a Finding of No Significant Impact for this project and preparation of an Environmental Impact Statement (EIS) is recommended. An adequate EIS would provide for a comprehensive assessment of the site specific and cumulative impacts of Bogue Banks Section 933 project and other related activities and projects on Bogue Banks. Furthermore, the potential for significant and adverse long-term impacts to nationally important living marine resources is such that NOAA Fisheries may elect to recommend that the project not be implemented and, depending on the content and conclusions reached in the Final EA or EIS, refer this project to the Council on Environmental Quality under Section 1504 of the Council's Regulations for implementing the Procedural Provisions of the National Environmental Policy Act.

Section 305(b)(4)(B) of the MSFCMA and NOAA Fisheries' implementing regulation at 50 CFR Section 600.920(k) require your office to provide a written response to this letter within 30 days of its receipt. If it is not possible to provide a substantive response within 30 days, then in accordance with our "findings" with your Regulatory Functions Branch, an interim response should be provided to NOAA Fisheries. A detailed response then must be provided prior to final approval of the action. Your detailed response must include a description of measures proposed by your agency to avoid, mitigate, or offset the adverse impacts of the activity. If your response is inconsistent with our EFH Conservation Recommendations, you must provide a substantive discussion justifying the reasons for not following the recommendations.

Finally, these comments do not satisfy your consultation responsibilities under Section 7 of the Endangered Species Act of 1973, as amended. If any activity(ies) "may effect" listed species and habitats under the purview of NOAA Fisheries, consultation should be initiated with our Protected Resources Division at the letterhead address.

Thank you for the opportunity to provide these comments. Related questions or comments should be directed to the attention of Mr. Ronald S. Sechler at our Beaufort Office, 101 Pivers Island Road, Beaufort, North Carolina, or at (252) 728-5090.

Sincerely,

David H. Rackley

for Frederick C. Sutter III
Deputy Regional Administrator

cc:
USFWS Raleigh, NC
USEPA Athens, GA
NCWRC, Raleigh NC
NCDMF, Morehead City NC
SAFMC, Charleston NC

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

June 6, 2003

W. Coleman Long, Chief
Planning and Environmental Branch
Wilmington District
U.S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Dear Mr. Long:

This letter acknowledges the U.S. Fish and Wildlife Service's (Service) May 5, 2003 receipt of your May 3, 2003 letter requesting initiation of formal section 7 consultation under the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 et seq.). The consultation concerns the possible effects of your proposed Morehead City Harbor Section 933 Project on Federally-listed species, including the roseate tern (*Sterna dougallii*), piping plover (*Charadrius melodus*), West Indian manatee (*Trichechus manatus*), seabeach amaranth (*Amaranthus pumilus*), and green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), and loggerhead (*Caretta caretta*) sea turtles. All information required of you to initiate consultation was either included with your letter or is otherwise accessible for our consideration and reference.

The proposed action, as detailed in your draft Environmental Assessment and Evaluation Report, dated May 2003, consists of placing approximately 6.3 million cubic yards of dredged material stored in the Brandt Island disposal site and sediments from maintenance dredging of the inner and outer harbor navigation channels of Morehead City and Beaufort Inlet along approximately 13.2 miles of oceanfront beaches of Bogue Banks (including Fort Macon, Atlantic Beach, Pine Knoll Shores, Salter Path, and Indian Beach), Carteret County, North Carolina (hereafter referred to as Morehead City Harbor Section 933 Project). The proposed project is a one-time action scheduled to begin November 16, 2003 and continue for up to 16 months (estimated completion date April 30, 2005). However, the pump-out of Brandt Island and disposal of these sediments on the oceanfront beaches of Bogue Banks is expected to occur, as it has in the past, every 8 to 10 years.

The Service prepared a biological opinion, dated December 7, 1989, for the proposed dredging of Morehead City Harbor and subsequent disposal of dredged sediments in a Morehead City Ocean Dredged Material Disposal Site, an upland diked dredge disposal area on Brandt Island, or pumped directly onto the oceanfront beach at Atlantic Beach. In our biological opinion we concurred with your findings that the proposed action would have no effect on the piping plover, roseate tern, and hawksbill and Kemp's ridley sea turtles, and that the proposed action may affect loggerhead and green sea turtles. Our biological opinion concluded that the proposed action was not likely to jeopardize the continued existence of loggerhead and green sea turtles.

An amendment to the biological opinion, dated April 19, 1993, was prepared in response to updated project plans of the original dredge and disposal action. The project modifications included the disposal of additional dredged sediment material on oceanfront beaches from Fort Macon State Park to Pine Knoll Shores and a different pipeline route than reviewed in the original project. The amended biological opinion concluded that the proposed project modifications were not likely to jeopardize the continued existence of loggerhead and green sea turtles. The amended biological opinion also included a conference opinion for the proposed Federally-threatened seabeach amaranth in which we concluded that the proposed action would not likely jeopardize the continued existence of this species.

In your Biological Assessment, dated May 2003, you determined that the updated project plans for the proposed Morehead City Harbor Section 933 Project are not likely to adversely affect the roseate tern or the West Indian manatee. Moreover, you determined that the proposed activities may affect the piping plover, seabeach amaranth, and green, hawksbill, Kemp's ridley, leatherback, and loggerhead sea turtles. We concur with your determination that the proposed action may affect the hawksbill, Kemp's ridley, and leatherback sea turtles; however, we conclude that the proposed action is not likely to adversely affect these species. In addition, based on the information provided and other information available, we concur with your determination that the proposed action is not likely to adversely affect the roseate tern. With regard to the West Indian manatee, however, the Service would concur with your determination that the proposed action is not likely to adversely affect this species if the measures detailed in the *Precautionary Measures For Activities In North Carolina Waters Which May Be Used By The West Indian Manatee* (attached) are implemented.

Because the proposed action is different in timing and scope from the project reviewed in the original biological opinion and amendment, and new information is available on the piping plover, seabeach amaranth, and green and loggerhead sea turtles, we are initiating formal consultation for these species. Section 7 allows the Service up to 90 calendar days to conclude formal consultation with your agency and an additional 45 calendar days to prepare our biological opinion (unless we mutually agree to an extension). However, we expect to provide you our second amendment to the biological opinion by late-July. Based on the information provided and other information available, we anticipate the second amendment to conclude that the proposed action is not likely to jeopardize the continued existence of the piping plover, seabeach amaranth, and green and loggerhead sea turtles. The second amendment will primarily update the incidental take statement and the reasonable and prudent measures with their implementing terms and conditions based on information obtained since the last project review and first amendment to the biological opinion.

We have assigned log number 03-S243 to this consultation. Please refer to that number in future correspondence on this consultation. If you have any questions or concerns about this consultation or the consultation process in general, please feel free to contact me or Mr. David Rabon of my staff at (919) 856-4520 extensions 11 or 16, respectively.

Sincerely,

Garland B. Pardue

Dr. Garland B. Pardue
Ecological Services Supervisor

Encl.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

PRECAUTIONARY MEASURES FOR ACTIVITIES IN NORTH CAROLINA WATERS WHICH MAY BE USED BY THE WEST INDIAN MANATEE

The West Indian manatee (*Trichechus manatus*), also known as the Florida manatee, is a Federally-listed endangered aquatic mammal protected under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*) and the Marine Mammal Protection Act of 1972, as amended (16 U.S.C 1461 *et seq.*). The manatee is also listed as endangered under the North Carolina Endangered Species Act of 1987 (Article 25 of Chapter 113 of the General Statutes). The U.S. Fish and Wildlife Service (Service) is the lead Federal agency responsible for the protection and recovery of the West Indian manatee under the provisions of the Endangered Species Act.

Adult manatees average 10 feet long and weigh about 2,200 pounds, although some individuals have been recorded at lengths greater than 13 feet and weighing as much as 3,500 pounds. Manatees are commonly found in fresh, brackish, or marine water habitats, including shallow coastal bays, lagoons, estuaries, and inland rivers of varying salinity extremes. Manatees spend much of their time underwater or partly submerged, making them difficult to detect even in shallow water. While the manatee's principal stronghold in the United States is Florida, the species is considered a seasonal inhabitant of North Carolina with most occurrences reported from June through October.

To protect manatees in North Carolina, the Service's Raleigh Field Office has prepared precautionary measures for general construction activities in waters used by the species. Implementation of these measure will allow in-water projects which do not require blasting to proceed without adverse impacts to manatees. In addition, inclusion of these guidelines as conservation measures in a Biological Assessment or Biological Evaluation, or as part of the determination of impacts on the manatee in an environmental document prepared pursuant to the National Environmental Policy Act, will expedite the Service's review of the document for the fulfillment of requirements under Section 7 of the Endangered Species Act. These measures include:

1. The project manager and/or contractor will inform all personnel associated with the project that manatees may be present in the project area, and the need to avoid any harm to these endangered mammals. The project manager will ensure that all construction personnel know the general appearance of the species and their habit of moving about completely or partially submerged in shallow water. All construction personnel will be informed that they are responsible for observing water-related activities for the presence of manatees.

2. The project manager and/or the contractor will advise all construction personnel that

there are civil and criminal penalties for harming, harassing, or killing manatees which are protected under the Marine Mammal Protection Act and the Endangered Species Act.

3. If a manatee is seen within 100 yards of the active construction and/or dredging operation or vessel movement, all appropriate precautions will be implemented to ensure protection of the manatee. These precautions will include the immediate shutdown of moving equipment if a manatee comes within 50 feet of the operational area of the equipment. Activities will not resume until the manatee has departed the project area on its own volition (i.e., it may not be herded or harassed from the area).

4. Any collision with and/or injury to a manatee will be reported immediately. The report must be made to the U.S. Fish and Wildlife Service (ph. 919.856.4520 ext. 16), the National Marine Fisheries Service (ph. 252.728.8762), and the North Carolina Wildlife Resources Commission (ph. 252.448.1546).

5. A sign will be posted in all vessels associated with the project where it is clearly visible to the vessel operator. The sign should state:

> CAUTION: The endangered manatee may occur in these waters during the warmer months, primarily from June through October. Idle speed is required if operating this vessel in shallow water during these months. All equipment must be shut down if a manatee comes within 50 feet of the vessel or operating equipment. A collision with and/or injury to the manatee must be reported immediately to the U.S. Fish and Wildlife Service (919-856-4520 ext. 16), the National Marine Fisheries Service (252.728.8762), and the North Carolina Wildlife Resources Commission (252.448.1546).

6. The contractor will maintain a log detailing sightings, collisions, and/or injuries to manatees during project activities. Upon completion of the action, the project manager will prepare a report which summarizes all information on manatees encountered and submit the report to the Service's Raleigh Field Office.

7. All vessels associated with the construction project will operate at "no wake/idle" speeds at all times while in water where the draft of the vessel provides less than a four foot clearance from the bottom. All vessels will follow routes of deep water whenever possible.

8. If siltation barriers must be placed in shallow water, these barriers will be: (a) made of material in which manatees cannot become entangled; (b) secured in a manner that they cannot break free and entangle manatees; and, (c) regularly monitored to ensure that manatees have not become entangled. Barriers will be placed in a manner to allow manatees entry to or exit from essential habitat.

Prepared by (rev. 06/2003):
U.S. Fish and Wildlife Service
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726
919/856-4520

Figure 1. The whole body of the West Indian manatee may be visible in clear water; but in the dark and muddy waters of coastal North Carolina, one normally sees only a small part of the head when the manatee raises its nose to breathe.

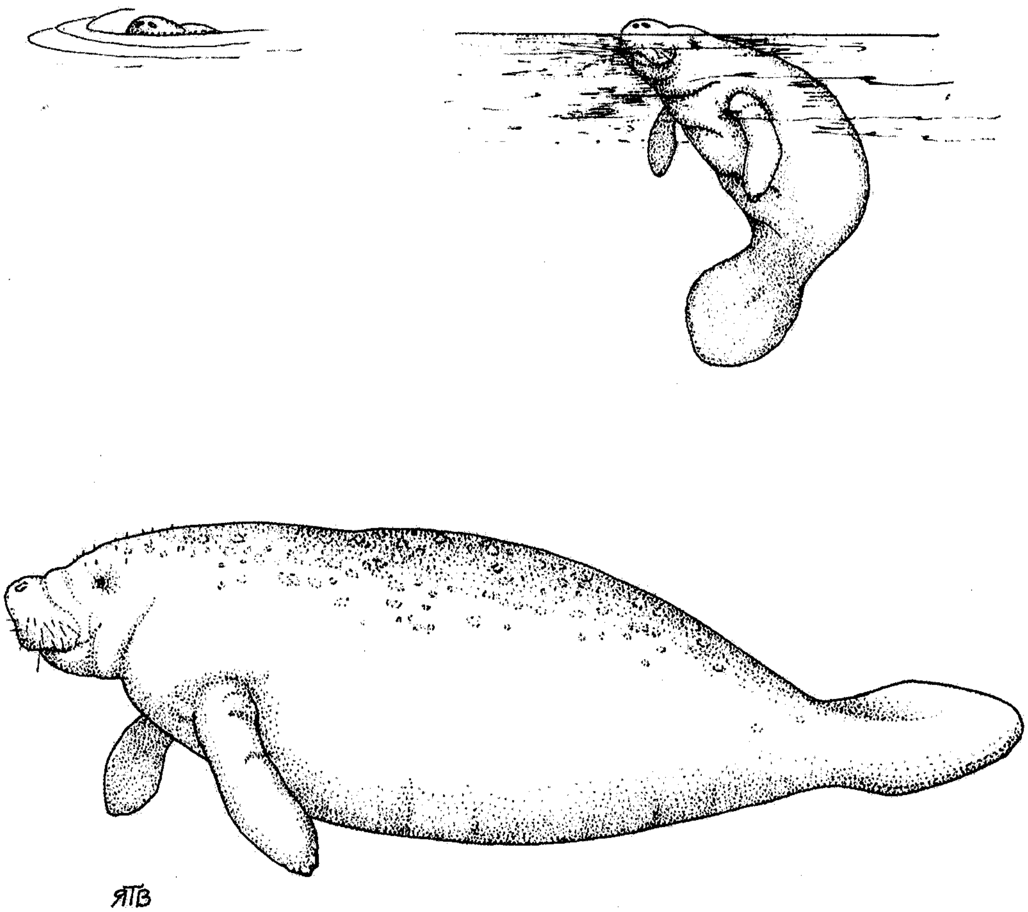


Illustration used with the permission of the North Carolina State Museum of Natural Sciences. Source: Clark, M. K. 1987. Endangered, Threatened, and Rare Fauna of North Carolina: Part I. A re-evaluation of the mammals. Occasional Papers of the North Carolina Biological Survey 1987-3. North Carolina State Museum of Natural Sciences. Raleigh, NC. pp. 52.

: 19 June 03 (GTB)
TS

P, DX, PM

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

June 6, 2003

Colonel Charles R. Alexander
District Engineer, Wilmington District
U.S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Dear Colonel Alexander:

The U.S. Fish and Wildlife Service (Service) has received the draft Environmental Assessment (EA) and Evaluation Report for the Section 933 project proposed for Bogue Banks in Carteret County, North Carolina. The U.S. Army Corps of Engineers (Corps) proposes to place material stored in the Brandt island disposal site and dredged during maintenance of the inner and outer harbor navigation channels of Morehead City and Beaufort Inlet on the oceanfront beaches of Fort Macon, Atlantic Beach, Pine Knoll Shores and Indian Beach. The currently authorized dredge disposal area is along approximately 6 miles of beach in Fort Macon and Atlantic Beach, and the proposed Section 933 project would extend the disposal area an additional 7.2 miles in Pine Knoll Shores and Indian Beach (which includes Salter Path). Up to 6.3 million cubic yards (mcy) of material are anticipated for placement along a total of 70,000 feet (13.2 miles) of oceanfront beach on Bogue Banks. Construction is proposed from November 16, 2003, through April 30, 2005.

These comments are submitted pursuant to, and in accordance with, provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and the Endangered Species Act of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.). This letter does not constitute the Service's report in accordance with Section 2(b) of the Fish and Wildlife Coordination Act (FWCA).

The Service issued a draft Fish and Wildlife Coordination Act (FWCA) report on the Federal shore protection project for Bogue Banks in November 2002 (available on our website at http://nc-es.fws.gov/pubs/fwca/bogue.html). This project is distinct from the Section 933 project and is a storm damage reduction project along the entire 26 mile length of Bogue Banks. In this report the Service summarized the fish and wildlife resources in the Bogue Banks area, which includes the project area for the proposed Section 933 project. The Service incorporates this report by reference, particularly its list of conservation measures for avoiding, minimizing and mitigating potential adverse environmental impacts resulting from the placement of fill material via dredging equipment on oceanfront beaches.

The Service supports projects that (1) are ecologically sound; (2) are the least environmentally damaging alternative; (3) have avoided and minimized damage or loss of fish and wildlife resources and uses; (4) have adopted all important recommended conservation measures to compensate for unavoidable damage or loss to fish and wildlife resources; and (5) are clearly a water dependent activity with a demonstrated public need if there are wetland or shallow water habitats in the project area (January 23, 1981, Federal Register v. 46, n. 15, p. 7659).

The Service does not believe that this project, as currently proposed, gives equal consideration to fish and wildlife resources and may generate adverse impacts to aquatic resources of national importance. In addition, we do not think this project meets the 404(b)(1) guidelines for the Clean Water Act.

Environmental Acceptability

The project documents do not adequately consider the locally constructed Bogue Banks Beach Restoration Project (BBBRP). The Evaluation Report and EA cite recent storm damages and erosion as the need for the project, and reduction in storm damages and erosional losses as the beneficial use of the dredged material. However, the Evaluation Report states that "the 'most likely future' scenario along the Section 933 project area is that erosion control measures by local and state interests are not expected to provide significant protection against the erosion and flooding associated with hurricane and storm events" (p. 19).

The Service strongly disagrees with this finding. The Section 933 project evaluation determined that a 30 foot wide addition to the beach would significantly reduce storm damages, for a total of \$8.95 million in annual benefits in Pine Knoll Shores and Indian Beach. The BBBRP had a design width of over 30 feet throughout these communities, however. To make a determination that the locally constructed beach wider than what the Corps has determined will significantly reduce storm damages and erosional losses (30 feet) as insignificant is not sound.

Secondly, the material to be pumped from Brandt Island (an estimated 4 mcy) has not been tested for sedimentary characteristics known to be ecologically significant to fish and wildlife resources (i.e., carbonate content, color, grain size). The Corps assumes that material presently within the navigational channels of the inner harbor are representative of the dredged materials currently residing in Brandt Island. The EA does not include the sedimentary analyses of this material (which the Service understands is presently underway) and makes the assumption that it is suitable for beach placement.

The Service does not concur with either of these assumptions. Material previously pumped from Brandt Island to Fort Macon contained dark gray and highly shelly material that created tall scarps that are still sometimes visible at the park (Figure 1). This material is similar to the ecologically incompatible material used in the BBBRP. It is not reasonable to assume that all of the material presently within Brandt Island is ecologically compatible with the native beaches of Bogue Banks. The Service strongly recommends sampling the sediments currently within Brandt Island to determine the compatibility of this material for beach placement.

Moreover, sediments that settle within navigation channels may be significantly finer than beach sands and contain high percentages of silt and clay. The Evaluation Report and EA assume that only beach quality sand will be present in the deepwater channels of the inner harbor. That assumption is premature. Since geotechnical data are presently being compiled for the sediments in the inner harbor channels, the Service recommends that any evaluation of the suitability of the material for beach placement be delayed until the data are available.

The least environmentally damaging alternative would utilize sediments that are ecologically compatible with Bogue Banks beaches. A recent study by the Service determined that native sediments of North Carolina beaches contain less than 12.8 % gravel (sediments larger than 2 millimeters (mm)), less than 4.1 % fines (sediments smaller than 1/16 mm), and an average of 7.4 % carbonate or shelly material. Site specific data available for Bogue Banks indicate that the native sediments for the sandy beach ecosystem contain 4.9 % gravel, 0.6 % fines, and 13.3 % shell material. The limited data utilized to assess sediment compatibility for the Section 933 project indicate that the proportion of fines may be 6 % to 12 % (p. EA-15, EA-16). The absence of sedimentary data for the Brandt Island fill material preclude a determination that the material is similar to existing material and suitable for fish and wildlife resources. Previous experiences with ecologically incompatible sediments at both Fort Macon and the BBBRP project area do not support a reasonable assumption that the Section 933 project will only place beach compatible material on the beaches of Bogue Banks.

Ecological Impacts

The local communities of Pine Knoll Shores, Indian Beach and Emerald Isle currently have a Regulatory Permit for the three phase Bogue Banks Beach Restoration Project along 16.8 miles of beach on Bogue Banks. Pine Knoll Shores and Indian Beach were constructed in 2001-02 (Phase I). Eastern Emerald Isle was constructed from January to March 2003 (Phase II). The third phase of this project is scheduled for western Emerald Isle during the winter of 2004-05. These oceanfront beaches were impacted by a dredge and fill project with dimensions similar to those proposed by the Section 933 project.

The available data indicate that the sandy beach ecosystem in the BBBRP area has not recovered, and the Section 933 project would eliminate any recovery gains made by the system in the last year. Furthermore, the Section 933 project would bury the closest recruitment population for macroinvertebrates at Atlantic Beach. The macroinvertebrate population, dominated by coquina clams (*Donax variabilis*) and mole crabs (*Emerita talpoida*), is the prey base for regionally and nationally significant waterbirds, shorebirds, and fishery species. The Service believes that burial of the macroinvertebrate prey population twice within a three year period will generate significant ecological impacts, delaying the recovery of the food source for longer than would occur if the Section 933 project were constructed after the prey base within the BBBRP area was fully recovered.

Furthermore, the cumulative impacts of multiple dredge and fill projects on Bogue Banks within a short period of time will be significant. The Service does not concur with the Corps' finding that cumulative impacts will be insignificant. Phase I of the BBBRP was constructed from December 2001 through April 2002. Phase II of the BBBRP was constructed from January to March 2003. Maintenance dredge disposal of navigational channels in and around the Morehead City harbor placed 209,348 cubic yards of material at Fort Macon during early 2002. The Section 933 project proposed to place 6.3 mcy of material on Bogue Banks in 2003, 2004 and 2005. Phase III of the BBBRP is currently scheduled for the winter months of 2004 and 2005.

The cumulative impacts of five large scale dredge and fill projects on the same barrier island within less than 4 years will be significant. Less than one mile of oceanfront beach on the island would remain undisturbed by fill placement in western Emerald Isle near Bogue Inlet. That less than one mile area would be indirectly impacted by the proposed Bogue Inlet Relocation Project during the same time period (as Bogue Inlet is proposed for relocation and/or mining for Phase III of the BBBRP). Migratory populations of waterbirds, shorebirds and fishery resources are not likely to have reliable sources of food along virtually the entire 26 mile long barrier island for a number of years.

Although the islands to the east and southwest of Bogue Banks are in conservation, several studies indicate that migratory birds have high site fidelity to migratory staging, stopover and overwintering sites that are smaller in areal extent (e.g., 10 kilometers (6.2 miles)) than Bogue Banks is long (e.g., 41.8 km (26 mi) (Dinsmore et al. (1998); Pfister et al. (1998); Johnson and Baldassarre (1988)). The Section 933 project documentation concludes that habitat disturbance from beach fill projects is not likely to have population level impacts on avifauna. Dinsmore et al. (1998, p. 171)), however, concluded that "habitat loss or alteration [on the Outer Banks of North Carolina] could adversely affect the Atlantic Flyway population of several [bird] species (e.g., Sanderlings) as well as the threatened Piping Plover." The draft EA does not adequately address the continuous perturbation of the Bogue Banks sandy beach ecosystem and the impacts it will have on migratory birds. Chronic disturbance of valuable foraging habitat may be more important than occasional disturbances and may affect shorebird survival rates (Pfister et al. (1992, 1998); West et al. (2002)). The Service disagrees with the Corps' finding that the proposed project will not significantly impact migratory bird populations and recommends that an Environmental Impact Statement be prepared to fully evaluate this concern.

As currently proposed, the Section 933 project anticipates a year-round construction schedule that would start November 16, 2003 and proceed for up to 16 months through April 30, 2005. The Corps proposes a Finding of No Significant Impact (FONSI) for this construction schedule, even though the generally accepted environmental window for dredge and fill projects in North Carolina occurs during the winter months from November 16 to the end of March or April annually. The Corps has determined that the year-round construction schedule and the use of hopper dredges may adversely impact federally-protected species such as sea turtles, piping plover (*Charadrius melodus*) and seabeach amaranth (*Amaranthus pumilus*). The Service contends that a FONSI is inconsistent with any shoreline stabilization or dredge disposal project (on beaches) scheduled for the summer months, which are the peak biological productivity period for coastal North Carolina.

404(b)(1) Guidelines

Environmental impacts should first be avoided, then minimized. Any unavoidable environmental impacts should then be compensated with mitigation. The draft EA has determined that the proposed Section 933 project has avoided and minimized environmental impacts. The Service does not concur with this finding.

If the project proceeds, the Service has identified the following conservation measures to avoid and minimize environmental impacts from a Section 933 project at Pine Knoll Shores and Indian Beach:

1) Avoid periods of peak biological activity, limiting construction to the environmentally acceptable window of November 16 to March 1 annually.

2) Use fill material that has been adequately evaluated and is ecologically compatible with the native beach material on Bogue Banks.

3) Update the without project condition and existing conditions of the project area to include the locally constructed Bogue Banks Beach Restoration Project.

4) Avoid pumping out Brandt Island during colonial waterbird and shorebird nesting seasons, when these species are likely to be nesting on Brandt Island.

5) Avoid destruction of habitat for the as yet unidentified skipper (*Atrytonopsis* new species 1) Brandt Island, which may be endemic to the greater project area, until ecological studies of the species are completed.

6) Avoid complete elimination of nesting waterbird and shorebird habitat on Brandt Island by configuring the remaining dikes and spoil material to include a bare sand island less than 15 feet in elevation and separated from vegetated areas by a minimum of 100 yards of deep water.

The Service has also identified several potential measures for compensatory mitigation for unavoidable ecological impacts:

1) Maintain a semi-permanent bare ground nesting island within the Brandt Island complex for shorebird and waterbird nesting, separated from vegetated areas by at least 100 yards of deep water to minimize predation of nests.

2) Enhance shorebird and waterbird nesting and foraging habitat in the area by working with the local sponsors to implement leash laws, bird nesting areas (denoted by signage and post and rope fencing), prohibiting beach driving in certain areas, and banning kites and fireworks. West Point near Bogue Inlet is a potential location for such mitigation.

3) Implement year-round bird monitoring in the project area to determine the longevity of ecological impacts to nesting and foraging waterbirds and shorebirds.

4) Implement a survey and monitoring program for the unnamed skipper to aid in the identification, description and conservation of this potentially new species.

5) Enhance the recovery of macroinvertebrate species in the fill placement areas by harvesting and transplanting dominant species or stocking the new fill material with cultured populations.

6) Design a remediation plan for inadvertent placement of incompatible fill materials on the beach. Remediation measures may include removal of incompatible material, replacement with compatible material, and increased scientific monitoring of the magnitude and longevity of ecological impacts.

The Service believes that incorporation of these conservation measures to avoid, minimize and mitigate for ecological impacts would satisfy the 404(b)(1) guidelines. At present the draft EA does not include conservation measures to sufficiently avoid and minimize impacts.

In conclusion, the Service does not believe that the proposed Section 933 project for Bogue Banks, as presently designed, gives equal consideration to fish and wildlife resources. The project as proposed does not meet the criteria of the Service's Mitigation Policy. A Finding of No Significant Impact is not warranted and the Service requests an Environmental Impact Statement be prepared. The ecological impacts of the project are likely to be significant, particularly if the current perturbations to the Bogue Banks sandy beach ecosystem and the migratory populations that it supports are continued. In accordance with the procedural requirements of the 1992 404(q) Memorandum of Agreement, Part IV.3(a), we are advising you that the proposed work may result in substantial and unacceptable impacts to aquatic resources of national importance.

We appreciate the opportunity to provide comments on the draft Evaluation Report and

Environmental Assessment. Please contact Tracy Rice of my staff at (919) 856-4520 extension 12 with any questions or comments.

Sincerely,

Garland B. Pardue, Ph.D.
Ecological Services Supervisor

References

Dinsmore, S.J., J.A. Collazo, and J.R. Walters. 1998. Seasonal numbers and distribution of shorebirds on North Carolina's Outer Banks. *Wilson Bull.*, 110(2): 171-181.

Johnson, C.M., and G.A. Baldassarre. 1988. Aspects of the wintering ecology of piping plovers in coastal Alabama. *Wilson Bull.*, 100: 214-223.

Pfister, C., B.A. Harrington, and M. Lavine. 1992. The impact of human disturbance on shorebirds at a migration staging area. *Biological Conservation* 60: 115-126.

Pfister, C., M.J. Kasprzyk, and B.A. Harrington. 1998. Body fat levels and annual return in migrating Semipalmated Sandpipers. *Auk* 115: 904-915.

West, A.D., J.D. Goss-Custard, R.A. Stillman, R.W.G. Caldow, S.E.A. le V. Dit Durell, and S. McGrorty. 2002. Predicting the impacts of disturbance on shorebird mortality using a behaviour-based model. *Biological Conservation* 106: 219-328.

cc: NC WRC, Washington, NC (David McHenry)
NC WRC, Trenton, NC (David Allen)
NC WRC, Beaufort, NC (Matt Godfrey)
NC DMF, Morehead City, NC (Mike Street)
NC DCM, Raleigh, NC (Donna Moffitt)
NMFS, Beaufort, NC (Ron Sechler)
EPA, Atlanta, GA (Gerald Miller)
North Carolina Coastal Federation, Newport, NC (Todd Miller)

Figure 1. A previous placement of dredged material at Fort Macon contained ecologically incompatible material that was dark gray and shelly. This material still forms resistant scarps over 5 feet tall at Fort Macon State Park. Note the 15 centimeter scale propped on the vertical scarp. A dredge pipe from the 2002 fill placement at Fort Macon is visible at the base of the scarp. Photo taken March 2002.

North Carolina
Department of Administration

Michael F. Easley, Governor

Gwynn T. Swinson, Secretary

June 9, 2003

Mr. Hugh Heine
Dept. of the Army/Corps of Engineers
Environmental Resources Section
PO Box 1890
Wilmington, NC 28402-1890

Dear Mr. Heine:

Re: SCH File # 03-E-0000-0315; Environmental Assessment; Morehead City Harbor Section 933; Placement of dredged same beach quality sand on about 13 miles of Bogue Bank beaches to reduce potential of erosion and storm damage.

The above referenced environmental impact information has been submitted to the State Clearinghouse under the provisions of the National Environmental Policy Act. According to G.S. 113A-10, when a state agency is required to prepare an environmental document under the provisions of federal law, the environmental document meets the provisions of the State Environmental Policy Act. Attached to this letter for your consideration are the comments made by agencies/organizations to this office in the course of this review.

If any further environmental review documents are prepared for this project, they should be forwarded to this office for intergovernmental review.

Should you have any questions, please do not hesitate to call.

Sincerely,

Chrys Baggett

Ms. Chrys Baggett
Environmental Policy Act Coordinator

Attachments

cc: Region P

Mailing Address:
1302 Mail Service Center
Raleigh, NC 27699-1302

Telephone: (919)807-2425
Fax (919)733-9571
State Courier #51-01-00
e-mail Chrys.Baggett@ncmail.net

Location Address:
116 West Jones Street
Raleigh, North Carolina

NCDENR
North Carolina Department of Environment and Natural Resources

Michael F. Easley, Governor

William G. Ross Jr., Secretary

MEMORANDUM

TO: Chrys Baggett
State Clearinghouse

FROM: Melba McGee
Environmental Review Coordinator

RE: 03-0315 DEA for Morehead City Harbor Section 933, Bogue Banks, Carteret County

DATE: June 6, 2003

The Department of Environment and Natural Resources has completed its review of the proposed draft evaluation report. The purpose of this report is to investigate the placement of dredged maintenance material along a portion of Bogue Banks beaches.

The primary concern with the beach disposal is the potential for indirect impacts to mole crabs, coquina clams, sea turtles and shore birds due to potential reductions on food resources. The department is equally concerned with the effects of year round disposal on fish and birds, the quality of the disposal material, its effect on sand temperature, meeting recommended moratorium deadlines and monitoring. The department does not believe the Environmental Assessment provided a thorough discussion of these points and believes division's concerns should be thoroughly addressed prior to this project moving forward. It is our recommendation that the Corps of Engineers would benefit more by preparing an Environmental Impact Statement. The Environmental Impact Statement would give a more accurate picture of the direct impacts and evaluate whether the dredge disposal would have insignificant impacts on the beach ecosystem.

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone: 919-733-4984 \ FAX: 919-715-3060 \ Internet: www.enr.state.nc.us/ENR

Thank you for the opportunity to respond. The Corps is encouraged to notify our reviewing divisions with any problems or questions they may have in resolving their concerns. Final approval will depend on the impacts of this project being adequately addressed.

Attachments

NCDENR
North Carolina Department of Environment and Natural Resources
Division of Marine Fisheries

Michael F. Easley, Governor
William G. Ross, Jr., Secretary

Preston P. Pate, Jr., Director

MEMORANDUM

TO: Melba McGee
Environmental Coordinator
Office of Legislative & Intergovernmental Affairs

FROM: Preston P. Pate, Jr., Director
Division of Marine Fisheries

DATE: May 27, 2003

SUBJ: Morehead City Harbor Section 933 EA
Carteret County

I have reviewed the comments provided by the District Manager and/or Bio-Supervisor and concur with their recommendation(s).

Preston P. Pate Jr. 5/23/03
Director, Date
Preston P. Pate, Jr.

____
Deputy Director, Date
Michael G. Buhl

____
Habitat Protection Section Date
Section Chief,
Michael W. Street

3441 Arendell St., P.O. Box 769 Morehead City, North Carolina 28557
Phone: 252-726-7021 \ FAX: 252-727-5127 \ Internet: www.ncdmf.net

Subject: Morehead City Harbor/Bogue Banks 933 project
Date: Fri, 06 Jun 2003 09:10:57 -0400
From: Mike Street <mike.street@ncmail.net>
To: Melba McGee <Melba.McGee@ncmail.net>
CC: Mike Marshall <Mike.Marshall@ncmail.net>

Melba -- Mike Marshall and I have discussed the subject project. We agree that there are several issues of sufficient importance that they cannot be adequately addressed in a revised Environmental Assessment. Of special concern are cumulative impacts of this proposed one-time project and all the other proposed (reasonably foreseeable) and ongoing beach nourishment projects along Bogue Banks, including work in both Beaufort and Bogue inlets. It is simply unrealistic scientifically to continue to examine these many projects independently when the effects of these projects are not independent. Therefore, the Division of Marine Fisheries urges that an Environmental Impact Statement be prepared for the subject project.
Street

Michael W. Street <Mike.Street@ncmail.net>

State of North Carolina
Department of Environment
and Natural Resources
Division of Marine Fisheries

Michael F. Easley, Governor
William G. Ross. Jr., Secretary
Preston P. Pate, Jr., Director

NCDENR
North Carolina Department of Environment and Natural Resources

May 19, 2003

MEMORANDUM

TO: Melba McGee
THROUGH: Mike Street
FROM: Mike Marshall
SUBJECT: Morehead City Harbor Section 933 EA

The NC Division of Marine Fisheries (DMF) has reviewed the subject environmental assessment (EA) under authority of G. S. 113-131 and according to the Policies of the North Carolina Marine Fisheries Commission for Beach Dredge and Fill Projects, and we offer the following comments.

The subject EA discusses the impacts of lengthening the authorized beach disposal area for the Morehead City Harbor navigation project from 7 miles to 13 miles. The increased area will include western Pine Knoll Shores and Indian Beach along with the authorized areas of Fort Macon, Atlantic Beach and eastern Pine Knoll Shores.

Continuous pipeline construction is proposed beginning November 16, 2003 and construction is possible after May 1, 2004 in western Pine Knoll Shores and Indian Beach. Construction on a year round basis will result in impacts to local recreational and commercial fishing activities. Public trust uses of the surf zone and intertidal beach will also be affected during intensive use periods if construction extends into the summer months. These impacts should be examined in the EA.

The EA does not address the effects of year round pumping on beach prey species. The anticipated rate of 200 feet per day could have significant impacts on populations of mole crabs and coquina clams if allowed during the months when these species inhabit the interitdal beach. These impacts need to be discussed.

The EA rejects our earlier recommendation to monitor the impacts of the project and to coordinate that monitoring with the Bogue Banks monitoring plan. This course of action presents several problems that will affect our comments on further requests for large scale beach nourishment utilizing offshore borrow sites. The Morehead City Harbor Dredging and 933 beach disposal will progressively alter by pumping spoil onto sampling stations designed to evaluate the impacts of the Bogue Banks project. By May 1, 2004, at least three control stations and three monitoring stations will have been altered and two years of monitoring data will not be collected or will be compromised for those sites. Those six sites are 40% of the sites to be sampled and 50% of the control sites. Monitoring of the Bogue Banks project has taken on higher significance due to the high shell content of much of the nourishment material. This material may require extended

P.O. Box 769, Morehead City, North Carolina 28557-0769 Telephone 252-726-7021 FAX 252-726-0254

time for the beach to recover from making extended sampling critical. The impacts of the current project on this sampling should be addressed in the EA.

The possibility that a prolonged recovery period may be necessary for the Bogue Banks project indicates that further recovery time may be created by the additional nourishment in Pine Knoll Shores and Indian Beach. However, the initial recovery period may be reduced if the additional material is of better quality. Both of these possibilities should be examined in the EA.

Thank you for the opportunity to review and comment on the EA.

DMF finds the EA inadequate unless it is amended as indicated.

NCDENR
North Carolina Department of Environment and Natural Resources
Division of Coastal Management
Michael F. Easley, Governor **Donna D. Moffitt, Director** William G. Ross Jr., Secretary

MEMORANDUM

RECEIVED
JUN 1 0 2003
DIV. OF COASTAL MANAGEMENT RALEIGH

TO: Guy Pearce, Consistency Coordinator

FROM: M. Ted Tyndall, Morehead City District Manager

SUBJECT: DCM03-06; Draft Environmental Assessment – Morehead City Harbor – Section 933, Carteret County

DATE: June 6, 2003

The project is located on Bogue Banks in the communities of Atlantic Beach, Pine Knoll Shores, and Indian Beach (which includes Salter Path) and includes Fort Macon State Park. This office offers the following comments and recommendation on the subject project.

Brandt Island was previously pumped out back in 1986 and 1994. The material was placed onto the beaches of Atlantic Beach and Fort Macon. These projects were found consistent with the Coastal Management Program in late 1985 and amended in March of 1986. Then in early 1993, the DCM made a determination that the "base disposal area" covering some 6 miles of Atlantic Beach and Fort Macon remained consistent with the Coastal Management Program. Similarly, the area to be nourished under the authority of Section 933 includes over 7 miles of Pine Knoll Shores, Indian Beach and Salter Path. This is the same area that was authorized for beach nourishment under CAMA Major Permit #124-01 and most of which was completed.

Based on our review, this office would offer the following comments regarding the Draft Evaluation and Environmental Assessment.

1) On page EA-3, there is a statement that "beach-quality dredged material" must not have more than 10 percent fine sediment. This statement read in conjunction with the preceding statement on that page about the Coastal Management Program requiring beach-quality sand dredged from navigation channels not being permanently removed from the system is somewhat misleading. Currently, the Division of Coastal Management does not have any rules that reference a specific sand/silt percentage for beach deposition.

2) The document states that the towns of Atlantic Beach and Pine Knoll Shores will be responsible for surveying the first line of stable natural vegetation along the beach strand within their jurisdiction. By CRC rule, this line is the vegetation line that existed before commencement of the 1986 and 1994 projects. The division requests copies of these maps, preferably done as overlays on ortho aerial photographs.
3) The Division of Coastal Management would echo sentiments made by Jody Merritt, the Park Superintendent, in his February 2, 2002 letter regarding the importance of sand being placed on the recreation beach at the Fort. The Division of Coastal Management concurs that the beach access point near the western end of the Park should be a high priority for sand deposition. The sand pumped in front of the Fort back in 2002 stopped short of this area leaving a very narrow useable beach at high tide.
4) The office would also request that if a consistency statement is issued that all commitments made in the EA, including those listed on page EA-52, be listed as conditions of that consistency.

Based on our review, it appears that the proposal is consistent with the North Carolina Coastal Management Program.

cc: Charles Jones - Assistant Director, DCM
Brad Shaver - Field Representative, DCM
Tracey Wheeler - Field Representative, DCM

North Carolina Wildlife Resources Commission

Charles R. Fullwood, Executive Director

MEMORANDUM

TO: Melba McGee, Environmental Coordinator
Office of Legislative and Intergovernmental Affairs
North Carolina Department of Environment and Natural Resources

and

Guy Pearce, Consistency Coordinator
Division of Coastal Management
North Carolina Department of Environment and Natural Resources

FROM: Shannon Deaton, Section Manager
Habitat Conservation Section

DATE: May 27, 2003

SUBJECT: Comments on Draft Evaluation Report and Environmental Assessment for Morehead City Harbor Section 933, Bogue Banks, Carteret County, North Carolina.

OLIA project # 03-0315
DCM03-06

Biologists with the North Carolina Wildlife Resources Commission (Commission) reviewed the Environmental Assessment (EA) with regard to impacts of the project on fish and wildlife resources. Our comments are provided in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and the North Carolina Environmental Policy Act (G.S. 113A-1 et seq., as amended; 1 NCAC-25).

The United States Army Corps of Engineers (Corps) is proposing disposal of dredge material on Bogue Banks to replenish the eroding beaches and reduce the potential for storm damage. The Corps currently disposes of dredged material from the Brandt Island disposal site and Morehead City Harbor navigation channels along a 32,000' base disposal area extending from Fort Macon to Atlantic Beach. Under provisions of Section 933 of the Water Resources Development Act, the Corps, with cost-sharing support from Carteret County, is proposing extending the disposal area by 38,000' on beach along the towns of Pine Knoll Shores, Indian Beach, and Salter Path. If the Section 933 project is implemented, the existing base disposal area will receive 1.8 million cubic yards of material with a design berm width reduced from 150' to 30'. The Section 933 project area would receive approximately 4.5 million cubic yards of material to construct a design berm with a width of 30 feet and elevation of 7 feet. Project construction with pipeline and hopper dredges may begin November 16, 2003 and continue uninterrupted for up to 16 months. Hopper dredging would only be used in the Morehead City outer harbor from January 1 to March 31 of any year to minimize the potential take of sea turtles.

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 733-3633 ext. 281 • **Fax:** (919) 715-7643

DENR Fax:9197152060 Jun 9 2003 10:21 P.07

The proposed Section 933 project is inconsistent with our *Policies and Guidelines for Conservation of Wetlands and Aquatic Habitats*. The Commission recognizes that beach renourishment is sometimes necessary to counteract erosion that threatens developed coastal areas. However, renourishment should be conducted in a manner that minimizes direct, adverse impacts on wildlife resources and their habitat. Avoidance of critical nesting or foraging periods is often used to minimize impacts on wildlife resources. Beach or dune construction activities during these critical periods should only be conducted when human health and safety are in eminent danger. Beach renourishment conducted from 2001 to 2002 along the Section 933 project area has largely precluded the urgency to conduct additional beach disposal during recommended moratoriums. The Commission has the following additional comments and concerns regarding impacts of the proposed project on fish and wildlife resources and recommended mitigation strategies for those impacts:

Sea Turtle and Shorebird Impacts

- The Commission disagrees with the inference that beaches on Bogue Banks are suitable for only loggerhead (*Caretta caretta*) turtles. In fact, during the 2000 nesting season, there was a confirmed green (*Chelonia mydas*) turtle nest on Bogue Banks and habitat there is also suitable for leatherback (*Dermochelys coriacea*) turtles. Given that nesting by both leatherbacks and green turtles has sharply increased in the last 10 years in the Southeastern United States, and North Carolina represents the northern limit of nesting for both of these species, increased nesting in the state in the near future would not be unexpected. Therefore, Bogue Banks must be considered suitable nesting habitat for loggerheads, as well as greens and leatherbacks.
- Restricting hopper dredging between January and March is appropriate because water temperatures are cool and sea turtle abundance is likely to be lowest. However, as experienced with other similar projects, anticipated schedules are sometimes delayed, which places sea turtles at substantial risk. Therefore, the Commission feels that contingency sea turtle protection plans need to be prepared including anticipatory trawling to remove any turtles in the project area.
- In addition to in-water measures, if renourishment occurs during the sea turtle nesting season, sufficient time must be provided on a daily basis to allow volunteers/monitors to locate at-risk nests for subsequent relocation. The Commission recommends a no-work window until 10 am each day during the nesting season to ensure sufficient time to get any nests off the beach, and also to locate any turtles that nest late into the night and do not return to the ocean until around sunrise. Effective communication between the monitors and the dredge workers is essential to these mitigation efforts.
- The Commission is encouraged by the prospect that the material proposed for placement on the beaches might be more suitable material than that placed by previous renourishment work on Bogue Banks. However, recent work also resulted in the placement of incompatible materials on the beach despite extensive pre-project sediment quality testing of the source areas. Therefore, the Commission feels that, in additional to thorough testing of the dredge and pumpout areas, a inviolate protocol for monitoring, communicating, and responding to any unforeseen placements of incompatible material on the beach should be implemented for any Section 933 project on Bogue Banks.
- Several factors would counteract the perceived benefit of additional disposal of more compatible material so soon after the previous renourishment project. The EA states that "migratory shorebirds may use the project area for foraging and roosting habitat, but would not be adversely affected by the proposed action." While the beachfront of Bogue Banks does not support much nesting habitat because of the extensive development, some nesting by Wilson's plovers (*Charadrius wilsonia*), willets (*Catoptrophorus semipalmatus*) and American oystercatchers (*Haematopus palliatus*) may still occur on wider beach stretches and migratory shorebirds such as sanderlings (*Calidris alba*) and ruddy turnstones (*Arenaria intrepres*) do forage and roost in the project area. Any depletion of the prey base could certainly have a negative affect on these latter bird species. The pumping of sand onto the beach covers and depletes invertebrate resources and successive burial, as would be the case for Indian Beach and Pine Knoll Shores, greatly delays recovery. Further, renourishment during the

months of March through May is particularly destructive since this is the primary recruitment period for most beach macroinvertebrates. The EA also mentions a recent year-round study of shorebird use in Brunswick County, North Carolina (USACE 2002). Although this report indicated that beach nourishment had "no measurable impact on bird use during the first year of monitoring.", it was also concluded that "...the power for all statistical comparisons regarding the effects of renourishment was generally low, indicating that additional surveys or data will be required prior to confident conclusions."

- Since renourishment would deplete beach macroinvertebrate populations, particularly if conducted during the primary recruitment period, the Commission recommends implementation of a restocking program for coquina clams and/or mole crabs to accelerate recovery from any Section 933 project. This program could either involve collection at the project site before spoil placement or possibly the use of cultured sources of these invertebrates.
- In addition to impacts on macroinvertebrate resources and waterbirds, the new spoil material may adversely effect sea turtle nesting. For example, the disposal may alter the thermal environment during incubation, and hence alter the sex ratios of the hatchlings produced by eggs laid there in future years. Similarly, turtle nests moved from the work area may experience different temperatures in their relocated positions. If such measures are implemented, the Commission recommends that dataloggers be purchased to not only monitor sand temperatures both pre and post project, but also nest temperatures of relocated nests. The Commission has some dataloggers for Atlantic Beach to Bogue Inlet, but more (approximately 20) are needed to monitor sand temperatures of the beach in Fort Macon and also nest temperatures of any nests that are relocated because of a Section 933 project.

Brandt Island Habitat

- Brant Island is a site of extraordinary nesting numbers of North Carolina's highest priority migratory bird species. In particular, as many as 576 pairs of common terns (*Sterna hirundo*) have nested on the site with as many as 182 pairs of black skimmers (*Rynchops niger*), 175 pairs of state threatened gull-billed terns (*Sterna nilotica*) and 90 pairs of least terns (*Sterna albifrons*). In comparison, the entire nesting population of these four species in North Carolina based on the last statewide census is as follows:

  common tern = 1131 nests
  black skimmer = 594 nests
  gull-billed tern = 258 nests
  least tern = 1742

  Clearly, Brandt Island is very important to these four colonial nesting species, although habitat quality there is declining because of tall vegetation and increased predator populations. However, other priority species such as Wilson's plovers and American oystercatchers nest on the site each year regardless of the mammalian predators that have managed to populate the area.
- While pumpout of Brandt Island during the nesting season is strongly discouraged, if it does occur, measures should be taken to mitigate for the disturbance. Given the ephemeral nature of waterbird nesting habitat there, we feel it is imperative that pumpout activities be done in a way consistent with the continued use of this site by nesting waterbirds. This will entail a simple modification of the pumpout activities so that a small isolated island is retained with the remaining 5-10 acres in a dome (less than 15 feet above mean high tide) of primarily sand and shell that is void of heavy grass or shrubs. The island should be separated from remaining disposal areas with at least 100 yards of deep water. Whether or not the Section 933 project is implemented, the base plan could also implement the pumpout activities to isolate the nesting island.
- Since Brandt Island serves as habitat for an undescribed skipper, the Commission believes that surveys and subsequent monitoring for this species are appropriate. Information is needed about this

species to assess the impacts of the proposed Brandt Island pumpout, and possibly the subsequent mitigation efforts to create more suitable shorebird habitat.

Additional Shorebird Mitigation

- There are some opportunities to protect the West Point near Bogue Inlet as mitigation for foraging area losses, and perhaps nesting habitat losses, attributable to the Section 933 project and Brant Island pumpout. These measures include year-round posting of mud/sand flats, a year-round leash law for dogs, no driving on the spit and a ban on fireworks and kites. The Commission believes that the magnitude of the proposed project warrants these mitigation efforts.
- The Commission believes year-round bird monitoring on the beach as well as Brant Island should be implemented.

Based on the preceding concerns, the Commission feels that a Finding of No Significant Impact for the proposed project is not appropriate and that an Environmental Impact Statement should be prepared. The Commission appreciates the opportunity to comment on the impacts of the project on fish and wildlife resources. If you need to discuss these comments please call David McHenry at 252/946-6481 extension 345.

cc:
Sugg, M. – US Army Corps of Engineers, Wilmington
Rice, T. – US Fish and Wildlife Service, Raleigh
Matthews, K. – US Environmental Protection Agency
Sechler, R. – National Marine Fisheries Service
Marshall, M. – NC Division of Marine Fisheries
Allen, D. – NC Wildlife Resources Commission
Cameron, S. – NC Wildlife Resources Commission
Godfrey, M. - NC Wildlife Resources Commission
Stephenson, J. – NC Coastal Federation

RECEIVED
MAY 21 2003
PUBLIC WATER SUPPLY SECTION

MEMORANDUM

TO: Jim McRight
Public Water Supply

FROM: Patti Fowler
Shellfish Sanitation and Recreational Water Quality Section

DATE: May 20, 2003

SUBJECT: Environmental Assessment – US Army Corps of Engineers – Morehead City Harbor Project – Place beach material on Bogue Banks

The Shellfish Sanitation and Recreational Water Quality Section would have no objection to the above mentioned project provided that beach disposal occurs only between November 1 and April 30, when recreational usage is low and that clean sand is used and not dredged sand from closed shellfishing areas. If beach disposal was to occur at times other than stated above or if sand from a closed shellfishing area is to be used, a swimming advisory may be posted and a press release may be made. Please notify this office when such disposal occurs.

NCDENR

North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Michael F. Easley, Governor | Donna D. Moffitt, Director | William G. Ross Jr., Secretary

June 5, 2003

MEMORANDUM

To: Ms. Melba McGee - Environmental Coordinator
DENR Office of Legislative and Intergovernmental Affairs
C/O Archdale Bldg
Raleigh, NC

From: Guy C. Pearce, Consistency Coordinator-Division of Coastal Management

Subject: Project Number SCH03-0315, Dated 05/01/2003
Draft Environmental Assessment-Morehead City Harbor Dredging/Spoil Disposal
Proposed by: U.S. Army Corps of Engineers
Location: Carteret County

Dear Ms. McGee:

The subject project is currently under a consistency review by the Division. Our office will make comments on the proposed project during the consistency determination. If you have any questions, or wish to discuss this matter further, please contact me at (919) 933-2293 ext 249. Thank you.

C: DCM Files

1638 Mail Service Center, Raleigh, North Carolina 27699-1638
Phone: 919-733-2293 \ FAX: 919-733-1495 \ Internet: www.nccoastalmanagement.net

State of North Carolina
NCDENR Department of Environment and Natural Resources

Reviewing Office: WiRO
Project Number: 03-0311 Due Date: 5/23/03

INTERGOVERNMENTAL REVIEW - PROJECT COMMENTS

After review of this project it has been determined that the DENR permit(s) and/or approvals indicated may need to be obtained in order for this project to comply with North Carolina Law. Questions regarding these permits should be addressed to the Regional Office indicated on the reverse of this form. All applications, information and guidelines relative to these plans and permits are available from the same Regional Office.

	PERMITS	SPECIAL APPLICATION PROCEDURES or REQUIREMENTS	Normal Process Time (Statutory Time Limit)
[ ]	Permit to construct & operate wastewater treatment facilities, sewer system extensions & sewer systems not discharging into state surface waters.	Application 90 days before begin construction or award of construction contracts. On-site inspection. Post-application technical conference usual.	30 days (90 days)
[ ]	NPDES-permit to discharge into surface water and/or permit to operate and construct wastewater facilities discharging into state surface waters.	Application 180 days before begin activity. On-site inspection preapplication conference usual. Additionally, obtain permit to construct wastewater treatment facility-granted after NPDES. Reply time, 30 days after receipt of plans or issue of NPDES permit-whichever is later.	90 - 120 days (N/A)
[ ]	Water Use Permit	Preapplication technical conference usually necessary	30 days (N/A)
[ ]	Well Construction Permit	Complete application must be received and permit issued prior to the installation of a well.	7 days (15 days)
[ ]	Dredge and Fill Permit	Application copy must be served on each adjacent riparian property owner. On-site inspection. Preapplication conference usual. Filling may require Easement to Fill from N.C. Department of Administration and Federal Dredge and Fill Permit.	55 days (90 days)
[ ]	Permit to construct & operate Air Pollution Abatement facilities and/or Emission Sources as per 15 A NCAC (2Q.0100, 2Q.0300, 2H.0600)	N/A	60 days
[ ]	Any open burning associated with subject proposal must be in compliance with 15 A NCAC 2D.1900	N/A	60 days (90 days)
[ ]	Demolition or renovations of structures containing asbestos material must be in compliance with 15 A NCAC 2D.1110 (a) (1) which requires notification and removal prior to demolition. Contact Asbestos Control Group 919-733-0820.		
[ ]	Complex Source Permit required under 15 A NCAC 2D.0800		
[x]	The Sedimentation Pollution Control Act of 1973 must be properly addressed for any land disturbing activity. An erosion & sedimentation control plan will be required if one or more acres to be disturbed. Plan filed with proper Regional Office (Land Quality Section) at least 30 days before beginning activity. A fee of $40 for the first acre or any part of an acre.		20 days (30 days)
[ ]	The Sedimentation Pollution Control Act of 1973 must be addressed with respect to the referenced Local Ordinance.		30 days
[ ]	Mining Permit	On-site inspection usual. Surety bond filed with DENR. Bond amount varies with type mine and number of acres of affected land. Any are mined greater than one acre must be permitted. The appropriate bond must be received before the permit can be issued.	30 days (60 days)
[ ]	North Carolina Burning permit	On-site inspection by N.C. Division of Forest Resources if permit exceeds 4 days	1 day (N/A)
[ ]	Special Ground Clearance Burning Permit-22 counties in coastal N.C. with organic soils.	On-site inspection by N.C. Division of Forest Resources required "if more than five acres of ground clearing activities are involved. Inspections should be requested at least ten days before actual burn is planned."	1 day (N/A)
[ ]	Oil Refining Facilities	N/A	90 - 120 days (N/A)
[ ]	Dam Safety Permit	If permit required, application 60 days before begin construction. Applicant must hire N.C. qualified engineer to: prepare plans, inspect construction, certify construction is according to DENR approved plans. May also require permit under mosquito control program, and a 404 permit from Corps of Engineers. An inspection of site is necessary to verify Hazard Classification. A minimum fee of $200.00 must accompany the application. An additional processing fee based on a percentage or the total project cost will be required upon completion.	30 days (60 days)

	PERMITS	SPECIAL APPLICATION PROCEDURES or REQUIREMENTS	Normal Process Time (Statutory Time Limit)
☐	Permit to drill exploratory oil or gas well	File surety bond of $5,000 with DENR running to State of N.C. conditional that any well opened by drill operator shall, upon abandonment, be plugged according to DENR rules and regulations.	10 days (N/A)
☐	Geophysical Exploration Permit	Application filed with DENR at least 10 days prior to issue of permit. Application by letter. No standard application form.	10 days (N/A)
☐	State Lakes Construction Permit	Application fees based on structure size is charged. Must include descriptions & drawings of structure & proof of ownership of riparian property.	15 - 20 days (N/A)
☐	401 Water Quality Certification	N/A	55 days (130 days)
☐	CAMA Permit for MAJOR development	$250.00 fee must accompany application	60 days (130 days)
☐	CAMA Permit for MINOR development	$50.00 fee must accompany application	22 days (25 days)
☐	Several geodetic monuments are located in or near the project area. If any monument needs to be moved or destroyed, please notify: N.C. Geodetic Survey, Box 27687 Raleigh, N.C. 27611		
☐	Abandonment of any wells, if required must be in accordance with Title 15A. Subchapter 2C.0100.		
☐	Notification of the proper regional office is requested if "orphan" underground storage tanks (USTS) are discovered during any excavation operation.		
☐	Compliance with 15A NCAC 2H 1000 (Coastal Stormwater Rules) is required.		45 days (N/A)
*	Other comments (attach additional pages as necessary, being certain to cite comment authority)		

REGIONAL OFFICES

Questions regarding these permits should be addressed to the Regional Office marked below.

☐ **Asheville Regional Office**
59 Woodfin Place
Asheville, N.C. 28801
(828) 251-6208

☐ **Mooresville Regional Office**
919 North Main Street
Mooresville, N.C. 28115
(704) 663-1699

☒ **Wilmington Regional Office**
127 Cardinal Drive Extension
Wilmington, N.C. 28405
(910) 395-3900

☐ **Fayetteville Regional Office**
225 Green Street, Suite 714
Fayetteville, N.C. 28301
(910) 486-1541

☐ **Raleigh Regional Office**
3800 Barrett Drive, P.O. Box 27687
Raleigh, N.C. 27611
(919) 571-4700

☐ **Winston-Salem Regional Office**
585 Waughtown Street
Winston-Salem, N.C. 27107
(336) 771-4600

☐ **Washington Regional Office**
943 Washington Square Mall
Washington, N.C. 27889
(252) 946-6481

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Institute of Marine Sciences
252-726-6841
FAX: 252-726-2426

The University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, North Carolina 28557

MAY 2003
RECEIVED
Secretary's Office
DOA

28 May 2003

Chrys Baggett
State Clearinghouse
NC Department of Administration
1302 Mail Service Center
Raleigh, NC 27699-1302

Re: NEPA EA for US ACE 933 Project for Morehead City Harbor-Bogue Banks placing 13 miles of dredge material

Dear Dr. Baggett:

I write in response to my review of the EA for the deposition of dredged materials on 13 miles of the Bogue Banks beaches as part of a proposed 933 project. I serve as a member of the NC Environmental Management Commission, the Chair of the Water Quality Committee, a member of the Inter-commission Team on Coastal Habitat Protection Plan for fisheries, a member of the Science Panel on Coastal Hazards for the NC Coastal Resources Commission, and a two-term former member of the NC Marine Fisheries Commission. I also am professor of marine ecology at UNC, with extensive experience on sand beach ecology. Thus I have both management and scientific experience and expertise.

The EA is so grossly inadequate in its failure to treat cumulative impacts as to be in full violation of NEPA at the federal level and its state counterpart. Specifically, the beaches of Pine Knoll Shores, Salter Path, and part of Indian Beach were already nourished in winter 2001-2. The benthic biological communities of the beach and the shorebirds that utilize them as vital prey have not yet recovered from that event that occurred over one and a half years ago. I have data on this absence of recovery that I am happy to share and have shared with federal and state agencies from an ongoing monitoring project that we are conducting under Sea Grant funding. This EA violates NEPA and the state counterpart in the area of cumulative impacts in two ways. First, there is no mention and analysis of the cumulative impacts issue. So there is a procedural violation. Second, the available information known to the US ACE and to DENR from our research on the last nourishment is not used to construct a credible evaluation of how a second perturbation will affect the beach ecosystem and its ecosystem services to fish and wildlife before recovery from the first one has even occurred. The spatial issue of cumulative impacts also needs attention because the majority of the western end of Bogue Banks has also been nourished and our data show that this project has had a huge impact on the benthic invertebrates and vertebrate consumers as of the present date. Many of these species would normally help in recovery of eastern Bogue Banks through migration but cannot because they are depleted in the potential source area. Both temporal and spatial aspects of cumulative effects are utterly ignored in this EA.

In addition to ignoring cumulative impacts of multiple beach nourishment projects within a 2+year period, the EA fails to evaluate the known impacts of previous beach nourishments on Bogue Banks. Bogue Banks has relatively little long-shore transport and perhaps for that reason has slow recolonization and recovery rates of beach invertebrates. Transport and immigration of beach invertebrates is not achieved over long distances under low longshore transport conditions. The failure to recover promptly creates important impacts on fisheries habitat in direct contradiction to the NC Fisheries Reform Act of 1987 and its focus on enhancing fisheries habitat through the CHPP process. This impact is especially serious for Florida pompano, Gulf kingfish, and flounders, all of which use the surf zone and beach invertebrate prey as primary nursery. The EA claim of perhaps as short as two months until recovery is unrealistic in light of known durations of impact from previous Bogue Banks nourishments.

Finally, the plan for 16 months of continuous project activity through the biologically productive warm months violates the tenets of minimization and avoidance in environmental management. Such a plan is certain to cause higher impacts on habitat usage and recruitment of surf fish and shorebirds. There is no justification except financial and the only reason it is cheaper is that no mitigation is proposed. All the costs to public trust resources are externalized so as to create a false economy. If summertime activity is desired, then proper habitat mitigation should be included. Project activity in summertime will also have a large economic impact on the hotel, hospitality, and tourism business on Bogue Banks, an impact not addressed in the EA and not compensated for in the plan.

Sincerely,

CH Peterson

Charles H. Peterson
Alumni Distinguished Professor of Marine Sciences
University of North Carolina at Chapel Hill

e

ENVIRONMENTAL DEFENSE

finding the ways that work

June 2, 2003

Ms. Chrys Baggett
State Clearinghouse
1302 Mail Service Center
Raleigh, N.C. 27699-1302

RE: Draft Evaluation Report and Environmental Assessment -- Bogue Banks/Morehead City Harbor Section 933 Project

Dear Mr. Heine,

Please accept these brief comments regarding the aforementioned project on behalf of Environmental Defense and our members in North Carolina. First and foremost, we believe that a full EIS, rather than an Environmental Assessment, is warranted. Clearly, there will be environmental impacts from this project, and in light of the significant impacts from previous beach nourishment projects on Bogue Banks a more thorough analysis is needed. We have the following specific concerns:

- The cumulative impacts analysis is non-existent with regard to biological resources and includes no data. It is merely a comparison of the percentage of area being impacted by sand deposition activities and does not even address differences in habitat quality which might occur along the ocean beaches. Dr. Charles H. (Pete) Peterson has conducted several studies examining the recovery rates of intertidal infauna on Bogue Banks, and his findings are not nearly as optimistic as the conclusion stated in the EA. A full EIS which incorporates these data is necessary. Lack of recovery of these species has the potential to significantly affect shorebird populations.

- There is no pre- or post-project monitoring plan. Although there is a commitment to monitor and relocate sea turtle nests should construction occur during the nesting season, this only applies during the construction period. It should be clear from the sand placement activities which occurred occurred on Emerald Isle and Pine Knoll Shores the past two seasons that biological monitoring must be a required component of any beach nourishment activities. The EA states that because the project is "one time only", it is not "appropriate for adaptive management". The sand placement activities at Emerald Isle and Pine Knoll Shores were also part of a one time event. Without monitoring and data collection, there is no justification for the assertion that recovery of biological communities will be quick and complete.

North Carolina Office · 2500 Blue Ridge Road, Suite 330 · Raleigh, NC 27607 · Tel 919 881 2601 · Fax 919 881 2607 · www.environmentaldefense.org
New York, NY · Washington, DC · Oakland, CA · Boulder, CO · Austin, TX · Boston, MA Project Office: Los Angeles, CA

- The sediment analysis for source material from Brandt Island was performed over 10 years ago and must be updated, particularly in light of the poor quality of material placed on the beaches at Pine Knoll Shores and Emerald Isle during the past two seasons. The borrow site for those sand placement events was supposedly thoroughly sampled and analyzed, yet failed to reveal the presence of tires and cobble-sized material. Furthermore, an analysis of the potential biological impacts of placing finer grained materials on top of the very coarse material already on the beach needs to be performed.

We have many other concerns regarding the impacts of turbidity to surf-dwelling fish species, as well as species which use the nearshore subtidal environment as overwintering habitat, but wanted to highlight the specifics above. Thank you for your consideration and for the opportunity to comment on projects which impact our coastal public trust resources.

Sincerely,

Michelle Duval

Michelle Duval, Ph.D.
Scientist

Bogue Banks Environmental Stewardship Corporation
Post Office Box 475
Snow Hill, NC 28580

May 16, 2003

Mr. Steve Aiken
Chief Of Operations Wilmington District USACE
Wilmington, NC 28402

Dear Mr. Aiken,

Please have someone on your staff review the attached comment to the United States Army Corps of Engineers (USACE) The Port of Morehead City, N.C., Beaufort Inlet, ***EVALUATION AND ENVIRONMENTAL ASSESSMENT REPORT.*** I am submitting this comment on behalf of our membership to the Wilmington District, United States Army Corps of Engineers

Permitting and funding of this project are essential to preserve one of North Carolina's oldest and most precious natural resources: Bogue Banks. If you have questions, please contact me at 252-747-2911 or at home 252-522-4229.

Warmest personal regards,

Joe Exum, Executive Director
Bogue Banks Environmental Stewardship Committee

Cc: The Honorable William Ross, Director
Department of Environment and Natural Resources

COMMENTS

On the

United States Army Corps of Engineers (USACE) 933 Project

The Port of Morehead City, N.C., Beaufort Inlet

EVALUATION AND ENVIRONMENTAL ASSESSMENT REPORT

May 12, 2003

Joe Exum, Executive Director
Bogue Banks Environmental Stewardship Corporation
Post Office Box 475
Snow Hill, North Carolina 28580

To: Mr. Steve Aiken
Mr. Glenn McIntosh
The United States Army Corps of Engineers (USACE)
Wilmington District

From: Joe Exum, Executive Director
Bogue Banks Environmental Stewardship Corporation (BBESC)

Date: May 11, 2003

Subject: **Evaluation & Environmental Impact Assessment USACE Morehead City, Beaufort Inlet 933 Maintenance Project**

Introductory Remarks:

The *BBESC* was incorporated in June of 2001. The membership consists of 281 homeowners along Bogue Banks. The goal of our organization is simple:

> *We are seeking a similar sand management system used by the* ***United States Army Corps of Engineers (USACE)*** *to maintain Wilmington Harbor and Cape Canaveral Harbor in Florida to be put into practice at Morehead City Harbor. Sand presently being removed from the littoral system by* ***USACE*** *in maintenance of Beaufort Inlet and dumped at sea must be put on adjacent beaches*

In a meeting requested by the *BBESC* and held in Raleigh in August of 2002, representatives from the *Department of Environment and Natural Resources*, including the *Department of Water Resources* and the *Department of Coastal Management (DCM)*, along with representatives from the *USACE* Wilmington District, Mr. Aiken was requested to consider a maintenance project for Beaufort Inlet that would combine outer and inner harbor sediment disposal practices in which spoils could be distributed along adjacent beaches west to Indian Beach. The *Morehead City Harbor/Beaufort Inlet Proposed 933 Project* is the answer for which we had hoped.

Brief History of Accelerated Erosion Rates at Pine Knoll Shores since 1993:

The dry beach at Pine Knoll Shores actually accreted from 1987 to 1992. My home was built in 1987 with a 100' setback. My neighbor built in 1992. His footprint is five feet in front of mine. The *1993 Morehead City Harbor Project* deepened Beaufort Inlet from 40' to 47' and broadened the inlet 100' to 450'. In 1994, Hurricane Gordon brushed the eastern coast of North Carolina in November. Although the effects on the eastern end of the island were minimal, the primary vegetation line from Pine Knoll Shores to Emerald Isle was devastated. Pine Knoll Shores and Emerald Isle have never recovered from Hurricane Gordon, and each successive hurricane has wreaked havoc with 1000 year old sand ridges, Maritime forests, and turtle sanctuaries. **(Please see the attached newspaper account.)**

In the *Morehead Improvement Design Memorandum & Environmental Assessment* in March of 1992, the USACE describes the berm design as:

> "...a feeder berm which purpose is to keep the material within the littoral system...This berm is not intended to replenish the beach...The existing disposal method...removes the sand from the littoral system entirely..."

In 1994, at the Request of the N.C. Department of Coastal Management (DCM), the USACE ceased disposal of dredged material on the Offshore Dredged Material Disposal Site (ODMDS) "when weather permitted" and disposed of the sand on a newly created near shore berm in expectation the sand would return to the active littoral system. *DCM* has observed sand on the near shore berm has **not** returned to the active littoral system over the last 10 years. *DCM* has notified the *USACE* on two occasions this disposal practice is not consistent with the North Carolina Coastal Zone Management Plan. In October of 2002, "disposal of sand outside the active littoral system" was forbidden by North Carolina statue.

There is no definitive sediment transport study for Bogue Banks and according to the June 2001 USACE 111 Study we do not have time to assign blame for the accelerated erosion rates since 1993:

> *...The overall net loss of littoral sediment from the beaches adjacent to Beaufort Inlet between 1936 and 1994 is 19,205,5000 cubic yards...Beaufort Inlet, in particular, and Morehead City Harbor in general, has trapped littoral material at a higher rate each time the project has been deepened... The offshore profiles six miles west of Beaufort Inlet and all of Shackleford Banks appear to be getting steeper, closer to shore. These offshore changes appear to be directly related to the deflation or deepening of the ebb tide delta of Beaufort Inlet, which is a direct impact of the dredging operations. Unfortunately, the shoreline data does not demonstrate an impact at this time. However, the continuing deepening of the offshore profile is a major concern that needs to be addressed. —Section 111 June 2001*

Our organization believes this *933 Project Proposal* is the *USACE* good faith effort to incorporate disposal practices consistent with the *May 2000 Wilmington Harbor Environmental Assessment*, which articulates the geological correlation principle between sediment removal and beach erosion.

Section 209 of PL 91-611 (WRDA 1970) states:

"...the impact of sediment removal...tends to be diffused throughout the impacted area. Since this diffusion process can extend over miles of shoreline, the erosive impact of the sediment removed from the navigation channel and its deposition outside the active littoral zone is difficult to detect in the short term...Years of research by USACE and practical knowledge gained from the operation of the numerous coastal navigation projects dictate this material must be conserved...the removal of a cubic yard of littoral sediment from a tidal entrance or inlet with deposition outside the active littoral zone of the beach will ultimately cause a cubic yard deficit somewhere within the sand sharing system...The impact of the removal of littoral sediment from the active littoral zone through channel maintenance is identified as a major cause of man-induced erosion."

The years of research by USACE and practical knowledge gained there from are confirmed in Dr. Orin Pilkey's 1975 novel, ***Living With an Island:***

- *The cause of erosion on Bogue Banks (Atlantic Beach/Ft. Macon Park) is not altogether certain. ... A significant part, however, is very likely due to hopper dredging. Hopper dredging consists of removing the sand from channels and dumping it at sea, entirely out of the shoreline system. Thus, sand that would naturally drift across and replenish the beach is lost and erosion rates increase. This is a major problem nationwide.*

Environmental Concerns:

During the permitting process, various government agencies and environmental groups will raise the following environmental concerns.

1. Shell content.
2. Microbial life recovery
3. "Fish Feed" life recovery
4. Coquina, mole crab, destruction
5. Various avarian concerns

There has never been an incident of sand bypassing/beach nourishment in which microbial life did not recover. Turtle sanctuaries are reinvigorated, maritime forests flourish, and 1000-year-old sand ridges become a new line of primary vegetation. The east end of Bogue Banks is testimony to a beach that recovers its natural vegetation and wildlife following renourishment.

Conclusion:

Section 209 of PL 91-611 (WRDA 1970) states:

> *It is the intent of Congress that the objectives of enhancing regional economic development, the quality of the total environment, including its protection and improvement, the well-being of the people of the United States, and the national economic development are the objectives to be included in federally financed water resource projects, and in the evaluation of benefits and cost attributable thereto.*

In the cost benefit equation the environmental concerns raised during previous renourishment projects must be weighed against the benefits derived from beach nourishment during initial storm surges. A recent article published by the **North Carolina Sea Grant** program concluded:

> *The benefits (of beach renourishment) are actually more dramatic than implied... All of the threatened buildings listed for the three communities were located outside the nourishment project limits or in transition areas at the ends of the projects where the dunes were not constructed. Hurricanes Floyd and Dennis threatened or destroyed 968 buildings outside the three Corps-designed nourishment projects' manmade dunes. Remarkably, not even one building behind the project dunes was threatened by erosion — that's ZERO. (Wrightsville, Kure, and Carolina Beach)*

Failure to permit or fund the project will eventually result in catastrophic loss of property. A chilling review of the USACE *Final Section 111 Feasibility Report: Morehead City Harbor: June, 2001,* by Olsen Associates articulates the consequences.

> *Indeed, from a coastal engineering or geology standpoint, it is well known that removal of littoral material in excess of natural conditions results in (erosion) of the shorelines within the littoral system. The significant deflation of the offshore beach profiles documented in the study...must ultimately translate to destabilization of the beach and shoreline...the beach profile cannot continue to steepen without resulting in a landward translation of the shoreline. The condition is analogous to the foundation of a house: i.e., a structure's foundation cannot continue to be undermined without ultimate destabilization of that structure.*

Joe Exum, Executive Director
Bogue Banks Environmental Stewardship Committee

e

environmental defense

finding the ways that work

June 2, 2003

Mr. Hugh Heine
Wilmington District
U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402

RE: Draft Evaluation Report and Environmental Assessment -- Bogue Banks/Morehead City Harbor Section 933 Project

Dear Mr. Heine,

Please accept these brief comments regarding the aforementioned project on behalf of Environmental Defense and our members in North Carolina. First and foremost, we believe that a full EIS, rather than an Environmental Assessment, is warranted. Clearly, there will be environmental impacts from this project; in light of the significant impacts from recent beach nourishment projects on Bogue Banks a more thorough analysis is needed. We have the following specific concerns:

- Cumulative Impacts: The cumulative impacts analysis is non-existent with regard to biological resources and includes no data. It is merely a comparison of the percentage of area being impacted by this project versus sand deposition activities throughout the state. No attempt is made to address differences in habitat quality which might occur along the ocean beaches, or . Dr. Charles H. (Pete) Peterson has conducted several studies examining the recovery rates of intertidal infauna on Bogue Banks, and his findings are not nearly as optimistic as the conclusion stated in the EA. A full EIS which incorporates these data and evaluates the impact of the project on the recovery rates of intertidal infauna is necessary. Lack of recovery of these infaunal species has the potential to significantly affect shorebird populations.

- Monitoring: There is no pre- or post-project monitoring plan. There is only a commitment to monitor and relocate sea turtle nests should construction occur during the nesting season. It should be clear from the sand placement activities which occurred occurred on Emerald Isle and Pine Knoll Shores the past two winters that biological monitoring at the placement site and the mine site must be a required component of any beach nourishment project. The EA states that because the project is "one time only", it is not "appropriate for adaptive management". The sand placement activities at Emerald Isle and Pine Knoll Shores are also part of a one time only project. Without monitoring and data collection, there is no justification for the assertion that recovery of biological communities will be rapid and complete.

North Carolina Office · 2500 Blue Ridge Road, Suite 330 · Raleigh, NC 27607 · Tel 919 881 2601 · Fax 919 881 2607 · www.environmentaldefense.org
New York, NY · Washington, DC · Oakland, CA · Boulder, CO · Austin, TX · Boston, MA Project Office: Los Angeles, CA

- Sediment Analysis: The sediment analysis for source material from Brandt Island was performed over 10 years ago and must be updated, particularly in light of the poor quality of material placed on the beaches at Pine Knoll Shores and Emerald Isle during the past two seasons. The borrow site for those sand placement events was supposedly thoroughly sampled and analyzed, yet failed to reveal the presence of tires and cobble-sized material. In addition, an analysis of the potential biological impacts of placing presumably finer grained materials on top of the very coarse material already on the beach needs to be performed. Finally, the composition of the material at Brandt Island could alter the frequency and duration of the turbidity plume and therefore, impacts to surf zone fish species their prey.

Again, we must emphasize that the certain impacts from this project warrant the development of a full EIS with a comprehensive analysis of cumulative impacts. Until such time as an EIS is prepared and the concerns expressed above are addressed, we cannot support this project. Thank you for your consideration and for the opportunity to comment on projects which impact our coastal public trust resources.

Sincerely,

Michelle Duval

Michelle Duval, Ph.D.
Scientist

North Carolina Coastal Federation
3609 Highway 24 (Ocean) Newport, NC 28570

June 2, 2003

Hugh Heine
District Engineer
U.S. Army Engineer District, Wilmington
P.O. Box 1890
Wilmington, NC 28402

Re: Draft Evaluation Report and Environmental Assessment, Morehead City Harbor, Section 933, Carteret County, North Carolina

Dear Mr. Heine:

The North Carolina Coastal Federation staff has reviewed the document entitled *Draft Evaluation Report and Environmental Assessment, Morehead City Harbor, Section 933, Carteret County, North Carolina.* The following represents our comments on the document and the project.

If there is one lesson we have learned from our experience in reviewing and critiquing beach renourishment projects over the past four years, it is that haste makes waste. Whenever the applicants and/or the Corps of Engineers have sought expedited or cursory review of projects, including the local beach renourishment projects on Bogue Banks, the Sea Turtle Restoration Project on Oak Island, and the Mason Inlet Relocation Project, the projects have been laden with unexpected environmental problems. In the interest of time, the Corps chose not to proceed with an EIS in either the Bogue Banks and Mason Inlet projects. In the Oak Island Sea Turtle Restoration Project, the Corps failed to adequately characterize the sediment at the Yellow Banks disposal area, and boulders were pumped onto the beach. More boulders are uncovered on the Oak Island beach with each high tide even today, several years after project completion.

We strongly recommend that an environmental impact statement (EIS) be prepared for this 933 project. Recommendations that an EIS be conducted were made to the Corps by federal and state resource agencies during the scooping period. If the Corps is not willing to recognize the appropriateness and necessity of an EIS for this project, we will recommend that the Division of Coastal Management find the project inconsistent with state policies due to the potential environmental impacts described in this letter.

Alternatives

The alternatives analysis should include an alternative that spreads the pump out of Brandt Island over several seasons. The Environmental Policy Act requires the Corps to evaluate an alternative that would avoid environmental impacts, in addition to the no action alternative. In this case the no action alternative is identical to the existing authority to dispose of dredged material on the beaches of Fort Macon and Atlantic Beach. The Corps must also analyze a less damaging practicable alternative that would avoid, rather than minimize, environmental impacts by honoring the moratorium for shorebirds as established by the NC Wildlife Resources Commission and for fisheries as established by the NC Marine Fisheries Commission. These moratoria would limit the period for beach disposal of sediment to November 16 until March 31. While it is clear that this alternative would require the redeployment of pipelines and other equipment in future years, it is an alternative that requires further analysis and public review. We request that the Corps include an analysis of this alternative in its EIS.

Project Timetable
The Draft 933 Environmental Assessment proposes to pump out Brandt Island and place sediment material on the beach from Fort Macon State Park to Indian Beach for 16 consecutive months. The NC Wildlife Resources Commission and the NC Marine Fisheries Commission have established moratoria on beach fill activities that would limit construction to the period from November 16 to March 31. These moratoria were developed to protect the food sources for migrating shorebirds and fish in the surf zone during periods of peak biological activity. The Draft EA is inconsistent with state policies inasmuch as it proposes to violate these moratoria.

Economic Impact
The Draft 933 EA has determined that the benefits of this project outweigh the costs by a factor of 4.9 to 1. The singular argument made by the Corps in its EA for conducting nonstop beach fill activities for 16 consecutive months is the increased redeployment cost of pipelines and other equipment in future years if the project was required to honor the NC Wildlife Resources Commission and NC Marine Fisheries Commission moratoria policy on the placement of fill on the beach during periods of high biological activity. Given the high benefit to cost ratio established in the economic impact analysis, the cost of redeploying pipeline and other equipment is a reasonable and practicable expense. The cost of mobilization and deployment is estimated to be $2.85 million. If the cost of redeploying pipeline and other equipment were added to the costs of the project, the benefit to cost ratio would still be approximately 4 to 1. Given this generous benefit to cost ratio, there is no compelling economic argument not to honor the moratoria.

The Draft 933 EA estimates the benefits of the 933 project using storm damage reduction savings and recreational benefits to day users, among other criteria. During 2001-2002, a locally funded beach renourishment project was conducted on the same beaches (Pine Knoll Shores, Salter Path and Indian Beach) that are under consideration in the Draft 933 EA. The locally funded project was reviewed and permitted by the Corps of Engineers Wilmington District. The longevity of the locally funded project was ten years. The locally funded project also projected storm damage reduction savings and benefits to day users, among other criteria. The Draft 933 EA also has a projected life of ten years. Both projects propose to save the same oceanfront and second row structures from storm damage and long-term erosion. The Draft 933 EA is in effect double counting benefits that have already accrued to the protection of structures and recreation on Pine Knoll Shores, Salter Path and Indian Beach. Since the Corps of Engineers reviewed and approved the locally funded economic impact analysis, these benefits should serve as a baseline upon which the additional benefits of the 933 project can be calculated. The question is how much additional benefit will these same said structures and beachgoers receive over and above the benefits provided by the locally funded beach fill project? If the locally funded project did not meets its objectives, then what is the revised lifespan of the locally funded project and what is the revised baseline, i.e. costs and benefits, of the locally funded project?

The Corps should also explain why it uses a 20-year period for its cost benefit analysis when the project is only expected to last 10 years. The use of a 20-year period is particularly important inasmuch as the Corps is also evaluating a 50-year civil works project for the entirety of Bogue Banks that is expected to be built prior to the end of the 10-year life of the proposed 933 project. We question whether the proposed 933 project has any economic benefits that have not already been realized by the locally funded project, or that will be realized by the 50-year civil works project.

Environmental Impacts/Cumulative Impacts
The Draft 933 EA fails to seriously consider the environmental impacts and the cumulative impacts of the proposed 933 project on biological resources on Pine Knoll Shores, Salter Path and Indian Beach. The locally funded project has had a devastating effect on macro faunal invertebrates on these beaches as documented by Peterson, et al. The Draft EA fails to consider any biological monitoring data from scientists such as Peterson or from the local project's biologist. The Draft 933 EA examines the impact of beach fill projects in the abstract, rather than evaluating the wealth of current data that is available for these beaches. The question that should have been addressed in the Draft 933 EA and which must be examined in the EIS is what is the cumulative biological impact of burying invertebrates on beaches that have not fully recovered? In addition, fill material that is widely regarded as incompatible was placed on a significant portion of Emerald Isle. The question this Draft EA failed to consider is what is the cumulative impact on birds, fish, and invertebrates of conducting another beach fill project before the beach ecosystem has had time to reestablish itself? As the Draft 933 EA notes, the recovery rates for beach ecosystems is generally from 1 to 3 years. The timeframe is shorter when beach material is compatible and longer when beach material is not compatible. These are questions that will require close examination of existing research as well as field studies that are appropriate to the EIS.

Sediment Compatibility
The draft environmental document is the appropriate vehicle to publicly share data collected on a given project. In the Draft 933 EA, the Corps shares its belief (ER-43) and provides assurance (ER-44) that the sediment will be compatible with the natural beach and for sea turtle nesting. The Draft 933 EA indicates that data will be collected on sand compatibility along portions of the proposed project area, but this data is not contained in the Draft EA and is not available for public review. All relevant data must be included in

draft environmental documents. The public has a right to comment on data, not beliefs and assurances, particularly given the Corps' past acceptance of incompatible material on Bogue Banks, Oak Island and from Mason Inlet.

Public Access and Parking

The Corps' guidelines require public access in order for the federal government to share in the costs of a storm damage reduction project. These guidelines for public access and parking indicate "public use means use by all on equal terms." The public access and parking plan in the Draft 933 EA presents a stark disparity between public access and parking sites along the project area. It is remarkable that the areas that provide the greatest public access, Fort Macon State Park, are slated to receive the same volume of sand as areas with the least amount of public access.

The Corps conducted its public access survey using aerial photography taken between 11:15 AM and 11:40 AM on July 4, 2002. The Town of Pine Knoll Shores had only one public access site open on that date, which was opened during a June 28 ribbon cutting. On the day of the Corps' survey, Pine Knoll Shores was essentially a privately accessed beach. It is not feasible to evaluate public access on a privately accessed beach. We also question how the time between 11:15 and 11:40 on a single day constitutes peak hour demand. I personally have traveled to the state beach access at Salter Path on numerous occasions to find the lot full and cars parked illegally on Highway 54.

The survey methodology is seriously flawed, as are the results. We strongly recommend that the Corp follow through on the revised parking survey methodology as described in Appendix E-5 to revisit the parking issue this summer. The revised parking survey should also be conducted on multiple peak days and at a variety of times and locations on those days.

The access plan for Pine Knoll Shores is a violation of Corps guidelines governing public use. The Corps guidelines for public use states:

Lack of sufficient parking facilities for the general public (including non-resident users) located reasonably near and accessible to the project beaches or lack of public pedestrian rights-of-way to the beaches at suitable intervals would constitute de facto restriction on public access and use of such beaches, thereby precluding eligibility for Federal assistance. EP 1165-2-1 Chapter 14-1(b)(2)

The use of public transportation by the Town of Pine Knoll Shores to transport visitors from existing beach parking areas to planned beach access areas meets neither the letter or the spirit of the public use definition in Corps guidelines. Historically, Corps guidelines have allowed public transportation, but only "to reduce automobile pollutants by encouraging public transportation." Nowhere has Pine Knoll Shores stated that its motivation is in reducing automobile pollutants and the public access plan would not reduce automobile pollutants anyway.

The Corps has offered no corroborating data from any comparable beach community to justify that this experiment will provide any benefit to day users of the beaches at Pine Knoll Shores. Why would a day user park near the beach and then take a shuttle to another access area? Is the public expected to carry cellular phones in order to reach the public transportation carrier during the off-season? Unless the Corp can provide data and justification that this transportation system has worked in a town setting similar to Pine Knoll Shores, we strongly recommend that the project be scrapped.

In our view, the primary purpose of the public transportation plan is to gain a higher percentage of federal cost share funds. It is not clear to us that the Town of Pine Knoll Shores has exhausted all practical options in providing appropriate parking at each proposed access site. There are gated private parking lots within walking distance to the beach that could be purchased or condemned that could accommodate ten or more parking spaces.

The public transportation plan does not provide a realistic alternative for the public to access what will continue to be privately accessible beaches. By accepting the flawed concept of public transportation to reach multiple beach accesses in Pine Knoll Shores, the Corps has violated public faith in the notion that Federal funds will only be used to provide storm damage reduction benefits to beaches that the public can access on an equal basis.

We recommend that the Corps provide the Town of Pine Knoll Shores until November 1, 2004 to meet the public parking criteria that requires a minimum of ten parking places and handicapped access for each beach access within the town limits. If the town cannot meet the public access requirement by that date, the Corps should require the town to pay 100 percent of the cost of placing beach fill on areas that do not conform to the Corps guidelines.

State Easements

North Carolina law requires an easement for performing work that involves alterations to state lands. The beach up to the high tide land is state property in North Carolina. Any land disturbing activity requires an easement from the Department of Administration and approval of the Council of State. The Corps should describe how it plans to obtain an easement to alter state lands.

Turbidity in the Construction Area

The Draft 933 EA states "Turbidities outside of the construction or mixing zone would not exceed the state standard of 25 NTU's in all saltwater classes." The EA has not indicated how the Section 401 Water Quality Unit defines and delineates the area of construction. The EA also does not indicate when a portion of the beach ceases to be a construction area in time or spatial terms. Research by Peterson, et al, has shown that turbidity continued for months after the completion of beach construction at Emerald Isle. The EIS should evaluate Peterson's data and model the turbidity that will be generated during the proposed project.

Thank you for this opportunity to comment on the Draft 933 Environmental Assessment.

Sincerely,

James H. Stephenson
Policy Analyst

Cc: Chrys Baggett
State Environmental Policy Act Coordinator

This document contains comments and questions pertaining to the ***Draft Evaluation Report and Environmental Assessment: Morehead City Harbor Section 933*** and is being submitted to the US Army Corps of Engineers Wilmington District by the Duke University Program for the Study of Developed Shorelines.

Comments on Appendix E: Beach Access/Parking Analysis and Requirements

Appendix E contains a significant number of errors, issues and discrepancies that need to be resolved. The quality of data used to determine current and projected public access and public parking needs is inaccurate; the analyses that rely on this data are flawed; population growth rates used to estimate the future peak hour usage are incorrect and huge discrepancies regarding beach usage remain unresolved. It is also clear that the study area fails to meet Federal Policies and Authorities regarding the geographic distribution of public access and public parking. Specific comments and questions follow:

Determinations of public access, public use and public parking needs and demands are based on one 25-minute observation along a shoreline that is classified as private in Engineering Regulations 1105-2-100 or 1165-2-130.

- What procedures are typically employed by Wilmington District to evaluate public beach use and public parking demands?
- How can the Corps justify its decision to spend tens of millions of taxpayer dollars on this project when it fails to meet the cost-share criteria outlined in Engineering Regulations 1105-2-100 or 1165-2-130?

The EA makes projections based on the amount of public access and parking currently available in the study area, which does not meet the federal cost share guidelines.

- How can the Corps make an accurate estimate of future peak hour demand when the area fails to provide either adequate public access or public parking, as defined in Engineering Regulations 1105-2-100 or 1165-2-130?

In a letter dated May 16, 2003 Colonel Charles Alexander states, "…the US Army Corps of Engineers, Wilmington District intends to ensure the requirements as indicated in US Army Corps of Engineers Engineering Regulations 1105-2-100 and 1165-2-130 are adhered to for this and all shoreline protection projects." However, neither existing Department of the Army public access nor public parking requirements contained in Engineering Regulations 1105-2-100 and 1165-2-130 are being adhered to in the project area.

- Please explain the discrepancy between Colonel Alexander's stated position and the fact that minimum public access and parking requirements as indicated in US Army Corps of Engineers Engineering Regulations 1105-2-100 and 1165-2-130 are not being adhered to.

According to ER 1165-2-130, "In the event public access points are not within one-half mile of each other, either an item of local cooperation specifying such a requirement and public use throughout the project life must be included in project recommendations or the cost sharing must be based on private use." According to Appendix E, public access points are not available, nor are they projected to be available, every one half mile in the project area.

- Since the project area fails to meet existing policies and authorities concerning public access and parking, and since no item of local cooperation specifying such a requirement is provided, why isn't the project being cost-shared based on private use?

According to ER 1165-2-130, public transportation facilities may substitute for or complement parking facilities in some instances in which state and local plans call for a reduction in automobile pollutants.

- Please provide a compilation of all state and local plans that call for a reduction in automobile pollutants in the project area.
- In the absence of such documentation, please provide the specific rules under which the Wilmington District has the authority to allow a public transportation system to serve as a substitute for meeting explicit public access and parking policies and authorities as contained in ER 1165-2-130 and 1105-2-100.
- How many Section 933 projects have allowed public transportation in lieu of providing adequate parking, and where are they located?

On Page E-1, an assumption is made that visitors require 100 square feet of beach per visit.

- Upon what data is this assumption based?

The estimation of peak hour usage/demand is based upon a 25-minute snapshot of beach visitation taken between 11:15 and 11:40 am on July 4, 2002, and the EA assumes that almost the same number of people were under tents and umbrellas than were visible on the beach.

- What was the weather in the study area between 11:15 and 11:40 am on July 4, 2002?
- Is it reasonable to assume that the number of people under a tent or umbrella would be equal to the number of people visible on the beach?
- Upon what data is the assumption that an average of 2 people were under each tent and 1.5 people were under each umbrella based?
- How can peak hour usage/demand be estimated with any degree of accuracy using one 25-minute aerial observation taken on one day of the year?

On page E-2, the EA states that July 4 is assumed to be the peak day of the year for visitors on beaches.

- Upon what data is this assumption based?
- What evidence is available to show that peak beach usage occurs between 11:15 and 11:40 am?

On page E-2, the EA states that a higher number of visitors may have been present if July 4 had fallen on a weekend, and that the actual numbers were increased by 14.2% based on the volume of traffic crossing the two bridges onto Bogue Banks on Friday, July 5.

- Page E-2 states that the assessment completed on July 4 is not accurate. Why wasn't the assessment undertaken on Saturday July 6 or Sunday July 7?
- Since Friday is not typically considered a weekend, why were traffic counts for Friday July 5th used instead of traffic counts for Saturday July 6 and/or Sunday July 7?
- What was the actual volume of traffic on each bridge on July 5th?
- During what time period was the traffic count conducted on July 5?
- What percentage of traffic crossing these bridges used the beaches in the study area?
- What was the actual traffic volume on each bridge on July 4?
- During what time period was the traffic count conducted on July 4?
- How, exactly, was the figure of 14.2% obtained?

On page E-2, the peak hour demand in the project area is projected to be 2,835 in the year 2014. This figure is based upon an average North Carolina annual growth rate of 1.8% between 2000 and 2010. It is implausible to assume that daily visitors to the project area are, and will be, distributed equally throughout the entire state. A more accurate analysis should assume that the majority of daily visitors to the project area is, and will remain, from North Carolina's coastal region. Therefore, population growth rates specific to North Carolina's coastal municipalities, as contained in 15A NCAC 07B .0701, should have been used to predict future beach and parking demand.

- Why were CRC-approved population growth rates for coastal NC not used in this study?

On page E-2, the EA states that only 30% (59 out of 171) of all available parking spaces in the project area were filled during the peak usage time period between 11:15 and 11:40 am on July 4, 2002. Such a low demand for parking during the stated peak period of demand appears inconsistent with the definition of "peak demand."

- Could this indicate that the peak demand did not actually occur during the time of observation?
- How does the Wilmington District resolve or explain this discrepancy?

On Page E-3, the Corps estimates that each car contains 2 persons. The communities in the study region actively promote themselves as "family beaches" which means there is a strong likelihood that each car contained more than 2 persons.

- Upon what data is the assumption that each car contains only two individuals based?

The peak hour parking demand projections on page E-3 use the 1.8% growth rate for the entire state of NC.

- Why wasn't this calculation based on coastal growth rate projections contained in 15A NCAC 07B .0701?

On Page E-4 the EA states, "...it is important to keep in mind that meeting peek hour capacity does not alleviate the sponsor's obligation to provide parking within one quarter mile of each access site."

- Does the sponsor provide parking within one-quarter mile of each access site?

On Page E-4, the EA states that the percentage of "day-users" in PKS is 3.5% and is significantly lower than the average for beach studies.

- What is the average percentage of "day-users" for Corps beach studies?
- How does the Corps resolve or describe this significant discrepancy?
- Why shouldn't this significant difference affect the validity of the EA?

The Corps, under NOTE on Page E-4, admits that the calculations in the document are inaccurate due to a number of factors including a discrepancy in the estimated peak day, day-visitor beach population in Pine Knoll Shores. According to the Pine Knoll Shores' 1996 Land Use Plan, the town estimated its peak day, day-visitor population to be in excess of 50,000 persons. The EA, however, determined the peak hour, day-visitor beach population demand in PKS to be 50 persons. Even if this hourly demand is multiplied by 24, the peak day, day-visitor beach population in PKS, according to the EA, is 1,200.

- How does the Corps explain the enormous discrepancy in peak day, day-visitor populations between its calculations and the estimates provided by the PKS police department?
- What reason can the Corps provide for not using the peak day, day-visitor population data contained in the Pine Knoll Shores 1996 Land Use Plan?

On page E-5, under Parking Analysis Methodology, the proposed project is compared to a recently completed, locally funded project with no federal public access/parking policies and authorities in which the local communities still have not met pre-project public access promises made to secure state funding.

- How can the Corps compare a federally funded project to a locally funded project with no federal public access/parking policies and authorities?

On page E-5, under Parking Analysis Methodology, the EA states that parking is a component of the recreation analysis.

- Assuming the EA is accurate and significantly fewer people are using the beach on a daily basis, how will this affect future analyses of recreational benefits?

The conditions and stipulations contained under Access and Parking Requirements on Page E-5 are ambiguous and confusing.

According to ER 1165-2-130 and 1105-2-100, adequate parking must be within ¼ mile of each access. On Page E-6, the Corps is allowing parking to be equally distributed within 2-mile stretches. The criteria presented for the selection of two miles is irrelevant. The issue is the geographic distribution of public parking and public access, not the minimum length of a Corps beach nourishment project. The fact remains that the study area does not meet existing federal policies and authorities pertaining to public access and parking.

- What authority does the Corps' Wilmington District have to disregard existing federal policies and authorities regarding the geographic distribution of public access and public parking?

On Page E-6, section 4 B is extremely confusing. The passage reads, in part, "In order to meet the spirit of the regulations to provide public access to those beaches receiving Federal funding for a Section 933 project, it was decided that the sponsor should provide this minimum." From this wording, it appears that the regulations have not been met.

- What does the "spirit" of the regulations mean, how does this differ from actually meeting the regulations?
- If the regulations have not been met, why isn't the Corps enforcing them?

In Section 5 on Page E-6:

- How will the sponsor be held responsible for providing the required number of parking spaces?
- What is the period of analysis of the project?
- What is meant by "on an equal basis?"
- What is meant by "Failure to do so would result in sections of the project reverting to private beach status...?"
- What is the timeframe being discussed?
- What criteria will be used to determine whether a section of the project does not meet "Corps parking criteria" and what parking criteria is being referred to here?

In Item 6 on page E-6:

- What authority does the Corps Wilmington District have to allow public transportation to substitute for adequate public parking as defined in to ER 1165-2-130 and 1105-2-100?
- What enforcement mechanism will be used by the Corps to ensure that a public transportation system is provided year-round?
- What happens if the local sponsor fails to follow through on its commitment?

Under Existing and Proposed Parking and Access Sites on Page E-7:

- What authority does the Wilmington District have to allow public transportation to substitute for adequate public parking as defined in to ER 1165-2-130 and 1105-2-100?

Under Existing and Proposed Parking and Access Sites on Page E-7, the EA states that there is an 82% decrease in demand during the off-peak season.

- How was this figure calculated?

On Page E-8, an exception to existing public access requirements was given to a section of Indian Beach based on "environmental conditions."

- What are the specific environmental conditions that prompted the exception, and what authority does the Wilmington District have to make such an exception?

Submitted by,

Andrew Coburn, Associate Director
Orrin Pilkey, Director

Program for the Study of Developed Shorelines
Nicholas School of the Environment and Earth Sciences
Duke University
Campus Box 90227
Durham, NC 27708-0227
Tel: 919-684-2206
Fax: 919-684-5833

624 Sugar Lake Road
Pittsboro, NC 27312

2 June 03

Mr. Hugh Heine
re: Morehead City 933 Project
Office of the District Engineer
U.S. Army Engineer District, Wilmington
P.O. Box 1890
Wilmington, NC 28402

Dear Mr. Heine:

I have read the "Draft Evaluation Report and Environmental Assessment, Morehead City Harbor, Section 933, Carteret County, North Carolina, May 2003" and offer the following comments regarding the conclusions drawn with regard to the economic benefits and costs of the project.

In general, it is my professional opinion that the document fails to provide an economically valid or reliable basis for conclusions regarding the benefits of the project, and that therefore the economic conclusions drawn must be regarded as, at best, speculative. This opinion is based upon the following considerations:

1. **Failure to fully assess the in-progress locally-financed project:** if I recall correctly, the project currently underway in this area with local financing was purported to provide 8-10 years of storm protection. If it IS performing as promised, then much of the storm protection claimed for the 933 project is attributable to the existing project, and should not be counted again as benefits for the 933 project. If the current project IS NOT performing as promised by USACE and the local sponsors, then it remains to be shown (1) why that (almost immediate) failure has occurred, and, (2) how/why the design of the 933 project differs in such ways that the failure will not be repeated. Otherwise, the economic analyst has no choice to presume that the 933 project will also fail almost immediately, thereby eliminating most of the claimed future benefits.

2. **Inadequate analysis of severe storm events:** the discussion (and presumably, analysis) of major storm events is limited to categories 1 and 2. This omission is presumably justified by the fact that neither the existing beach nor the augmented beach provide much protection against the larger, more damaging storms, and therefore the augmentation would provide no benefit to analyze. What's missing is the possibility that a Category 4 or 5 storm could destroy many of the structures as well as much of the augmented beach, leaving no protection at all against future

storms of any category, and thereby reducing the benefits of the project to essentially zero, thereafter. [Obviously, this line of reasoning contradicts the notion expressed in the document that short-term storm-damage to beaches quickly re-equilibrates to pre-existing conditions and contours; but if that reasoning is correct, how is it that we're still trying to "correct" damage that occurred in 1996?]

3. **Inappropriate period for analysis:** one searches in vain for any serious, substantive justification for analyzing a 10-year project over a 20-year period. One supposes that it might be argued that simply by delaying until 2015-2024 the damage that otherwise would have occurred during 2005-2014 there is a gain in present value. (That's true, but it's also true that the gain would be small.) If that is the reason for the 20-year observation period, it should be made explicit, and data presented so that the reader may verify that this indeed is what has been done. If there is some other reason for the 20-year observation period, then that should be presented. Otherwise, it must be concluded that the doubling of the observation period is both arbitrary and capricious, and that estimated benefits are therefore too large by a factor of 2.

4. **Inadequate analysis of recreational benefits:** the valuation of recreational benefits is highly speculative, for several reasons: (a) the unit day-value lacked theoretical justification when it was first adopted some 40 years ago, and is now quite hopelessly obsolete; estimates based on this method are presumed to be completely lacking in economic validity; (b) the number of people using the beach can be estimated far more reliably than by aerial photographs; given the simplicity (and low cost) of simply sending an observer to the beach to count the people on the beach at various times on various days, the use of the far-less-direct aerial observance is simply not good science; (c) similarly, the estimates of room occupancy, conjoined with the assumption that every dweller in every room goes to the beach, perhaps contains an upward bias. Taking these deficiencies together, one is forced to conclude that the analysis of recreational benefits (as presented) is seriously biased and unreliable, and should not play any role in evaluating the 933 project. [One also notes that the language in the enabling statute refers explicitly to storm damage, but makes no mention of recreational value. A compelling legal case could be made that recreational value has no legal standing in a 933 analysis.]

5. **Contents value:** the assumption that contents of commercial structures are valued at 50% of the structures' value is another empirical issue that could easily be verified by actual survey of actual commercial structures, rather than relying on local expert opinion. To rely on opinion when data can so easily be gathered is simply not acceptable procedure.

6. **Excess burden of taxation:** although USACE procedures do not require it, sound economic analysis of economic benefits and costs requires consideration of the benefit reductions caused by the behavioral alterations caused by the use of taxation to finance projects. As per OMB suggestion, the analyst should increase cost estimates by about 25% to account for this effect; this adjustment results in a substantial reduction on net benefits.

7. **Linear loss of land value:** it is assumed that land's loss of value is linear with the loss of

area (i.e., that every 1% reduction in area produces a 1% loss of value); further, it is asserted that this assumption is "reasonable and non-subjective." It may be indeed be reasonable, but it is absolutely subjective, insofar as many other relationships are both possible and reasonable. For instance, it is also reasonable to believe that small changes in area are largely unnoticed by the market as long as the lot remains (re-)buildable, followed by a very large loss of value for the potentially very small loss of land that takes away the ability to build and/or rebuild. Which is correct? Once again, as we say in economics, that's an empirical question, to be answered not by theory but by statistical reasearch. Otherwise, the choice is wholly subjective, and results based thereupon must be regarded as speculation.

Taking all of these issues into account, it appears that the analysis as presented provides no sound economic basis for a conclusion regard the net economic benefits of the Morehead City 933 project. It is my belief that if all of these issues were fully and appropriately addressed, that the resulting net economic benefits would be far lower than as presented in the document, and quite possibly negative. Sound public policy demands that no action be taken pending correction of these deficiencies.

Thank you for your consideration of these observations.

Cordially,

Douglas J. Wakeman, Ph.D.
Professor of Economics
School of Business
Meredith College

T. B. Doe, III
114 Club Colony Drive
Atlantic Beach, North Carolina, 28512
Telephone ☎ 252-726-8952 - Facsimile - 603-710-0574
tom@tomdoe.com
May 8, 2003

Department of the Army
Wilmington District, U. S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Re: **CESAW-TS-PE-03-16-002**

PUBLIC NOTICE
AND
NOTICE OF AVAILABILITY
Environmental Assessment
Morehead City Harbor Section 933
Carteret County, North Carolina

Ladies/Gentlemen:

This is in reference to your above titled May 2, 2003 document. Be advised that page 2, second paragraph, sentence three is in error. The notice specifically states, "...the proposed project is consistent with...........the land use plan for.............Towns of Atlantic Beach........." In fact, the proposed 933 project is in direct violation of the approved 1993 Town of Atlantic Beach Land Use Plan. Specifically, the Atlantic Beach Land Use Plan makes three references to the long standing disposal of Beaufort Inlet and Harbor spoils on Atlantic Beach.

- Page I-71, (i) Excessive Erosion Areas.

"Numerous spoil projects performed by the U. S. Army Corps of Engineers as a result of dredging projects around the State Port have preserved the Atlantic Beach ocean shoreline. The sand utilized for the spoil was obtained from dredging projects in Beaufort Inlet and Bogue Sound."

- Page IV-6, Ocean Hazard Areas: (b)

"Atlantic Beach supports the deposit of dredge spoil by the U.S. Army Corps of Engineers on the beach and relocation as the preferred erosion control measures for ocean hazard areas."

- Page IV-7, Ocean Hazard Areas: (e)

"Atlantic Beach will support the limited adjustment of the CAMA setback line in association with ongoing deposit of sand from dredge spoil projects and the establishment of new permanent dune and vegetation lines. However, it is understood that this policy will not impact permit decisions regarding CAMA setback line in ocean hazard areas unless the Coastal Resources Commission modifies the State use standards for this AEC."

These three sections of the document clearly tie into the ongoing placement of inner harbor spoils on Atlantic Beach. Transfer of more than 70% of the spoils required to continue this plan, elsewhere, to supply sand for the 933 project, clearly violates Atlantic Beach's Land Use Plan. A 933 plan that builds itself by taking the sand supporting Atlantic Beach's Land Use Plan must be rejected as not "consistent to the maximum extent.....".

Cordially,

T. B. Doe, III

cc: Town of Atlantic Beach

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive North
St. Petersburg, Florida 33702

July 16, 2003

Colonel Charles R. Alexander, Jr.
District Engineer, Wilmington District
Department of the Army, Corps of Engineers
Regulatory Division
P. O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Coleman Long

Dear Colonel Alexander:

The National Marine Fisheries Services (NOAA Fisheries) has reviewed the modified Draft Environmental Assessment/ Finding of No Significant Impact (EA/FONSI) and Final Evaluation Report (FER) for the Morehead City, Section 933 Project, located on Bogue Banks in Carteret County, North Carolina. The documents were provided by your staff via electronic mail on July 10, 2003.

The May 2, 2003, public notice for this project initiated consultation pursuant to the Essential Fish Habitat (EFH) provisions of the Magnuson-Stevens Fisheries Coordination and Management Act and, by letter dated June 5, 2003, NOAA Fisheries provided its EFH Conservation Recommendations. We also participated in a June 24, 2003, interagency meeting to discuss the project and your staff responded to our EFH Conservation Recommendations by letter dated June 27, 2003. While the June 27th letter did not fully alleviate our concerns regarding certain aspects of the project, further coordination between our agencies resulted in changes that are desirable and largely address our concerns. In connection with this, NOAA Fisheries has reviewed the revised EA/FONSI and FER as they relate to our EFH Conservation Recommendations and we provide the following comments:

EFH Conservation Recommendation No. 1 Additional information provided at the most recent interagency meeting and included in the modified EA/FONSI adequately addresses our concerns regarding full assessment of "without project conditions." Since the completed Bogue Banks Beach Nourishment Project (BBBNP), Phases I and II, failed to provide the approved volume of fill, the Section 933 project would supplement erosion control on portions of Bogue Banks while a long-term solution is being investigated by the Wilmington District. NOAA Fisheries remains concerned over repetitive beach nourishment that precludes recovery of aquatic species and we continue to recommend that this issue be examined in detail in association with the Corps' long-term study of beach nourishment needs on Bogue Banks.

EFH Conservation Recommendation No. 2 The project construction time frame has been reduced from 16 months of continuous dredging to the period of November 1, 2003, through April 30, 2004, which is acceptable to NOAA Fisheries. We also do not object to extension of this period to May 31, 2004, if necessary to complete the project. However, agreement to extension of the work period is based on an absolute commitment by the Wilmington District to terminate all dredging, disposal of dredged material, and reworking of dredged material with heavy equipment on May 31, 2003.

EFH Conservation Recommendation No. 3 To ensure compatibility of dredged material with that found on Bogue Banks beaches, NOAA Fisheries recommended analysis of sediment grain size on Brandt Island and in the Morehead City inner harbor. The sediment analysis, which is contained in the FER, Section 505, Table 1, indicates the sediments in the Morehead City inner harbor are compatible with those found on Bogue Banks beaches. We remain concerned that a silt layer was detected at the Brandt Island borrow site; however, according to the FER, fine sediment comprises only two percent of the total volume of material to be removed from Brandt Island and placed on beaches at Pine Knoll Shores, Indian Beach, and Salter Path. Also, the project plans include a requirement for Corps inspectors to monitor all dredging and, if incompatible sediments are encountered, the dredge will be immediately relocated to an area with compatible sediments. These modifications adequately address and resolve our concerns and previous recommendation.

EFH Conservation Recommendation No. 4 NOAA Fisheries seeks to ensure that populations of mole crab (*Emerita talpoida*) and coquina clam (*Donax variabilis*) are provided sufficient time to repopulate nourished sections of beach before additional re-nourishment commences. The modified dredging schedule calls for completion of biological sampling to evaluate species recovery in connection with the BBBNP; however, monitoring performed thus far has not demonstrated that recovery by mole crab and coquina clam is occurring. This may be due to placement of incompatible material on sections of beach during the BBBNP. If, the Section 933 project results in burial of areas that are undergoing slow recovery and compatible sediments are used, then population recovery may be expedited. Based on this, NOAA Fisheries withdraws the previously recommended three year lapse in beach disposal to allow for mole crab and coquina clam recovery. However, if final monitoring of beaches at Pine Knoll Shores does not demonstrate adequate recovery of mole crabs and coquina clams, then the Wilmington District should monitor these areas to determine when pre-project population levels are, in fact, attained.

EFH Conservation Recommendation No. 5 The Wilmington District has provided assurance that sediments to be placed on Bogue Banks are compatible with the exiting beach sand. However, we remain concerned that should non-compatible sediments be placed on Bogue Banks, there are no contingency plans for beach restoration. Therefore, NOAA Fisheries continues to recommend that the Corps develop a feasibility plan for beach restoration in the event that incompatible material is placed on the beach.

EFH Conservation Recommendation No. 6 Based our review of the modified EA/FONSI and FER, NOAA Fisheries finds that individual and cumulative adverse impacts to fishery resource have been minimized. Therefore, we agree that the EA/FONSI is adequate and preparation of a full EIS is not warranted.

In view of the preceding, we do not object to undertaking the project, provided the above recommendations, and the modifications proposed by the Wilmington District, are effectuated.

Thank you for the opportunity to provide these additional comments. Related questions or comments should be directed to the attention of Mr. Ronald S. Sechler at our Beaufort Office, 101 Pivers Island Road, Beaufort, North Carolina, or at (252) 728-5090.

Sincerely,

for Frederick C. Sutter III
Deputy Regional Administrator

cc:
USFWS Raleigh, NC
USEPA Athens, GA
NCWRC, Raleigh NC
NCDMF, Morehead City NC
SAFMC, Charleston NC

NCDENR
North Carolina Department of Environment and Natural Resources
Division of Coastal Management
Michael F. Easley, Governor Donna D. Moffitt, Director William G. Ross Jr., Secretary

July 18, 2003

Mr. W. Coleman Long
Chief – Planning and Environmental Branch
U.S. Army Corps of Engineer – Wilmington District
Post Office Box 1890
Wilmington, North Carolina 28402-1890

REFERENCE: DCM03-06 Environmental Assessment, Morehead City Harbor Section 933, Carteret County, North Carolina - U. S. Army Corps of Engineers Public Notice Issued on May 2, 2003
And
Draft Final Evaluation Report and Finding of No Significant Impact (FONSI) – Morehead City Harbor Section 933

Dear Mr. Long:

The State of North Carolina has completed its review pursuant to 15 CFR 930 Subpart C - Consistency for Federal Activities of the above referenced Public Notice and the Draft Final Evaluation Report – FONSI. As part of its review, the N.C. Division of Coastal Management (DCM) has circulated the U.S. Army Corps of Engineers (USACE) public notice to state agency reviewers for comment.

The USACE public notice issued on May 2, 2003 states that the Wilmington District of the USACE is proposing to place beach quality material from the pumpout of the Brandt Island spoil disposal site and the maintenance dredging of Morehead City Harbor navigation channels onto Bogue Banks beaches, off the Atlantic Ocean. The Bogue Banks beaches include Atlantic Beach, Pine Knoll Shores, Indian Beach (including Salter Path), and Fort Macon State Park. The proposed project is being undertaken under the authority of Section 933 of the Water Resources Development act of 1986 (Public law 99-662), as amended. The Draft Final Evaluation Report and FONSI reflect modifications to the initial proposal to address concerns raised in the June 24, 2003 interagency meeting held to discuss this proposal.

1638 Mail Service Center, Raleigh, North Carolina 27699-1638
Phone: 919-733-2293 \ FAX: 919-733-1495 \ Internet: www.nccoastalmanagement.net

Based upon our review, we agree with your determination that the proposed activity is consistent with the North Carolina Coastal Management Program to the maximum extent practicable provided the following conditions are satisfied:

1. The North Carolina Wildlife Resources Commission has expressed concerns about the potential impacts of repeated nourishment projects on the Bogue Banks beaches, and the cumulative impacts to macroinvertebrate populations and the shorebirds that prey on them. The USACE should continue to evaluate measures to help mitigate any unavoidable effects of the project on waterbirds and shorebirds, as discussed at the June 24, 2003 meeting.

2. The North Carolina Division of Marine Fisheries (DMF) has also expressed concerns about the cumulative impacts to important commercial fish stocks and birds of repeated beach nourishment events over relatively short time intervals. DMF recommends that monitoring associated with the Bogue Banks Beach Nourishment Project (BBBNP) be reviewed and, if it does not demonstrate recovery of beach invertebrates, the USACE should coordinate with the BBBNP project sponsors to ensure that monitoring continues until recovery is attained.

3. The North Carolina Division of Coastal Management (DCM) has expressed concern related to the presence of a silt layer on Brandt Island. DCM recommends that the questionable material not be pumped along the public beach areas of Fort Macon and the circle of Atlantic Beach.

4. DCM is concerned about the access channel that would be cut into Brandt Island and its potential to cause erosion of the dike walls (over time) and the impacts associated with such problems. The USACE should restore that portion of the channel adjacent to the island back to its original condition to alleviate any potential erosion problems.

5. The North Carolina Division of Environmental Health -- Shellfish and Recreational Water Quality Section has expressed concerns about the potential human health hazard associated with the placement of dredged material obtained from areas closed to shellfishing on the beaches between May 1 and October 31 when recreational usage is high. Therefore, the USACE must notify the Shellfish Sanitation and Recreational Water Quality Section prior to dredging from an area closed to shellfishing with placement on a recreational swimming area so that a public release can be made and a swimming advisory can be posted.

If you have any questions, please contact Guy C. Pearce by phone at (919) 733-2293, extension 249. Thank you for your consideration of the North Carolina Coastal Management Program.

Sincerely,

Doug Huggett
Major Permits and Consistency Coordinator

cc:

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

July 22, 2003

Colonel Charles R. Alexander, Jr.
District Engineer, Wilmington District
U.S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Attn: Coleman Long

Dear Colonel Alexander:

This letter constitutes a second amendment to the U.S. Fish and Wildlife Service's (Service) biological opinion, dated December 7, 1989, as amended April 19, 1993, for the U.S. Army Corps of Engineers' (Corps) proposed dredging of Morehead City Harbor and subsequent disposal of dredged sediments in a Morehead City Ocean Dredged Material Disposal Site, an upland diked dredge disposal area on Brandt Island, or pumped directly to the ocean front beaches at Fort Macon State Park to Atlantic Beach, in Carteret County, North Carolina. The Service received a written request from the Corps on May 5, 2003, to initiate formal section 7 consultation under the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 et seq.) (Act) based on changes in the proposed project's scope of work and timing.

The Service prepared a biological opinion, dated December 7, 1989, for the proposed dredging of Morehead City Harbor with subsequent disposal of dredged sediments in a Morehead City Ocean Dredged Material Disposal Site, an upland diked dredge disposal area on Brandt Island, or pumped directly onto the oceanfront beach at Fort Macon State Park and Atlantic Beach. In our biological opinion we concurred with your findings that the proposed action would have no effect on the piping plover (*Charadrius melodus*), roseate tern (*Sterna dougallii*), and hawksbill (*Eretmochelys imbricata*) and Kemp's ridley (*Lepidochelys kempii*) sea turtles, and that the proposed action may affect loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtles. Our biological opinion concluded that the proposed action was not likely to jeopardize the continued existence of loggerhead and green sea turtles.

An amendment to the biological opinion, dated April 19, 1993, was prepared in response to updated project plans of the original dredge and disposal action. The project modifications included the disposal of additional dredged sediment material on oceanfront beaches from Fort Macon State Park to Pine Knoll Shores and a different pipeline route than reviewed in the original project. The amended biological opinion concluded that the proposed project modifications were not likely to jeopardize the continued existence of loggerhead and green sea turtles. The amended biological opinion also included a conference opinion for the proposed federally-threatened seabeach amaranth (*Amaranthus pumilus*) in which we concluded that the proposed action would not likely jeopardize the continued existence of this species. Seabeach amaranth was formally listed as threatened on May 7, 1993 (58 FR 18035).

The proposed action, as detailed in your Draft Evaluation Report and Environmental Assessment (DER/EA), dated May 2003, consists of placing approximately 6.3 million cubic yards of dredged material stored in the Brandt Island disposal site and sediments from maintenance dredging of the inner and outer harbor navigation channels of Morehead City and Beaufort Inlet along approximately 13.2 linear miles of oceanfront beaches of Bogue Banks (including Fort Macon, Atlantic Beach, Pine Knoll Shores, Salter Path, and Indian Beach), Carteret County, North Carolina (hereafter referred to as Morehead City Harbor Section 933 Project). The proposed action is a modification to the previously reviewed project in that it includes the disposal of dredged sediments on the beaches of Salter Path and Indian Beach. The proposed project is a one-time action to dispose of sediments beginning November 16, 2003 and continue for up to 16 months (estimated completion date April 30, 2005). However, the pump-out of Brandt Island and disposal of these sediments on the oceanfront beaches of Bogue Banks is expected to occur, as it has in the past, every 8 to 10 years. The proposed action is scheduled to operate 24 hours a day, seven days a week for the duration of the project.

In your Draft Final Evaluation Report and Finding Of No Significant Impact (DFER/FONSI), dated July 2003, for the Morehead City Harbor Section 933 Project, the proposed action was modified to reduce the period of time that sediments will be deposited on the area beaches from 16 months to approximately six months. The proposed action still consists of pumping approximately 6.3 million cubic yards of material on the 13.2 linear miles of oceanfront beaches of Bogue Banks, but the time period sediment disposal will occur will be limited from November 1, 2003 to April 30, 2004 (extended to May 31, 2004 if the contractor experiences mechanical problems). These dates do not include pre- and post-project mobilization or the placement and removal of equipment, which requires an additional two to three weeks on each end of the proposed construction dates specified above.

In response to your DER/EA, dated May 2003, for the proposed Morehead City Harbor Section 933 Project, we concluded in a letter, dated June 6, 2003, that the proposed action is not likely to adversely affect the roseate tern and hawksbill, Kemp's ridley, and leatherback (*Dermochelys coriacea*) sea turtles. With regard to the West Indian manatee (*Trichechus manatus*), however, we could not concur with your determination that the proposed action is not likely to adversely affect this species unless the measures detailed in the *Precautionary Measures For Activities In North Carolina Waters Which May Be Used By The West Indian Manatee* were implemented.

In your DFER/FONSI, dated July 2003, you stated that the Corps would abide by the conditions and restrictions found within the *Precautionary Measures For Activities In North Carolina Waters Which May Be Used By The West Indian Manatee* document submitted to you along with our June 6, 2003 letter. Based on your commitment to include these measures, we conclude that the proposed action is not likely to adversely affect the West Indian manatee. To further reduce the potential impacts of the proposed project on federally-protected species, the Corps has also offered a list of environmental commitments in Section 9.0 of the DFER/FONSI. These commitments are incorporated by reference and were considered as conservation measures in our review of the proposed project. The Service considers conservation measures part of the proposed action; therefore, their implementation is required under the terms of the consultation.

Because the proposed Morehead City Harbor Section 933 Project is different in timing and scope from the project reviewed in the original biological opinion and amendment, and new information is available on seabeach amaranth, the piping plover, and green and loggerhead sea turtles, we initiated formal consultation in a letter, dated June 6, 2003, for these species.

Based on information provided in your DFER/FONSI and a change in the timing of the proposed action, and other information available, we have determined that the proposed project is not likely to adversely affect the piping plover. The piping plover has not been reported to nest in the vicinity of the proposed dredging, on Brandt Island, in the areas of dredge pipe placement, or sediment disposal; therefore, none would likely be affected. A single piping plover was recorded in the vicinity of the proposed action in Fort Macon State Park on January 18, 1996; although, it should be noted that all areas impacted by the proposed action have not been extensively surveyed during the migration and overwintering periods.

The remaining portions of this amendment are based on information provided in the DER/EA, DFER/FONSI, supplemental information, and other sources of information available. The status of seabeach amaranth and green and loggerhead sea turtles, including species descriptions, life histories, population dynamics, and an analysis of the habitats likely affected have been reviewed in the biological opinion for this project, dated December 7, 1989, as amended April 19, 1993. A complete administrative record of this consultation is on file in the Ecological Services Field Office in Raleigh, North Carolina.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered or threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this incidental take statement.

The measures described below are non-discretionary, and must be undertaken by the Corps so that they become binding conditions of any grant or permit issued, as appropriate, for the exemption in section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered by this incidental take statement. If the Corps (1) fails to assume and implement the terms and conditions or (2) fails to require a contractor to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Corps must report the progress of the action and its impacts on the species to the Service as specified in the incidental take statement (50 CFR § 402.14(i)(3)).

AMOUNT OR EXTENT OF INCIDENTAL TAKE

Seabeach Amaranth – Sections 7(b)(4) and 7(o)(2) of the Act generally do not apply to listed plant species. However, limited protection of listed plants from take is provided to the extent that the Act prohibits the removal and reduction to possession of federally-listed endangered plants or the malicious damage of such plants on areas under federal jurisdiction, or the destruction of endangered plants on non-federal areas in violation of state law or regulation or in the course of any violation of a State criminal trespass law. Applicable provisions of the North Carolina Plant Protection and Conservation Act (GS 106-202.12 to 202.22) should be followed.

Sea Turtles – The Service anticipates approximately 13.2 linear miles of nesting beach habitat on the beaches of Bogue Banks from Fort Macon State Park to Indian Beach (including Salter Path) could be taken as a result of this proposed action. Based on the review of biological information and other information relevant to this action, incidental take is anticipated to be in the form of: (1) destruction of all sea turtle nests that may be constructed and eggs that may be deposited and missed by a nest survey and egg relocation program within the boundaries of the proposed project; (2) destruction of all sea turtle nests deposited when a nest survey and egg relocation program is not required to be in place within the boundaries of the proposed project; (3) reduced hatching success due to egg mortality during relocation and adverse conditions at the relocation site; (4) harassment in the form of disturbing or interfering with female turtles attempting to nest within the nourishment area or on adjacent beaches as a result of nourishment activities; (5) disorientation of hatchling turtles on beaches adjacent to the nourishment area as they emerge from the nest and crawl to the water as a result of project lighting; (6) behavior modification of nesting females due to escarpment formation within the project area during a nesting season, resulting in false crawls or situations where they choose marginal or unsuitable nesting areas to deposit eggs; and, (7) destruction of all nests destroyed as a result of escarpment leveling within a nesting season when such leveling has been approved by the Service.

Incidental take is anticipated for only the 13.2 linear miles of nesting beach habitat on the beaches of Bogue Banks from Fort Macon State Park to Indian Beach (including Salter Path) that have been identified for sediment disposal. The Service anticipates incidental take of sea turtles will be difficult to detect for the following reasons: (1) turtles nest primarily at night and all nests are not found because (a) natural factors, such as rainfall, wind, and tides may obscure crawls, and (b) human-caused factors, such as pedestrian traffic, may obscure crawls, and result in nests being destroyed because they were missed during a nesting survey and egg relocation program; (2) the total number of hatchlings per undiscovered nest is unknown; (3) the reduction in percent hatching and emerging success per relocated nest over the natural nest site is unknown; (4) an unknown number of females may avoid the project beaches and be forced to nest in a less than optimal area; (5) lights may disorient an unknown number of hatchlings and cause death; and, (6) escarpments may form and cause an unknown number of females from accessing a suitable nesting site. However, the level of take of these species can be anticipated by the disturbance of suitable turtle nesting beach habitat because: (1) turtles nest within the project site; (2) sediment disposal will likely occur during a portion of the nesting season; (3) the sediment disposal project will modify the incubation substrate, beach slope, and sand compaction; and, (4) artificial lighting will disorient nesting females and hatchlings.

EFFECT OF THE TAKE

In the accompanying biological opinion amendment, the Service determined that this level of anticipated take is not likely to result in jeopardy to seabeach amaranth or loggerhead and green sea turtles.

REASONABLE AND PRUDENT MEASURES

The Service believes that the following reasonable and prudent measures are necessary and appropriate to minimize take of seabeach amaranth and loggerhead and green sea turtles:

(1) Only high-quality, beach-compatible sand should be deposited on the beaches of Bogue Banks as part of this project;

(2) If the construction phase is conducted during the seabeach amaranth growing season (May 1 through October 31), surveys for seabeach amaranth will be conducted prior to the start of any sediment disposal and again prior to any tilling operation. If plants are found within the area of sediment disposal or tilling, the plants shall be protected with an adequate buffer zone;

(3) The Corps will ensure that contractors doing the work fully understand the seabeach amaranth protection measures detailed in this opinion;

(4) Patrols for nesting turtles will be required if the project is conducted during the sea turtle nesting season (May 1 through November 15). If nests are constructed in the area of sediment disposal, the eggs will be relocated following the protocols of a nest relocation program approved by the North Carolina Wildlife Resources Commission and the Service;

(5) Immediately after completion of the project and prior to the next three sea turtle nesting seasons, beach compaction will be monitored and tilling will be conducted as required to reduce the likelihood of impacting sea turtle nesting and hatching activities;

(6) Immediately after completion of the project and prior to the next three sea turtle nesting seasons, monitoring will be conducted to determine if escarpments are present, and

escarpments will be leveled as required to reduce the likelihood of impacting sea turtle nesting and hatching activities;

(7) During the sea turtle nesting season (May 1 through November 15), lighting associated with the project will be minimized to reduce the possibility of disrupting and disorienting nesting and/or hatchling sea turtles;

(8) During the sea turtle nesting season (May 1 through November 15), construction equipment and pipes will be stored in a manner that will minimize impacts to sea turtles to the maximum extent practicable; and,

(9) The Corps will ensure that contractors doing the work fully understand the sea turtle protection measures detailed in this amendment.

TERMS AND CONDITIONS

In order to be exempt from the prohibitions of section 9 of the Act, the Corps must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

Terms and Conditions: All Species

A report describing the actions taken to implement the terms and conditions of this incidental take statement will be submitted to the Service's Raleigh Field Office, Post Office Box 33726, Raleigh, North Carolina 27636-3726 within 60 days of completion of the proposed work. This report will include the status of the species – seabeach amaranth and nesting loggerhead and green sea turtles – addressed in this opinion amendment and any known impacts, either beneficial or adverse, of the project upon completion of the construction phase and following each maintenance phase, inclusive of the years between each operational event. The dates of actual construction activities and the names and qualifications of personnel involved in species surveys should also be included.

Terms and Conditions: Seabeach Amaranth

Seabeach amaranth surveys will be required if any portion of the sediment disposal project or tilling operation occurs during the period May 1 through October 31. Plant surveys will be initiated prior to sediment disposal, dredge pipe placement or removal, and/or tilling activities. If plants are discovered in areas where they may be affected by sediment disposal, dredge pipe placement or removal, and/or tilling activities, the plants will be protected by an adequate buffer zone. The protected area will not identify the plants to protect them from collectors, but will be of adequate size to obscure the specific plant site.

Terms and Conditions: Sea Turtles

1. All fill material placed on beaches will be sand that is similar to that of the native beach in both coloration and grain size distribution. All such fill material will be free of construction debris, rocks, organic materials, or other foreign matter and will not contain, on average, greater than 10 percent fines (i.e., silt and clay; passing the # 200 sieve) and will not contain, on average, greater than 5 percent coarse gravel or cobble, exclusive of shell material (retained by the # 4 sieve).

2. Daily early morning nesting surveys will begin when mobilization and construction begins and continue through November 15. Nightly (from dark till dawn) sea turtle nesting patrols will be required if any portion of the sediment disposal project continues after May 1. Nightly nesting patrols will be initiated on May 1 and continue throughout the construction and demobilization periods. Daily early morning nesting surveys will commence again upon completion of the disposal project and demobilization and continue through November 15. If vehicles are used for nest monitoring, the vehicles should stay below the high tide line, whenever possible, and use modified headlamps (e.g., red headlamps) or the minimal lighting necessary to comply with safety requirements. If nests are constructed in areas where they may be affected by construction disposal activities, eggs will be relocated per the following requirements.

    2a. Nesting surveys and egg relocations will only be conducted by personnel with prior experience and training in nest survey and egg relocation procedures. Surveyors must have a valid North Carolina Wildlife Resources Commission permit.

    2b. Only those nests that may be affected by construction activities will be relocated. Nests and eggs that require relocation will be moved no later than 9 a.m. the morning following deposition to a nearby self-release beach site in a secure setting where artificial lighting will not interfere with hatchling orientation. Nest relocations in association with construction activities will cease when construction activities no longer threaten nests. Nests deposited within the areas where construction activities have ceased or will not occur for 65 days will be marked and left in place unless other factors threaten the success of the nest. Any nests left in the active construction zones will be clearly marked, and all mechanical equipment will avoid nests by at least 20 feet. The nest site will also be cleared of materials or equipment that could potentially block passage of hatchlings from leaving the nest and approaching the ocean.

3. Immediately after completion of sediment placement on beaches and prior to May 1 for three subsequent years, sand compaction will be monitored in the placement area in accordance with a protocol agreed to by the Service, the North Carolina Wildlife Resources Commission, and the Corps. At a minimum, the protocol provided under 3a and 3b below will be followed. If required, the area will be tilled to a depth of 36 inches. All tilling activity must be completed prior to May 1. If the project is completed during the nesting season, tilling will not be performed unless specifically authorized by the Service under a separate letter. A report on the results of compaction monitoring will be

submitted to the Service prior to any tilling actions being taken. An annual summary of compaction surveys and the actions taken will be submitted to the Service. This condition will be evaluated annually and may be modified if necessary to address sand compaction problems identified during the previous year. Please note that the requirement for compaction monitoring and remediation is not required if placed material no longer remains on the beach.

3a. Transects consisting of two compaction sampling stations will be located at 500 foot intervals along the sediment disposal area. One station will be at the seaward edge of the dune line (when material is placed in this area); and one station will be midway between the dune line and the high water line (normal wrack line). Two additional transects are recommended on each side of the sediment disposal area so that comparisons can be made between effected and unaffected areas.

At each station, the cone penetrometer will be pushed to a depth of 6, 12, and 18 inches three times (three replicates). Material may be removed from the hole if necessary to ensure accurate readings of successive levels of sediment. The penetrometer may need to be reset between pushes, especially if sediment layering exists. Layers of highly compact material may lay over less compact layers. Replicates will be located as close to each other as possible, without interacting with the previous hole and/or disturbed sediments. The three replicate compaction values for each depth will be averaged to produce final values for each depth at each station. Reports will include all 18 values for each transect line, and the final six averaged compaction values.

3b. If the average value for any depth exceeds 500 psi for any two or more adjacent stations, or if values exceeding 500 psi are distributed throughout the sediment placement areas but in no case do those values exist at two adjacent stations at the same depth, then consultation with the Service will be required to determine if tilling is required. If a few values exceeding 500 psi are present randomly within the placement area, then tilling will not be required.

4. Sand compaction data will be collected on beaches scheduled for sediment disposal prior to the disposal operation following the protocols described above. Such pre-disposal beach compaction data will establish a range of values for areas in which sea turtles actually nest. These data will form a valuable baseline for comparison with post-disposal compaction values and could influence the necessity for post-disposal tilling.

5. Visual surveys for escarpments along the project area will be made immediately after completion of the sediment placement and prior to May 1 for three subsequent years. Results of the surveys will be submitted to the Service prior to any action being taken. Escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet will be leveled to the natural beach contour by May 1. The Service will be contacted immediately if subsequent reformation of escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet occur

during the nesting and hatching season to determine the appropriate action to be taken. If it is determined that escarpment leveling is required during the nesting or hatching season, the Service will provide a brief written authorization that describes methods to be used to reduce the likelihood of impacting existing nests. An annual summary of escarpment surveys and actions taken will be submitted to the Service. Please note that the requirement for escarpment monitoring and remediation is not required if placed material no longer remains on the beach.

6. The Corps will arrange a meeting between representatives of the contractor, the Service, the Commission, and the permitted person responsible for egg relocation at least 30 days prior to the commencement of work on this project. At least 10-days advanced notice will be provided prior to conducting this meeting. This will provide an opportunity for explanation and/or clarification of the sea turtle protection measures.

7. From May 1 through November 15, staging areas for construction equipment will be located off the beach to the maximum extent practicable. Nighttime storage of construction equipment not in use will be off the beach to minimize disturbance to sea turtle nesting and hatching activities. In addition, all construction pipes that are placed on the beach will be located as far landward as possible without compromising the integrity of the existing or reconstructed dune system. Temporary storage of pipes will be off the beach to the maximum extent possible. Temporary storage of pipes on the beach will be in such a manner so as to impact the least amount of nesting habitat and will likewise not compromise the integrity of the dune systems (placement of pipes perpendicular to the shoreline is recommended as the method of storage).

8. From May 1 through November 15, all lighting associated with the project will be limited to the immediate area of active construction only and will be the minimal lighting necessary to comply with safety requirements. Shielded lights are recommended to minimize illumination of the nesting beach and nearshore waters. Lighting on offshore equipment will be minimized through reduction, shielding, lowering, and appropriate placement of lights to avoid excessive illumination of the water, while meeting all U.S. Coast Guard and Occupational Safety and Health Administration requirements. Shielded lights are highly recommended for lights on offshore equipment that cannot be eliminated.

9. A report describing the actions taken to implement the terms and conditions of this incidental take statement will be submitted to Mr. David Rabon of the Service's Raleigh Field Office within 60 days of completion of the proposed work. This report will include the dates of actual construction activities, names and qualifications of personnel involved in nest surveys and relocation activities, descriptions and locations of self-release beach sites, nest survey and relocation results, and hatching success of nests.

10. In the event a sea turtle nest is excavated during construction activities, the permitted person responsible for egg relocation for the project should be notified so the eggs can be moved to a suitable relocation site.

11. Upon locating a dead, injured, or a sick sea turtle specimen, initial notification must be made to Dr. Matthew Godfrey, Sea Turtle Coordinator, North Carolina Wildlife Resources Commission, at 252-728-1528 (or emergency pager 252-247-8117) prior to transporting live debilitated turtles to a rehabilitation facility or disposing of carcasses. Care will be taken in handling sick or injured specimens to ensure effective treatment and care and in handling dead specimens to preserve biological materials in the best possible state for later analysis of cause of death. In conjunction with the care of a sick or injured sea turtle or preservation of biological materials from a dead animal, the finder has the responsibility to ensure that evidence intrinsic to the specimen is not disturbed.

The Service believes that incidental take of sea turtles will be limited to the 13.2 linear miles of nesting beach habitat on Bogue Banks that has been identified for sand placement. The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. The Service believes that no more than the following types of incidental take will result from the proposed action: (1) destruction of all sea turtle nests that may be constructed and eggs that may be deposited and missed by a nest survey and egg relocation program within the boundaries of the proposed project; (2) destruction of all sea turtle nests deposited during the period when a nest survey and egg relocation program is not required to be in place within the boundaries of the proposed project; (3) reduced hatching success due to egg mortality during relocation and adverse conditions at the relocation site; (4) harassment in the form of disturbing or interfering with female turtles attempting to nest within the construction area or on adjacent beaches as a result of construction activities; (5) disorientation of hatchling turtles on beaches adjacent to the construction area as they emerge from the nest and crawl to the water as a result of project lighting; (6) behavior modification of nesting females due to escarpment formation within the project area during a nesting season, resulting in false crawls or situations where they choose marginal or unsuitable nesting areas to deposit eggs; and, (7) destruction of all nests destroyed as a result of escarpment leveling within a nesting season when such leveling has been approved by the Service. The amount or extent of incidental take for sea turtles will be considered exceeded if the project results in sediment disposal occurring more than once or on more than the 13.2 linear miles of beach shoreline identified for sand placement in the Morehead City Harbor Section 933 Project without reinitiation of consultation and/or the prior written consent of the Service. If, during the course of the action, this level of incidental take is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided. The federal action agency must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the reasonable and prudent measures.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Endangered Species Act directs federal action agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. The Service encourages the Corps to implement the following conservation recommendations as part of the project plans.

(1) Although the Service has determined that the subject action is not likely to jeopardize the continued existence of the loggerhead and green sea turtles and seabeach amaranth, from the Service's viewpoint, summer work on beaches with seabeach amaranth and sea turtle nesting is completely undesirable. Although this biological opinion amendment allows the Corps of Engineers to conduct beach disposal activities during the beginning and ending parts of the sea turtle nesting and hatching seasons in accordance with both section 7 and 9 of the Act, the Service recommends that the Corps avoid the sea turtle nesting and hatching seasons when conducting future beach disposal activities.

(2) Provide additional funding for a nest and sand temperature and sand compaction study. The Corps has contributed to the North Carolina Wildlife Resources Commission and the Service's project already underway on Bogue Banks. Additional funding will allow the purchase of extra equipment and supplies to ensure that the joint agency study can continue in its entirety (6 years) on all the beaches of Bogue Banks. The information gained from this study would be beneficial in determining the impacts of sediments on sea turtle nesting success, hatchling sex ratios, and hatching success. Furthermore, the information would be useful in determining if remedial action is necessary and in assessing whether the impacts of the proposed action would have long-term effects on the beaches' ecosystem. Please note that components of this study also satisfy conditions related to sand compaction and escarpment monitoring.

(3) Survey for breeding piping plovers within the project area, specifically in the area of pipe placement along Fort Macon State Park, prior to the removal of any construction equipment between April 1 and July 31. If nesting piping plovers are found, then please report the findings to the Service and the North Carolina Wildlife Resources Commission prior to the removal of any dredge pipe or other construction equipment so that measures can be taken to protect the nests. The Service and the Commission will establish protective markings or symbolic fencing around the nests, protective buffer zones, and work restrictions within the protective buffer zones. The Corps can then proceed with the removal of any construction equipment or dredge pipe and the assurance that those activities will not disturb the protected areas or the nesting piping plovers.

(4) For this project as well as future projects, require the non-federal project partner(s), as part of the contractual agreement between the non-federal project partner(s) and the Corps, to develop and implement a habitat conservation and lighting management plan to protect federally-protected coastal species (e.g., sea turtles, piping plover, seabeach amaranth) within the boundaries of their jurisdiction (i.e., municipality, county, or other area of jurisdiction). The Service and the North Carolina Wildlife Resources Commission are available and willing to assist the non-federal project partner in the development of such a plan.

(5) Modify and create new habitat for the *Atrytonopsis* skipper on Brandt Island and other Corps defined disposal facilities in the Bogue Banks area. Modification and creation of habitats can include mowing or vegetation removal to promote the occurrence of the species' host plant, seaside little bluestem (*Schizachyrium littorale*), and/or planting or sprigging seaside little bluestem along dike walls or other areas suitable for this species.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

This concludes consultation on the action outlined in your request for formal consultation for the Morehead City Harbor Section 933 Project. As provided in 50 CFR § 402.16, reinitiation of formal consultation is required where discretionary federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in the opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in the opinion; or, (4) a new species is listed or critical habitat designated that may be affected by the action.

Thank you for your cooperation with our agency in protecting federally-listed species. If you or your staff have any questions concerning this amendment, please contact Mr. David Rabon of this office at (919) 856.4520 extension 16, or via email at david_rabon@fws.gov.

Sincerely,

/signed/

Garland B. Pardue, Ph.D.
Ecological Services Supervisor

cc: NCWRC, Beaufort, NC (Matthew Godfrey)
NCWRC, Stella, NC (Sue Cameron)

MOREHEAD CITY HARBOR
CARTERET COUNTY, NORTH CAROLINA
SECTION 933
EVALUATION REPORT

APPENDIX A

CORRESPONDENCE

Appendix A
Pertinent Correspondence

NOTE: This appendix includes general correspondence concerning the project.

Table of Contents

EXHIBIT 1

North Carolina
Department of Environment and Natural Resources
Division of Water Resources

Michael F. Easley, Governor
William G. Ross, Jr., Secretary
John Morris, Director

NCDENR

February 22, 2001

Mr. Steve F. Aiken
US Army Corps of Engineers
Wilmington District
PO Box 1890
Wilmington, NC 28402-1890

Dear Mr. Aiken:

The State of North Carolina supports the interest of Carteret County in a study for a potential Section 933 Project for use of spoil material from Morehead City Harbor on Bogue Bank beaches.

Please contact us for any assistance that we can provide in getting this study under way. Financial participation by the State of North Carolina in the study and in an eventual Section 933 Project will be determined through the State's budget decision process.

We will look forward to working with Carteret County and with the Corps of Engineers on this study.

Sincerely,

John N. Morris

JNM/km

cc: Mr. Frank Rush

1611 Mail Service Center, Raleigh, North Carolina, 27699-1611
Phone: 919 – 733-4064 \ FAX: 919 – 733-3558 \ Internet: www.ncwater.org

EXHIBIT 2

Board of Commissioners
Doug Brady, Chairman
Jonathan Robinson, Vice-Chairman
Bettie Bell
David Wheatly
mmy LaShan
am Stell
Mac Wells

County Manager
Robert M. Murphy
Tel: (252) 728-8450
Fax: (252) 728-2092
bobm@co.carteret.nc.us
www.co.carteret.nc.us

ROUTED: 26 Jan 01
ACTION: PM
CF: DE
DD
DP
DX
TS

January 22, 2001

Mr. John Morris, Director
NC Division of Water Resources
Archdale Building
512 N. Salisbury Street
Raleigh, NC 27611

Dear John:

At its January 8, 2001 meeting, the Carteret County Board of Commissioners approved the attached resolution requesting a Section 933 project for eastern Bogue Banks. We understand that the State of North Carolina must submit such requests to the US Army Corps of Engineers on behalf of local governments, and hereby request that the State submit a formal request to the Corps for a Section 933 project that would utilize dredge spoils currently stored on Brandt Island to nourish Bogue Banks beaches in the winter of 2003-2004.

I have been in contact with Steve Aiken in the Corps' Wilmington District office over the past few months regarding the potential Section 933 project. According to the attached letter from Mr. Aiken, a request for such a project must be made as soon as possible in order to provide enough time for the Corps to complete the required studies and secure the necessary permits to place the sand on the beach strand in 2003-2004. As you know, Carteret County continues to pursue a long-term Shore Protection Project through the Corps. We are currently in the Feasibility Phase, and estimate that initial nourishment under the Shore Protection Project would not occur until FY 2008-2009 or later. The Section 933 project would provide an interim solution to the erosion problems on eastern Bogue Banks until the long-term Shore Protection Project is constructed.

Although details of the project are very preliminary, Mr. Aiken has indicated that the Corps plans to pump out approximately 6 million cubic yards of dredge spoils from the Brandt Island site in 2003-2004. A portion of this material will be placed on the beach in Atlantic Beach and Fort Macon State Park free of charge, as it represents the Corps' least cost disposal method. The remainder of the dredge spoils would be placed as far west on Bogue Banks as feasible, beginning at the eastern town limits of the Town of Pine Knoll Shores. Mr. Aiken has indicated that it appears to be feasible to pump this additional material to a substantial portion, if not all, of Pine Knoll Shores' 4.5 miles of beachfront. You will note that Carteret County is also requesting that a portion of this additional material be placed on 2.5 miles of beachfront in the Town of Indian Beach and the Village of Salter Path at the same time if feasible. All three of these areas of Bogue Banks are faced with severe erosion problems, and the implementation of a Section 933 project would provide much needed storm protection and recreational benefits.

The attached summary sheet contains some of the preliminary estimates for volume, placement, and cost of such a project. You will note that the placement of 4 million (of the 6 million total cubic yards) cubic yards along the 7 miles of beach in Pine Knoll Shores, Indian Beach, and Salter Path would yield approximately 107 cubic yards per linear foot. Based on a total of 4 million cubic yards, the total estimated cost of this project is approximately $19.2 million. Under the current cost-sharing formula (the State provides 75% of the non-federal share), the total State share for this project would be approximately $5.1 million. Please note that this contribution would not be due to the Corps until FY 2003-2004. Carteret County would provide the remainder of the non-federal share, approximately $1.7 million, in FY 2003-2004.

Carteret County appreciates the State's assistance as we address the beach erosion problems on Bogue Banks. Your agency has been supportive of our efforts to date, and we hope to continue to receive your support for this and other requests. Please contact me if you need any additional information about Carteret County's Section 933 request. I will be happy to provide any assistance necessary to move this project forward.

Thanks again for all of your help.

Sincerely,

Frank A. Rush, Jr.
Assistant to the County Manager

copy: State Senator Patrick Ballantine
State Senator Scott Thomas
State Representative Jean Preston
State Representative Ronnie Smith
US Representative Walter B. Jones
US Senator Jesse Helms
US Senator John Edwards
Robert Murphy, County Manager
Colonel James DeLony, US Army Corps of Engineers
Steve Aiken, US Army Corps of Engineers
John Sutherland, NCDENR Water Resources
David Walker, Atlantic Beach Town Manager
Joe Stroud, Atlantic Beach Mayor
Betty Carr, Pine Knoll Shores Town Administrator
Reese Musgrave, Pine Knoll Shores Mayor
Buck Fugate, Indian Beach Mayor

Board of Commissioners
Doug Brady, Chairman
Jonathan Robinson, Vice-Chairman
Bettie Bell
David Wheatly
Jimmy LaShan
Sam Stell
Mac Wells

County Manager
Robert M. Murphy
Tel: (252) 728-8450
Fax: (252) 728-2092
bobm@co.carteret.nc.us
www.co.carteret.nc.us

RESOLUTION REQUESTING THAT THE STATE OF NORTH CAROLINA REQUEST A SECTION 933 PROJECT TO PLACE BEAUFORT INLET DREDGE SPOILS ON BOGUE BANKS

WHEREAS, the beaches of Bogue Banks are in need of nourishment to provide storm protection for valuable properties and an attractive recreational beach for visitors to Carteret County, and

WHEREAS, the US Army Corps of Engineers is scheduled to pump out the Brandt Island dredge spoil disposal site (which holds material dredged from Beaufort Inlet) in the winter of 2003-2004, and

WHEREAS, Carteret County believes it is essential that dredge spoils derived from navigation dredging activities be placed back on the beaches of Bogue Banks, and

WHEREAS, the Corps estimates a volume of approximately 6 million cubic yards of sand is available for placement on the beaches of Bogue Banks from this pump-out, and

WHEREAS, the beaches of Fort Macon and Atlantic Beach will receive a portion of this sand free of charge because it represents the Corps' least cost disposal area, and

WHEREAS, the Corps has alerted Carteret County to the possibility of placing the balance of this sand on the beaches of Pine Knoll Shores and, if feasible, Indian Beach and Salter Path if a Section 933 project is authorized and funded, and

WHEREAS, a Section 933 project in FY 2003-2004 would provide additional sand for these areas of Bogue Banks after proposed locally funded projects occur in FY 2001-2002 and before the projected date of the initial nourishment under the Shore Protection Project in FY 2008-2009, and

WHEREAS, the additional cost to pump sand from Brandt Island beyond Atlantic Beach is estimated at approximately $19.2 million (preliminary estimate), and

WHEREAS, under a Section 933 project, the Corps would provide 65% of the funding, and the State of NC has historically provided an additional 26.25% of the funding, leaving the Carteret County share at 8.75%, and

WHEREAS, this cost-sharing arrangement would result in an estimated local cost of $1.7 million, and no financial commitment is necessary until FY 2003-2004, and

WHEREAS, the State of NC must make the formal request for a Section 933 project on behalf of Carteret County, and

WHEREAS, the Carteret County Beach Preservation Task Force has passed a resolution urging Carteret County to request that the State of NC formally request a Section 933 project for Bogue Banks,

NOW, THEREFORE, BE IT RESOLVED by the Carteret County Board of Commissioners that Carteret County hereby requests that the State of NC formally request that the US Army Corps of Engineers undertake a Section 933

Carteret County Courthouse • Courthouse Square • Beaufort, North Carolina 28516-1898

project to place Beaufort Inlet dredge spoils on Bogue Banks when Brandt Island is pumped out in the winter of 2003-2004. The County Manager is hereby authorized to submit this request to the State of North Carolina.

Adopted this 8 th day of January, 2001.

W. Douglas Brady, Chairman

ATTEST:

Robert Murphy, Clerk to the Board

Appendix A-5

EXHIBIT 3

Board of Commissioners

Bettie H. Bell, Chair
Doug Brady
Lynda Clay
Jack Dawsey
Raymond N. Muns
Jonathan Robinson, Vice-Chair
David Wheatly

CARTERET COUNTY NORTH CAROLINA

Interim County Manager

Bettie H. Bell
Tel: (252) 728.8450
Fax: (252) 728.2092

www.co.carteret.nc.us

Routed: 13 Jan 03
Action: PM
Sus: None
CF: DE, DD, DP, DX

January 6, 2003

Colonel Charles R. Alexander
U.S. Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, North Carolina 28402-1890

Re: Project Cooperation Agreement
Morehead City Harbor Section 933 Project
Bogue Banks, Carteret County

Dear Colonel Alexander:

The purpose of this correspondence is to confirm Carteret County's intent and willingness to execute a Project Cooperation Agreement (PCA) with the U. S. Army Corps of Engineers (USACE) regarding the Section 933 Project that has been developed for Bogue Banks and is scheduled for Federal fiscal year 2004. It is anticipated that the Project will be constructed concurrently with operation and maintenance activities associated with the Morehead City Harbor Federal Navigation Project. The decision to execute a PCA is predicated on the information provided by the Wilmington District and their dedication in formulating a locally-preferred plan.

It is the County's understanding as the local sponsor that the estimated non-federal cost for design and construction of the Section 933 Project is approximately $6.3 million. The federal cost is approximately $11.6 million. It is our understanding that this cost will be finalized with the completion of the Section 933 Report in late January 2003 and is still subject to change once bids are opened in August/September 2003. Under State statutory provisions guiding the North Carolina Water Resources Development Project Grant Program, local governments are eligible for up to 75 percent of the non-federal share of beach protection projects where public access is allowed and provided for. The County and the N.C. Division of Water Resources, the agency responsible for administering water resource grants, have been in communication regarding the design and cost parameters of the Section 933 Project. The N.C. Division of Water Resources generally supports local funding requests and has already shown strong support for the Section 933 Project, however State funding is dependent upon appropriation decisions by the General Assembly and upon the priority of the Morehead City Harbor Section 933 Project compared to other projects throughout the State. The County anticipates the local cost share to be approximately $1.6 million, assuming successful procurement of a N.C. Water Resources Development Project Grant.

The County, in direct cooperation and agreement with the municipalities of Pine Knoll Shores and Indian Beach, will secure necessary easements, access/parking accommodations, and has a revenue stream dedicated to cover the local, non-federal costs for the Section 933 project. The municipalities of Pine Knoll Shores and Indian Beach have forwarded us correspondences ensuring their abilities and willingness to participate in the Project. The County will also provide all other terms and requirements of local cooperation as may be required for construction of the project. The County is in agreement with the Project as presented in the Evaluation Report dated January 2003, and intends to sign a PCA when and as required.

The Morehead City Harbor Section 933 Project will be a tremendous asset for the County, State, and Country in preserving, protecting, and improving the recreational benefits, environmental habitats, economic well-being, and shore protection capabilities associated with wide and healthy beaches. The USACE's support and assistance in expediting the approval of the Morehead City Harbor Section 933 Project is most greatly appreciated. Please do not hesitate to contact the County's Shore Protection Office if you require any assistance or additional information.

Sincerely,

Bettie H. Bell

Bettie Bell
Chairperson, Carteret County Board of Commissioners

Cc: Mayor Buck Fugate, Indian Beach
Mayor Bob Gallo, Pine Knoll Shores
John Morris, N.C. Division of Water Resources
The Honorable Walter B. Jones, Jr., United States Congress
The Honorable Elizabeth Dole, United States Senate
The Honorable John R. Edwards, United States Senate

MOREHEAD CITY HARBOR
CARTERET COUNTY, NORTH CAROLINA
SECTION 933
EVALUATION REPORT

APPENDIX B

FEDERAL STANDARD - BASE DISPOSAL PLAN

APPENDIX B
FEDERAL STANDARD - BASE DISPOSAL PLAN

The purpose for the Brandt Island pump-out is to create capacity for future maintenance dredging of Morehead City Harbor. In addition to this general purpose, there exist specific criteria for the disposal of material on adjacent area beaches:

a. minimize scarping;
b. minimize trapped/ponded water on beach;
c. minimize lateral and offshore losses due to excessive berm width; and
d. minimize losses into entrance channel.

These criteria address the Federal standard as defined in 33 CFR Part 335 where identified alternatives should “represent the least costly alternatives consistent with sound engineering practices and meeting the environmental standards...” Therefore, considering the above factors, the disposal fill should:

a. be placed at the natural berm elevation, which historic surveys and monitoring have demonstrated to be +7 ft NGVD;
b. have acceptable berm widths to minimize risk of channel shoaling;
c. have transitions at the lateral extents to tie in with the adjacent shoreline

The total volume of material available for the November 2003 Brandt Island Pumpout and Inner Harbor maintenance is approximately 4.8 Million cubic yards (M cy). The distribution of the 4.8 M cy consists of 4.0 M cy presently in the Brandt Island Disposal Facility and an additional 0.8 M cy estimated dredging of the Inner Harbor for November 2003.

It is assumed that all of the material will be removed as part of the Least Cost Disposal action. Actual quantity removed will depend on available funding. Based on previous beach nourishment experience in NC and at Bogue Banks, it is also assumed that an average of 10% losses will occur during dredging, pumping and placement operations (which is an accepted standard loss rate for this type of material being dredged, pumped and placed via pipeline dredge). Therefore, it is estimated that the resulting volume of material that will remain on the beach is approximately 4.3 M cy.

Beach nourishment design practice distinguishes between a “construction” profile and a “design” profile because as a practical matter, dredges and earth moving equipment cannot distribute sand below the approximate mean low water (MLW) elevation (i.e., below water). Therefore, sand for beachfill is placed in a construction profile, which includes a wider berm than ultimately desired. This sand quickly re-distributes along the profile nourishing the below water areas to the depth of closure resulting in the design profile (which includes the design berm width). Design berm widths ranging from 50 ft to 200 ft were analyzed for this analysis. The upper and lower bounds are based on historic beachfill experience. Comparison of the design template to existing beachfill conditions as determined through recent surveys resulted in required volumes per linear ft and associated construction width. The minimum 50-ft design berm results in an average construction berm of 140 ft with an average of 88 cubic yards per linear ft being placed along the beach. The large 200-ft design berm, comparable to that placed along Fort Macon during the 1994 beach disposal operation, results in an average construction berm width of 341 ft with an average of 199 cubic yards per linear ft being placed along the beach. Table 1 summarizes all berm widths evaluated with resulting construction berm widths and unit volume requirements.

Previous disposal experience at Fort Macon has indicated placement of large berm widths near the inlet may result in negative impacts (i.e., excessive shoaling) on the adjacent channel. During the 1994 disposal operation, approximately 1.15 M cy were placed in the vicinity of Fort Macon, resulting in an average construction berm width of 340 ft and transition angles of 10 to 12 degrees. These large transition angles and the offshore extent of the fill exposed to the inlet’s currents contributed to the rapid loss of material from the disposal areas. While the disposal of Morehead City harbor dredged material on the east end of Bogue Banks has substantially improved the condition of this section of the island, the disposal practice, which creates inordinately wide beaches with very sharp transition angles, is not the most efficient use of the material (USACE 2001, Summary of Morehead City Harbor Section 111 Study). The analysis of the performance of the three major disposal operations on the east end of Bogue Banks revealed rapid loss of material from the disposal areas. Significant portions of the material placed on the Fort Macon shoreline in 1978 and 1994 appeared to be transported directly into Beaufort Inlet within a few years following disposal. The return of this material to Beaufort Inlet may be partly responsible for the increase in dredging required to maintain the Morehead City Harbor project, but a definitive conclusion in this regard is not possible due to the increased shoaling rates associated with the incremental increases in project depth since 1978.

For the fixed volume of 4.8 M cy to be removed from Brandt Island and the Inner Harbor and pumped throughout the project area, the lowest cost for a contiguous beachfill placement for each berm width was evaluated. The least cost for all cases (berm widths), resulted from starting placement at Fort Macon and extending westward. Figures 1 and 2 display the cumulative volume and cumulative cost, respectively for uniformly placing the 4.8 Million cy from Fort Macon until the location where material ran out. Figure 1 shows that a 50-ft berm could be spread uniformly from Fort Macon through most of Pine Knoll Shores, while the 200-ft berm could only be placed approximately halfway through Atlantic Beach.

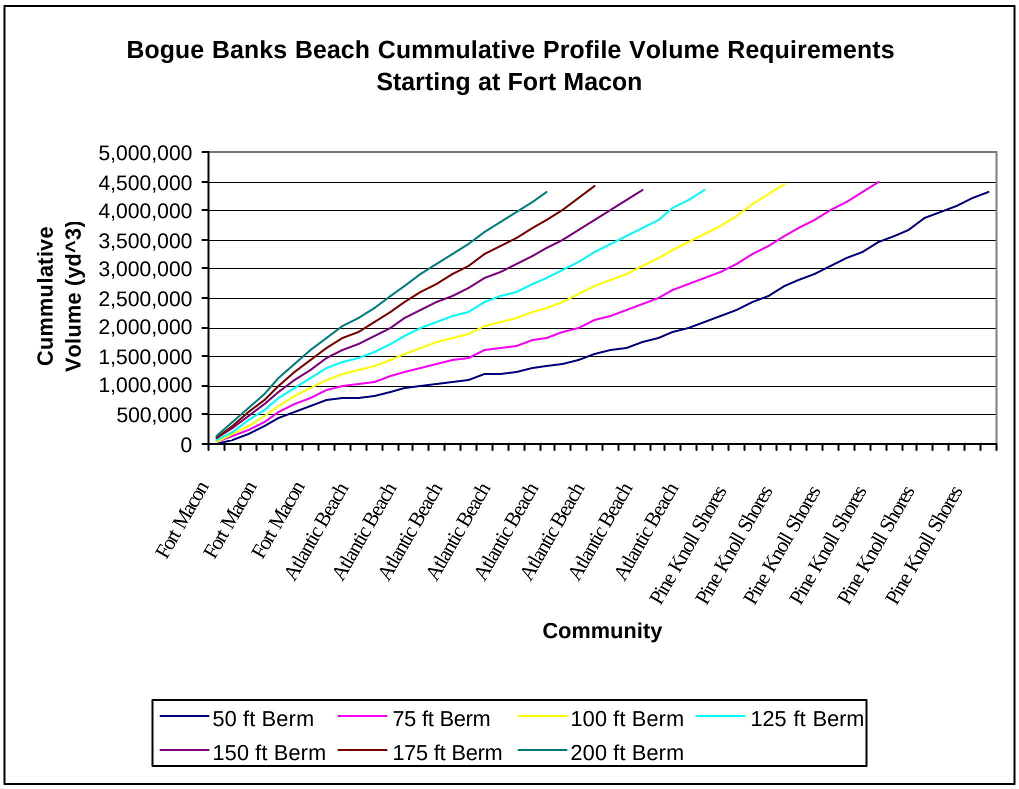


Figure 1. Cumulative volume requirements for various berm widths

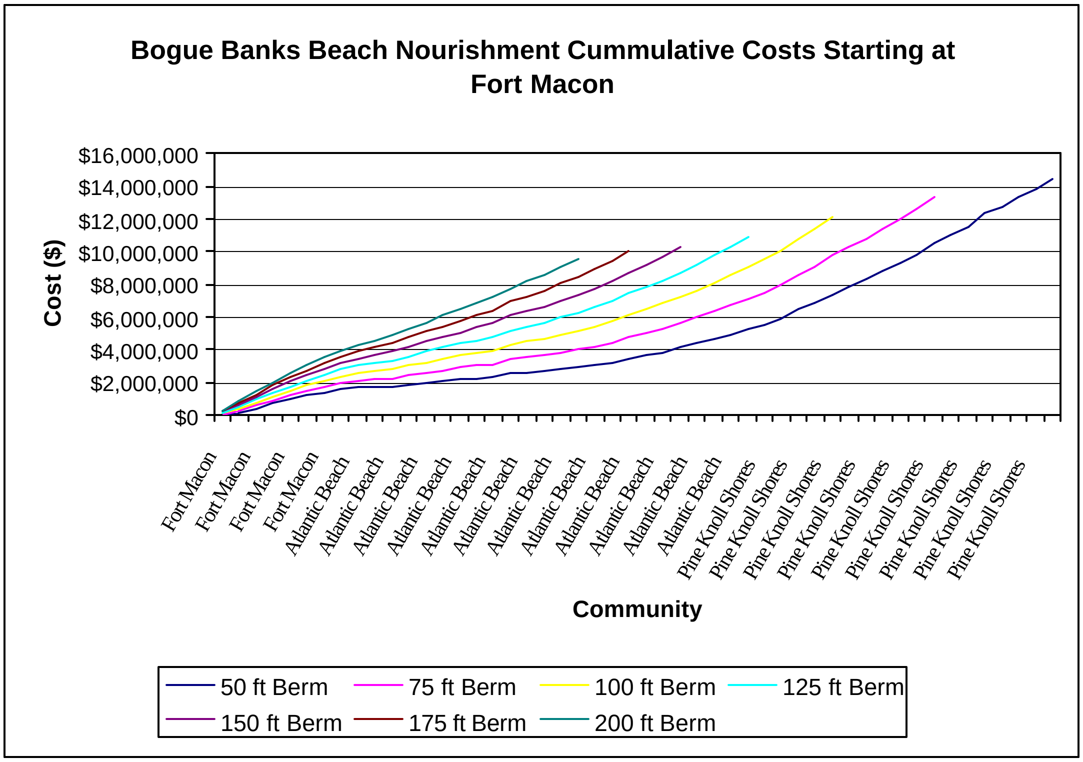


Figure 2. Cumulative costs of placing material

As indicated in Table 1, the least cost for pumping 4.8 M cy of sand onto the beach is $9.488M for the 200-ft design berm width. However, this is not a practical engineering alternative due to the high risk of fill loss and increase in channel shoaling. Therefore, to minimize risk of entrance channel shoaling and adjacent fill losses, we suggest significantly reducing the berm width. The acceptable berm width was determined by comparing the average volume of material placed per ft along the beach to recently constructed beachfills with acceptable performance. Several USACE projects along beaches that were classified as being in relatively "poor" shape have required unit volumes on the order of 140 cubic yards per ft and have thus had acceptable performance.

Table 1. Berm volumes and costs

Design Berm width (ft)	Brandt Island and Inner Harbor (4.8 Million Cubic Yards)			
	Length	Avg Const Berm (ft)	Avg Vol/ft (c.y./ft)	Cost
50	50,000	140	88	14,341,248
75	42,250	175	104	12,705,694
100	36,500	209	120	11,540,078
125	32,000	240	138	10,741,541
150	28,000	275	157	10,164,736
175	25,000	309	178	9,765,095
200	22,250	341	199	9,488,025

From an engineering perspective, a Base Disposal Plan berm width of near 125 ft design width is ideal because the required volume/linear foot (138 cy/lf) is consistent with normal beach nourishment practices for stability on the beach. Environmental staff indicated that and environmentally acceptable berm width based on needs for sea turtle nesting was a design berm width of 150 ft (construction berm width of 275 ft). Though this width is slightly larger than the preferred width for stability on the beach, it is only 25 ft larger in design (35 ft in construction) and will meet sound engineering practice especially considering the needs for construction of a berm as wide as possible.

This Base Disposal Plan (150 ft design berm) will start in Fort Macon at Station 15+25, leaving no sand placed within approximately 2,250 ft of the jetty (Figure 3). Station 0+00 is located 725 ft west of the jetty. The fill will transition for approximately 1,500 ft towards the west to achieve a full 150 ft berm at Station 30+00. Assuming all of the 4.8 M cubic yards available is placed from this location westward with consideration of the fishing piers, the 150 ft design berm will end approximately 900 ft east of the Atlantic Beach/Pine Knoll Shores border at Station 305+00 (Figure 4). The presence of a fishing pier in the vicinity of the Atlantic Beach / Pine Knoll Shores border prevents placement of the materia l throughout Atlantic Beach (Figure 5). It is recommended the Base Disposal limits consist of all of Fort Macon and Atlantic Beach for economic analyses associated with the Section 933 Study.

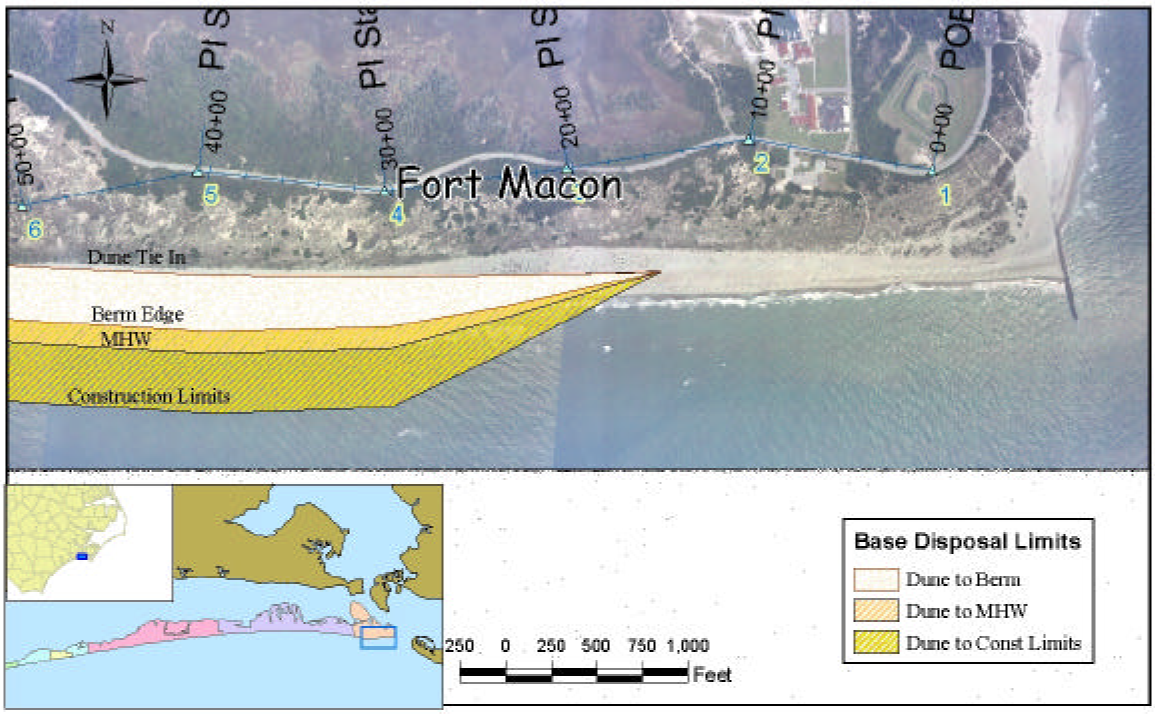


Figure 3. Base Disposal Limits in the vicinity of Fort Macon.

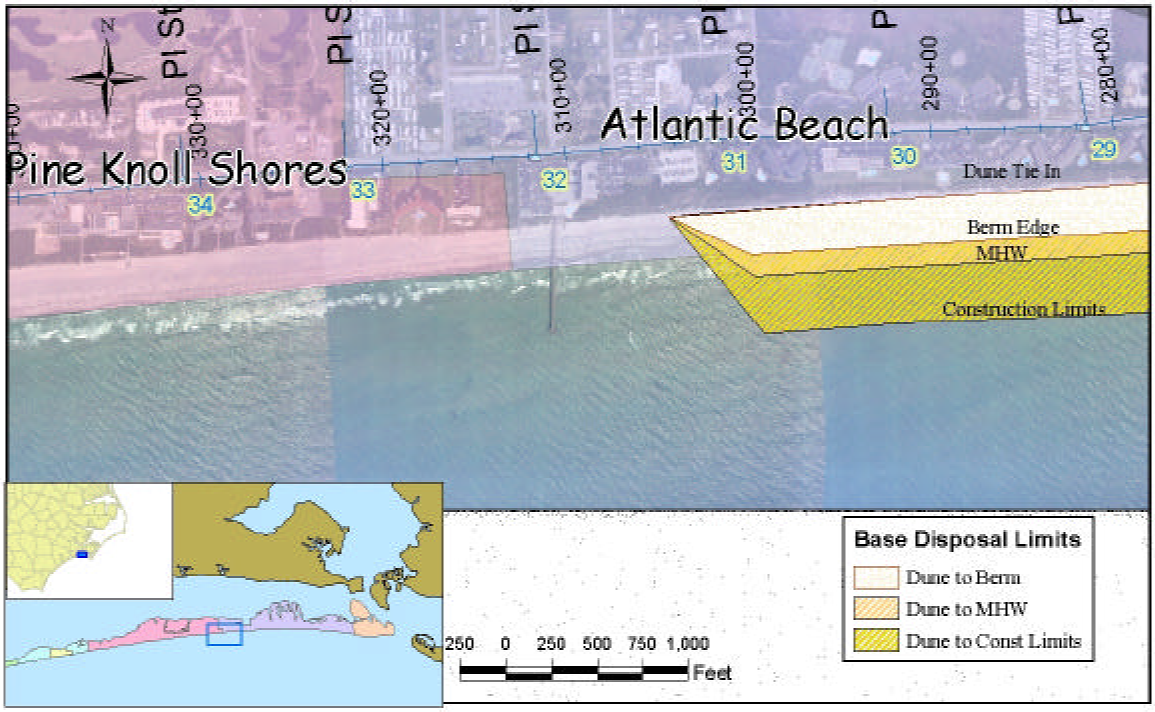


Figure 4. Base Disposal Limits in the vicinity of Atlantic Beach and Pine Knoll Shores border

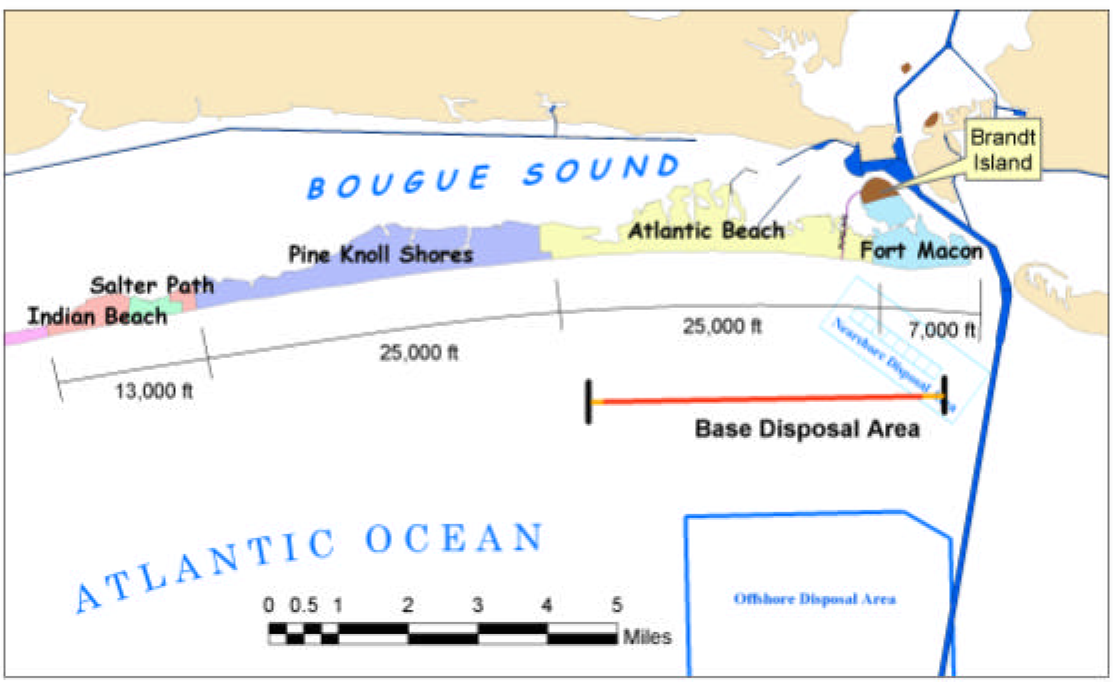


Figure 5. Morehead City Section 933 Base Disposal Plan Location.

MOREHEAD CITY HARBOR
CARTERET COUNTY, NORTH CAROLINA
SECTION 933
EVALUATION REPORT

APPENDIX C

C Coastal Analysis

Detailed investigations of the geomorphologic conditions and coastal processes associated with Bogue Banks, North Carolina were conducted through a combination of field data analysis and numerical modeling. Numerical simulations of wave transformations, tidal circulation, sediment transport, and storm-induced beach profile response along Bogue Banks were conducted to evaluate and compare engineering alternatives to reduce storm damages in the vicinity of Morehead City Harbor.

The purpose of this chapter is to summarize the technical details of the coastal analysis and to describe the hydraulic conditions that will be used to evaluate the Base Disposal and Recommended Plans as described in the Main Report. First, the existing beach conditions (beach profiles and shoreline positions) and representative coastal processes (waves, water levels, sediment transport) will be described. Next, simulations of storm conditions, storm-induced beach profile response modeling, shoreline response modeling, and the generation of frequency-of-occurrence relationships for select response parameters will be discussed. Finally, the inputs into the storm damage model are presented.

Existing Conditions

Bogue Banks is a barrier island with a southward facing ocean shoreline stretching approximately 25 miles between two large tidal inlets, Bogue Inlet to the west and Beaufort Inlet to the east. The Banks are surrounded by Bogue Sound on the north and Onslow Bay of the Atlantic Ocean on the south. The island is made up of the Fort Macon State Park, the Towns of Atlantic Beach, Pine Knoll Shores, Indian Beach, and Emerald Isle and the unincorporated area of Salter Path (Figure C-1). Morehead City Harbor is located in the Beaufort Inlet complex between Bogue Banks to the west and Shackleford Banks to the east. Brandt Island is located north of Fort Macon State Park in the Inner Harbor section of Morehead City Harbor.

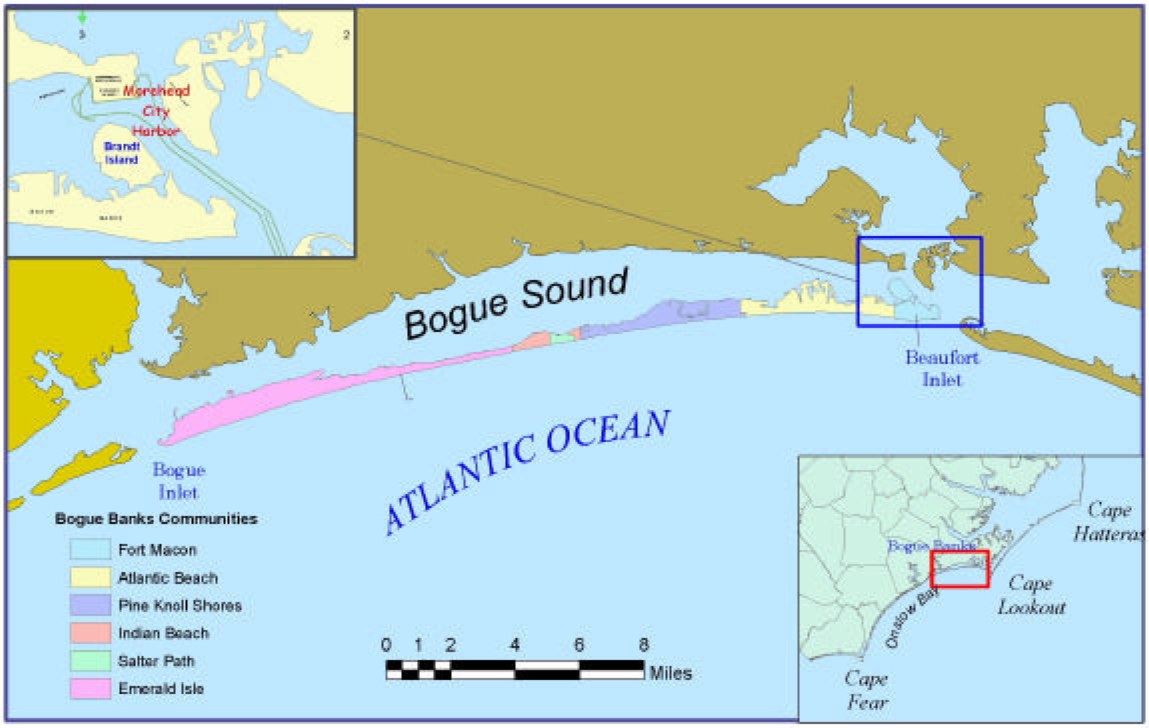


Figure C-1. Bogue Banks Location Map.

Existing and historical conditions at Bogue Banks, North Carolina were characterized utilizing aerial photographs, bathymetric and topographic survey data, National Ocean Service (NOS) water level data, NOS LIDAR data, Wave Information Studies (WIS) wave hindcast data and coastal processes models. Historical shoreline positions, delineated from aerial photographs, LIDAR data, and beach profile data document the range in shoreline conditions and relative beach stability in the Bogue Banks area over an extended time period. Recent bathymetry and topographic surveys served as input for coastal processes model grids. NOS water level data were used to drive coastal process models and to define water level datum relationships for the area. Coastal process models were used in this investigation to characterize wave and current conditions for existing conditions, develop storm conditions used in the storm damage analysis, and to characterize performance of alternatives designed to reduce storm damage potential.

Beach Profile Characteristics

During the Fall of 2001, beach profile data were collected along 129 transects at approximately 1000 ft spacing throughout the island (Figure C-2). Dune crest elevations typically exceeded +14 ft NGVD, indicating a healthy dune system. The average berm elevation is approximately +7 ft NGVD with an average nearshore slope of 1V:25H. The existing berm widths however are very narrow, allowing the toe of the dune to be inundated and exposed to direct wave attack during moderate storm surge events. The beach profile data were utilized with the structure database and historic shoreline change rates to develop representative reaches as shown in Figure C-3.

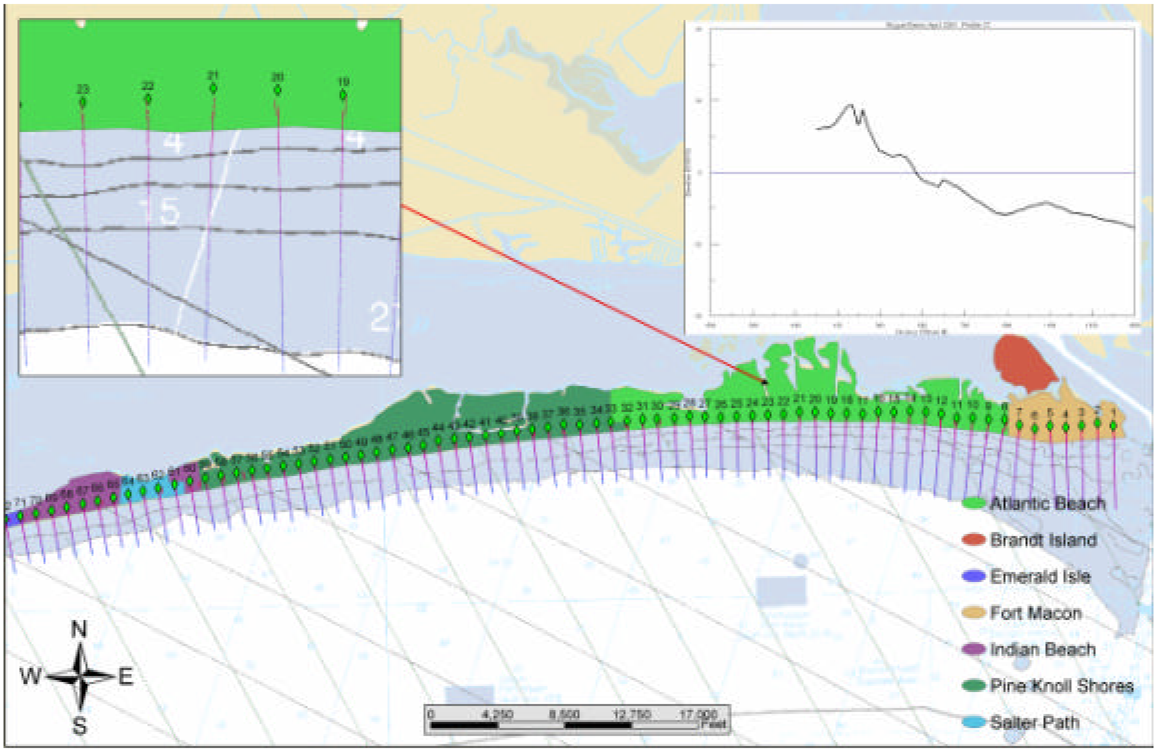


Figure C-2. Bogue Banks April 2001 Beach Profile Survey Layout.

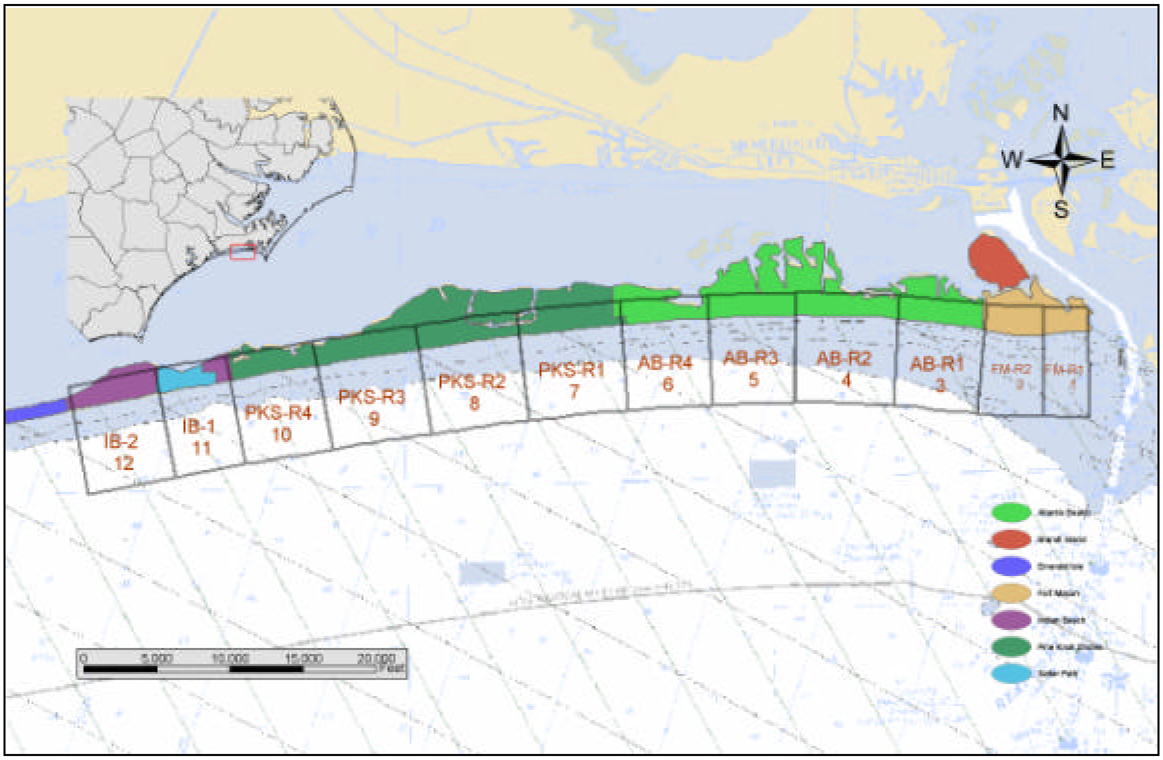


Figure C-3. Representative Reach Locations.

Representative beach profiles were developed for each of the representative reaches by combining the 1000-ft spaced profiles together. Significant care was taken to maintain important features such as the berm and nearshore bar. Figures C-4 through C-7 show the representative beach profile conditions developed. The profiles were utilized as input into the storm damage modeling for existing conditions.

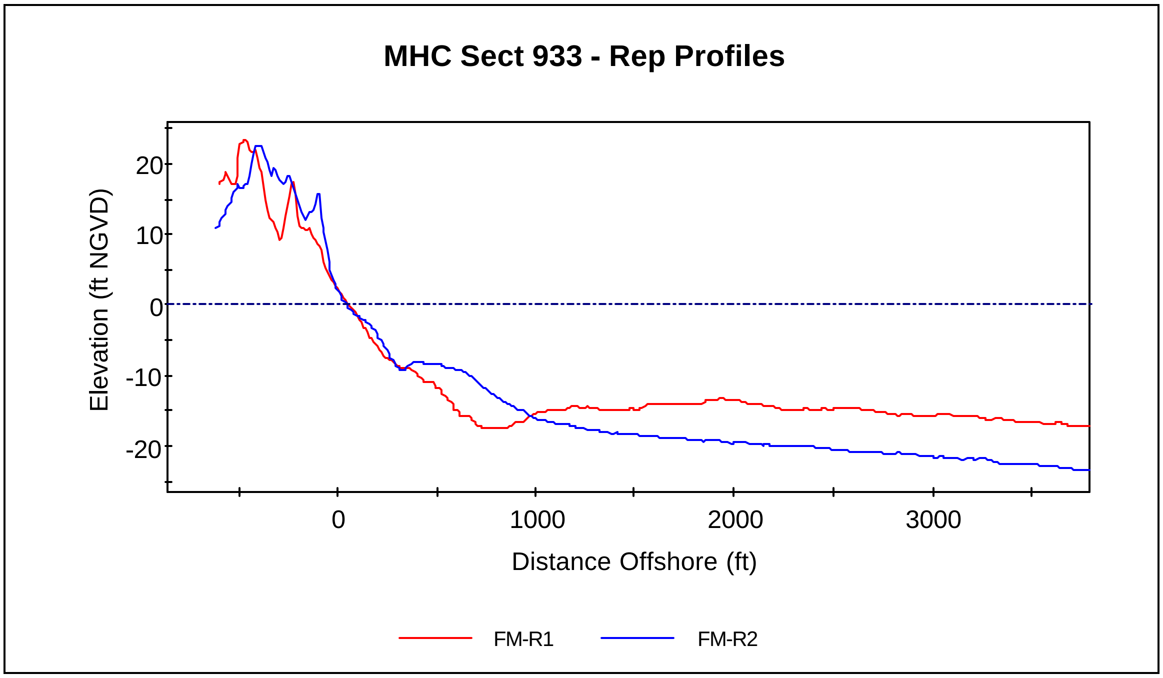


Figure C-4. Representative Beach Profiles at Fort Macon.

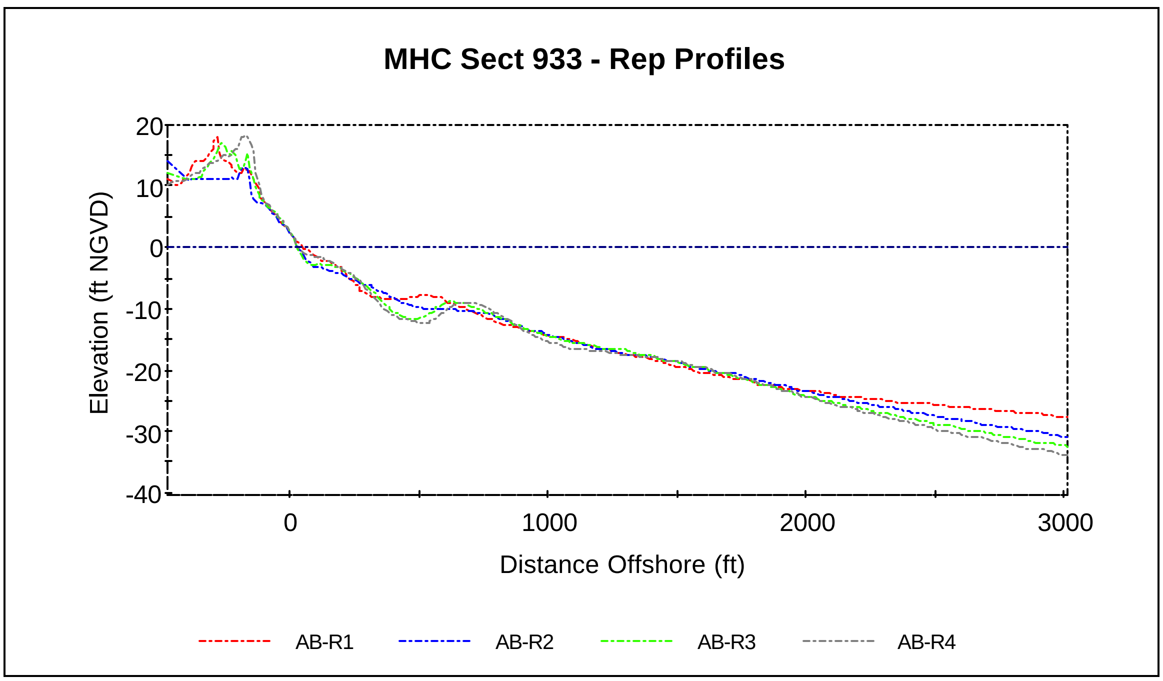


Figure C-5. Representative Beach Profiles at Atlantic Beach.

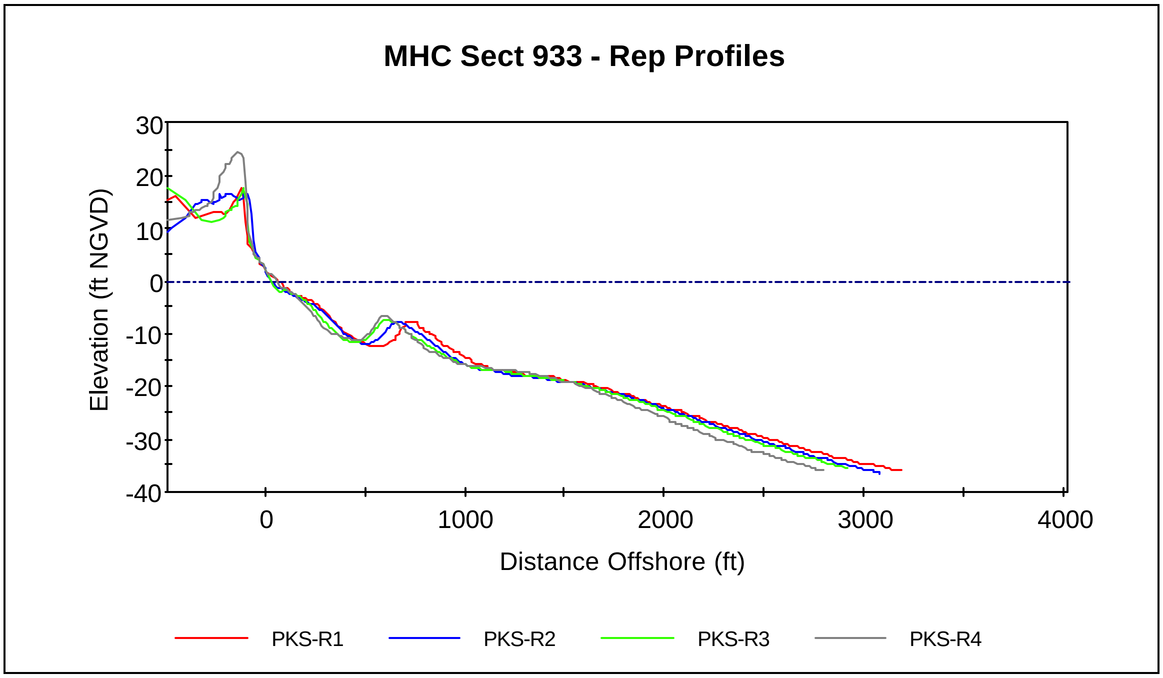


Figure C-6. Representative Beach Profiles at Pine Knoll Shores.

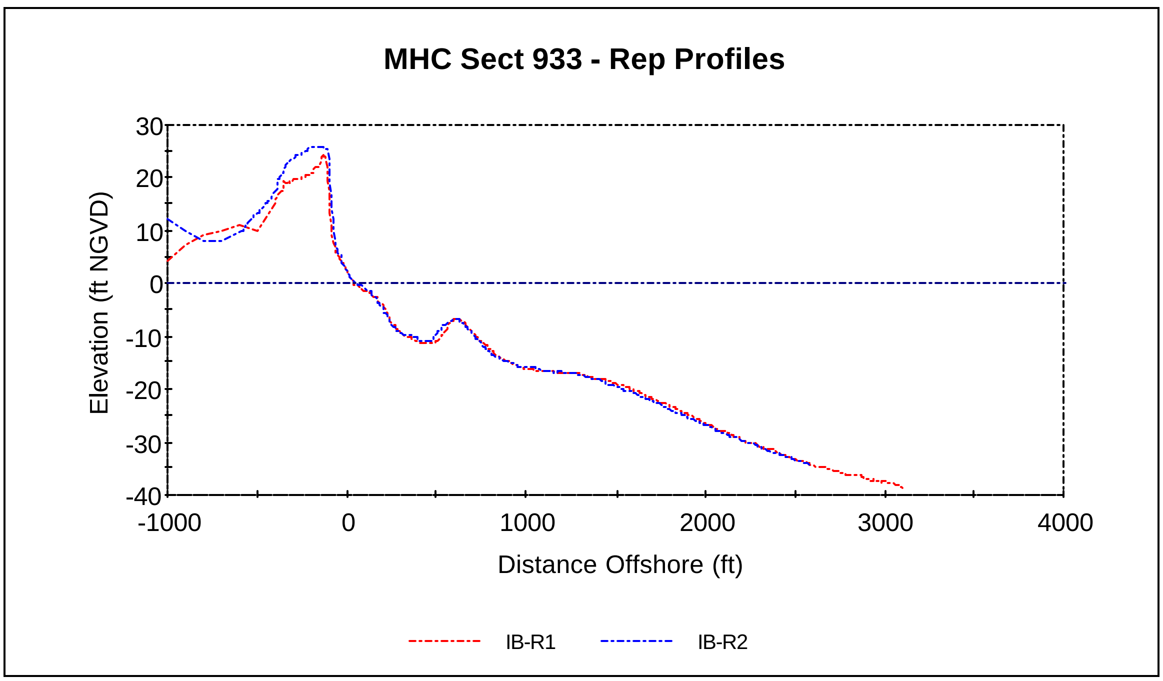


Figure C-7. Representative Beach Profiles at Indian Beach.

Shorelines

A detailed examination of historic and recent shoreline conditions was performed to compute shoreline change rates and to serve as input into the sediment transport analysis. All shorelines utilized were projected to the North Carolina State Plane (NAD 83) coordinate system, interpolated to previously established shore-perpendicular transects, and added to the shoreline geodatabase. A Geographic Information System (GIS) was utilized to help visualize the range in shoreline conditions.

Shoreline Database

Shoreline positions were developed for numerous dates through analysis of NOS T-sheets, aerial photography, beach profiles, and LIDAR data. Table C-1 displays the shoreline dates and corresponding sources available for use in shoreline change analysis.

Table C-1. Shoreline Data Inventory.

Date	Type	Source
03/30/43	NOS T-Sheet	NC DCM
08/16/59	NOS T-Sheet	NC DCM
05/11/78	Beach Profile Survey	USACE
12/08/80	Interpreted Aerial Photography	NC DCM
08/25/86	Beach Profile Survey	USACE
06/17/92	Interpreted Aerial Photography	NC DCM
09/02/97	LIDAR	NOS CSC
08/02/98	LIDAR	NOS CSC
06/10/99	LIDAR	NOS CSC
06/20/00	Beach Profiles and Scatter	UNC
08/08/00	LIDAR	NOS CSC
04/30/01	Beach Profile Survey	USACE
5/15/2002	Beach Profiles and Scatter	UNC
8/15/2002	Beach Profiles and Scatter	UNC

The shoreline position extracted for each data set was the Mean High Water (MHW) contour. The MHW contour was derived through both aerial photography interpretation and topographic survey data analysis. The North Carolina Department of Environmental and Natural Resource Division of Coastal Management (NC DCM) shoreline database for the Bogue Banks area was provided to the USACE. Shoreline positions derived for the database were commonly done through interpretation of aerial photography. The database consists of a series of baselines parallel to the shore and shore perpendicular transects as shown in Figure C-8. There are 73 transects spaced every 50 meters for each baseline. The Bogue Banks area consists of 13 baselines from Bogue Inlet to Fort Macon. Shoreline positions at each of the transects were referenced in the original database as distance from the seaward most location of the transect. The relative distances along each transect from one shoreline date to another provides a quick means of evaluating shoreline change. Additionally, geographic coordinates were computed for each transect value by projecting the distance along the transect azimuth from the transect origin. This geo-referenced shorelines improved visualization of the relative shoreline conditions, especially when viewed along with recent aerial photography as shown in Figure C-9.

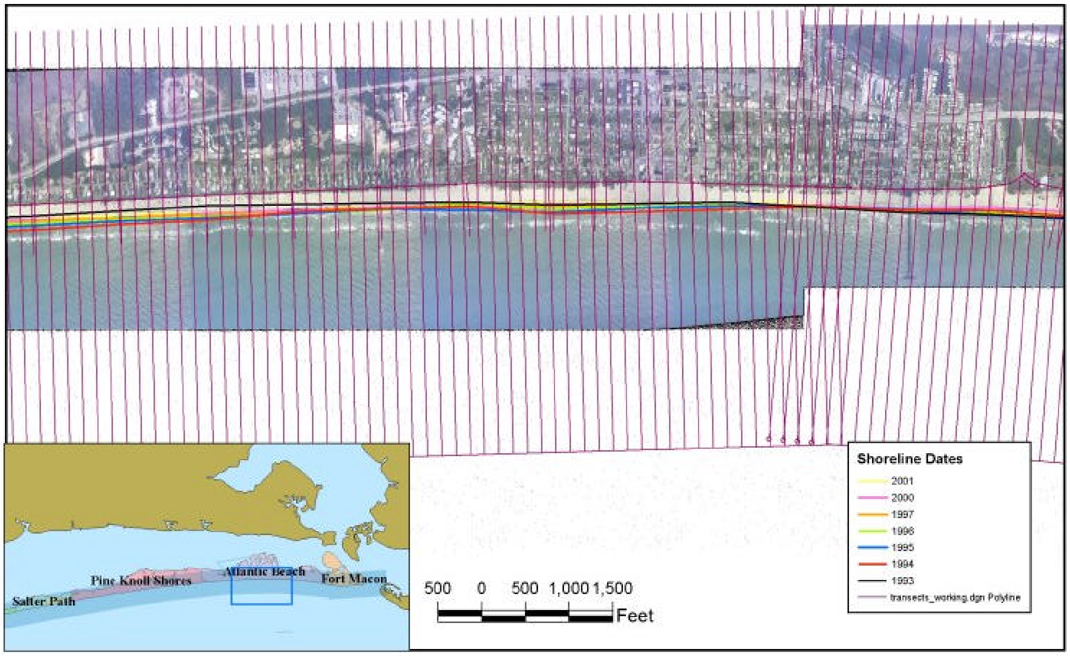


Figure C-8. NC CZM Transect Locations along Bogue Banks.

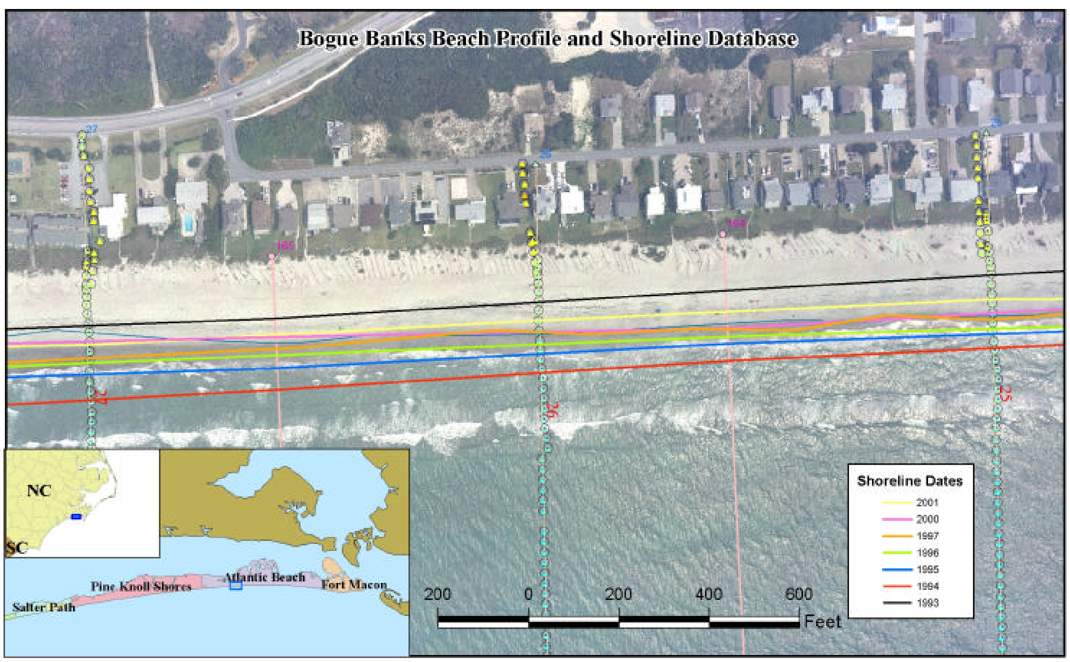


Figure C-9. Recent Shoreline Conditions on July 2002 Imagery Along Atlantic Beach, NC.

In addition to the CZM shoreline database, several recent shorelines were derived through analysis of topographic survey data. Historical beach profile survey data have been conducted by the Corps of Engineers from Fort Macon through Atlantic Beach semi-annually since 1986. Several beach profile surveys were conducted for the entire island, including the years 1978 and 2001. The beach profiles are typically spaced approximately 1,000 ft alongshore. The MHW elevation is +2.21 ft above NGVD. The distance of the MHW contour from the profile origin along each profile was computed. The shoreline positions were then projected (using known profile origin and azimuth) and interpolated onto the CZM transects.

Scatter data sets were also utilized to compute shoreline positions. Three topographic LIDAR data sets were obtained from the NOS Coastal Services Center. Each survey provides a high density coverage from the water line typically through the second row of houses. Figure C-10 displays the August 2000 LIDAR data overlaid on July 2002 imagery. The SHOALS Toolbox software (contained in the Surfacewater Modeling Software) was utilized to extract the MHW contour from the high density data. The MHW contour was interpolated to the transect lines and added to the geodatabase.

Figure C-10. Oblique view August 2000 LIDAR surface overlayed on July 2002 Imagery.

Prior to the construction of the local beachfill (July 2000, Pine Knoll Shores through Indian Beach), Carteret County contracted UNC-Chapel Hill Institute of Marine Science Personnel to conduct quarterly surveys along Bogue Banks. The survey was conducted utilizing a combination of ATV and Jet boat equipment with RTK capabilities. In addition to surveying defined profile lines, multiple shore-parallel lines were surveyed to better define the berm and nearshore conditions. SMS was utilized to extract the MHW contour for each survey. Figure C-11 displays three surveys in the vicinity of the local beachfill.

Figure C-11. Shoreline position (MHW) data derived from survey data displaying influence of local beachfill.

Shoreline Change Rates

Rates of erosion/accretion were computed for all communities of Bogue Banks using various shoreline position data sets derived from aerial photography, LIDAR data, and beach profile data with dates ranging from 1978 to present. North Carolina's Division of Coastal Management updates shoreline change rates from aerial photographs every 6 years. Erosion maps for Bogue Banks are available for Bogue Banks for 1980, 1986, and 1992. Updated rates using 1998 shorelines are expected to be released to the public by CNC CZM early 2003. The resulting erosion rates are computed as changes from a baseline set of photos (i.e., 1978). The Corps of Engineers performed similar analyses in a study to evaluate the effects of the Morehead City Harbor dredging activities (Section 111, June 2001). Both analyses utilized an end point method to compute the shoreline change rates. Figure C-12 displays the NC CZM published shoreline change rates for 1992.

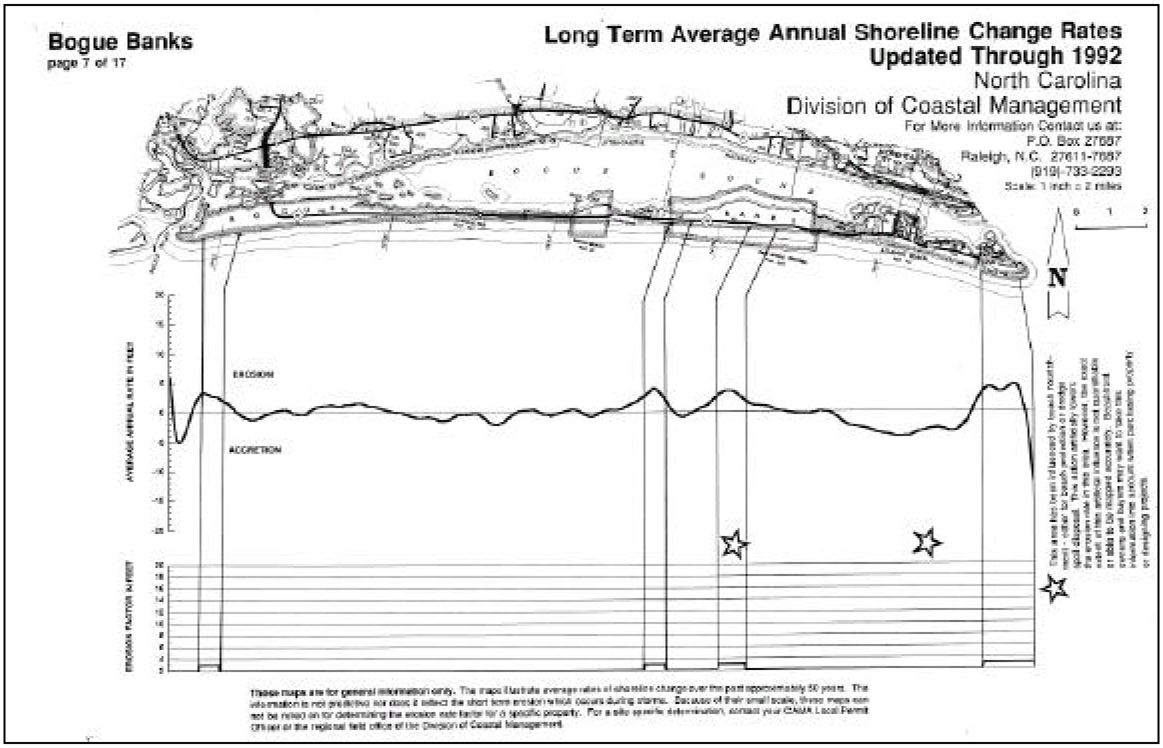


Figure C-12. NC DCM Published Shoreline Change Rates for Bogue Banks.

A detailed shoreline change analysis was performed for this study, incorporating recent LIDAR data and beach profile data with the objective of computing true "background" erosion rates in the vicinity of previous beachfill activities (i.e., Brandt Island pumpout to Atlantic Beach). Shoreline change rates were computed by performing a least-squares fit through select shoreline dates as shown in Figure C-13. A computer program was developed to rapidly compute shoreline change rates for user-specified shoreline data and baseline locations. This utility improved the effectiveness of computing "background" erosion rates by selecting locations and dates before or after beachfill placement.

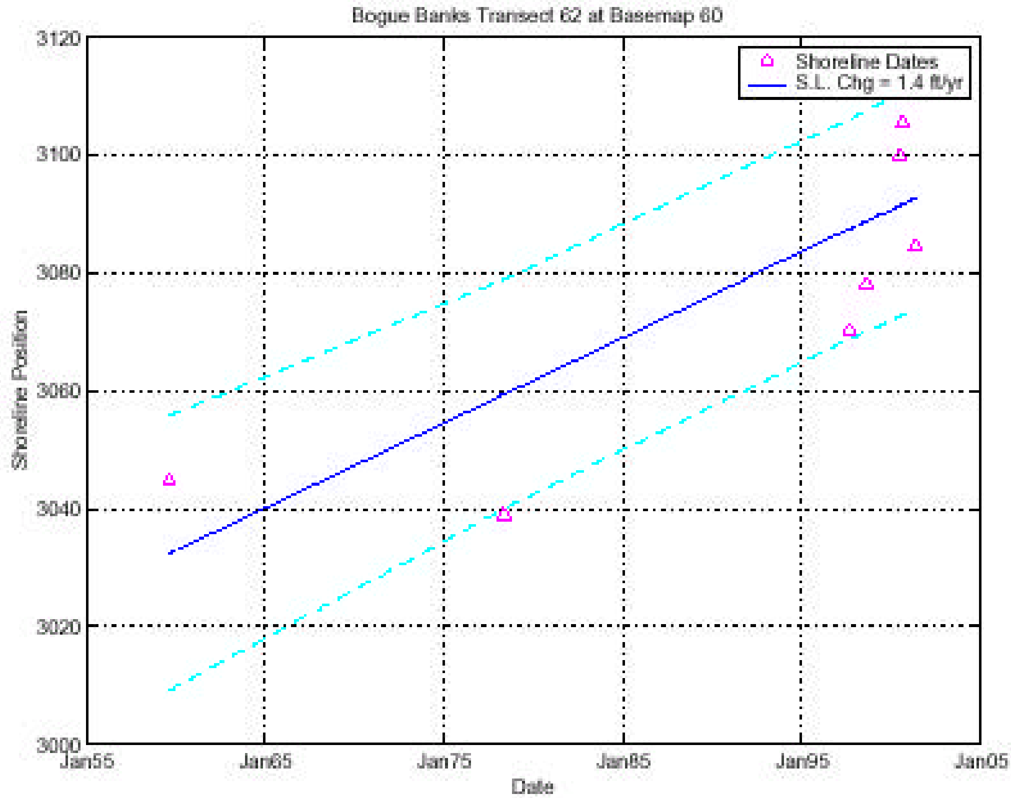


Figure C-13. Shoreline change rate calculated at single transect utilizing least-squares fit along Atlantic Beach.

The various data sources and methods confirm relatively low shoreline change over the past 5-20 years. Highest erosion rates (2 to 3 ft/yr) were found along Fort Macon State Park, Pine Knoll Shores, and Emerald Isle-East. Some reaches were found to be relatively stable (0-1 ft/yr), with only minor erosion (e.g., Emerald Isle-West, Salter Path, Indian Beach, and Atlantic Beach (background)), and some were accreting (Emerald Isle near Bogue Inlet and Atlantic Beach due to nourishment). Figure C-14 displays the shoreline change rates computed and utilized in the storm damage analysis.

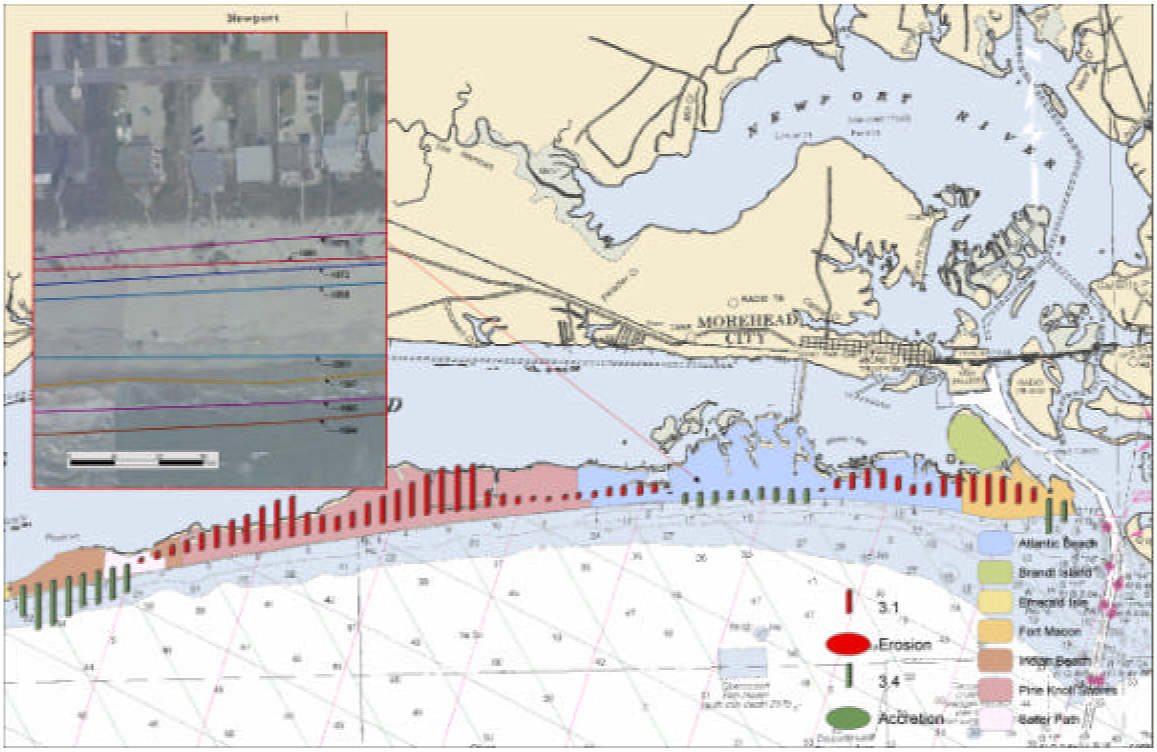


Figure C-14. Shoreline Change Rates (ft/yr) along Bogue Banks.

Coastal Processes

Detailed investigations of the coastal processes associated with Bogue Banks were conducted through a combination of field data analysis and numerical modeling. Numerical simulations of wave transformations, tidal circulation, and sediment transport at Bogue Banks were conducted to provide a better understanding of existing conditions and to evaluate and compare alternatives to improve storm protection and beachfill stability in the vicinity of the study area. This approach provides an objective means for comparing the performance of alternatives.

Water Levels

Water level fluctuations in the vicinity of Bogue Banks are primarily due to astronomical tides, storm surge, and wave-induced setup. Tidal datum relationships have been developed through field data collection at a water level gage located near Atlantic Beach. Storm surge and wave setup values were computed through numerical modeling efforts. The datum relationships were utilized to derive the MHW shoreline position and other key features along the shoreline. Time series of water levels for storm events were utilized to assess potential storm-induced damage due to inundation.

Tides

The mean tidal range measured at the Triple S pier on Atlantic Beach by the National Oceanic and Atmospheric Adminstration (NOAA), National Ocean Service (NOS) is 3.7 feet with a mean spring tide range of 4.3 feet. Mean Low Water (MLW) and Mean High Water are –1.75 ft NGVD and +2.21 ft NGVD, respectively. The ocean tides are semidiurnal with almost equal high and low tides during successive tide cycles. Inside the inlet, the mean tide range is 3.0 feet at the State Port at the Duke University Marine Laboratory. Figure C-15 displays the tidal datum relationships developed for the Triple S Pier gage. The National Geodetic Vertical Datum 1929 (NGVD) was utilized to reference all elevation data throughout this report. An important relationship to note is that Mean High Water (MHW) is +2.21 ft NGVD for the study area.

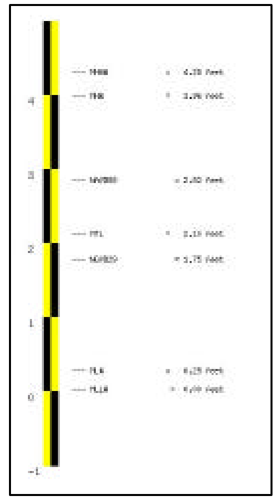


Figure C-15.

Storm Surge

Tidal surges from storms ("Storm Surge") add to the astronomically produced tides for a total still-water superelevation. Storm surge time series were developed for all significant hurricanes in the Atlantic Ocean from 1890 to 1990 as part of the Dredging Research Program (DRP-1-17, Scheffner, 1994). The ADCIRC model was used to update the hindcast to include recent hurricanes from 1990 to present, including named hurricanes Bertha, Fran, Dennis, Floyd, Bonnie and Irene. Time series of storms surge were coupled with astronomical tide data to serve as input to SBEACH for the storm damage assessment. Frequency-of-occurrence relationships were also developed for both storm surge and total water level.

DRP Storm Surge Database

The tropical storm database, consisting of surge elevation and current hydrographs corresponding to selected WIS and nearshore stations along the east and Gulf coasts of the United States and Puerto Rico, was developed as part of the Dredging Research Program (Scheffner and others, 1994). The database was constructed by numerically simulating 134 historically based hurricanes that have impacted the eastern and Gulf coasts of the United States during the period 1886 to 1989. The source of data for these simulations is the National Oceanic and Atmospheric Administration's National Hurricane Centers HURDAT (HURricane DATabase), described by Jarvinen, Neumann, and Davis (1988).

Figure C-16 displays the station locations where storm surge data are available in the vicinity of the study area. The offshore nodes correspond to Wave Information Study (WIS) stations with the corresponding nearshore station locations selected to provide most accurate storm surge values. Stations 405 and 406 were utilized for this study. Significant tropical events were extracted from the database based on storm surge values exceeding select threshold conditions. For the 100-plus years of coverage, 37 events were identified using a minimum storm surge threshold of 1 ft. In addition to the tropical storm surge database, extratropical storm surge values were calculated for the same locations for the dates from 1976 to 1993. Instead of the storm specific time series, a continuous hourly time series was developed for the non-tropical season times of the year (September through March). Discrete event time series were extracted from the continuous time series using a combination of storm surge and wave height threshold criteria along with visual analysis to identify the start/stop times. There were 23 extratropical events identified over the 16-years of data coverage.

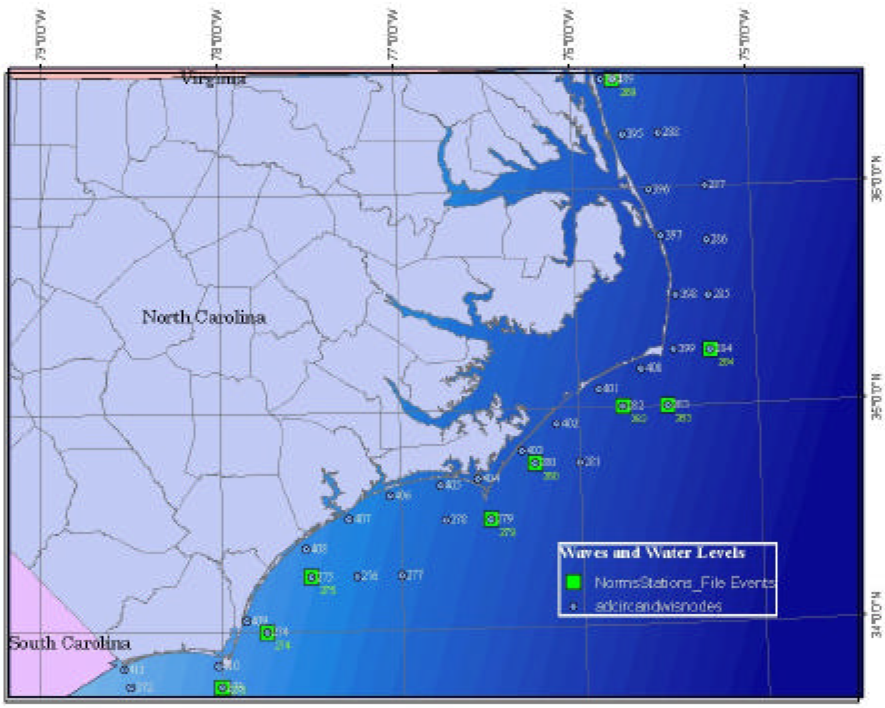


Figure C-16. Storm Surge Model Output Locations from DRP database.

Recent Hurricane Storm Surge Modeling

The magnitude of the recent hurricanes to impact North Carolina since the mid-1990's required the storm surge database to be updated. Generation of hurricane storm surge values required two major tasks, each using a numerical model. In the first task, hurricane-induced wind and atmospheric pressure fields are generated to replicate those hurricanes (Bertha, Fran, Dennis, Floyd, Bonnie and Irene) that have impacted the study area. Using these wind and pressure fields, storm-surge events are simulated in the second task using a long-wave hydrodynamic model to obtain water-surface levels.

Wind and Atmospheric Pressure Model

The Planetary Boundary Layer (PBL) wind field model was selected for simulating hurricane-generated wind and atmospheric pressure fields. The PBL hurricane wind model requires a series of "snapshots" for input consisting of a set of meteorological storm parameters defining the storm at various stages in its development or at particular times during its life. These parameters include latitude and longitude of the storm's eye, track direction and forward speed measured at the eye, radius to maximum winds, central and peripheral atmospheric pressures, and an estimate of the geostrophic wind speed and direction. Some meteorological storm parameters were obtained from the hurricane database developed by the National Oceanic and Atmospheric Administration (NOAA)'s National Hurricane Center (NHC). This database summarizes all hurricanes and tropical storms that occurred in the North Atlantic Ocean over the 104-year period from 1886 through 1989. Information contained in this database is provided at 0000, 0600, 1200, and 1800 hr Greenwich Mean Time (GMT) and includes latitude and longitude of the storm, central pressure, and maximum wind speed. Radius to maximum winds is approximated using a function that incorporates the maximum wind speed and atmospheric pressure anomaly. Track directions and forward speeds required by the PBL model are approximated hourly, using cubic spline interpolation technique, from the storm's 6 hr latitudinal and longitudinal positions provided in the database.

Hourly wind and atmospheric pressure fields are computed for each snapshot and interpolated using a nonlinear blending algorithm that produces a smooth transition from one snapshot to the next. Hourly wind and pressure fields are then interpolated from the PBL grid onto the hydrodynamic grid and subsequently stored for use by the hydrodynamic model.

Storm Surge Model

The ADvanced CIRCulation (ADCIRC) numerical model was chosen for simulating the long-wave hydrodynamic processes in the study area. Imposing the wind and atmospheric pressure fields computed with the PBL model, the ADCIRC model can accurately replicate hurricane-induced storm-surge levels. The ADCIRC model was developed in the USACE Dredging Research Program (DRP) as a family of two- and three-dimensional finite element-based models (Luettich, Westerink, and Scheffner 1992; Westerink et al. 1992).

ADCIRC is a finite element long-wave hydrodynamic model applied for simulating water-surface elevation and circulation over the entire model domain as a function of tidal forcing, freshwater inflow, wave stress forcing, and wind forcing. The finite element formulation has the advantage of great flexibility in resolution over the calculation domain. Coarse resolution can be specified in areas distant from the local region of interest, and fine resolution can be specified locally to meet project requirements. For instance, channels and structures can be defined for accurate calculation of flow through and around them.

The basis for the model bathymetry was an ADCIRC grid developed by the Corps of Engineers Waterways Experimental Station for the North Atlantic Ocean and the East Coast of the United States. The grid was modified to include only the areas of interest for this project. A finite element mesh was developed for the modeled area, as shown in Figure C-17.

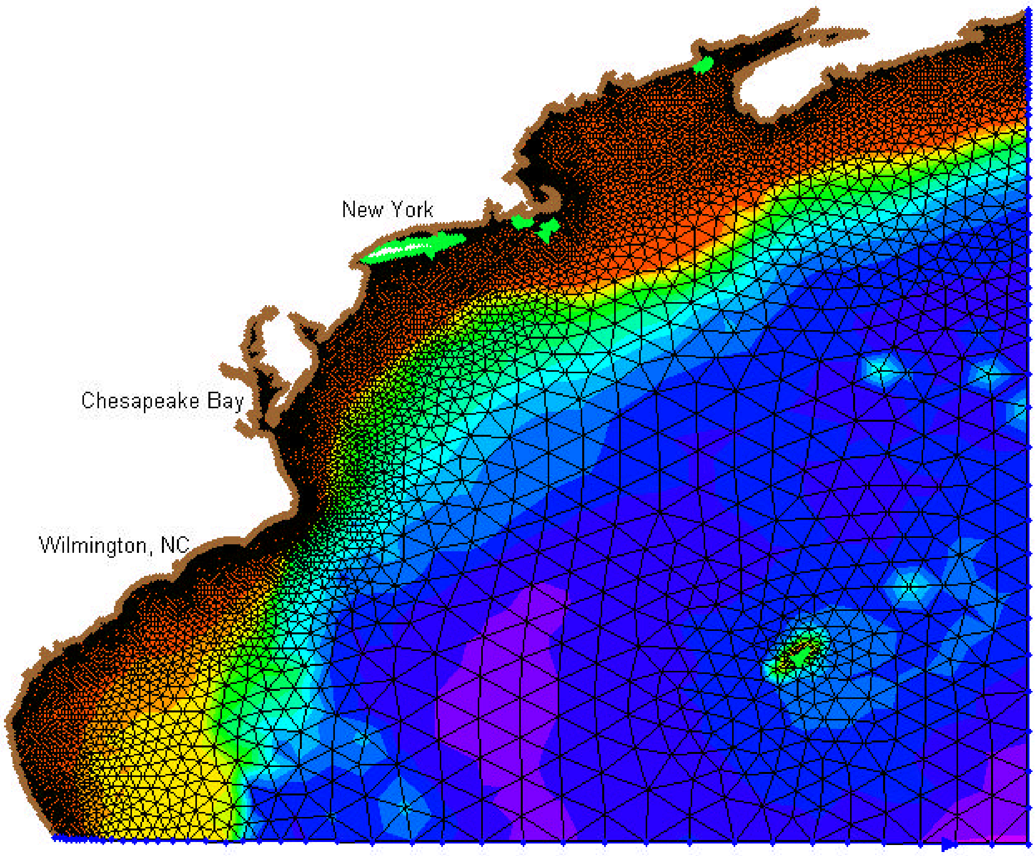


Figure C-17. ADCIRC Model Domain.

The recent storms (Bertha, Fran, Dennis, Floyd, Bonnie and Irene) were simulated with the storm-surge model. Starting and ending times of each storm simulation corresponds to the first and last entry contained in the NHC database for that particular storm. Furthermore, each storm-surge simulation began with the hurricane residing at its initial position listed in the database and concluded at its ending position. Thus, each simulation began when the hurricane was far away from the study area. For all hurricanes, a temporal "ramp" was used to slowly increase, over a 1-day period, wind stresses and pressure gradients from zero to their measured intensity. Using this ramp eliminates spurious modes of oscillation caused by suddenly imposing full-force winds and pressure gradients on the flow field.

All storm-surge simulations were performed independently of tidal action, eliminating the task of extracting surge levels from a time-series of combined tide-and surge-induced water-surface elevations. Figure C-18 displays surge values at select output locations for the Hurricane Fran simulation. Astronomical tide conditions were generated for each event using NOS derived tidal constituents at Triple S Pier and combined with storm-surge values to produce a Total Water Level (TWL) time series. The TWL served as input into SBEACH for storm-induced beach profile response modeling.

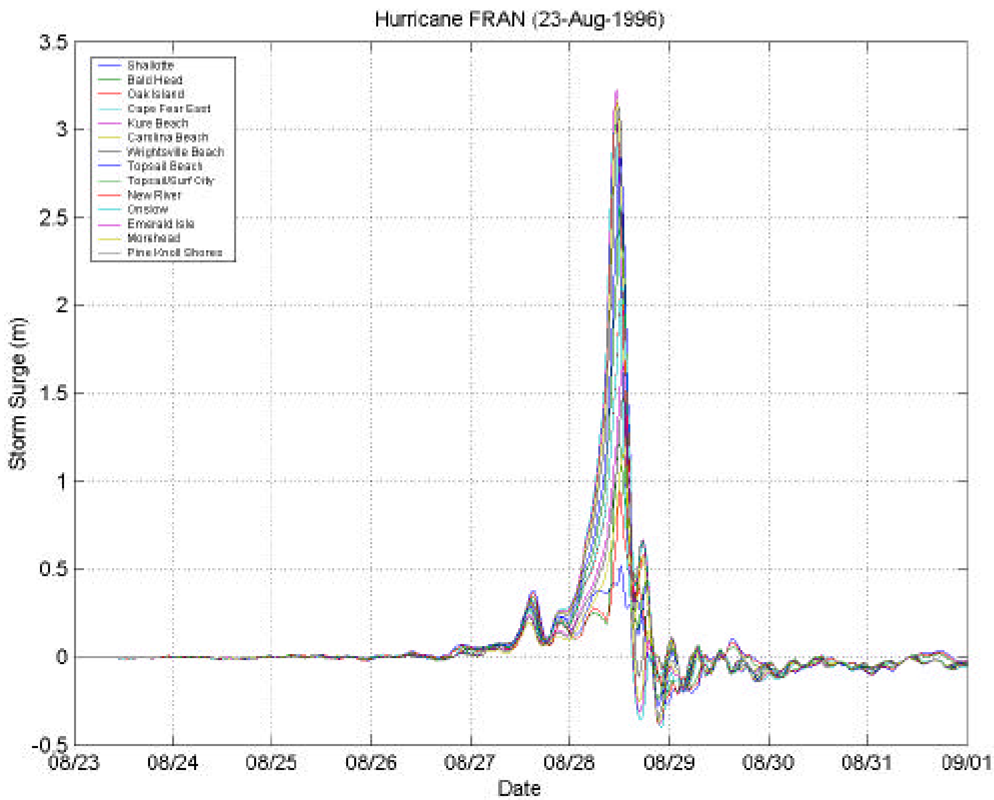


Figure C-18. ADCIRC Model Output for Hurricane Fran Simulation.

Storm-surge elevations computed in this task can be considered as approximations of the historical events. Although the frequencies associated with their maximum surge may be considered relatively accurate, the value of the peak surge may not correspond to historically observed surge elevations. The hydrographs should therefore not be considered hindcast of the historical events due to the fact that the hurricane parameters estimated from the storm database are only approximate; all information necessary to numerically simulate each event is unknown and has not been calibrated. For example, values of central pressure, radius to maximum winds, and far-field pressure are not known and were estimated from available data or observations. Because little data exist for the earlier storms, a consistent approach for selecting storm parameters was developed. This approach may not produce an accurate surge elevation for a particular event; however, it is felt that the final full population of storm data from which storm statistics are computed is representative of the range of historical events and should produce reliable and accurate hurricane stage-frequency relationships.

Waves

Wind waves and swell that are generated by local or distant storms are defined as short waves. These surface gravity waves have periods less than about 25 sec. Quantitative information about short waves in the vicinity of Bogue Banks is required in this study for determining storm-induced beach profile responses, simulating wave-induced structural damages, and estimating longshore sediment transport.

Wave heights, frequencies, and directions have been evaluated for this area using various methods. The Wave Information Study (WIS) hindcast with dates from 1976-1995 and recent hindcast from 1995 to 1999 were the main sources to characterize expected long term wave conditions and serve as input to longshore sediment transport analyses. Figure C-19 shows WIS Station locations in the Mid-Atlantic. Station 46 was utilized to characterize offshore wave conditions in the study area. To construct the wave climate, percent occurrence tables (broken down by height, period, and direction) were calculated for the entire hindcast. The Bogue Banks wave climate is illustrated in Figure C-20 as a wave rose with directional resolution of 22.25 deg. Figure C-21 also shows overall distributions by height, period, and direction in a histogram format. The average annual wave height is approximately 1 meter. Wave heights exceeding 1 meter only exist approximately 25 percent of the time. Although the largest percentage of waves are shown to be from the east, wave heights greater than 8 ft are shown to originate from east to southwest, as shown in Figure C-22. Improvements are being made to the WISWAVE model, including improved bathymetry and wind fields. It is expected that ten years of hourly hindcast wave data (1990-1999) will be available Spring 2003 for the Atlantic Coast. Such data are expected to greatly improve confidence in sediment transport magnitude estimates.

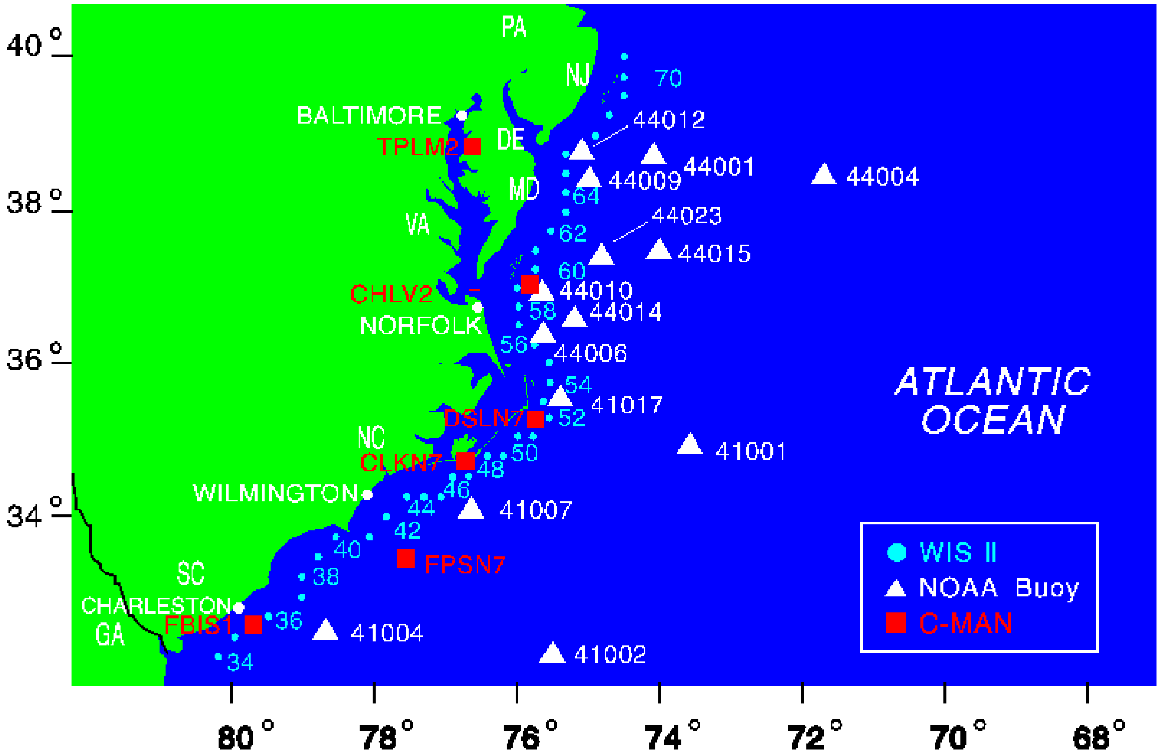


Figure C-19. WIS Station Locations.

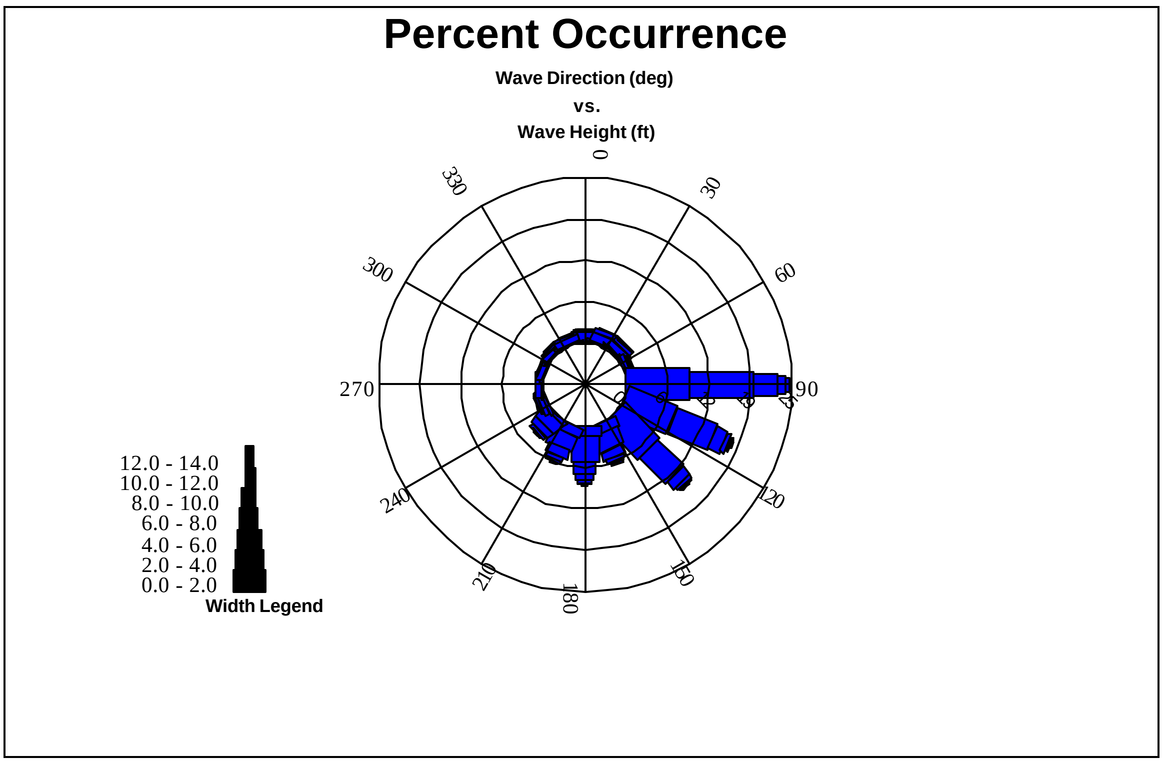


Figure C-20. Wave Rose for WIS Station 46 (1976-1995) Hindcast.

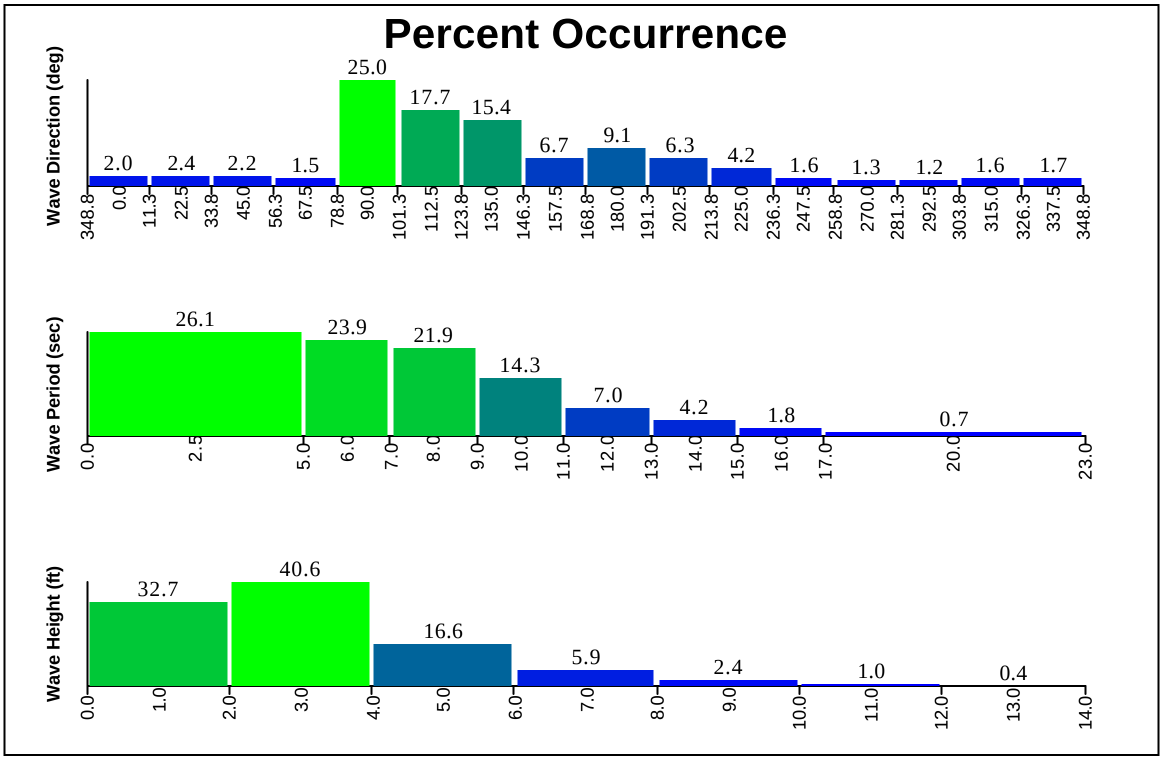


Figure C-21. Wave Histogram for WIS Station 46 (1976 to 1995) Hindcast.

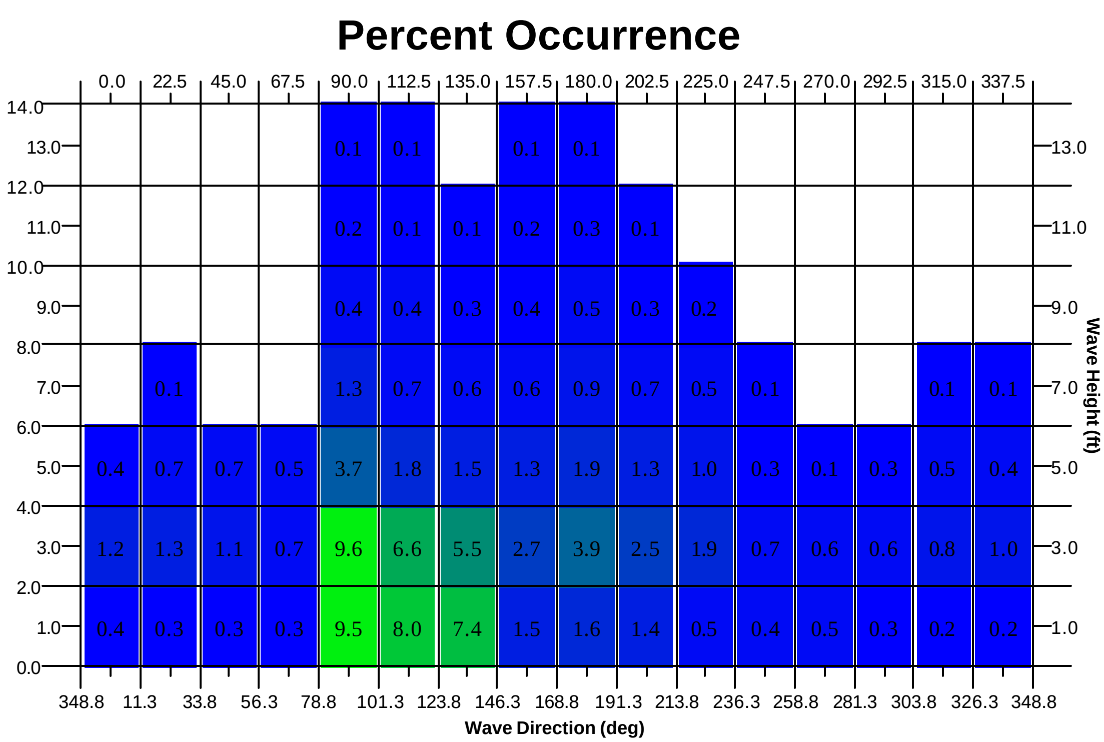


Figure C-22. Block Diagram for WIS Station 46 (1976-1995) Hindcast.

In addition to the long-term wave data, significant events were identified for input to the storm damage analysis. Time series of wave conditions for the extratropical and tropical events corresponding to those discussed in the water level analysis were developed using a combination of WIS data and numerical modeling. Extratropical storm events were extracted from the updated WIS hindcast (1976-1995). Tropical storm events (hurricanes) were included in the updated and recent WIS hindcast efforts (1976-1995, 1995-1999); however, the original WIS hindcast (1956-1975) did not include hurricanes. Therefore, in order to provide corresponding wave conditions to previously identified significant hurricanes, Wilmington District personnel utilized an empirical hurricane wave model to generate wave time series. Figure C-23 displays a typical time series of The combined time series of water levels and wave conditions (height, period, and direction) will serve as input to SBEACH for the storm damage analysis.

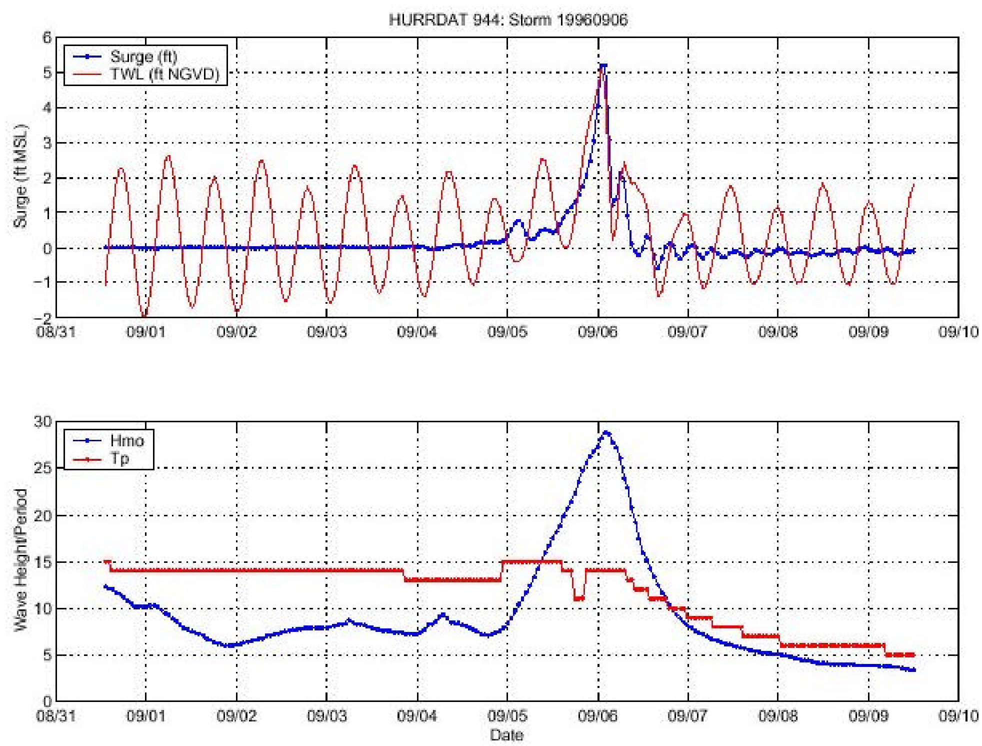


Figure C-23. Example Storm Time Series for Hurricane Event.

Sediment Transport

Several studies of potential longshore transport have been previously conducted for this area. The results of the studies are widely scattered and indicate that the magnitudes and direction of transport are solely a function of which wave database was used. Net longshore transport rates are low along Bogue Banks as evidenced by small shoreline change rates and no large accumulations of sand at the end of the cell (western Emerald Isle). The numerical model GENESIS was utilized to compute potential longshore sediment transport rates for existing shoreline conditions.

The model was setup with the origin in the vicinity of Fort Macon in order for the jetty to serve as the eastern-most lateral boundary condition. Model grid azimuth was 262.16 deg north, representative of the average shoreline angle throughout the Island for recent conditions. The model extended 119,250 ft through Emerald Isle near Bogue Inlet where historical shoreline change rates were minimal and a pinned boundary condition was applied. The model was configured using effective grain size and active profile depths representative of existing conditions. Additionally, longshore sediment transport calibration coefficients were established through a calibration and verification effort. Utilizing the April 2001 shoreline and recent WIS hindcast wave data, potential longshore transport rates were determined as shown if Figure C-24. The gradients in transport correlate well to known areas of historical shoreline change. The GENESIS model was not used to evaluate explicit beachfill alternatives, but used primarily to identify potential transport rates that served as input into a more simplified beachfill planform evolution model.

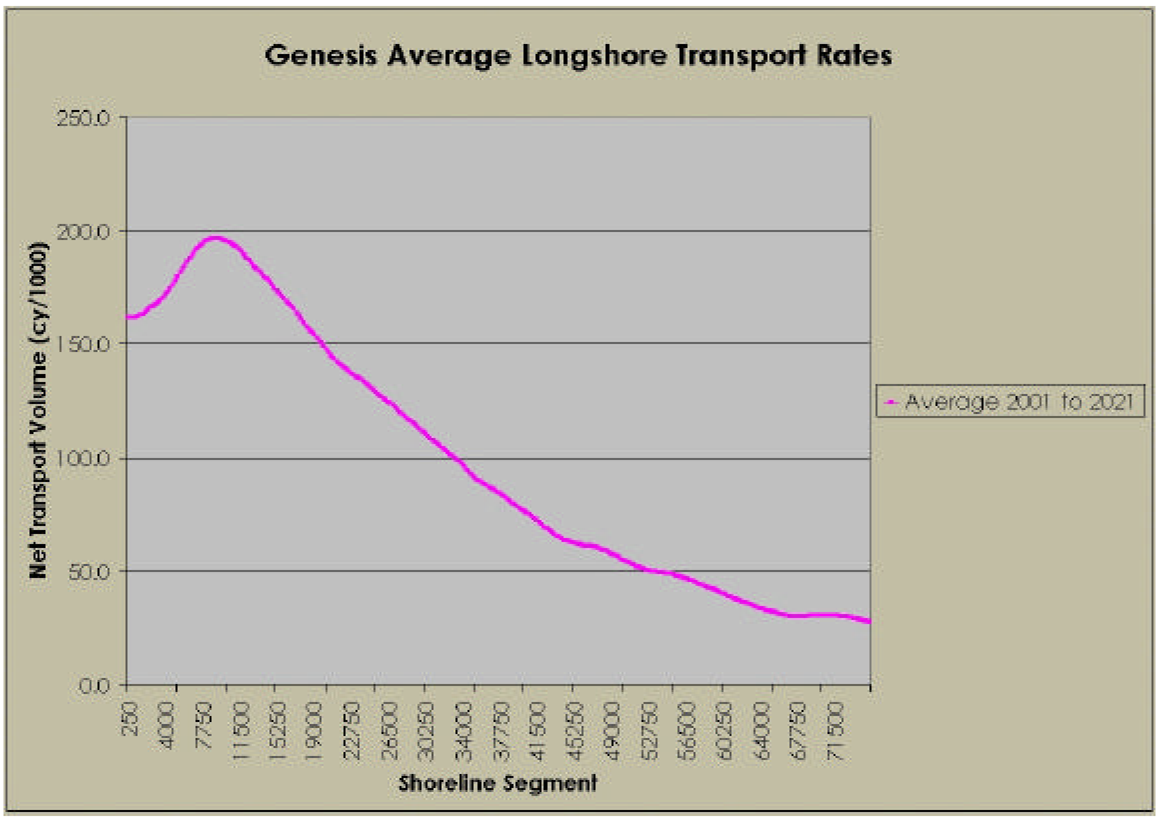


Figure C-24. Potential Net Longshore Transport (yd^3/yr) along Bogue Banks throughout Study Area.

Beachfill Evolution

Beachfill or beach disposal planform evolution was evaluated for both recent local nourishment activities and potential study alternatives. In general, when sand is placed in conjunction with a beach nourishment or beach disposal project, this project represents an “anomally” to the shoreline planform and the natural processes will tend to smooth out this anomally. The Planform Evolution Model within the Beach Fill Module developed by the Engineering Research and Development Center's Coastal and Hydraulics Laboratory was used to simulate beachfill planform evolution. The model is based on Dean's model developed for thirty-year shoreline projections in the vicinity of beach nourishment projects (Dean, 1989). The model is a rapidly applied model that considers both background erosion rate which is the normal rate in areas that have not been nourished and the shoreline retreat component due to "spreading out" losses from the beach nourishment project. The model also requires input of sediment characteristics and effective wave conditions for longshore transport. The effective wave conditions consist of a single set of wave parameters that result in the same net longshore transport as determined in the GENESIS analysis. Model output consists of shoreline positions at user-specified time intervals along with sediment transport rates. Post-processing of the output was performed to compute shoreline change rates associated with the nourisment/disposal project.

Local Nourishment Activities

The first phase of the locally funded (Carteret County) beach nourishment project resulted in approximately 1.73 million cubic yards being placed from Pine Knoll Shores to Indian Beach (39,200 ft). The berm-only project averaged less than 45 cubic yards per foot, a very small beachfill. Assuming an active profile of 25 ft would result in an increased berm width of less than 50 ft, not accounting for losses.

The beachfill conditions were specified in the Beach Fill Module along with other necessary parameters and simulations of shoreline evolution were performed through the anticipated construction date (November 2003) and to the anticipated economic life of the project. The resulting shoreline positions were post-processed to compute with-project shoreline change rates. The anticipated berm widths at the base year of construction were incorporated into existing beach profile conditions and were utilized as base conditions for the storm damage analysis.

Study Alternatives

Similar analyses were conducted for the Base Disposal and Recommended 933 Plans. Figure C-25 displays the Beach Fill Module results for the Section 933 Recommended Plan. While it is common for short beachfills to have larger shoreline change rates than the background erosion rate, the length of the Recommended Plan results in a fairly stable planform with relatively uniform shoreline change rates on the order of –2 ft/year. The with-project shoreline change rates exceed background rates in some locations such as Atlantic Beach, however the distribution of the fill material due to spreading losses results in lower erosion rates in the vicinity of Pine Knoll Shores. The with-project shoreline change rates were utilized as input into the economics analysis (GRANDUC) to compute potential damages, part of which is land loss.

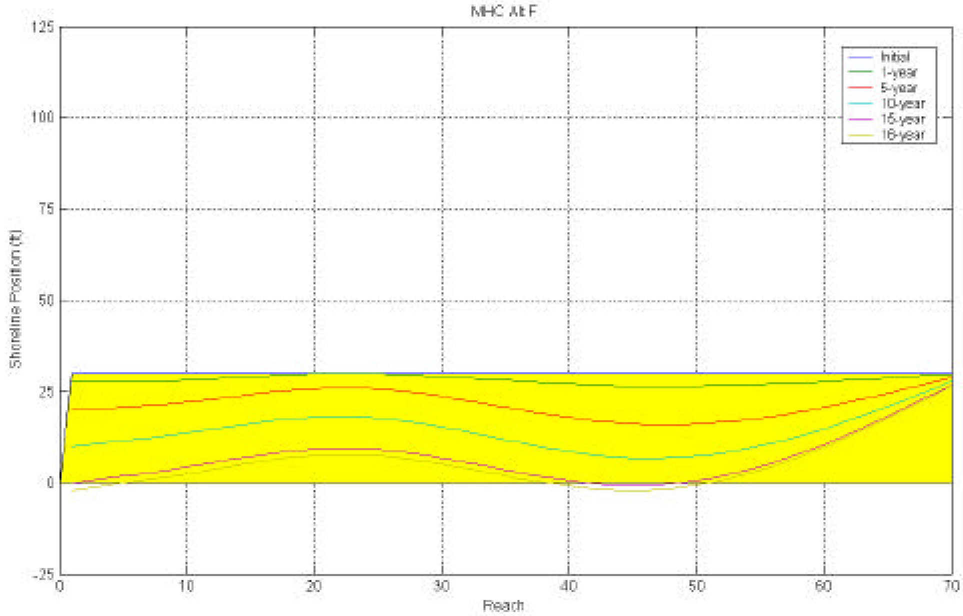


Figure C-25. Beach Fill Module Results for the Section 933 Recommended Plan.

Storm Damage Analysis

The economic analysis of storm damages for the range of beach conditions throughout the study area requires development of frequency-of-occurrence relationships for water levels, wave conditions, and erosion distances. In order to account for risks and uncertainties inherent to the analysis procedure, methods were selected to express storm damages in a probabilistic manner. In other words, the results were required in the form of erosion distance or water levels versus frequency-of-occurrence relationships.

A suite of storm events was used to assess the performance of alternatives in reducing potential damages due to erosion, wave attack, and inundation. Profiles were developed to characterize the alternatives dimensions and serve as input to the storm damage calculations. The numerical model SBEACH (Storm Induced BEAch CHange) was used to further transform the waves into the nearshore across proposed alternatives and simulate beach profile change, including the formation and movement of major morphological features such as longshore bars, troughs, and berms, under varying storm waves and water levels. In addition to computing beach profile response, the wave transformation algorithms within SBEACH were utilized to characterize incident wave conditions and total water levels (including wave setup) for each storm. Key response parameters from the SBEACH output were extracted for each storm and used to generate frequency of occurrence relationships using the Empirical Simulation Technique (EST) model. The frequency of occurrence relationships for erosion distances and other parameters serve as input to the GRANDUC model for computation of storm damages.

SBEACH Analysis

The computer model SBEACH was used to estimate erosion expected to occur during various storm events for the without project condition and the with-project template considered. Additionally, the wave transformation routines in SBEACH provide transformed wave conditions and wave-induced setup values for each simulation. SBEACH simulations were performed for the suite of storm events against the range of beach profile conditions. Input data for the SBEACH model included onshore and offshore survey data, storm water elevations, and storm wave heights and periods as discussed previously. The results from SBEACH modeling (i.e., "response parameters") that are used in storm damage calculations include: distances from the baseline to the point where select vertical feet of erosion occurs (i.e., 0.5, 2, 4 ft), the ground elevations at these erosion points, erosion volumes, maximum dune elevation, maximum wave height at dune crest, and maximum total water level (including wave setup).

Alternative Profiles

In addition to the representative beach profile conditions developed for existing conditions, a range of with-project alternative profiles were developed. Since the existing dune conditions typically have elevations in excess of what is commonly designed for a storm protection project, all alternatives consisted of berm only plans. Alternative profiles were developed with berm widths ranging from 25 ft to 125 ft at 25 ft intervals for each representative profile. The berm elevation was set at +7 ft NGVD as representative of natural berm elevation found along Bogue Banks. The berm tied into the existing dune conditions at +7 ft NGVD and extended seaward for the defined berm width (i.e., 100 ft) and then sloped seaward to Mean Tide Level (MTL) at a 1V:25H slope that was found to be representative of average nearshore conditions along Bogue Banks. The offset at MTL was maintained along the offshore component of the profile to depth of closure. Figure C-26 displays the existing beach profile conditions along with the range of alternative berm conditions.

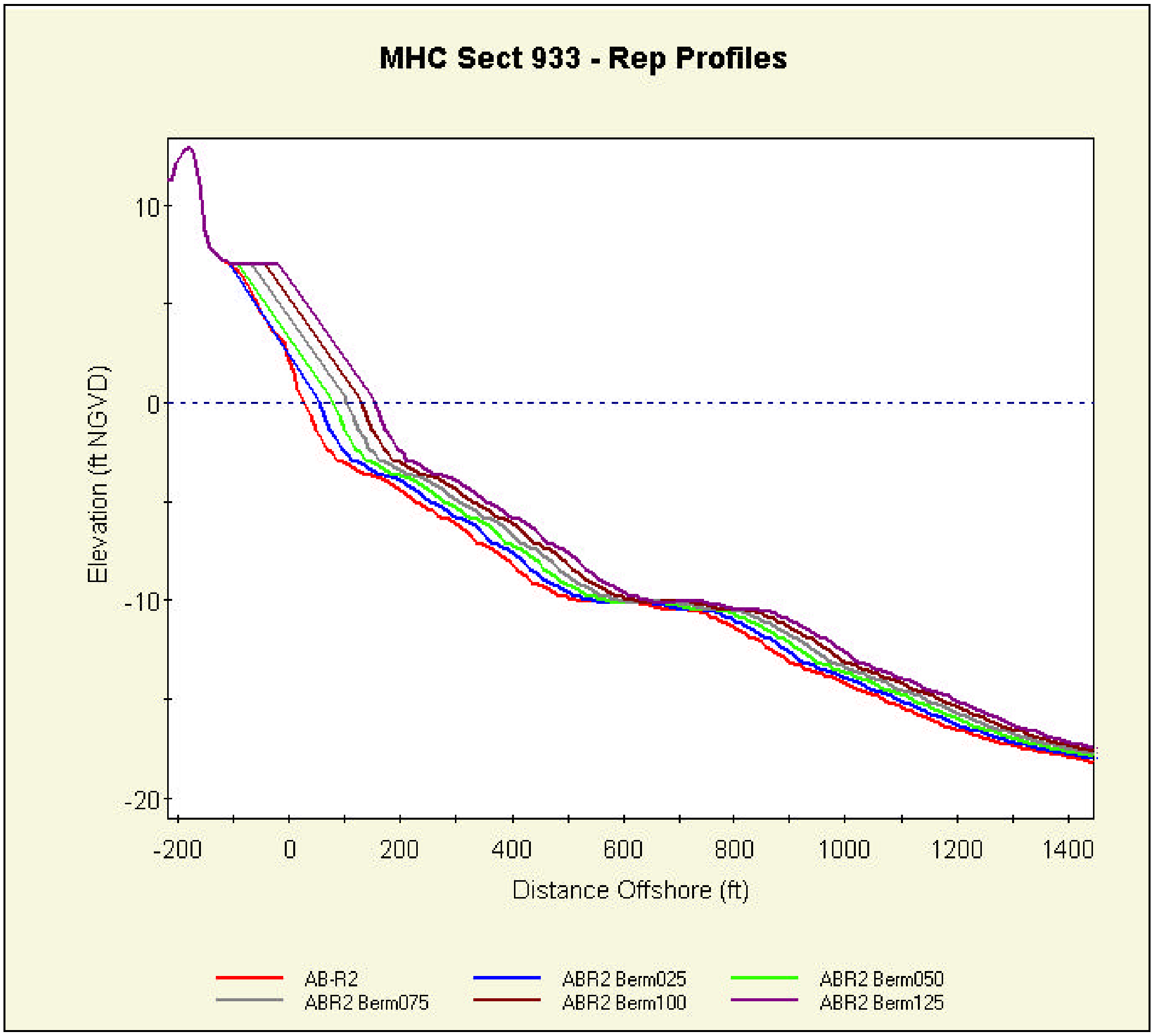


Figure C-26. Alternative Profile Conditions.

Storm Response Parameters

Simulation of storm events yields various responses. The parameters that directly impact storm damage include nearshore wave height, total water level, storm surge, wave setup, runup, erosion distances (0.5, 2.0, and 4.0 ft), dune lowering, dune recession, and volumetric changes above MHW. Select parameters were extracted from the SBEACH analysis and used to characterize the performance of the alternatives against each storm event. Figure C-27 displays SBEACH output for an extreme event for existing conditions at Atlantic Beach. The plots display initial and final profile conditions, along with maximum water elevations (includes storm surge and wave setup) and maximum wave height observed throughout the simulation. The profile response over the simulation, as indicated by the difference between initial and final profiles, provides an indicator of the severity of the storm on potential offshore losses.

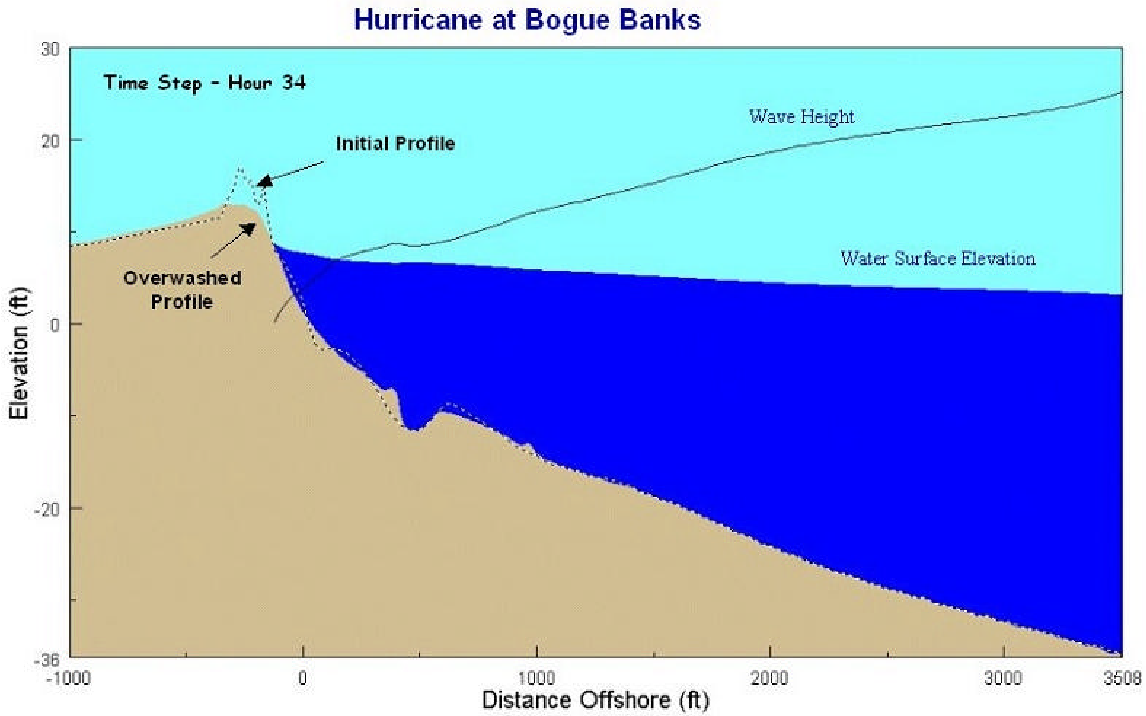


Figure C-27. SBEACH Profile Response Parameters

EST Analysis

The EST (Empirical Simulation Technique, Scheffner and Borgman, 1992) utilizes observed and computed parameters associated with site-specific historical events as a basis for developing multiple life-cycle simulations of storm activity and the effects associated with each simulated event. The first step in EST is an analysis of historical events that have impacted a specific locale. The storm events analyzed for the Bogue Banks area have been described previously. The storm events simulated were parameterized to define the characteristics of each event and the impacts of that event. Parameters that define the event are referred to as input vectors. Response vectors define storm-related impacts such as total water level and shoreline/dune erosion. These input and response vectors were then used as a basis for generating life-cycle simulations of storm-event activity with corresponding impacts. Results of the multiple repetitions were post-processed to generate frequency-of-occurrence relationships. Because multiple life-cycle scenarios were simulated through the EST, mean values frequencies (or return periods) were computed along with error estimates about the mean.

Frequency Distributions

The frequency of occurrence relationships for Total Water Level and the 0.5 Erosion Distance are shown in Figures C-28 and C-29 for the Atlantic Beach existing conditions. These relationships were developed for all profile conditions and all response parameters. Select return periods were extracted from each frequency-of-occurrence relationship and provided as input to the GRANDUC model used to calculate storm-induced damages.

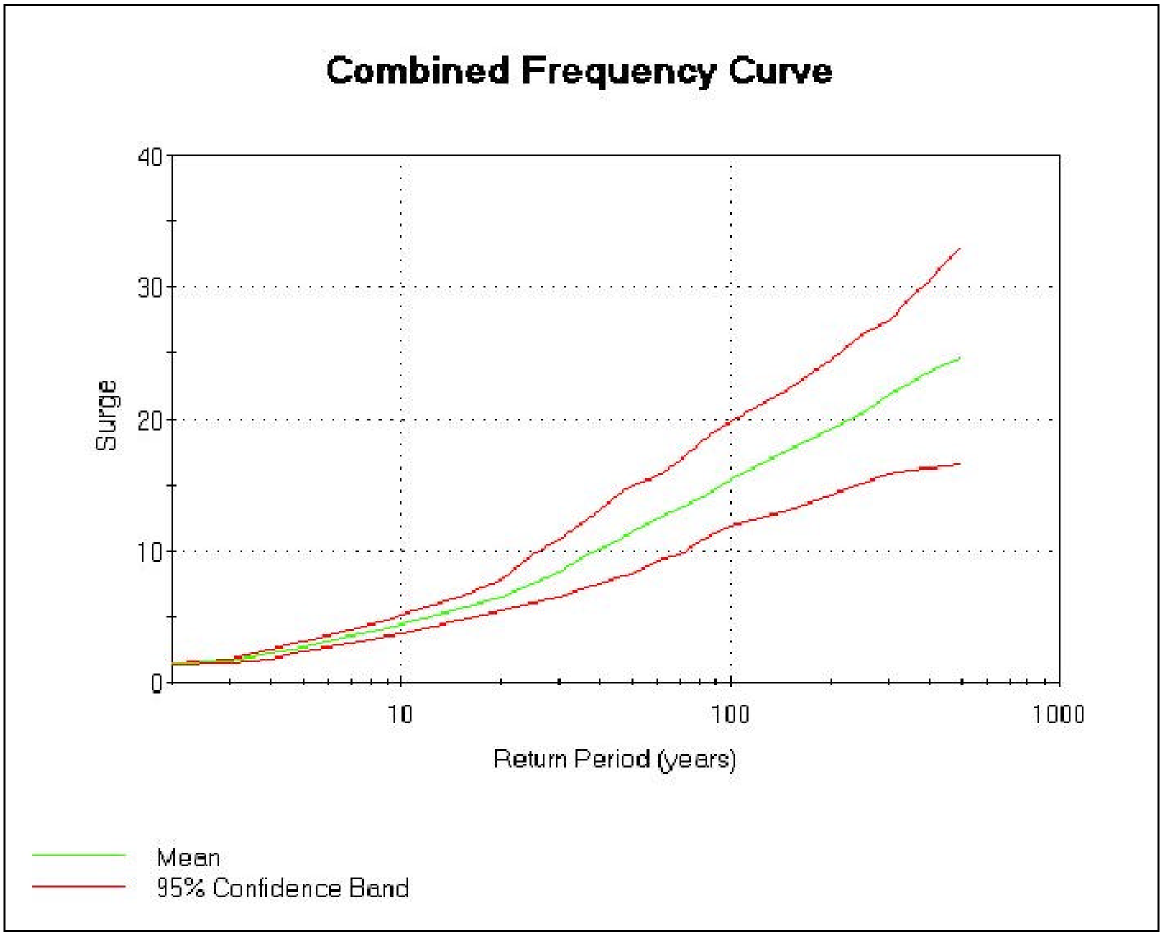


Figure C-28. Frequency-of-Occurrence Relationships for Surge Along Bigue Banks.

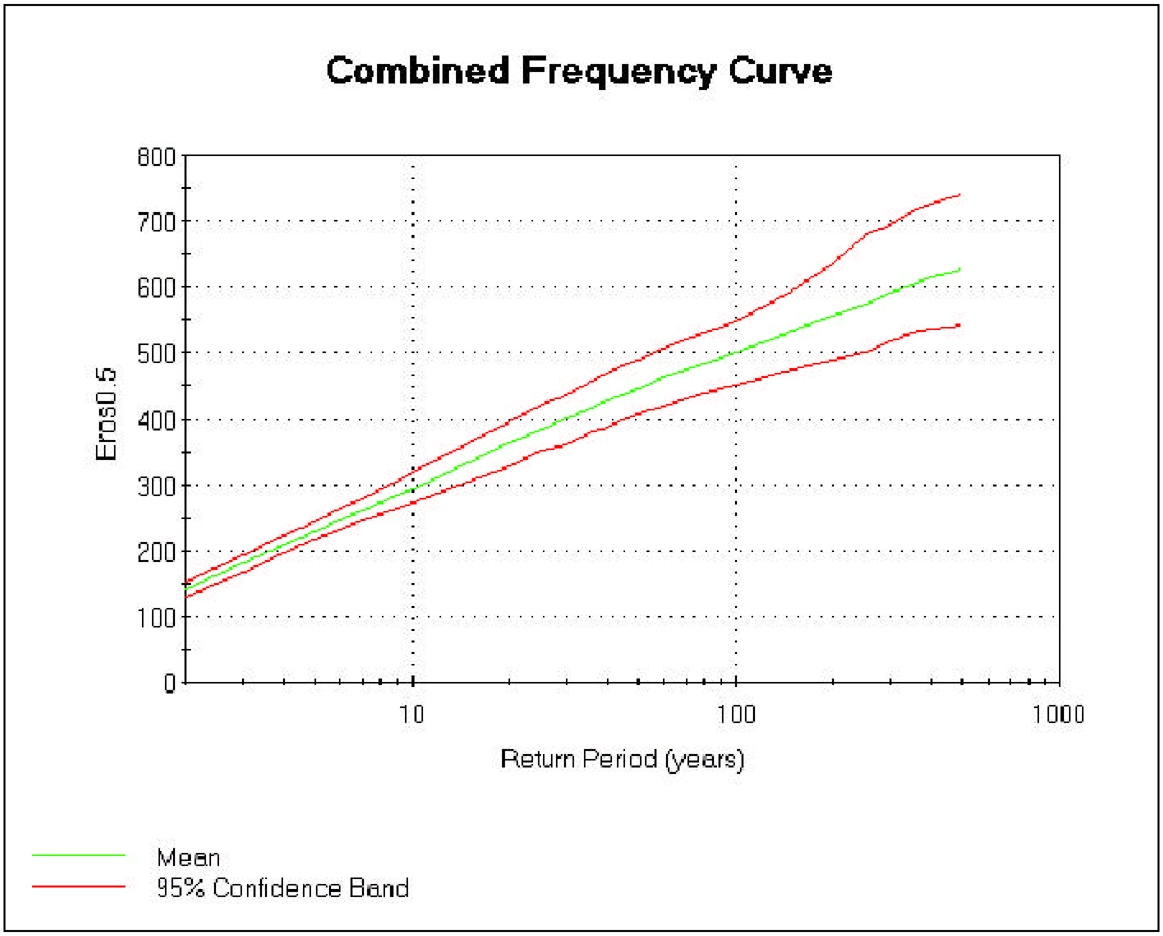


Figure C-29. Frequency-of-Occurrence Relationships for Erosion Distance Indicator (0.5 ft) Along Bogue Banks.

MOREHEAD CITY HARBOR
CARTERET COUNTY, NORTH CAROLINA
SECTION 933
EVALUATION REPORT

APPENDIX D

ECONOMIC ANALYSIS

APPENDIX D
ECONOMIC ANALYSIS

Introduction

The purpose of this study is to investigate the beneficial placement of dredged maintenance material from the authorized pump out of Brandt Island confined dike disposal area, and the maintenance dredging of the Morehead City Harbor navigation project, both of which are scheduled for the Winter of 2003-2004. This study analyzes the deposition of this dredged material along a portion of Bogue Banks beaches beyond the Corps' Base Disposal Plan, referred to as the "Section 933 Study Area." The Section 933 Study Area must be assessed for hurricane and storm damage reduction needs. This study also develops a plan of protection for this area based on the economic, engineering, and environmental feasibility, as well as the requests of the local sponsor.

Located on the central North Carolina coast in Carteret County, the beach communities of Atlantic Beach, Pine Knoll Shores, Indian Beach, and Salter Path, and Fort Macon State Park are collectively referred to as Bogue Banks. Fort Macon and Atlantic Beach fall within the normal Base Disposal Area for disposal operations associated with the maintenance of Morehead City Harbor. Disposal operations in 1986 and 1994 have kept the majority of this shoreline in a satisfactory condition. A much more vulnerable situation exists over the shoreline of the resort communities of Pine Knoll Shores, Indian Beach, and Salter Path. Hurricanes, subtropical storms, progressive erosion, and increasing development over the last several years have raised the potential for damages considerably over this 7.2-mile reach. Numerous structures in this area are highly vulnerable to damage by storm action due to the eroded dune system and loss of natural protection. It is for Pine Knoll Shores, Indian Beach, and Salter Path that this Section 933 economic analysis of the beneficial placement of dredged material from the maintenance of Morehead City Harbor channels is evaluated. Emerald Isle is experiencing similar problems but was not included in the Section 933 evaluation because of volume limitations of the disposal material and increasing distances associated with its transport.

Based on analyses conducted during this study, the most practicable beneficial placement of dredged material for hurricane and storm damage reduction is a beach berm (with transitions) along Pine Knoll Shores and Indian Beach and Salter Path. This is the reach that Carteret County, the non-Federal sponsor, requested to be studied and, as this appendix demonstrates, where a Section 933 project has been determined to be economically justified.

The Study Area.

Carteret County is located on the central North Carolina coast. Bogue Banks is a 25.4 miles long south-facing barrier island located on the low-energy limb of the Cape Lookout foreland within Carteret County. It is oriented in an approximate east to west direction between Beaufort and Bogue Inlets, located on the east and west terminuses of the island, respectively. The island is bound to the north by Bogue Sound, a relatively shallow water body through which the Atlantic Intracoastal Waterway passes.

Fort Macon State Park occupies the eastern 1.4 miles of the island. Political subdivisions on the rest of the island include, from east to west: the Town of Atlantic Beach, the Town of Pine Knoll Shores, an unincorporated area known as Salter Path, the Town of Indian Beach, and the Town of Emerald Isle. Hereafter in this analysis, for simplicity, the unicorporated area of Salter Path is included in all references to Indian Beach. The width of the upland portions of the island (the landmass above mean high water) varies from a minimum of approximately 800 feet to a maximum of over 4,000 feet. The narrowest part of the island, which ranges in width from 800 feet to 1,000 feet, is located along the easternmost 2.8 miles of Emerald Isle. The widest part of the island, which measures over 4,000 feet, is located on the westernmost 5.1 miles of the island, also within the corporate limits of Emerald Isle.

A maritime forest area is located on the sound side of Bogue Banks between the east portion of Indian Beach through Pine Knoll Shores. This reach of the island includes the Theodore Roosevelt Natural Area on the sound side, which is the only portion of Bogue Banks included in the Coastal Barrier Resources System. In general, the island has been developed in such a manner as to preserve as much of the natural vegetation from the ocean to the sound as possible.

Federal Standard - Base Disposal Area.

Should present plans for sharing sand by Bogue Banks beaches not materialize due to funding problems or other unforeseen reasons, dredged maintenance material from the entrance and inner harbor channels of Morehead City Harbor, as well as the pump out of Brandt Island, would be distributed according to the Base Disposal Plan as determined using the Federal Standard (see Appendix B). The Base Disposal Plan represents the least cost alternative for the government to dispose of navigation dredged material, which is engineeringly feasible and environmentally acceptable. Therefore, all material disposed over the limits of the Base Disposal Area does not have to be economically justified. It is only necessary to demonstrate economic feasibility over those areas outside the Base Disposal Area (i.e., Pine Knoll Shores and Indian Beach).

Under the Base Disposal Plan, the outer harbor would be maintained by hopper dredge and the resultant 1.5 million cubic yards of excavated material would be placed in the Ocean Dredged Material Disposal Site or the previously approved nearshore area. The pumpout of Brandt Island and the maintenance dredging of the inner harbor by pipeline dredge would be placed from Fort Macon State Park throughout the Atlantic Beach shoreline.   Up to 4.8 million cubic yards (i.e., about 4.0 million from Brandt Island and about 0.8 million from the inner harbor) of beach quality sand may be placed along the shoreline from Fort Macon State Park to Atlantic Beach. If the North Carolina State Ports Authority does not pay for its share (i.e., 1.2 million cubic yards), this amount could be reduced to 3.6 million cubic yards.

Section 933 Project.

Alternatively, Carteret County, the non-Federal sponsor, has requested under the Section 933 authority that the dregded material be shared between Fort Macon State Park, Atlantic Beach, Pine Knoll Shores, and Indian Beach. Working with the sponsor, the Corps of Engineers has formulated a plan that would distribute the dredged material in a uniform 30-ft berm design width stretching from Fort Macon to the Indian Beach/Emerald Isle border. Because Pine Knoll Shores and Indian Beach fall outside the Base Disposal Area, this portion of the beachfill referred to as the Section 933 Project is the portion that must be economically justified. That is the purpose of this economic analysis.

Establishing Property Values

Structural Inventory

A complete structural inventory of the oceanfront and second row of development along the shoreline of Bogue Banks was completed during the summer of 2001. This structural database, which is entered into the damage assessment program GRANDUC for this analysis, was collected and compiled by the Planning Services Section (CESAW-TS-PS). The applicable price level is July 2001, but remains suitable for October 2002 price levels. That summer, every individual structure along the first two rows of development was field checked, and a staff economist assigned it an estimate of its depreciated replacement value. Input from local builders and real estate people on structural values and current construction costs and practices went into the analysis. Factors such as age, condition, pile depth, quality of materials, and type and quality of construction also entered into this value determination.

The structural inventory of the relvant study area is made up of the oceanfront and second row of development in the towns of Atlantic Beach, Pine Knoll Shores, and Indian Beach. These first two rows are developed in a fairly continuous way with a wide range of structures including single-family homes, multi-unit condominium buildings, hotels, motels, and commercial buildings of various sorts. Values and susceptibility to storm damages vary considerably.   Because of substantial variations in every factor that will affect storm damages, it is impossible to select any small areas or segments that could be considered representative of the study area as a whole. Therefore, an incremental analysis of segments of the beach is required.

The most common type structure found in the primary study area is the single family residential dwelling. These dwellings are typically one, two, or three-story frame or concrete block structures. Most are elevated on pilings but have a partially to fully enclosed ground level. The pilings may be embedded from 8 to 16 feet deep. In compliance with North Carolina State law, structures built since the mid 1970's must have the first floor constructed above the 100-year storm water surface elevation.

There are also many multi-story condominiums within the three-town study area. In addition, there is a large commercial base. Dozens of oceanfront motels and hotels comprise the most valuable of the commercial structures, but other types of commercial development comprised mostly of convenience stores, retail stores, offices, and restaurants are also found along the first two rows of development. Table 1 shows the number of buildings and total structure value of all structures along the oceanfront and second row by town. Altogether, a total of 842 structures were inventoried at a value of about $377 million.

TABLE 1
Structural Inventory by Town

Town	Number	Oceanfront Structure Value	Second Row Structure Value	Total Structure Value
Fort Macon	1	$160,000	$0	$160,000
Atlantic Beach	470	$105,959,000	$31,768,000	$137,727,000
Pine Knoll Shores	258	$119,791,000	$27,688,000	$147,479,000
Indian Beach (Salter Path)	113	$77,258,000	$14,039,000	$91,297,000
TOTAL	842	$303,168,000	$73,495,000	$376,663,000

Content Value of the Structural Database.

Estimates of values of contents of commercial structures in the primary study area are based on interviews with businessmen and insurance agents familiar with the Bogue Banks oceanfront, as well as empirical data collected for past studies. Businesses are entered into the damage model with a code for type of commercial activity. Each type of business has a unique content factor applied to its structural value.

For estimating the value of household contents of residential structures in the study area, 40 percent of the structural value is used. This is based on site-specific responses from Bogue Banks officials, insurance agents, realtors, and home owners familiar with the development along this section of oceanfront. The majority of these properties are rentals but tend to be upscale, often renting for thousands of dollars per week during the summer months. There is a trend towards putting better quality furnishings in these homes as vacation tenants expect the same high quality and thoroughness of furnishings that one would find in second homes. Second home owners, who live in these homes several months of the year, are also better equiping these houses. Forty percent content to structure value is within the usual range of consistency with other beach nourishment studies along the North Carolina coast and is reasonable and appropriate for this study. Sensitivity analyses were done to examine the effects of changes in content value percentages. Using a content to structure value of 30 percent, for example, does not significantly change the outcome of the project's economic feasibility.

Nearshore Land Value.

One of the components of hurricane and storm damages is land loss due to long term erosion. Long term erosion is accounted for in each year and in each method of damage calculation. As a structure is lost to long term erosion, the value of the structure is taken as a loss that year, and the structure is taken out of the calculation process for the remainder of the period of analysis. Land lost to long term erosion is computed by multiplying the expected annual loss of land in acres by the value of nearshore upland. The value of nearshore land was determined through an analysis of recent sales of interior lots with no view of the ocean or sound. This value varies from town to town and is highest in Atlantic Beach. This is beacause Atlantic Beach is virtually built-out and there are no undeveloped interior lots. When an interior lot does sell for its land value, the price is relatively high and there is usually an older home on the lot that must be demolished. Table 2 shows the nearshore land values per acre and per square foot used for each town.

TABLE 2
Nearshore Land Values by Town

Area	Value/Acre	Value/Sq.Ft.
Fort Macon	$175,000	$4.00
Atlantic Beach	565,000	13.00
Pine Knoll Shores	300,000	7.00
Indian Beach (Salter Path)	220,000	5.00

For example, as increments of land erode away in Pine Knoll Shores under the without project condition, $300,000 per acre represents the decrease in value to the oceanfront parcels. These increments of land loss are computed linearly and annually in square feet. In this example, the value of an oceanfront lot 100 feet across by 100 feet deep is about $70,000 when restricted to its nearshore land value. If it is eroding at 5 feet per year, the lot would lose 5 percent, or about $3,500 of its value each year. This linear assumption is reasonable and non-subjective.

Plan Formulation And Evaluation

Existing Conditions.

Over recent years, hurricanes, subtropical storms, progressive erosion, and increasing development have greatly increased the potential for damages over the entire length of Bogue Banks. Except for the lands designated as public parks, the oceanfront is practically built-out and numerous structures are left vulnerable to damage by storms due to the eroded dune system and loss of natural protection. In an effort to combat shoreline erosion, a locally funded beach nourishment project is ongoing over much of the study area. This project proposes to place approximately 4.5 million cubic yards of sand over Pine Knoll Shores, Indian Beach, Salter Path, and Emerald Isle, approximately 16.8 miles of ocean shoreline. The project is planned to be completed in three phases over a three-year period. The first phase has been completed with the nourishment of 6.6 miles of beach in Pine Knoll Shores and Indian Beach with approximately 1.7 million cubic yards of sand. The second phase will place 1.8 million cubic yards of sand on three miles of Emerald Isle (and potentially .7 miles of Indian Beach that was not able to be completed in Phase I) in the winter months of 2002/2003. And the final phase, if implemented, would place 1million cubic yards of sand on 6.7 miles of Emerald Isle in the winter of 2003/2004.

These one-time, locally funded nourishment efforts are not large enough to be considered anything other than stop-gap measures. The Section 933 Project, another one-time nourishment effort, is to be added seaward of the remainder of the locally funded beachfills in Pine Knoll Shores and Indian Beach. It too is expected to have a limited life and not be a permanent solution to the erosion problems of these communities.

The Without Project Condition.

This report presents two areas of beach placement. The Base Disposal Area would be along Fort Macon and Atlantic Beach, which is a distance of 32,000 feet. This area of least cost disposal will receive up to 4.8 million cubic yards of sand from Brandt Island and the normal maintenance cycle of Morehead City Harbor. Critical to this study is the estimate of the vulnerability to damages from coastal storms along the beaches of Bogue Banks associated with the Base Disposal Plan placement of material only on Fort Macon and Atlantic Beach. This alternative would amount to the "without project condition" and forms the basis for evaluating the degree of damage reduction that would be provided by the alternative, Section 933 Project on Pine Knoll Shores and Indian Beach.

In most cases, the without project condition is usually more akin to a “no action” plan. However, in the case of Morehead City Harbor maintenance, Base Disposal Plan includes pumping material to Fort Macon and Atlantic Beach. The alternative is to deposit some or all of the Brandt Island material along the 25,000 linear feet of oceanfront at Pine Knoll Shores and 13,000 linear feet of Indian Beach under the Section 933 authority.

Carteret County and the State of North Carolina have already committed large sums of money to studying long-term Federal nourishment projects along Bogue Banks. In the interim, the locally funded beach nourishment project described above is ongoing over much of the study area. Additionally, the State would likely help the locals governments battle erosion using the traditional emergency measures, including sandbagging, beach scraping, and piecemeal relocation. However, these measures are not expected to provide substantial reductions in storm damages over the long-term and, thus, would be the equivalent of a no action plan.

General Methodology.

To analyze this 12-mile long stretch of coastline from Fort Macon to Indian Beach that comprises the overall study area, the shoreline of three Bogue Banks beach communities is divided into segments according to similar development patterns, existing dune dimensions, and erosion rates. Fort Macon, Atlantic Beach, Pine Knoll Shores, and Indian Beach are divided into a total of 12 segments. These average about 6,000 feet in length, with six comprising Fort Macon and Atlantic Beach (ie., Base Disposal Area), and six comprising Pine Knoll Shores and Indian Beach (i.e, Section 933 Project). The costs versus benefits of a nourishment project for each segment are then evaluated incrementally.

Expected storm and erosion related damages are first computed for the Base Disposal Plan, and then again for the Section 933 Project. Both of these beach fill plans would prevent the progressive erosion of the shoreline, reduce damages caused by erosion, flooding, and wave impact during coastal storms, decrease storm related emergency expenditures, and increase the quality of recreational opportunities in the area.

Normally with beach nourishment evaluations, the plan formulation process involves the assessment of the degree of storm damage reduction provided by a wide range of beach fill configurations. However, with a Section 933 analysis, only one beach fill alternative must be demonstrated to be economically feasible taking into full account the benefits foregone from the normal Base Disposal Plan. Given the structural data base for the primary study area, the level of storm damage reduction for this beach fill configuration is determined by simulating hundreds of 20-year life cycles. This is accomplished through the use of the model, GRANDUC, which incorporates risk and uncertainty principles into the analysis.

Through a random selection process, a particular 20-year simulation may include several severe storms or perhaps none. All of the 20-year life cycle simulations are run for the existing conditions, then again for a particular plan. Then, the average storm damage reduction potential afforded by a particular design configuration is computed. These damages are then estimated at an expected annual amount. The storm damage reduction potential for a particular plan is computed in terms of the “net benefits” afforded by the plan. Normally, net benefit is defined as the difference in the expected annual benefits associated with a particular fill configuration and the average annual cost for that configuration. Plan formulation and evaluation using GRANDUC is based on the present value of the net benefits before annualizing.

Interest Rate and Period of Analysis.

The interest rate for the analysis is 5-7/8 percent and a 20-year Period of analysis is used. October 2002 price levels are applied. The "base year" used for the economic analysis is 2004. The period of analysis for the Section 933 Project has been selected to be 20 years. This is based on a 10-year physical life for the Section 933 Project and doubling this time period for the period of analysis of the project. This period approximates the time over which benefits would be realized for the Section 933 Project, plus the additional length of time it would take for the beach profile to reach equilibrium with the without project condition’s profile.

Alternative Plans.

Initially, the without project condition, or in this case, the Base Disposal Plan, for Fort Macon and Atlantic Beach was evaluated. The alternative is the Section 933 Project, which is the only plan considered in great detail. As explained above, only one plan need be evaluated in determining economic feasibility. Although the

Recommended Plan was the only plan analyzed in detail, there were several plans initially assessed which would have provided protection for a number of different combinations of areas within the Study Area and the Base Disposal Plan Area. These plans were used as tools to assist in the initial determination of the one plan to evaluate in more detail.

Refinement of Erosion-Damage Relationship.

Before describing estimates of potential damages, an explanation of one of the critical, underlying relationships that go into the damage calculations, namely, the erosion-damage curve is offered. The historical effects of long-term and storm related erosion on oceanfront structures along the beaches of North Carolina are not well documented. Very little data exists on how these structures react to storm forces of varying degrees of intensity. This lack of data has lead to the designing of erosion-damage curves comprised largely through professional judgment. The state of the art of modeling these relationships is improving, however, following the hurricanes of 1996-1999 along the North Carolina coast. Researchers like Spencer Rogers of North Carolina Sea Grant have begun collecting and analyzing data and publishing papers on this subject. In his report "Erosion Damage Thresholds in North Carolina," Mr. Rogers derived storm induced damage curves based on observed changes over time in coastal construction in North Carolina The curves used in the Morehead City Harbor Section 933 Study are derived from these erosion-damage curves and are based on field data including the following structure identities:

- Oceanfront or not
- Number of stories
- On piles or not, long or short piles
- Size of the under house enclosure (none, small, partial, fully enclosed)
- Type of enclosure (none, finished, unfinished)
- High or low existing dune
- Structure type (commercial or residential)

For this analysis, these data were collected for every structure along the oceanfront and first row of development back from the oceanfront, along with their elevation and depreciated replacement value. The following further describes the four-character coding scheme of structure types used for this study, which was originally developed by a North Carolina State University team of researchers including Mr. Rogers. These codes are assigned upon field inspection of each structures and matched with both an appropriate erosion-damage curve and an inundation-damage curve.

Building Inventories

Four character scheme used for Bogue Banks database:

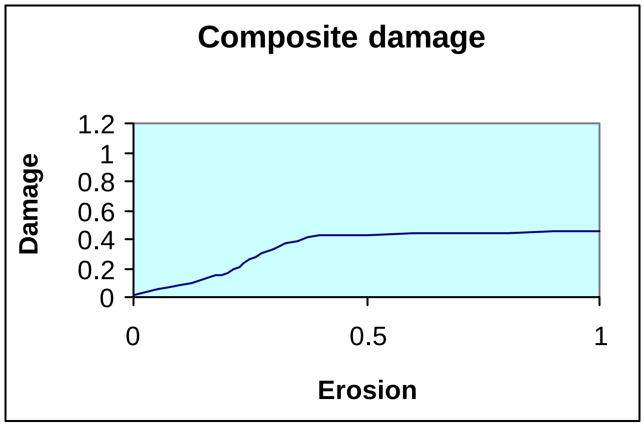
1. Number of stories (1,2,3)
2. On piles or not (P or N)
3. Size of underhouse enclosure (N=none, S=small (300 ft^2 or less), P=partial (300 ft^2 to full), F=fully enclosed)
4. Type of enclosure (N=none, F=finished, U=unfinished)

Yielding the following list of structure types:

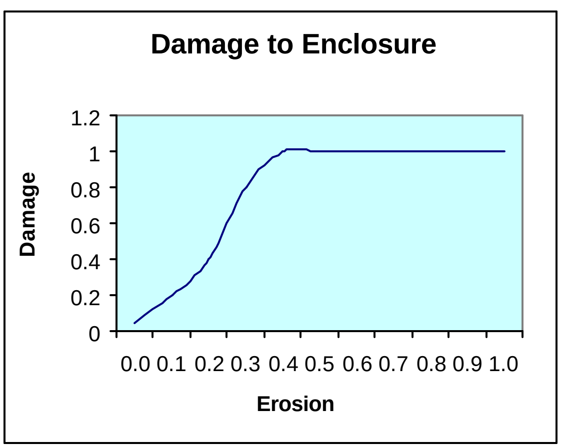
Type	Description
1NNN	One story on grade or low/crawl space foundation
1PNN	One story elevated on piles, no enclosures below
1PSF	One story elevated on piles, enclosed finished area below (enclosure less than or equal to 300 $ft^{2)}$
1PPF	One story elevated on piles, enclosed finished area below (enclosure greater than 300 ft^2 but less than full)
1PFF	One story elevated on piles, enclosed finished area below (full enclosure)
1PSU	One story elevated on piles, unfinished enclosure below (enclosure less than 300 ft^2)
1PPU	One story elevated on piles, unfinished enclosure below (enclosure greater than 300 ft^2 but less than full)
1PFU	One story elevated on piles, unfinished enclosure below (full enclosure)
2NNN	Two story on grade or low/crawl space foundation
2PNN	Two story elevated on piles, no enclosures below
2PSF	Two story elevated on piles, enclosed finished area below (enclosure less than 300 ft^2)
2PPF	Two story elevated on piles, enclosed finished area below (enclosure greater than 300 ft^2 but less than full)
2PFF	Two story elevated on piles, enclosed finished area below (full enclosure)
2PSU	Two story elevated on piles, unfinished enclosure below (enclosure less than 300 ft^2
2PPU	Two story elevated on piles, unfinished enclosure below (enclosure greater than 300 ft^2 but less than full)
2PFU	Two story elevated on piles, unfinished enclosure below (full enclosure)

The erosion-damage curves used for this analysis are compilations of curves assigned for each part of the structure. For example, the curve 1 below is a compilation of curves 2 and 3 with weight given in proportion to the value assigned to each part of the structure. This example is for a 1PF, which is a 1-story house on piling with a full enclosure. It is further described as having long pilings and on low elevation. The enclosure is given a value of 40% of the entire structure and the rest of the structure is given a value of 60% of the entire structure value. These percentages were then used to weight the damage curves for the home and the enclosure and derive a composite damage curve.

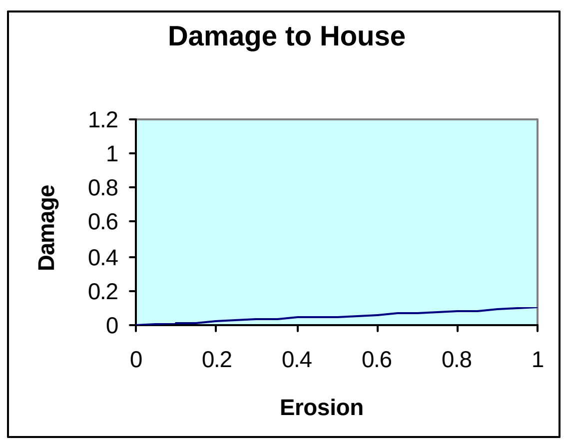
Curve 1



Curve 2



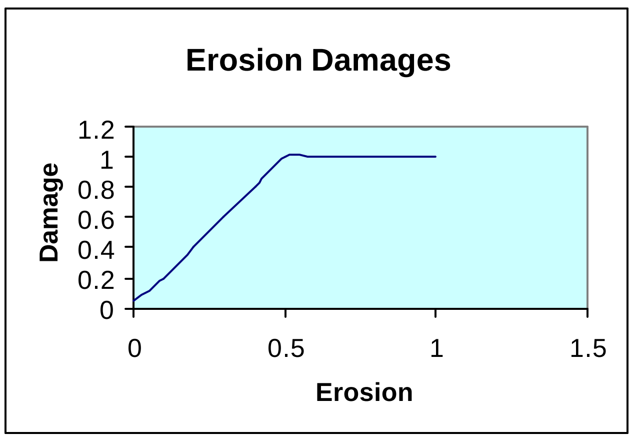
Curve 3



The use of construction dates estimated during the data collection assisted in determining of whether or not a structure was on long or short pilings. The North Carolina coastal construction codes changed in 1986 to require longer pilings than the 8 feet below grade to either-5 feet NGVD or 16 feet below grade, whichever is shallower. We developed our damage curves to distinguish between structures with long or short pilings because the storm damages are different for the two. The curves were different for high and low dune elevation as well (12 feet is the limit).

Another consideration for curve assignment is whether the structure is in the oceanfront row or the second row. Those residential oceanfront structures with enclosures were typically assigned some variation of curves 1 or 2 above, depending on their age, length of piling, and size and quality of enclosure. Oceanfront homes with no enclosure, on a low dune, and pilings embedded 16 feet were assigned curve 3, which produces relatively minor damages. Oeanfront structures are most vulnerable to erosive forces and are usually built to the higher building code standard. Residential structures along the second row of development were also assigned an erosion-damage curve specific to their building characteristics, which often include shorter pilings. In this case, the structures were often assigned a more aggressive erosion-damage curve like curve 4 shown below.

Curve 4



The erosion indicator, or erosion depth threshold, is a vertical measurement that is used to look at erosion through structures. As the land erodes by this vertical amount though a structure, damage accrues to the structure. An erosion indicator of 0.5 feet was used for this analysis. Sensitivity analyses were done to examine the effects of changes in content value percentages, erosion indicators, and assignment of erosion curves from the simplest to curves that are composites of damages to different parts of the structure.

Benefit Categories.

Three categories of benefits will be analyzed for the initial evaluation of the structural plans over the 12-mile study area. These benefit categories include: (1) hurricane and storm damage reduction, including land loss; (2) emergency costs and other damage reduction; and (3) recreation. Expected storm and erosion related damages are computed for three conditions: (1) existing conditions; (2) the Base Disposal Plan conditions; and (3), the Section 933 Project conditions. The benefits for the Section 933 Project for which economic justification must be demonstrated, are the difference between Pine Knoll Shores' and Indian Beaches existing damages and the damages with the 933 Project in place. The benefits for the Base Disposal Plan are also calculated to compute benefits foregone, which are added to the cost side of the Section 933 Project.

Potential Hurricane and Storm Damages.

Hurricane and storm damages are calculated under these three conditions for damages to structures and contents, roadways, and land lost due to long-term erosion. Land lost to long-term erosion is computed by multiplying the expected annual loss of land by the value of nearshore upland shown in table 2. Table 3 displays by segment the expected annual hurricane and storm damages, along with residual damages. Again, the residual damages illustrate how little the Base Disposal Plan helps in reducing hurricane and storm damages on Bogue Banks.

TABLE 3

Expected Annual Hurricane and Storm Damages by Town

TOWN	Existing	BD Plan	933 Plan
Fort Macon	$90,638	$6,874	$9,656
Atlantic Beach	$4,365,381	$2,495,970	$3,198,587
Pine Knoll Shores	$12,008,057	$12,008,057	$4,750,681
Indian Beach	$2,534,965	$2,534,965	$842,311
TOTAL (Residual)	$18,999,040	$17,045,866	$8,801,234

Hurricane and Storm Damage Reduction Benefits.

Expected annual hurricane and storm damage reduction benefits for the Section 933 Project amount to the difference between damages under the 933 plan and the Base Disposal (BD) Plan for Pine Knoll Shores and Indian Beach. As shown in table 4, the hurricane and storm damage reduction benefits are estimated at $8,950,000 (($18,912,000 - $4,751,000) + ($2,535,000 - $842,000)). The residual expected annual damages along the Section 933 study area are about $5,593,000. The decrease in Atlantic Beach and Fort Macon hurricane and storm damage benefits from the Section 933 Project (i.e., $705,000) will be added to the cost side of the Section 933 Project as a benefit foregone later in the appendix.

TABLE 4
Expected Annual Hurricane and Storm
Benefits for the Section 933 Project

TOWN	Expected Annual H&S Damages Existing	BD Plan	933 Plan	Expected Annual H&S Benefits 933 Plan
Pine Knoll Shores	$12,008,057	$12,008,057	$4,750,681	$7,257,376
Indian Beach	$2,534,965	$2,534,965	$842,311	$1,692,654
TOTAL	$14,543,022	$14,543,022	$5,592,991	$8,950,031

Testing the Economic Feasibility of the Section 933 Project.

Plan formulation is generally based on costs versus hurricane and storm damage reduction benefits. Therefore, before describing other benfits accruing from the Section 933 Project, a plan formulation test of basic economic feasibility based soley on hurricane and storm damage reduction is appropriate at this point. As mentioned earlier, the 12-mile long stretch of coastline from Fort Macon through Indian Beach was divided into 12 segments averageing about 6,000 feet in length. Table 5 and 6 show this process of incrementally evaluating the economic feasibility of each segment. First, table 5 shows the economics of the Base Disposal Plan, including costs of pipelining and hoppering the dredged material. Although this is least cost disposal plan and does not require a positive benefit-to-cost ratio (BCR), it is interesting to note that its overall BCR is 1.3, and its hurricane and storm damage reduction benefits do outweigh its costs. More importantly, these calculations are needed to compute benefits foregone in support of the economics of the Section 933 Project and to ensure that the project is not extended beyond what the benefits will support. Benefits in table 5 and 6 are in present value form so they are comparable to first costs.

TABLE 5

Base Disposal Plan Economic Feasibility by Segment

Seg-ment	Length (in feet)	Ave. Unit Cost-Pipeline-Base Plan	Volume (cu. Yd)	Volumetric Placement Cost	Mob/Demob (Divided Linearly)	Ocean Disposal Costs (Divided Linearly)	Total Costs Base Plan-(No Contingencies, etc. Included)	P.V. Benefits-Base Plan	Incremental Benefit Cost Ratio-933 Plan
1	3000	$2.18	427,740	$932,473	$187,500	$365,625	$1,485,598	$110,521	0.1
2	4000	$1.93	813,042	$1,569,171	$250,000	$487,500	$2,306,671	$860,067	0.4
3	6000	$1.73	802,132	$1,387,688	$375,000	$731,250	$2,493,938	$7,053,784	2.8
4	7000	$2.11	836,118	$1,764,209	$437,500	$853,125	$3,054,834	$4,428,195	1.4
5	6000	$2.51	882,272	$2,214,503	$375,000	$731,250	$3,320,753	$2,853,216	0.9
6	6000	$2.91	1,038,696	$3,022,605	$375,000	$731,250	$4,128,855	$7,326,072	1.8
7	7000								
8	7000								
9	7000								
10	6000								
11	5000								
12	6000								
Total	70000		4,800,000	$10,890,650	$2,000,000	$3,900,000	$16,790,650	$22,631,855	1.3

Similarly, table 6 examines the segment-by-segment economic feasibility of the Section 933 Project after adding the hurricane and storm damage reduction benefits foregone to the cost side. Table 6 demonstrates that every segment throughout the Section 933 Project Area (segments 7-12) is economically justified. Segment 10 is divided in half to accommodate the best estimate of where the pipeline operation would end and the hopper operation would begin.

TABLE 6

Section 933 Project Economic Feasibility by Segment

Seg-ment	Length (in feet)	Ave. Unit Cost-Pipeline-Total Plan	Ave. Unit Cost-Hopper to IB-Total Plan	Volume (cu. yd)	Volumetric Placement Cost	Mob/Demob (Divided Linearly)	Total Cost-Total Plan (No Contingencies, etc. included)	P.V. Benefits -Base Plan	P.V. Benefits-Total Plan	Costs of Benefits Foregone	Total Cos -933 Plan (No Contingencies, etc. included)	Incremental Benefit Cost Ratio-Total Plan
1	3000	$2.18		159,571	$347,865	$93,750	$441,615	$110,521	$103,327	$7,194	$448,809	0.2
2	4000	$1.93		458,750	$885,388	$125,000	$1,010,388	$860,067	$835,032	$25,035	$1,035,423	0.8
3	6000	$1.73		250,406	$433,202	$187,500	$620,702	$7,053,784	$4,930,409	$2,123,375	$2,744,077	1.8
4	7000	$2.11		209,642	$442,345	$218,750	$661,095	$4,428,195	$1,811,495	$2,616,700	$3,277,795	0.6
5	6000	$2.51		312,018	$783,165	$187,500	$970,665	$2,853,216	$871,613	$1,981,603	$2,952,268	0.3
6	6000	$2.91		443,329	$1,290,087	$187,500	$1,477,587	$7,326,072	$5,906,367	$1,419,705	$2,897,292	2.0
7	7000	$3.33		808,456	$2,692,158	$218,750	$2,910,908	$0	$9,013,190	$0	$2,910,908	3.1
8	7000	$3.83		954,648	$3,656,302	$218,750	$3,875,052	$0	$36,038,399	$0	$3,875,052	9.3
9	7000	$4.30		865,555	$3,721,887	$218,750	$3,940,637	$0	$18,793,214	$0	$3,940,637	4.8
10A	3000	$4.66		337,624	$1,573,328	$93,750	$1,667,078	$0	$8,394,110	$0	$1,667,078	5.0
10B	3000		$8.07	387,390	$3,126,237	$235,715	$3,361,952	$0	$11,853,882	$0	$3,361,952	3.5
11	5000		$8.29	530,322	$4,396,369	$392,860	$4,789,229	$0	$13,258,858	$0	$4,789,229	2.8
12	6000		$8.60	582,289	$5,007,685	$471,425	$5,479,110	$0	$6,354,294	$0	$5,479,110	1.2
Total	70000			6,300,000	$28,356,019	$2,850,000	$31,206,019	$22,631,855	$118,164,190	$8,173,612	$39,379,631	3.0

Potential Emergency Costs and Other Damages.

In this analysis, emergency costs prevented refer to expected annual expenditures that residents and governments are experiencing under the without project condition that the Section 933 Project would preclude. Other damages prevented include storm damages that are not covered under the National Flood Insurance Program, but represent financial drains on public and private storm victims that a large beach nourishment project could prevent. The categories lumped into this benefit called emergency costs and other damages prevented include (1) beach scraping/pushing; (2) sandbagging: (3) emergency costs incurred by the North Carolina Department of Transportation; (4) damages to public property; (5) damages to private property other than structures and contents; and, (6) post-storm recovery expenses. the difference in expected annual totals of emergency costs and other damages attributable to the existing condition, the Base Disposal Plan, and the Section 933 Project are displayed by towns in table 7. These are based on actual FEMA damage survey reports submitted by the towns following the recent hurricanes in North Carolina.

TABLE 7
Expected Annual Emergency Costs and Other Damages by Town

TOWN	Existing	BD Plan	933 Project
Fort Macon	$0	$0	$0
Atlantic Beach	$94,000	$10,000	$10,000
Pine Knoll Shores	$90,000	$90,000	$10,000
Indian Beach	$50,000	$50,000	$8,000
TOTAL (Residual)	$234,000	$150,000	$28,000

These emergency costs and other damage reduction benefits do not amount to much, largely because Bogue Banks has luckily dodged most of the recent North Carolina hurricane landfalls. However, these expenses are included in an effort to identify all potential damage reduction benefits.

Emergency Costs and Other Damages Reduction Benefits.

Just as with hurricane and storm damage reduction benefits, expected annual emergency costs and other damages reduction benefits over the Section 933 Study Area (i.e., Pine Knoll Shores and Indian Beach) amount to the difference between damages under the Section 933 Project and the Base Disposal (BD) Plan as shown in table 8. This amounts to expected annual emergency costs and other damage reduction (EC) benefits of $122,000 (($90,000 - $10,000) + ($50,000 - $8,000)). For these benefits, there are no benefits foregone.

TABLE 8
Emergency Costs and Other Damages Reduction Benefits

	Expected Annual EC Damages			Expected Annual EC Benefits
TOWN	Existing	BD Plan	933 Plan	933 Plan
Pine Knoll Shores	$90,000	$90,000	$10,000	$80,000
Indian Beach	$50,000	$50,000	$8,000	$42,000
TOTAL	$140,000	$140,000	$18,000	$122,000

Recreation Benefit Analysis.

The existing recreation demand for beach activities along Bogue Banks is generated primarily by seasonal residents and visitors in the area, who either own a second home or occupy rental units. As erosion threatens the homes and motels in these beach communities, it also threatens the recreation opportunities enjoyed by owners and seasonal visitors to the beach. Erosion in the last several years has severely narrowed the beach at Pine Knoll Shores and Indian Beach. This problem is expected to continue in the absence of a Federal beach fill project for these two towns. The Section 933 recreation analysis will compare the overall value of recreational experiences of continuing with the Base Disposal Plan versus the overall value of recreation experiences if the Section 933 Project were implemented.

The value of any improvement in the quality of recreation experience along these beaches will be analyzed using the unit-day value method. The unit-day method assigns a point value to various aspects of the recreation experience to determine the change in recreation values as a result of a project. Recreational values for the without project condition reflect a narrow, eroded beach having a pronounced escarpment and little width for picnicking, fishing, playing beach games, and sunbathing. The beach will likely be especially narrow or nonexistent at high tide.

One would expect recreation in the area protected by the Section 933 Project would have better recreation opportunities and a higher experience value for the new section of beach being nourished. The Section 933 Project would provide a berm of adequate width to accommodate the peak seasonal use expected by the towns of Pine Knoll Shores and Indian Beach. The recreational experience under this project condition would provide excellent conditions for swimming, fishing, sunbathing, walking, beach games, and other recreational activities. Recreation benefits for the plan of improvement are the difference in the value of a recreation experience per user day with the project and without it, times the estimated annual beach visitation for each town. Converting the point values to FY2002 unit-day values, and multiplying by the effected visitation will yield the recreation benefit attributable to the plan. A recreation benefits foregone adjustment may prove necessary if it is determined that Atlantic Beach and Fort Macon would suffer a decline in unit-day value if Section 933 Project were implemented.

The procedure used to estimate recreation benefits for the Section 933 analysis is explained in the following four steps. First, the maximum daily visitation for each town is estimated. With no pre-existing visitation estimates of Carteret County beaches use, the projected maximum daily visitation is based on filling all of the dwellings available to the beach users. This is accomplished in table 9.

TABLE 9
Estimate of Daily Peak Visitation by Town

Type of Accomodations	Ave.No.People per Unit	Pine Knoll Shores: Number of Units	Pine Knoll Shores: Estimated Peak Visitation	Indian Beach: Number of Units	Indian Beach: Estimated Peak Visitation	Salter Path: Number of Units	Salter Path: Estimated Peak Visitation
Single Family Houses	5	950	4750	64	320	135	675
Mobile Homes	3.5	0	0	0	0	9	31.5
Multi-Family Houses	12	8	96	0	0	0	0
Condos / Apartments	4	982	3928	345	1380	51	204
Motel/Hotel Rooms	4	650	2600	0	0	32	128
RVs/Tent Spaces	3.5	0	0	424	1484	0	0
Day Use (Public Parking)	2	195	975	56	280	75	375
Total Estimated Peak Visitation			12,349		3,464		1,414
Rounded to			12,300		3,500		1,400

Assumptions: New public parking added at PKS & IB;
Average number of people/unit is consistent with Land Use Plan;
Calculations for day use include a turnover factor of 2.5 for each parking space.

Second, this maximum daily visitation is used only for July 4, traditionally the heaviest beach usage day of the year. Therefore, the rest of the beach season must be defined and daily visitation adjusted for weather and occupancy rates. The bottom line is the estimated annual beach visitation for each town as shown in table 10. The seasonal factor in table 10 is based on Carteret County's monthly occupancy rates.

TABLE 10

Weighted Annual Visitation by Town

Month	Type	No. of Days	Seasonal Factor*	Visitation Factor	PKS	IB (w/SP)
Jan	Weekend	8	0.047	0.64	2,960	1,179
Feb	Weekend	8	0.0548	0.64	3,451	1,375
Mar	Weekday	21	0.0897	0.5	11,585	4,615
	Weekend	10	0.0897	0.64	7,061	2,813
Apr	Weekday	21	0.1832	0.5	23,660	9,426
	Weekend	8	0.1832	0.64	11,537	4,596
	Holiday	1	0.1832	0.64	1,442	575
May	Weekday	21	0.2846	0.5	36,756	14,643
	Weekend	9	0.2846	0.64	20,163	8,033
	Holiday	1	0.2846	0.64	2,240	893
Jun	Weekday	21	0.6517	0.5	84,167	33,530
	Weekend	9	0.6517	0.64	46,172	18,394
Jul	Weekday	22	1.00	0.5	135,300	53,900
	Weekend	8	1.00	0.64	62,976	25,088
	Holiday	1	1.00	1	**12,300**	**4,900**
Aug	Weekday	21	0.7346	0.5	94,874	37,795
	Weekend	10	0.7346	0.64	57,828	23,037
Sep	Weekday	21	0.284	0.5	36,679	14,612
	Weekend	8	0.284	0.64	17,885	7,125
	Holiday	1	0.284	0.64	2,236	891
Oct	Weekday	23	0.218	0.5	30,836	12,284
	Weekend	8	0.218	0.64	13,729	5,469
Nov	Weekday	19	0.1009	0.5	11,790	4,697
	Weekend	10	0.1009	0.64	7,943	3,164
	Holiday	1	0.1009	0.64	794	316
Dec	Weekend	8	0.0486	0.64	3,061	1,219
Total		299			739,425	294,568
Multiply by weather factor of .75					554,568	220,926
ANNUAL BEACH VISITATION, Rounded to					555,000	221,000

* Seasonal factor is based on Carteret County's monthly occupancy rates.

Next, the value of the recreation beach where it has changed is compared to the former value of the beach under without project conditions using the unit-day value method. The unit-day method assigns a point value to various aspects of the recreation experience to determine the change in recreation values as a result of the project. This is shown in table 11. With and without project beach profiles were generated for the purpose of assigning point values for the various quality categories in table 11. A beach width of 100 feet or greater is considered adequate to achieve the maximum allowable points that a wide beach would bring. That is, point changes are only taken for reaches of the beach that fall below 100 feet wide under the without project condition, and once the width is reestablished at 100 feet, points are maximized. In other words, a 150-foot wide beach is esthetically no more valuable than a 100-foot wide beach. The 30-foot wide berm to be constructed with the Section 933 Project will extend the beach fill seaward from the existing profile, with an elevation of 7 feet NGVD, approximately the elevation of the natural vegetation line along the Bogue Banks beaches. Berm width is measured seaward along the top of the berm from the point where the top of berm intersects the natural profile. Seaward of the designed berm width, the with-project profile parallels the existing profile out to the closure depth of –27 feet NGVD. This design will give the beach a much wider appearance than the 30-foot design width so that claiming maximum allowable points for a wide beach is a reasonable assumption.

TABLE 11
Unit-Day Value Point Assignment by Towns
(PKS = Pine Knoll Shores;
IB = Indian Beach including Salter Path)

Category	BDP		933 Project		Remarks
	PKS	IB	PKS	IB	
Recreation Experience	5	5	8	8	The natural, high foredune setting of Bogue Banks precludes overwash and the migration of beaches landward. For this reason, the without project condition would ultimately lead to a sharp interface between vertical, 25-foot high dune scarps and a small, almost non-existent beach platform. This would almost entirely preclude four wheel drive access, surf fishing, picnicking, sunbathing, launching small sailboats, accessing the ocean for swimming and surfing, and other recreational activities. The with project condition will allow numerous general activities.

Category	BDP		933 Project		Remarks
	PKS	IB	PKS	IB	
Availability of Opportunity	2	2	2	2	The beach towns are evaluated independently. However, there are only two bridges that connect the island to the mainland. If the beaches of Atlantic Beach were inaccessible, one would have to drive further west along Bogue Banks or drive to the Emerald Isle bridge. If all of Bogue Banks was inaccessible, then one could visit by boat to Shackleford Banks and Hammock's Beach, located to the east and west of Bogue Banks, respectively. By automobile only, the next accessible beaches are N. Topsail to the SW and Nags Head to the NE.
Carrying Capacity	5	5	8	8	Again, the natural, high foredune setting of Bogue Banks precludes overwash and the migration of beaches landward and had reduced the capacity of the beach under without project conditions. Under with project condtions, there would be plenty of capacity.
Accessibility	6	6	10	9	The roadway infrastructure for Bogue Banks is generally comprised of Hwy 58 that is situated along some the highest topography on the island. With few exceptions, the shore parallel and perpendicular roads seaward of Highway 58 should remain in good shape unless the frontal dune is completely compromised. Under with project conditions, additional public access and parking sites will improve assessibility.
Environmental Quality	5	5	11	10	The without project condition would lead to exposed septic tanks, broken stairs, and other debris along the beach. Also, the steep scarp with little or no beach would preclude turtle nesting activity, limit foraging bird activity, and would essentially represent a sharp line of submerged environments to maritime forest.
TOTAL	23	23	39	37	

Finally, the with and without project unit-day point difference is converted to dollars and multiplied by the annual beach visitation to arrive at a recreation benefit attributable to the total Section 933 Project. The total expected annual recreation benefit for all four areas for the Section 933 Project is $2,102,000, as shown in table 12. However, the additional recreation benefit above that of the Base Disposal Plan is $1,009,000.

TABLE 12
Expected Annual Recreation Benefits by Town

	Pine Knoll Shores	Indian Beach (w/SP)	TOTAL
Estimated Annual Beach Visitation	555,000	221,000	776,000
BDP (i.e., Existing Conditions) FY02 unit-day value points	23	23	
BDP FY02 unit-day value	$3.96	$3.96	
Expected Annual BDP value of recreation	$2,197,800	$875,160	$3,072,960
Section 933 Project FY02 unit-day value points	39	37	
Section 933 Project FY02 unit-day value	$5.32	$5.11	
Expected annual Section 933 Project value of recreation	$2,952,600	$1,129,310	$4,081,910
Expected Annual Recreation Benefit for Sec. 933 Project	$754,800	$254,150	$1,008,950

It is an important distinction that the recreation benefits for this project analysis stem from improving the quality of the recreation experience, not from drawing more people. In general, the supply of beach exceeds the demand for beach recreation along this 10-mile stretch of beach. The project would not be the draw; it merely enhances the experience for persons using the beach in the vicinity of their house or motel.

Because a beach width of 100 feet or greater is considered adequate to achieve the maximum allowable points and this width is achieved throughout Fort Macon and Atlantic Beach by both the Base Disposal Plan and Section 933 Project, there would be no benefits foregone attributable to recreation. In other words, the beneficial impact for recreation of either plan throughout Fort Macon and Atlantic Beach would be the same.

Benefits Foregone.

Benefits foregone were evaluated for the shoreline within the Base Disposal Plan (Fort Macon and Atlantic Beach) that would not receive the entire dredge disposal due to the proposed Section 933 Project. There are no benefits foregone related to emergency costs or recreation, only hurricane and storm damage reduction. As shown in table 6, the total expected annual benefits forgone are estimated at $705,400 (i.e., $8,173,612 in present value terms). This amount is added to the cost side of the Section 933 Project to account for the lower level of protection that the Base Disposal Plan would have offered Atlantic Beach and Fort Macon.

Benefits During Construction.

Benefits during construction (BDC) are those benefits that accrue to the project before its completion. In other words, as the beach fill is constructed, the benefits to the newly improved shoreline are essentially claimable from that time forward. In the case of the Section 933 Project, BDC begin accumulating as as the segments of the overall project are built. It is assumed that benefits accrue as expenditures for placement of the dredged material occur. The Section 933 Project is scheduled to be completed within 16 months. This monthly breakdown of the expected annual benefits is shown in table 13. Benefits foregone are subtracted from the total expected annual benefits before computing the monthly expected annual benefits (i.e., $8,367,000 / 12 = $697,250). Also, no recreation benefit is included in BDC since the esthetic quality of the beach would be questionable during construction. Therefore, the BDC are based on an expected annual benefit total of $8,367,000 ($8,950,000 (H&S Damage Reduction) + $122,000 (Emegency Costs Reduction) - $705,000 (Benefits Foregone)). As shown in table 14, BDC for the Section 933 Project amount to $574,000 on an annual basis.

TABLE 13

Computing Monthly Benfeits for Benefits During Construction

(5-7/8% Interest for 20 Years)

Period	Month	Monthly Expend. Pipeline*	Monthly Expend. Hopper*	Total Expend.*	% exp. = %benefits	Cumulative %	Monthly Benefits
1	N-03	$0				0.00%	$0
2	D-03	$2,035,686	$654,846	$2,690,532	9.49%	9.49%	$66,155
3	J-04	$2,035,686	$654,846	$2,690,532	9.49%	18.98%	$132,310
4	F-04	$2,035,686	$654,846	$2,690,532	9.49%	28.46%	$198,465
5	M-04	$2,035,686		$2,035,686	7.18%	35.64%	$248,518
6	A-04	$2,035,686		$2,035,686	7.18%	42.82%	$298,572
7	M-04	$2,035,686		$2,035,686	7.18%	50.00%	$348,625
8	J-04	$2,035,686		$2,035,686	7.18%	57.18%	$398,678
9	J-04	$2,035,686		$2,035,686	7.18%	64.36%	$448,732
10	A-04	$2,035,686		$2,035,686	7.18%	71.54%	$498,785
11	S-04	$2,035,686		$2,035,686	7.18%	78.71%	$548,839
12	O-04	$2,035,686		$2,035,686	7.18%	85.89%	$598,892
13	N-04	$2,035,686		$2,035,686	7.18%	93.07%	$648,946
14	D-04	$0	$654,846	$654,846	2.31%	95.38%	$665,047
15	J-05	$0	$654,846	$654,846	2.31%	97.69%	$681,149
16	F-05	$0	$654,846	$654,846	2.31%	100.00%	$697,250
Totals		$24,428,232	$3,929,076	$28,357,308	100.00%		
							$697,250

*Placement Costs Only--includes no Mob and Demob.

TABLE 14

Expected Annual Benefits During Construction

(5-7/8% Interest for 20 Years)

PERIOD	MONTH	MONTHLY BENEFITS	PERIODS	FACTOR	BDC
1	N-03	$0	15.5	1.078642	$0
2	D-03	$66,155	14.5	1.073387	$71,010
3	J-04	$132,310	13.5	1.068157	$141,328
4	F-04	$198,465	12.5	1.062953	$210,958
5	M-04	$248,518	11.5	1.057774	$262,876
6	A-04	$298,572	10.5	1.05262	$314,282
7	M-04	$348,625	9.5	1.047492	$365,182
8	J-04	$398,678	8.5	1.042388	$415,578
9	J-04	$448,732	7.5	1.03731	$465,474
10	A-04	$498,785	6.5	1.032256	$514,874
11	S-04	$548,839	5.5	1.027226	$563,782
12	O-04	$598,892	4.5	1.022222	$612,201
13	N-04	$648,946	3.5	1.017241	$660,134
14	D-04	$665,047	2.5	1.012285	$673,217
15	J-05	$681,149	1.5	1.007353	$686,157
16	F-05	$697,250	0.5	1.002445	$698,955
TOTAL					$6,656,008
				I&A	0.086302
ANNUAL	EXPECTED		BDC		$574,427

Economic Results

Benefit Summary.

Expected annual benefits for the Section 933 Project are summarized in table 15.

TABLE 15

Expected Annual Benefits

Hurricane and Storm Damage Reduction	$8,950,000
Emergency Costs and Other Damages Reduction	$122,000
Recreation	$1,009,000
Benefits During Construction	$574,000
TOTAL	$10,655,000

Cost Summary.

The first cost figures for the total Section 933 Project and the Base Disposal Plan are shown in table 16. The difference, or $16,354,000, is the amount that requires economic justification. Benefits forgone associated with the Base Disposal Plan will be added to the costs requiring economic justification during the computation of expected annual costs. The first costs for the Section 933 Project were computed using a construction schedule of 16 months and both pipeline and hopper dredges. This was determined to be the best way to balance costs, environmental resources, and to put the project in place quickly so that structures on the beach will not continue to be vulnerable to storm damages. These estimates of construction time periods become the basis for the Interest During Construction (IDC) calculations.

TABLE 16
First Cost Summary

Description	Sand Placement Location	Costs
TOTAL SECTION 933 PROJECT+ MODIFIED DISP PLAN:		
Mobilization & Demobilization		$2,850,000
Pumpout Brandt Island & Inner Harbor	Fort Macon & Atlantic Beach	$3,706,654
Pumpout Brandt Island, Inner Harbor, & Entrance Channel	AB, PKS, & IB	$24,654,870
Embankment Replacement		$500,000
Beach Tilling		$137,600
Planning Engineering & Design		$375,000
Construction Management		$100,000
SUBTOTAL before Contingencies		**$32,324,124**
Contingencies (10%)		$3,211,876
TOTAL Section 933 Project + Modified Disposal Plan		**$35,536,000**
BASE DISPOSAL PLAN:		
Mobilization & Demobilization		$1,750,000
Pumpout Brandt Island & Inner Harbor	Atlantic Beach and Fort Macon	$10,737,600
Mobilization & Demobilization		$250,000
Dredge Entrance Channel	Near Shore Disposal Area	$3,900,000
Embankment Replacement		$500,000
Beach Tilling		$130,400
Planning Engineering & Design		$120,000
Construction Management		$50,000
SUBTOTAL before Contingencies		**$17,438,000**
Contingencies (10%)		$1,744,000
TOTAL Base Disposal Plan		**$19,182,000**
SECTION 933 PROJECT (To Be Justified):		**$16,354,000**

Interest During Construction. The cost of tying up construction capital during a period of time in which no immediate benefits are produced is accounted for in table 17 as the item "interest during construction" (IDC). IDC costs are added to construction and other initial costs to determine investment costs. Average annual costs are determined based on investment costs which include IDC. IDC is based on $17,104,000, which includes the extra first costs ($16,354,000) and extra study costs ($750,000) associated with the Section 933 Project. The amount of IDC due to constructing the Section 933 Project instead of the Base Disposal Plan is $708,000, as shown in table 17.

Table 17
Interest During Construction

PROJECT: **Morehead City Harbor Section 933**
INTEREST RATE: 0.05875
NUMBER OF PERIODS: 38 MONTHS
NET CONSTRUCTION COST = $17,104,000
IDC= $708,081

PERIODS	MONTH	FACTOR	EXPENDITURE	PW AMT.
0.5	J-02	1.200989	$35,000	$42,035
1.5	F-02	1.195138	$35,000	$41,830
2.5	M-02	1.189316	$35,000	$41,626
3.5	A-02	1.183521	$35,000	$41,423
4.5	M-02	1.177755	$35,000	$41,221
5.5	J-02	1.172017	$35,000	$41,021
6.5	J-02	1.166307	$35,000	$40,821
7.5	A-02	1.160625	$35,000	$40,622
8.5	S-02	1.15497	$35,000	$40,424
9.5	O-02	1.149343	$35,000	$40,227
10.5	N-02	1.143744	$40,000	$45,750
11.5	D-02	1.138171	$20,000	$22,763
12.5	J-03	1.132626	$50,000	$56,631
13.5	F-03	1.127108	$50,000	$56,355
14.5	M-03	1.121617	$40,000	$44,865
15.5	A-03	1.116152	$40,000	$44,646
16.5	M-03	1.110715	$40,000	$44,429
17.5	J-03	1.105303	$40,000	$44,212
18.5	J-03	1.099918	$40,000	$43,997
19.5	A-03	1.094559	$10,000	$10,946
20.5	S-03	1.089227	$10,000	$10,892
21.5	O-03	1.08392	$20,000	$21,678
22.5	N-03	1.078639	$0	$0
23.5	D-03	1.073384	$580,000	$622,563
24.5	J-04	1.068155	$1,440,000	$1,538,143
25.5	F-04	1.062951	$1,440,000	$1,530,649
26.5	M-04	1.057772	$1,440,000	$1,523,192

	27.5	A-04	1.052618	$934,000	$983,146
	28.5	M-04	1.04749	$930,000	$974,166
	29.5	J-04	1.042387	$930,000	$969,420
	30.5	J-04	1.037308	$930,000	$964,697
	31.5	A-04	1.032255	$930,000	$959,997
	32.5	S-04	1.027225	$930,000	$955,320
	33.5	O-04	1.022221	$930,000	$950,665
	34.5	N-04	1.017241	$930,000	$946,034
	35.5	D-04	1.012285	$930,000	$941,425
	36.5	J-05	1.007353	$1,370,000	$1,380,073
	37.5	F-05	1.002445	$1,710,000	$1,714,181
total				$17,104,000	$17,812,081

Expected Annual Costs and Comparison of Benefits and Costs.

Table 18 shows the expected annual costs of the Section 933 Project that requires economic justification to be $2,178,000. When compared to expected annual benefits of $10,655,000, the result is a benefit-to-cost ratio of 4.9. This computation is based on an interest rate of 5-7/8 percent amortized over a 20-year period of analysis, and includes IDC and benefits foregone.

TABLE 18
Expected Annual Costs and Comparison of Benefits and Costs

Total Project Summary	**Total 933 Project**	**Base Disposal Plan**	**Difference to be Justified**
Total Initial Construction:	$36,927,000	$20,573,000	$16,354,000
Interest During Construction	$708,000	$0	$708,000
Total Investment Cost	$37,644,000	$20,573,000	$17,062,000
Expected Annual Cost:			
I&A-20 years			$1,473,000
Annual Benefits Foregone			$705,000
Total Expected Annual Cost			$2,208,000
Total Benefits:			$10,655,000
Net Benefits:			$8,477,000
Benefit-to-Cost Ratio:			4.9

Effectiveness of the Section 933 Project.

For the Section 933 Project study area, the effectiveness of the Section 933 Project at reducing hurricane and storm damages over Pine Knoll Shores and Indian Beach is about 62 percent (1 – ($5,593,000 / $14,543,000)). The residual expected annual damages along the Section 933 Study Area shoreline are estimated at $5,593,000. When the additional shorelines of Fort Macon and Atlantic Beach are considered with the Section 933 portion, the overall effectiveness of the beach fill from Fort Macon through Indian Beach goes to 54 percent (1 – ($8,801,000 / $18,999,000)). Either plan compares favorably to the Base Disposal Plan's effectiveness of only about 10 percent (1 – ($17,046,000 / $18,999,000)), which leaves about $17,046,000 in expected annual hurricane and storm damages. Again, this large difference is due to fact that the Section 933 Project addresses the areas where the damage potential is the greatest, namely, Pine Knoll Shores and Indian Beach.

Socioeconomic Conditions

Base Socioeconomic Conditions.

From 1990 to 2000, the population of Carteret County grew at a rate of 13% (i.e., 1990 population was 52,407 and 2000 population was 59,383) as shown in table 19. About 40 percent of the residents live in one of the county's municipalities. With its overwhelming economic emphasis on tourism, retail sales in Carteret County comprise the most important source of jobs and income for the county's economy. In 1993, total farm income for Carteret County was over 18 million dollars, with corn, soybeans, and tobacco the leading commodities. In 1995, the manufacturing sector employed about 10 percent of Carteret County workers.

The North Carolina Office of State Budget and Management estimates Carteret County's 1994 employment at 25,000, with about 35 percent in trade and 21 percent in Government employment. In 1997, per capita income in Carteret County was estimated at $21,624, somewhat higher than the North Carolina per capita income of $20,217.

The 1990's were a decade of rapid growth for the Carteret County beaches. The populations of the towns and Carteret County since 1990 are shown below. The total permanent population for the three principal towns in 2000 is estimated at 3,400. However, peak daily population in the summer can swell to more than 160,000 for the entire county.

TABLE 19
Population Statistics
Carteret County, North Carolina

Town/County	1990 Population	2000 Population
Atlantic Beach	720	789
Pine Knoll Shores	1,360	1,524
Indian Beach	153	95
Morehead City	6,046	7,691
Carteret County	52,407	59,383

Projected Socioeconomic Conditions.

Carteret County population projections for 2000 – 2020 are shown below in table 20.

TABLE 20
Population Projections
Carteret County, North Carolina

County	2005 Population	2010 Population	2020 Population
Carteret	65,633	69,358	76,341

Source: Office of State Planning, State of North Carolina.

In the summer months, a large portion of the homes along Bogue Banks are available as summer rentals to vacationers. Almost 2 million people, including those residing in the Research Triangle area of North Carolina, live within a two-hour drive of these beaches. During the summer months, the population of Carteret County is estimated to exceed 160,000 people. In the off-season months, it drops to 59,000, which includes about 789 permanent residents in Atlantic Beach (2000), 1,524 in Pine Knoll Shores, 95 in Indian Beach and 7,691 in Morehead City.

MOREHEAD CITY HARBOR
CARTERET COUNTY, NORTH CAROLINA
SECTION 933
EVALUATION REPORT

APPENDIX E

BEACH ACCESS/PARKING ANALYSIS AND REQUIREMENTS

APPENDIX E
BEACH ACCESS/PARKING ANALYSIS AND REQUIREMENTS

The construction of a Section 933 project is dependent in part upon the sponsor fulfilling the requirements as outlined in the "933 PROJECT REQUIREMENTS" section of the report. The stipulations (ER 1165-2-130, 15 June 1989, and ER 1105-2-100, 22 April 2000) that the beaches receiving the material must be open to the public and provide reasonable access has been carefully scrutinized. The Corps' regulations require that in order to be deemed "public" beaches, the sponsor must provide public access points every one-half mile with sufficient public parking within one-quarter mile. The regulations also refer to sufficient parking in terms of accommodating "projected use demands," and are further defined as sufficient to accommodate the lesser of the peak hour demand or the beach capacity. Finally, in computing parking requirements, the number of beach users not requiring parking is to be deducted from the design figure.

Beach Capacity vs. Peak Hour Demand

A determination was made that the maximum capacity of the 933 project area is significantly greater than the peak hour demand, which is assumed to be equivalent to peak hour usage, therefore peak hour usage was used to determine parking requirements. The following outlines the process and assumptions used to come to this conclusion.

This analysis assumes that visitors will each require 100 square feet of beach per visit. Because some visitors spend only part of the day at the beach, a turnover rate of 2 visitors per day per 100 square feet of beach is used as an adjustment. The smallest alternative project design considered proposes a 25-foot berm, resulting in 145 feet width of usable beach. Using this most conservative design template, the maximum project area would include 38,000 feet of shoreline of Indian Beach, Salter Path and Pine Knoll Shores. This would result in 5,510,000 square feet with an instantaneous capacity of 55,100, and using a turnover rate of 2, a maximum daily beach capacity of 110,200. This number is considered a conservative estimate because the other alternative design templates evaluated would result in an even larger beach capacity.

In an effort to ascertain data on peak hour usage, aerial photos were taken of the 933 project area between 11:15 and 11:40 a.m., EDT, on July 4, 2002. The aerial photos showed 828 people on the beaches of Pine Knoll Shores and 395 people on Indian Beach. The photos also identified tents and umbrellas on the beach; however, we were not able to discern whether an individual was underneath either of these items. Therefore, we made the assumption that there was an average of two (2) people under each tent, and an average of 1.5 persons under each umbrella. These additional numbers resulted in an adjusted peak hour usage total of 1,255 people on the beach within the Town of Pine Knoll

Shores and 760 people on Indian Beach and Salter Path beaches.

The 4th of July is assumed to be the peak day of the year for visitors on beaches. However, because the 4th of July fell on a Thursday, the peak hour usage was perhaps not accurately reflected, assuming that a higher number of visitors would have been present if the holiday had fallen on a weekend. Therefore, the numbers were adjusted accordingly. An increase of 14.2% was used as the adjustment. This adjustment was calculated to be the average percent difference in the volume of traffic crossing the Emerald Isle and Atlantic Bridges on Friday, July 5th, compared to Thursday, July 4th. The traffic survey data was provided by the Department of Transportation. Using the 14.2% adjustment the Pine Knoll Shores beaches would have had a peak hour usage of 1,433 and Indian Beach and Salter Path would have 868.

The projected growth rate of the peak hour usage over the life of the project was determined using the State of North Carolina Demographics Office data that projects a North Carolina average annual growth rate of 1.8% between 2000 and 2010. This rate was thus adopted as the project annual growth rate for the peak hour usage over the 10-year life span of the project with a base year of 2004 and continuing through 2014. The projected peak hour beach use demands for 2014 will therefore become 1,760 for Pine Knoll Shores and 1,075 for Indian Beach.

Table 1.

Beach Usage				
	# of People in Photos	*# Adjusted For Tents/Umbrellas.*	*Total # visitors on beach (14% Ad.j)*	*Yr 2014 Peak Hr. Beach Use*
PKS	828	1255	1433	1760
IB	395	760	868	1075

The capacity and usage of existing public parking for the 933 project area was evaluated using the 4 July 2002 aerial photography. The Town of Pine Knoll Shores had a total of 60 public parking spaces within one-quarter mile of the Iron Steamer public beach access while Indian Beach and Salter Path had a total of 111 at their two public beach access sites. The aerial photos indicated 22 of the 60 parking spaces available were filled in Pine Knoll Shores and 37 of the 111 parking spaces were occupied in Indian Beach.

Assuming that the number of parking spaces utilized would have also increased if the holiday had fallen on a Saturday, the number of parking spaces utilized was also adjusted by the 14.2% used previously. This results in an adjusted usage of 25 spaces for Pine Knoll Shores and 42 for Indian Beach. Assuming 2 persons per car, Pine Knoll Shores had a peak hour usage (peak hour demand), by those requiring parking, of 50 persons, and Indian Beach had 84 (Table 2). Dividing the peak hour usage for these visitors by the total number of visitors calculated from above (1,433 for Pine Knoll Shores and 868 for Indian Beach) leads to an estimate of 3.5% for Pine Knoll Shores and 9.7% for Indian Beach as the percentage of visitors that are considered "day-users" of the beach. These are the visitors that require public parking in order to access the beach (Table 3).

Table 2.

July 4th Parking				
	Spaces Available on July 4th	*# of Spaces Occupied on 4th*	*14% Weekend Adjustment*	*Peak Hour Demand (2/car)*
PKS	60	22	25	50
IB	111	37	42	84

Table 3.

Day Users on July 4th		
	Peak Hr Usage/Total # Visitors	*% Day Users*
PKS	50/1433	3.5%
IB	84/868	9.7%

Since these photos were taken an additional 130 spaces have been added to Pine Knoll Shores for a total of 190 spaces. An average of 2 persons per car on the peak day was assumed for the public parking spaces. Therefore, the current public parking provides a maximum capacity, at any one point in time, for 380 persons for Pine Knoll Shores and 222 persons for Indian Beach. These capacities clearly meet the criteria for providing adequate parking for the current demand (Table 4).

Table 4.

2002 Parking Analysis				
	Current # of Spaces Available	*Peak Hour Capacity (2/car)*	*Peak Hour Demand (2/car)*	*# of Spaces Req'd in Yr 2002*
PKS	190	380	50	25
IB	111	222	84	42

By projecting the current peak hour demands through the project life by the same 1.8% annually, the demand for Pine Knoll Shores grows to 62 persons and Indian Beach grows to 104, leading to requirements of 31 spaces for Pine Knoll Shores and 52 spaces for Indian Beach (Table 5). The Corps requires parking to be associated with public access sites. The parking must be within one-quarter mile of the access site and must be of sufficient quantity to meet the projected use demands, based on peak hour usage. Therefore, using the current data available, existing parking (Pine Knoll Shores = 190 spaces, Indian Beach = 111 spaces) currently meets the projected use demands (Pine Knoll Shores = 31 spaces, Indian Beach = 52 spaces).

Table 5.

2014 Parking Analysis				
	2002 Peak Hour Demand	*# of Spaces Req'd in Yr 2002*	*2014 Peak Hour Demand*	*# of Spaces Req'd in Yr 2014*
PKS	50	25	62	31
IB	84	42	104	52

An alternative assessment, although admittedly simplistic, can be done by observing the percentage of spaces not occupied at the "peak hour" (63% for Pine Knoll Shores, and 67% for Indian Beach) and the conclusion made that because there were unoccupied parking spaces (more supply than peak usage) at that time, the parking for the project areas meets peak capacity requirements.

However, it is important to keep in mind that meeting peak hour capacity does not alleviate the sponsor's obligation to provide parking within one-quarter mile of each access site. The details of which are discussed under the "Parking Criteria" section following below.

NOTE *In determining the peak hour demand for Pine Knoll Shores it became apparent that the aerial photography may not accurately represent the true demand for parking at Pine Knoll Shores. This is due to several factors. The first being that none of the parking spaces currently claimed by Pine Knoll Shores were available on the 4^{th} of July except for the Iron Steamer's 60 spaces. Since additional spaces have been added, the measurement made is already dated since increased supply will ultimately lead to increased demand and usage.*

Furthermore, the Iron Steamer's 60 spaces were unavailable during the construction of the private beach nourishment project, and had only been reopened to the public within a month of the 4^{th} of July. Therefore, for many months prior to the photographs, there effectively was no public parking (per Corps' definitions) available, and therefore, with no "supply" available, the usage would have similarly decreased. It is assumed that a majority of the public was still unaware of the opening of the Iron Steamer and therefore would not have made the effort to seek out this parking option.

Additionally, the percentage of Pine Knoll Shores "day-users" calculated using the data from these photographs resulted in a number significantly lower than what the Corps' has traditionally found to be the average for beach studies. Indian Beach was in the range that the Corps would expect (9.7%), as was Emerald Isle (15.0%) and Atlantic Beach (13.8%), whereas Pine Knoll Shores was at 3.5%.

And finally, Pine Knoll Shore's 1996 Land Use Plan, developed as required by the North Carolina Coastal Area Management Act (CAMA), estimates their peak day, day-visitor populations to be in excess of 50,000 persons, as estimated by the Pine Knoll Shores Police Department. It was noted in the 1996 Land Use Plan that the average daily traffic count (ADT) west of the Atlantic Beach Bridge in 1994 was 23,300 automobiles. If one automobile averages two persons, 46,600 persons would have entered Bogue Banks heading west on N.C. 58. It was assumed in the 1996 Land Use Plan that a considerable amount of this traffic enters Pine Knoll Shores on a daily basis. However, such a huge discrepancy between the Corps' findings and the Town's estimates leads to a *question of the validity of the numbers.*

Parking Analysis Methodology

Parking is a component of the recreation analysis, which uses the Unit Day Value (UDV) evaluation method to generate recreation benefits. This is discussed in further detail in the recreation analyses section within the economic analysis (see Appendix D) .

According to ER 1105-2-100, the estimation of visitation must be based on data, either at the existing project or by comparisons with other similar resources. Because the study area has recently completed a project very similar in nature to the one that is being proposed, it was deemed appropriate to look at the visitation on the existing area as the basis of our estimations.

The determination of peak hour demand ideally would involve gathering survey data from visitors on the beach. This would more closely identify the number and percentage of permanent residents, short-term renters, hotel guests, campers, and day users and their requirements (demands) for parking and access. The survey would also attempt to measure the demand not only from those at the beach, but those who would have come to the beach but did not do so based on a perceived parking availability problem. This type of survey requires peak day/peak hour data collection, and therefore will not be able to be conducted for this study. Therefore this report's findings will be used to assess the adequacy of parking.

Access and Parking Requirements

Sponsors must comply with the Section 933 requirements as outlined in Section I of the attached report as well those requirements detailed below:

1. For those areas to be included as part of the project, access must be provided a minimum of every one-half mile or either an item of local cooperation specifying such a requirement and public use throughout the period of analysis of the project must be included in the project recommendations, or the cost sharing must be based on private use (the sponsor must pay 100%).

2. Access every one-half mile implies parking and parking must be within one-quarter mile of any access site for which the sponsor wishes to take credit.

3. Sufficient parking must be provided to accommodate the lesser of beach capacity or peak hour demand. Peak hour demand will be calculated and separately applied to each Town, City, Village, etc., within the project area. If the project area does not include the entire limits of a Town, for example, only that portion which will receive the project will need to be included in the calculation. For example, if a Town is 6 miles long and the entire Town will be included in the

project, then the peak hour demand will be measured for the entire 6 miles. If, however, only 4 of the 6 miles of the Town will be included in the project, only the 4 miles need be considered in determining peak hour demand. The development of the peak hour demand will be conducted by the Corps of Engineers.

4. Because Federal investment is distributed throughout the 933 project area, the number of parking spaces must similarly be reasonably distributed. The following guidelines will be followed which are intended to provide the sponsor flexibility in their planning efforts to best fit the needs of their communities' unique situations, while ensuring that the general public is provided complete access to the beaches that have been nourished using Federal funds.

A. A percentage of the peak hour demand shall be distributed throughout the area from which it was calculated (see #3). This percentage will be determined by the length of the project. Every two (2) miles of the area shall contain the same percentage of the total peak hour demand. For example, a project area ten miles long, with a peak hour demand of 250 parking spaces would require a minimum of 20% of these spaces (50) to be located within each 2 miles of the project area. Two miles was selected as a criteria both because Corps' beach renourishment projects are typically not undertaken for projects under two miles in length, and also because no Town, City, etc., along the North Carolina barrier islands is less than two miles (Indian Beach/Salter Path was considered one "town").

B. A minimum of ten parking spaces must be associated with every access site claimed. The average area of a residential, ocean-front lot, within North Carolina would accommodate this minimum of ten parking spaces. In order to meet the spirit of the regulations to provide public access to those beaches receiving Federal funding for a Section 933 project, it was decided that the sponsor should provide this minimum.

5. The sponsor will be held responsible for the number of parking spaces committed to over the period of analysis of the project. If, for whatever reason, the parking spaces are no longer made available to the general public on an equal basis during the period of analysis of the project, the sponsor will be responsible for ensuring that the Corps parking criteria are still met. Failure to do so would result in sections of the project reverting to private beach status and therefore those sections in non-compliance would no longer qualify for Federal cost sharing.

6. The sponsor may also choose to provide public transportation to other beach access sites that do not meet the minimum requirement of 10 parking spaces. The intent of the Corps' criteria is to ensure access to the public on an equal basis for those sections of beach receiving Federal cost sharing. If a transportation option is chosen by the sponsor for certain sections of the beach, this intent must still be met by some combination of parking and transportation.

For example the plan would have to ensure that access is provided year-round and accommodates demand. The details outlining the specifics of what exactly the sponsor would commit to providing must be documented in an overall beach access and parking plan for the project which must be submitted and approved by the Corps of Engineers.

7. Handicap access and parking must be considered and implemented as required by State and Federal regulations. Section 504 of the Rehabilitation Act and the Architectural and Transportation Barriers Act ensure reasonable accommodation and accessibility for all individuals with disabilities to properties and programs that receive or benefit from Federal financial assistance.

8. Parking and access commitments made to meet the above criteria must either be in place, or be incorporated as a condition of the Project Cooperation Agreement (PCA). These commitments must be fulfilled prior to construction. Requests for exceptions to these criteria must be formally submitted to the project manager along with a detailed description of the situation and reasons why the exception is being sought.

Existing and Proposed Parking and Access Sites

The current and proposed future access/parking sites in the Section 933 project area are depicted in the sponsor's public beach access plan (Appendix E-9 - Exhibit 1). There are currently 8 public access sites and 301 public parking spaces within the project area. These sites are depicted in blue on the sponsor's map. The sponsor has committed to providing 8 additional access sites for a total of 16 access sites in the project area. These proposed access sites are depicted in red on the sponsor's map. Access sites are to be acquired in fee or as perpetual easements.

Some access sites will not have the minimum required number of parking spaces associated with them as the sponsor intends to provide public transportation as an alternative to parking for these access sites. This is an acceptable option as mentioned in #6 above. In addition, the Corps will accept an alternative plan that would provide a minimum of two parking spaces for those access sites that currently have no parking available, in lieu of a transportation plan. This would only apply to the "off-peak" season (November 1 – March 31). This modification to the requirements was determined to be acceptable due to a significant decrease in demand during the off-peak season of 82%. A similar decrease of 80% of the required 10 parking spaces was deemed reasonable during this time period.

The details of the sponsor's proposed public transportation strategy are outlined in their plan. The plan as currently proposed is acceptable to the Corps. Any changes to this plan or any new issues will need to be resolved prior to signing of the Project Cooperation Agreement. The Corps understands that the sponsor is adopting the public transportation strategy as an interim solution to their parking issues and will be actively working to replace the transportation system through the acquisition of additional parking.

The sponsor's current access and parking plan meets the Corps' parking and access criteria as previously detailed. A small section of Indian Beach fell outside of the requirements for access, but was granted an exception due to environmental considerations (See Appendix E – Exhibit 2) and therefore will be cost shared 65% Federal, 35% non-Federal.

Cost Sharing Percentage

Cost sharing of the portion of the project cost above the cost of the base disposal plan can be approved at the following percentages:

1) Those sections of the project area, which fully comply with Section 933 requirements are referred to as public shores and are cost shared 65% Federal, 35% non-Federal sponsor for the amount above the base disposal plan.

2) Those sections of the project area that do not meet all Section 933 requirements, are not eligible for Federal cost sharing and are referred to as private shores. Placement of dredged material at these locations may only take place at 100% sponsor funding and must meet the requirements as described in Section I of the attached report. Currently the westernmost 1900 feet of Indian Beach (Station 700+00 to Station 681+00) does not meet the access criteria. The local sponsor acknowledges this deficiency and does not intend to pursue the option of 100% sponsor funding for this area at this time. This decision effectively reduces the current 933 Project Area from 7.2 miles to approximately 6.8 miles. If the access and parking criteria are met prior to the signing of the PCA, this area could be increased to its full potential of 7.2 miles.

The current beach access and parking plan proposed by the sponsor (see Exhibit 1) would result in the following cost sharing percentages for the Recommended Plan.

Federal Cost Sharing
933 Project Area (6.8 miles)

Federal Share:

Public Shores	6.8 miles/6.8 miles	x	65%	= 65.0%
Private Shores	0.0 miles/6.8 miles	x	0%	= 0.0%
Total Federal Share:				= 65.0%

Sponsor Share:

Public Shores	6.8 miles/6.8 miles x 35%	= 35.0%
Private Shores	0.0 miles/6.8 miles x 100%	= 0.0%
Total Sponsor Share:		= 35.0%

These values are based on sponsor-provided measurements and will be subject to change if more, less, or different access sites are decided upon prior to signing of the Project Cooperation Agreement. Once all access and/or parking sites are obtained by the sponsor, and prior to signing the PCA, the Corps will gather more specific measurements using GIS and or survey data of these sites to make a final determination on project cost sharing.

CARTERET COUNTY
SHORE PROTECTION OFFICE

EXHIBIT 1

PUBLIC TRANSPORTATION AND PARKING/ACCESS PLAN
SECTION 933 PROJECT

Objective

The volume of accesses and parking facilities located along Bogue Banks meet the peak hour demand for beach visitation in accordance with the U.S. Army Corps of Engineers (USACE) Engineering Regulations 1105-2-100 and 1165-2-130. The non-federal sponsor fully intends to provide additional points of access, and to fulfill parking stipulations delineated in these regulations by employing a method of public transportation that will be used in consort with permanent parking facilities. By providing additional accesses and adequate parking accommodations, public use will be provided on equal terms for all beach visitors and therefore, the public shall be able to access all portions of the beach that encompass the Section 933 Project area. Based on the coverage described below, full federal cost share participation should be recommended for the entire proposed Section 933 Project reach.

Current and Proposed Facilities

Detailed maps of Indian Beach (IB) and Pine Knoll Shores (PKS) are enclosed as Figures 1 and 2, respectively. The Shore Protection Office and IB are in the process of securing the Ocean Club and Sea Isle Plantation-west accesses that will have associated parking located north of Highway 58 and within 0.25-mile of each respective access point. The IB and Salter Path accesses have 36 and 75 parking spaces, respectively. One issue that will require clarification is the USACE's access/parking position for the State-owned property in Salter Path. This oceanfront reach is a natural area with a central access accompanied by the 75 parking spaces referenced above. Because the oceanfront encompassed by the park is an undisturbed natural area for public use, the entire reach of the project for the State-owned property should receive full federal cost share funding. Moreover, the entire park should be considered as an "access" because the oceanfront is essentially owned by all of the public and residents of North Carolina. Therefore, the adjacent access points that are required per ER 1105-2-100 and 1165-2-130 shall be from the easternmost and westernmost boundaries of the State-owned park.

PKS has six accesses with associated parking that are denoted in Fig. 2. The access at the Sheraton borders the towns of PKS and Atlantic Beach, and parking is located within the Sheraton parking lot that is technically within the town limits of Atlantic Beach. The Shore Protection Office and PKS are also in the process of securing six additional accesses within Pine Knoll Shores that will not have associated parking, but will be served by a public transportation system. The distances between access sites (from east to west) is listed in Table 1.

Table 1
Distances Between Public Access Sites

Public Access	**Distance Between Access Points (E to W) in miles**
Sheraton	0.00
Ameri-Suites	0.36
Hammer Park	0.51
PIKSCO	0.50
PKSA	0.26
Ocean Terrace	0.55
Iron Steamer	0.50
Maritime West	0.50
Ramada	0.50
Beacon’s Reach (E)	0.18
Beacon’s Reach (W)	0.49
Trinity Center	0.47
Sea Isle Plantation (W)	0.35
Salter Path	0.57
Indian Beach	0.58
Ocean Club	0.40

The exact locations of proposed areas of access/parking and details concerning the public transportation system may be slightly modified before the non-federal sponsor enters into the Project Cooperation Agreement. However, it is the non-federal sponsor’s intention to meet the access/parking stipulations in full prior to signing the PCA

Pine Knoll Shores Public Transportation Plan

The public transportation system will utilize a contracted shuttle service to ferry visitors to all of the accesses in the Pine Knoll Shores project area. The cost of the shuttle service shall be paid by the non-federal sponsor and will operate on a regular schedule delineated as follows.

Peak Season (April 1 – November 1):

Hours:	8:00am to 6:00pm, 7 days a week
Frequency:	The shuttle will provide access to each access site every 30 minutes.
Vehicle:	12+ person, handicap-accessible van/bus with capability to accommodate beach umbrellas, fishing gear, etc.
Signage:	Signs at each access site will clearly define the times that the shuttle is expected to stop at that location. They will also highlight the fact that the service is being provided free of charge, and provide specifics as to what the shuttle can accommodate in regards to number of people and types of beach supplies. A phone number for the shuttle will also be included on the sign for any extraordinary circumstances.

Off-Peak Season (November 1 – March 31):

Hours:	8:00am to 6:00pm, 7 days a week
Frequency:	Shuttle will be available on an on-call basis only. Shuttle will arrive within 15 minutes of contacting shuttle service.
Vehicle:	Handicap-accessible vehicle capable of accommodating fishing gear, surf boards, etc.
Signage:	Signs at each access site will clearly define the number to contact the shuttle, what times the shuttle is available, what the shuttle can accommodate in regards to number of people and types of beach supplies, how long they should expect to wait, and any costs that will be associated with the service.

The time period selected to represent the "peak season" is substantiated by reviewing the occupancy tax collections for the past 10 years (Fig. 3). Analyses of occupancy tax collections provide a good proxy of beach visitation trends throughout the year

Monitoring/Adaptation of Transportation Plan

The non-Federal sponsor will monitor both the use of their public transportation system, as well as the amount of usage at their public parking facilities. A report of this data will be transmitted to the Corps of Engineers on an annual basis. The data will be analyzed by the Corps of Engineers to determine if any modifications to the transportation plan are warranted. Any changes proposed by the non-Federal sponsor would require written request to be approved by the Corps of Engineers.

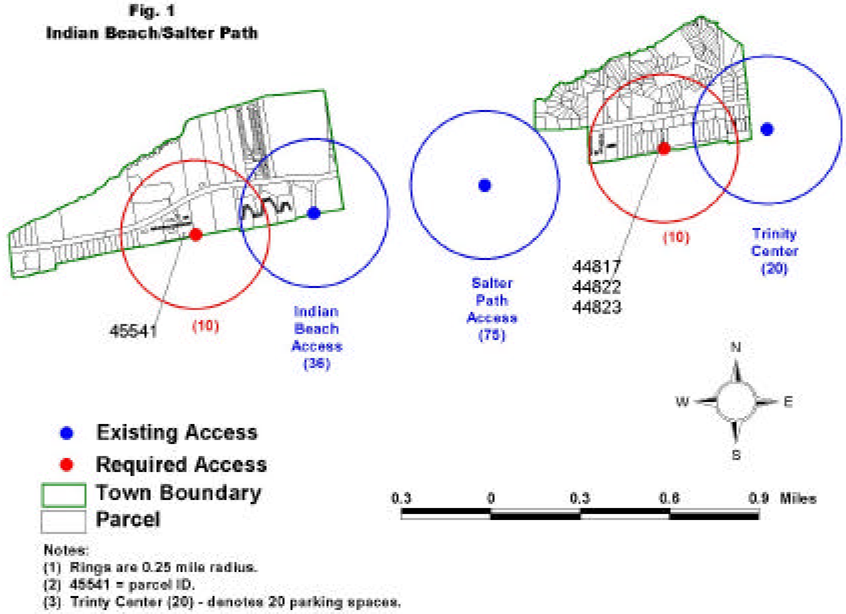
The non-Federal sponsor may decide in the future to incorporate additional parking at those access sites which currently have none. If two (2) or more parking spaces are included for each of those six access sites which currently have no parking, the Corps of Engineers has approved the off-peak portion of the transportation plan outlined above to be discontinued. The sponsor will notify the Corps of Engineers in writing of their intent to pursue this alternative prior to discontinuation of the off-peak shuttle service. If the sponsor provides the Corps' criteria of 10 parking spaces associated with each access, the entire transportation plan may be discontinued.

Public Awareness Plan

The sponsor intends to pursue several approaches to make the public aware of the public parking and access sites available as well as the details of the Pine Knoll Shores transportation plan. Those approaches include:

1. CAMA signs will be provided at each public access site. Signs will be posted on the main road (58) as well as at the access site itself if the site is off of the main road.
2. Large green signs at each access site where the shuttle will stop outlining those items discussed within the transportation plan.
3. Large public parking signs at each parking space or parking lot which will be included as part of the project.
4. Brochures will be developed outlining all of the parking sites, access sites, as well as outlining the specifics of the shuttle service. It may also serve as an education tool to inform the public about the project. These brochures will be placed at locations such as the Visitor Center, Town Hall, Hotels, and tourist attractions such as the PKS Aquarium.
5. The brochure material will also be placed on Pine Knoll Shores and Carteret County's websites.
6. The shuttle used during peak season will display signage to increase visibility of the program.

Fig. 1
Indian Beach/Salter Path



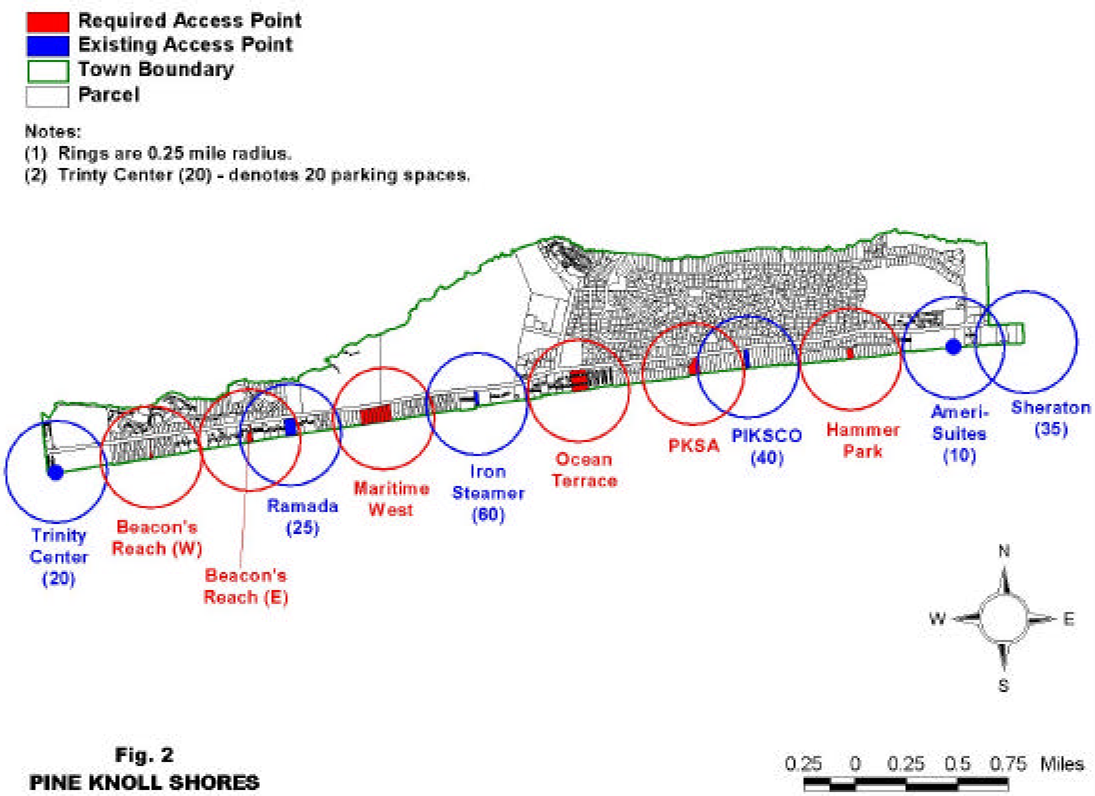


Fig. 2
PINE KNOLL SHORES

Fig. 3

Occupancy Tax Collections (1993-2002)

(collections prior to 2002 corrected to represent the current 5% rate)

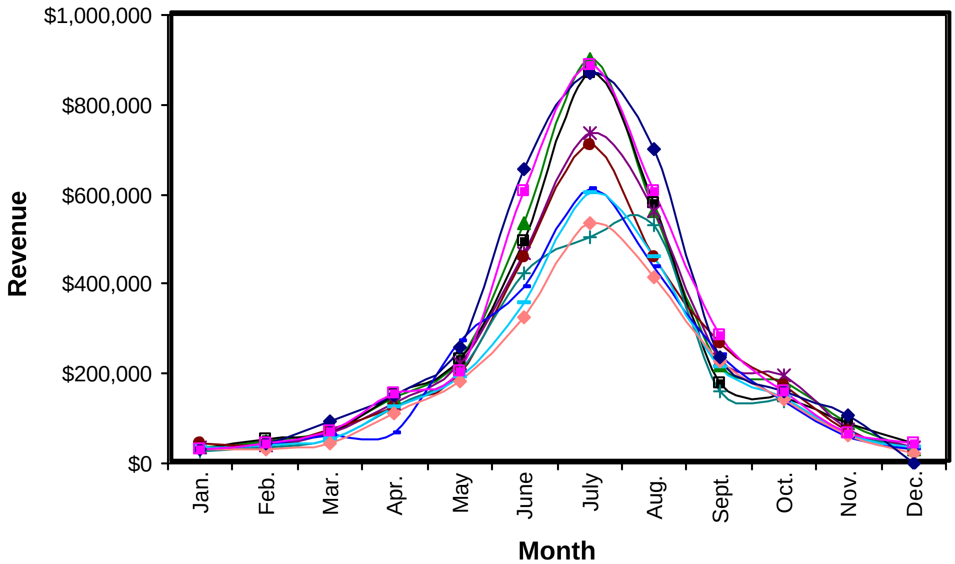


EXHIBIT 2

State Owned Property in Salter Path

Terms in Deed of Gift to North Carolina

STATE OF NORTH CAROLINA, COUNTY OF CARTERET
Book 439, Page 335

The deed of gift made the 3rd day of June 1980 states in part the following restrictions, which shall be binding upon the Grantee, its successors and assigns:

> "2. The property shall be maintained in its natural state insofar as possible.
>
> 3. The property shall be made available primarily for the purposes of scientific study and research, and secondarily for recreational purposes, but provided that these activities shall be conducted in such a fashion as to avoid significant damage to the topography or the flora and fauna of the property."

MOREHEAD CITY HARBOR
CARTERET COUNTY, NORTH CAROLINA
SECTION 933
EVALUATION REPORT

APPENDIX F

REAL ESTATE PLANAPPENDIX F
REAL ESTATE PLAN

1. THE REAL ESTATE REPORT

This report is tentative in nature and is to be used for planning purposes only. Although the report is written based on specific data from Wilmington District, some minor modifications to the plan may occur thus changing the final acquisition areas and/or administrative and land cost.

The Project Sponsor (PS) is Carteret County, in cooperation with the State of North Carolina.

The author of this report has inspected the Project areas.

2. AUTHORITY

This study was conducted under the authority of Section 145 of the Water Resources Development Act of 1976, P.L. 94-587, as amended by Section 933 of the Water Resources Development Act of 1986, P.L. 99-662, and other laws, 33 U.S.C. § 426j. Projects carried out under this authority are commonly referred to as "Section 933 projects."

3. PROJECT DESCRIPTION

The removal of fill materials from Brandt Island Disposal Area at Morehead City Harbor and the newly dredged material from the harbor is beneficial for use in nourishment of beach communities that have experienced severe storm damage and have erosion problems. In prior years, material removed from Brandt Island Disposal Area was placed along Fort Macon and Atlantic Beaches, a distance of approximately 32,000 feet, under authority of a previously approved project. This area is identified on exhibit A as the Least Cost Disposal Area.

The communities of Pine Knoll Shores, Indian Beach and Salter Path have suffered the effects of six named storms since 1996. These areas are being evaluated for eligibility under Section 933 and are shown on the attached exhibit A as the 933 Project area. The areas proposed for nourishment with cost sharing authority of Section 933 include approximately 25,000 feet along Pine Knoll Shores and 13,000 feet of Indian Beach (including Salter Path). Disposal of the material along this 38,000 feet reach would result in a beach fill with a minimum placement of 75 cubic yards per linear foot. Placement of fill will be to elevation 7 feet above mean sea level. This will be a one-time placement of sand with no periodic nourishment. The project will result in the reduction of erosion and substantially reduce the storm damage potential.

4. REAL ESTATE ACQUISITION

The requirements for lands, easements, rights-of-way and relocations, and disposal/borrow areas (LERRD's) will include the rights to place dredged material in a berm design to aid in the control of erosion over wash during storms. The placement of sand will be within the limits identified on exhibit "A" as the "933 Project Area." The project sponsor will be required to provide a Perpetual Beach Storm Damage Reduction Easement across properties that are located within the project area except for those lands that are below MHW. A copy of the Perpetual Beach Storm Damage Reduction Easement is attached as exhibit "B". A permit from the State of North Carolina is not required for placement of sand seaward of mean high water (MHW). However, the sponsor must provide a letter to the State notifying of the intent to place sand on land seaward of MHW. The material will be pumped through an existing perpetual pipeline easement acquired in 1993 for the Morehead City Harbor Improvement Project, Brandt Island to Atlantic Beach. Under the current project plans, no need for additional pipeline easements, temporary work area easements for staging or construction has been identified.

There are 259 tracts that are privately owned along the project area. Existing easements are in place that were acquired from the fee owners at no cost by the sponsor for a local, non-federally funded project. The easements incorporate the standard language in the Perpetual Beach Storm Damage Reduction Easement. A Gross Appraisal was not performed for this study, but historically appraisals for beach projects have estimated the easements to have zero value due to offsetting benefits.

After review of the existing easements, CESAS-RE has determined that if all sand is placed within the limits of the existing easement, no additional easements should be necessary. However, after completion of project design and surveys, should it be determined that sand will be placed outside the existing easement area, the PS will be responsible for providing any additional real estate interest required.

Access to the beach will be by public access points that are located along the beach area. Should the local sponsor be required to obtain additional public access areas, these areas should be acquired as easements for the term of years identified in the Project Cooperation Agreement (PCA) for which the local sponsor is responsible for providing public access for the project. Acquisition of public beach access is not considered a creditable expense towards project cost.

5. UTILITY RELOCATION

There will be no utility relocations.

6. EXISTING PROJECTS

The Morehead City Harbor Improvement Project, Brandt Island to Atlantic Beach, approved in 1986, is located east of the proposed project.

7. ENVIRONMENTAL IMPACTS

No adverse environmental impacts are expected.

8. PROJECT SPONSOR RESPONSIBILITES AND CAPABILITIES

Carteret County will be the Project Sponsors (PS). The PS has the responsibility to acquire all real estate interests required for the Project, should any additional real estate interest be identified. The PS shall accomplish all alterations and relocations of facilities, structures and improvements determined by the government to be necessary for construction of the Project.

Title will not be vested in the United States Government. The government will require access rights be provided by the PS for entry to the Project. Prior to advertisement of any construction contract, the PS shall furnish to the government an Authorization for Entry for Construction (Exhibit "C") to all lands, easements and rights-of-way, as necessary. The PS will also furnish to the government evidence supporting their legal authority to grant rights-of-way to such lands.

The PS shall comply with applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, approved 2 January 1971, and amended by Title IV of the Surface Transportation Uniform Relocation Assistance Act of 1987, Public Law 100-17, effective 2 April 1989, in acquiring real estate interests for the Project, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act(s). An assessment of the Non Federal Sponsors Real Estate Capability has been prepared with the cooperation of the Project Sponsor and is attached as exhibit D.

9. GOVERNMENT OWNED PROPERTY

There are no Government owned lands within the proposed project limits.

10. MINERAL RIGHTS

There are no known mineral activities within the scope of the proposed Project.

11. PUBLIC LAW 91-646, RELOCATION ASSISTANCE BENEFITS

Public Law 91-646, Uniform Relocation Assistance provides entitlement for various payments associated with federal participation in acquisition of real property. Title II makes provision for relocation expenses for displaced persons, and Title III provides for reimbursement of certain expenses incidental to transfer of property. There will be no relocation of persons or Title III costs associated with the project.

12. REAL ESTATE ESTIMATE

The estimated real estate costs include land and improvement values, damages, mineral rights, resettlement cost, and federal as well as non-federal administrative costs.

A 25% contingency is applied to the estimated total of these items. A Code of Accounts is at Exhibit "E".

Estimate (Includes Residential & Commercial Properties)

a. Lands			$ -0-
b. Improvements			-0-
c. Mineral Rights			-0-
d. Damages			-0-
e. P. L. 91-646 Relocation Costs (Recordation Fees)		-0-	
f. Acquisition Cost - Admin			$7,500
Prepare Mapping and RE Certification			
Federal	($ 2,500)		
Non-federal	($ 5,000)		
Sub-Total		$7,500	
Contingencies (25%)			$1,875
TOTAL			**$9,375**
ROUNDED TO			**$9,500***

*** This estimate assumes the fact that the PS will not have to acquire additional easements. Should additional easements be required, the cost will increase accordingly.**

Exhibit A

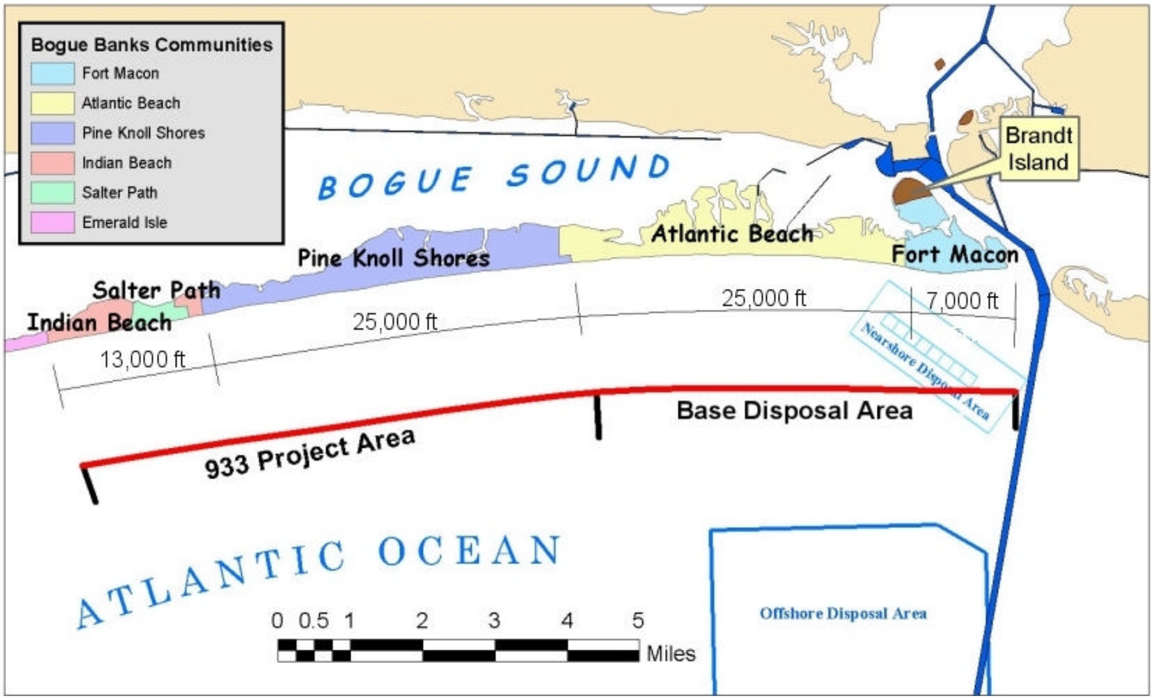

Bogue Banks Communities
Fort Macon
Atlantic Beach
Pine Knoll Shores
Indian Beach
Salter Path
Emerald Isle
BOGUE SOUND
Brandt Island
Atlantic Beach
Fort Macon
Pine Knoll Shores
Salter Path
Indian Beach
13,000 ft
25,000 ft
25,000 ft
7,000 ft
Nearshore Disposal Area
Base Disposal Area
933 Project Area
ATLANTIC OCEAN
Offshore Disposal Area
0 0.5 1 2 3 4 5
Miles

Exhibit B

PERPETUAL BEACH STORM DAMAGE REDUCTION EASEMENT

A perpetual and assignable easement and right-of-way in, on, over and across (the land described in Schedule A) (Tract No. __) for use by the (Project Sponsor), its representatives, agents, contractors, and assigns, to construct; preserve; patrol; operate; maintain; repair; rehabilitate; and replace; a public beach [a dune system] and other erosion control and storm damage reduction measures together with appurtenances thereto, including the right to deposit sand; to accomplish any alterations of contours on said land; to construct berms [and dunes]; to nourish and renourish periodically; to move, store and remove equipment and supplies; to erect and remove temporary structures; and to perform any other work necessary and incident to the construction, periodic renourishment and maintenance of the (Project Name), together with the right of public use and access; [to plant vegetation on said dunes and berms; to erect, maintain and remove silt screens and sand fences; to facilitate preservation of dunes and vegetation through the limitation of access to dune areas;] to trim, cut, fell, and remove from said land all trees, underbrush, debris, obstructions, and any other vegetation, structures and obstacles within the limits of the easement (except_____); [reserving, however, to the grantor(s), (his) (her) (its) (their) (heirs), successors and assigns, the right to construct dune overwalk structures in accordance with any applicable Federal, State or local laws or regulations, provided that such structures shall not violate the integrity of the dune in shape, dimension or function, and that prior approval of the plans and specifications for such structures is obtained from the (designated representative of the Project Sponsor) and provided further that such structures are subordinate to the construction, operation, maintenance, repair, rehabilitation and replacement of the project; and further] reserving to the grantor(s), (his) (her) (its) (their) (heirs), successors and assigns all such rights and privileges as may be used and enjoyed without interfering with or abridging the rights and easements hereby acquired; subject however to existing easements for public roads and highways, public utilities, railroads and pipelines.

Exhibit C

AUTHORIZATION FOR ENTRY FOR CONSTRUCTION

I, *(name of accountable official)*, *(title)* ________ for *(name of non-Federal sponsor)* ________, do hereby certify that the ________ *(name of non-Federal sponsor)* has acquired the real property interests required by the Department of the Army, and otherwise is vested with sufficient title and interest in lands to support construction of *(project name, specifically identified project features, etc.)*. Further, I hereby authorize the Department of the Army, its agents, employees and contractors, to enter upon ____ *(identify tracts)* to construct *(project name, specifically identified project features, etc.)* as set forth in the plans and specifications held in the U. S. Army Corps of Engineers' ____________________ District Office, (*city and state*)

WITNESS my signature as ______ *(title)* for *(name of non-Federal sponsor)* ____this ______ day of ________________, 19____________.

BY: ________ *(name)* ________________________

________ *(title)* ________________________

ATTORNEY'S CERTIFICATE OF AUTHORITY

I, ______ *(name)* ________________, ______ *(title of legal officer)* ____ for ____ *(name non-Federal sponsor)* _____, certify that ______ *(name of non-Federal sponsor)* ____ has authority to grant Authorization for Entry; that said Authorization for Entry is executed by the proper duly authorized officer; and that the Authorization for Entry is in sufficient form to grant the authorization therein stated.

WITNESS my signature as __________ *(title)* _______ for *(name of non-Federal sponsor)*, this___________day of________________, 20_____.

BY: ________ *(name)* ________________________

________ *(title)* ________________________

Exhibit D

Assessment of Non-Federal Sponsor's
Real Estate Acquisition Capability

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? (**yes**/no)

b. Does the sponsor have the power of eminent domain for this project? (**yes**/no)

c. Does the sponsor have "quick-take" authority for this project? (**yes**/no)

d. Are any of the land/interests in the land required for this project located outside the
sponsor's political boundary? (yes/**no**)

e. Are any of the lands/interests in land required for the project owned by an entity
whose property the sponsor cannot condemn? (yes/**no)**

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P. L. 91-646, as amended? (yes/**no**)

b. If the answer to II.a. is "yes", has a reasonable plan been developed to provide such
training? (yes/no)

b. Does the sponsor's in-house staff have sufficient real estate acquisition experience to
meet its responsibilities for the project? (**yes**/no)

c. Is the sponsor's projected in-house staffing level sufficient considering its other work
load, if any, and the project schedule? (**yes**/no)

e. Can the sponsor obtain contractor support, if required in a timely fashion? (**yes**/no)

f. Will the sponsor likely request USACE assistance in acquiring real estate? (yes/**no**)

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site?
(**yes**/no)

b. Has the sponsor approved the project/real estate schedule/milestones? (**yes**/no)

IV. Overall Assessment:

a. Has the sponsor performed satisfactory on other USACE projects?
(yes/no/not applicable)

b. With regard to the project, the sponsor is anticipated to be: **highly capable**/fully capable/moderately capable/marginally capable/insufficiently capable.

V. Coordination:

a. Has this assessment been coordinated with the sponsor? (**yes**/no)

b. Does the sponsor concur with this assessment? (**yes**/no) (If "no", provide explanation)

Prepared by:

John S. Hinely
Realty Specialist

Reviewed and approved by:

Vivian A. Davis
Acting Chief, Real Estate Division

Exhibit E

Morehead City Harbor Section 933
Carteret County, NC

CODE OF ACCOUNTS

		FEDERAL	NON-FEDERAL	TOTALS
01A	PROJECT PLANNING			
	Other			
	Project Cooperation Agreement	$	$	$
01AX	Contingencies (25%)	$	$	$
	Subtotal	$	$	$
01B	LANDS AND DAMAGES			
01B40	Acq/Review of PS	$ 2,500.00	$	$ 2,500.00
01B20	Acquisition by PS	$	$ 5,000.00	$ 5,000.00
01BX	Contingencies (25%)	$ 625.00	$ 1,250.00	$ 1,875.00
	Subtotal	$ 3,125.00	$ 6,250.00	$ 9,375.00
01H	AUDIT			
01H10	Real Estate Audit	$	$	$
01HX	Contingencies (25%)	$	$	$
	Subtotal	$	$	$
01R	REAL ESTATE LAND PAYMENTS			
01R1B	Land Payments by PS	$	$ 0.00	$ 0.00
01R2B	PL91-646,Recordation Fee- PS	$	$ 0.00	$ 0.00
01R2D	Review of PS	$	$	$
01RX	Contingencies (25%)	$	$ 0.00	$ 0.00
	Subtotal	$	$ 0.00	$ 0.00
	TOTALS	$ 3,125.00	$ 6,250.00	$ 9,375.00
	ROUNDED TO			**$ 9,500.00**

MOREHEAD CITY HARBOR
CARTERET COUNTY, NORTH CAROLINA
SECTION 933
EVALUATION REPORT

APPENDIX G

GEOTECHNICAL ANALYSIS

APPENDIX G
Geotechnical Analysis

BACKGROUND

Morehead City Harbor dredge material has traditionally been placed in Brandt Island or on the beach at Atlantic Beach and Fort Macon. The material in Brandt Island was sampled and grain size tests were performed in the mid-1980's prior to the initial pump out in 1986. The quality of the material was determined to be suitable for beach disposal. Brandt Island was pumped out again in 1994 with the material being disposed of on the beach.

Material for the Morehead City Inner Harbor is placed in the Brandt Island Disposal Area. The Inner Harbor material was tested and analyzed previously. The overfill ratio of this material ranges between 69 and 86 percent. These results show that the material is adequate for beach placement. The material to be placed on the beach as part of this project is expected to be similar to the material placed previously, as the material in Brandt Island was dredged from the same reaches of the Harbor as material previously pumped out of Brandt Island.

The Morehead City Harbor was dredged in spring of 2002. Material from the Harbor was placed on the beach at Fort Macon and in the Brandt Island Disposal Area. The subsurface investigation and analysis will be performed on the shoals that have formed since the 2002 dredging and that are to be removed from the Harbor under this project. It will be assumed that the material in Brandt Island is the same as the Inner Harbor material tested for this project, since the Inner Harbor material from previous dredging is stored in Brandt Island.

SUBSURFACE INVESTIGATION

The subsurface investigation will include drilling the shoals in Morehead City Harbor and the material in the Brandt Island Disposal Area, taking beach grab samples, and grain size testing the material collected from these samples.

Morehead City Harbor Drilling. The borings will be performed with the snagboat SNELL using a 3 7/8 inch diameter Alpine vibracore drill machine. It is planned to drill twenty, 10-foot borings in the Harbor area and the connecting channels with the worst shoals. It is expected to take two days to perform the borings, with one additional day is included for weather. Each tube is expected to have approximately 3 soil samples, for a total of 60 samples.

Brandt Island Land Drilling. No borings will be performed on Brandt Island as part of this project. It is assumed that the material in Brandt Island is the same as the Inner Harbor material tested for this project, since the Inner Harbor material from previous dredging is stored in Brand Island.

Beach and Near Shore Grab Samples. Grab samples will be collected from twenty-five profile lines perpendicular to Fort Macon, Atlantic Beach, Pine Knoll Shores, Indian Beach, Emerald Isle, and Bogue Inlet Area. In the foreshore area or beach area, it is estimated six surface samples will be collected from each of the twenty-five profile lines for a total of 150 samples. For each profile, one grab sample will be collected from each of the following six locations: 1) the seaward toe of the dune; 2) the seaward crest of the berm approximately at elevation +7 NGDV; 3) mean high water, approximately at elevation +2.2 NGVD; 4) mean sea level, approximately +0.35 ft NGVD; 5) mean low water, approximately elevation –1.5 NGVD; and 6) at -3 NGDV. In the ocean, it is estimated that an average of 15 surface samples will be collected from each of the twenty-five profile lines for a total of 375 samples. For each profile, one grab sample shall be taken at 2-foot increments of elevation beginning at elevation -4 NGVD through elevation –24 NGVD. The extra samples account for undulations of the ocean bottom. The samples shall be collected from the top one to four inches of ocean bottom.

Lab Testing. Approximately 60 Harbor soils samples and 525 beach and near shore samples are expected to be tested. These samples will be tested for grain size, silt content, and shell content in accordance with ASTM D 422 using a minimum of 12 sieves. Samples will be classified in accordance with the Unified Soils Classification system.

ANALYSIS AND REPORT PREPARATION

All the samples collected from the Harbor Shoal material and the beach grab samples will be analyzed to determine the material suitability for beach placement. Based on material removed from the Harbor and Brandt Island in the past, it is expected that the material designated for beach placement as part of this project will be suitable.

MOREHEAD CITY HARBOR
CARTERET COUNTY, NORTH CAROLINA
SECTION 933
EVALUATION REPORT

APPENDIX H

PROJECT COSTS

APPENDIX H
PROJECT COSTS

Project Costs

The general approach was to prepare an independent estimate for all items of work necessary to complete the project. The pricing level used was October 2002 because of the extensive data collected and evaluated through this period of time.

The majority of construction cost items were developed using the Corps of Engineers Dredge Estimating Program (CEDEP) along with historical production. The previous Brandt Island pump out by pipeline dredge, October 1993 till January 1994 (with Jan 94 thru Mar 94 for inner harbor deepening), with sand placement on Ft. Macon and Atlantic Beach was evaluated. Additional production and costs by pipeline dredge for recent beach placement projects were evaluated. Historical production and costs for hopper dredging with offshore disposal and sand placement on the beaches was used in the evaluation and preparing the cost estimate.

The dredging plant selected as the basis for the cost estimates is typical for similar projects along the east coast and historical plant for past projects. Pipeline dredging was based on 27 to 30 inch hydraulic cutterhead. Hopper dredging was based on medium class hopper of 2,500 to 3,000 cubic yard capacity for offshore disposal as well as pump out of the hopper to the beach from the near shore.

A reasonable approach for placing sand on the beach was pumping sand from Brandt Island and Inner Harbor to Fort Macon, Atlantic Beach and much of Pine Knoll Shores up to 8 or 9 miles. Hopper dredging of sand in the entrance channels would be placed on the beach by pump out from near shore at western Pine Knoll Shores through Indian Beach. The project should not require dredging of sand from the entrance channels with a hopper; however, it appears to be the most reasonable approach.

Placement of sand on the beach by pipeline dredge would begin after November 15 and continue until completion. Placement of sand on the beach after May 15 would require turtle monitoring until completion. Hopper dredging can only be done in the entrance channel from January 1 through March 31.

The costs for Planning, Engineering and Design as well as Construction Management were furnished by Project Management and coordinated with those responsible for performing activities within these disciplines.

A contingency of 10% was applied to cover potential variations in project requirements that may not be known or defined at the date of this report.

The cost estimate is shown on Table H-1 on the following page.

Prepared by: ________________________________

John C. Caldwell
Civil Engineer

Reviewed by: ________________________________

Charles D. Carmen
Chief, General Engineering Section

TABLE H-1
FIRST COST SUMMARY

Description	Sand Placement Location	Costs
TOTAL SECTION 933 PROJECT + MODIFIED DISPOSAL PLAN:		
Mobilization & Demobilization		$2,850,000
Pumpout Brandt Island & Inner Harbor	Fort Macon & Atlantic Beach	$3,706,654
Pumpout Brandt Island, Inner Harbor, & Entrance Channel	AB, PKS, & IB	$24,654,870
Embankment Replacement		$500,000
Beach Tilling		$137,600
Planning Engineering & Design		$375,000
Construction Management		$100,000
SUBTOTAL before Contingencies		**$32,324,124**
Contingencies (10%)		$3,211,876
TOTAL Section 933 Project + Modified Disposal Plan		**$35,536,000**
BASE DISPOSAL PLAN:		
Mobilization & Demobilization		$1,750,000
Pumpout Brandt Island & Inner Harbor	Atlantic Beach and Fort Macon	$10,737,600
Mobilization & Demobilization		$250,000
Dredge Entrance Channel	Near Shore Disposal Area	$3,900,000
Embankment Replacement		$500,000
Beach Tilling		$130,400
Planning Engineering & Design		$120,000
Construction Management		$50,000
SUBTOTAL before Contingencies		**$17,438,000**
Contingencies (10%)		$1,744,000
TOTAL Base Disposal Plan		**$19,182,000**
SECTION 933 PROJECT COSTS		**$16,354,000**

CESAW-RG-L March 11, 2004

MEMORANDUM FOR RECORD

ENVIRONMENTAL ASSESSMENT & STATEMENT OF FINDINGS

SUBJECT: 200000362: The purpose of this memorandum is to document our permit decision for the Town of Emerald Isle's permit modification request to our October 26, 2001 Department of the Army authorization and our October 22, 2002 issued modification to perform beach nourishment along 5.8 miles of Emerald Isle beach. The Town's request to dredge and discharge approximately 160,000 cubic yards of material into Section 10 navigable waters and Section 404 waters to renourish approximately 12,500 linear feet of beach that eroded, primarily during Hurricane Isabel, in Emerald Isle, Carteret County, North Carolina.

Incorporated by Reference:

1. The Final Environmental Assessment dated October 19, 2001.

2. The original October 26, 2001 permit authorizing the nourishment of 16.8 miles of Bogue Bank Beaches, which includes the Towns of Pine Knoll Shores, Indian Beach, Emerald Isle, and Carteret County.

3. Emerald Isle's first permit modification for Phase II dated October 22, 2002.

4. Emerald Isle's December 19, 2003 modification request, and subsequent information dated December 31, 2003.

5. Our January 15, 2004 Public Notice and subsequent Public Notice dated February 20, 2004.

Project Proposal: Plans are to renourish essentially three separate areas totaling approximately 12,500 linear feet, mostly in Reach 3 and the east end of Reach 2 as designated in the October 2001 permit. These segregated sections are along an approximate 19,500 linear feet of shoreline starting at the 100 Block and terminating at the 4200 Block of Emerald Isle Township. Areas identified as showing the greatest erosion occurred between 10^{th} and 14^{th} Streets, or 1000 to 1400 Blocks; in the vicinity of the Ocean Reef Villas; and within the western regional beach access, or 2400 to 2600 Blocks.

The renourishment project will utilize approximately 160,000 cubic yards of beach-quality sediment found within the Offshore Dredging Material Disposal Site (ODMDS), which is located approximately 3.0 miles offshore of Beaufort Inlet, near Fort Macon. The material will be extracted via hopper dredge within 200-foot wide by a maximum of 4.0- foot deep strips along the ocean bottom. Plans include leaving 25 to 50-foot undisturbed ocean bottom buffers between each dredged strip to aid in accelerating the recolonization of the benthic communities and other biological resources. As the material is dredged, it will be pumped through a submerged pipeline to the beach. The dredge pipelines will be positioned on the beach so as to extend no more than 3,000 feet in either direction from the point where the submerged pipe intersects the beach. Once the material is placed on the beach, land-based equipment (such as bulldozers and front end loaders) will spread and shape it into a recreational beach between the existing crest of the active beach face and the low watermark. A temporary dike will be pushed up about 100 feet seaward of the berm crest to help contain the slurry mixture of sediments and seawater. This will allow the coarser material to settle out within a contained system while the finer sediment washes into the surf zone. Approximately 50 percent of the sand would be deposited between existing mean low water and the outer bar (about 500-750 feet off shore). The remaining sand would be placed above the existing mean low water and graded to match the natural beach with berm elevations at approximately +7.0 feet NGVD, which are approximately +5.0 feet above mean high water. Typical rates of fill range from 16 cubic yards per foot to 24 cubic yards per foot. The final dimensions of the renourished beach will vary according to the site-specific storm losses.

Using calculations from the previous Phase I and II nourishment activities, the applicant has estimated a construction time of approximately two-weeks to complete all the work. The Town is anticipating a construction schedule of March 2004 depending on the availability of dredges and the timing of other dredging work being conducting in the county. If work is unable to be accomplished by March 31, 2004, the applicant is proposing a construction period not to exceed March 31, 2005. If the Town fails to initiate construction in the spring of 2004, all renourishment will be accomplished between 16 November 2004 and 31 March 2005.

Stated Purpose: The purpose of the proposed project is to restore approximately 152,000 cubic yards of last year's nourished shoreline that has been damaged by Hurricane Isabel. To protect and maintain the largest portion of the Town's overall economy and tax base, Emerald Isle has applied for and received monies through an established Federal Emergency Management Agency (FEMA) program for post-storm restoration that authorized renourishment to approximately 128,000 cubic yards along 31,111 linear feet of shoreline.

Affected Environment: See October 19, 2001 EA, pg. 41.

Environmental Consequences: See October 19, 2001 EA, pg. 113.

Comments from January 15, 2004 Public Notice:

A. Federal agencies:

1. In a January 6, 2004 telephone conversation with Mr. David Bernhardt of National Marine Fisheries Protective Resource Division, our office was informed that consultation, pursuant to the Endangered Species Act, for threatened or endangered species is not necessary provided the applicant comply with the 1997 Regional Biological Opinion as directed in the original 2001 permit.

2. In a their letter dated February 12, 2004, the National Marine Fisheries Service (NMFS) Habitat Conservation Division expressed concerns that this unanticipated new work will adversely impact living marine resources and important habitats including Essential Fish Habitat (EFH). Specific concerns include 1) cumulative adverse effects of beach nourishment on EFH due to ongoing nourishment activities along Bogue Bank beaches; 2) the long-term biological effects of placement of high shell content material on these beaches; and 3) the interruption of the monitoring protocol that is currently in affect. Based on these concerns, NMFS believes a supplement to the EIS that addresses the project specific and cumulative effects should be developed. In the letter, NFMS disclosed EFH conservation recommendation that the supplement must include a description of measure proposed to avoid, mitigate, or offset the adverse impacts of the activity. Additionally, all beach nourishment related activities, including dredging and the disposal of dredge material, must be completed no later than March 31, 2004 and the original monitoring requirements should be implemented.

3. The U.S. Fish and Wildlife Service expressed concerns regarding the modification in a letter dated February 24, 2004. The Service raised the following issues: 1) concern over the sediment compatibility of the offshore sites with the native beaches, specifically the higher shell content; 2) concern with the use of Borrow Site A due to higher shell content that contain the larger *Quahog* shell fragments; 3) the potential effect the higher shell percentage would have on feeding shorebirds and the burrowing capacity of invertebrates; and 4) the potential negative cumulative effects to federally-listed threatened and endangered species, specifically compaction and alteration of the physical composition of the sea turtle nesting environment. In the letter, the FWS stated it could concur that the modification would not likely to adversely affect federally-listed species if the Corps implements the minimum shell content standards and incorporates all measures to minimize impacts to these species as stated in the Corps' October 26, 2001 permit. Also, FWS recommended that the Town of Emerald Isle provide an additional one-year of funding to study the effects sediment disposal has on nesting sea turtles and the nesting environment. Additionally, the FWS believes other alternatives, whether found offshore or on upland sources, exist which demonstrate higher compatibility with the native beaches.

B. State agencies:

1. In its January 27, 2004 letter, the NC Wildlife Resource Commission (WRC) do not object to the modification provided the following take place: 1) the incorporation of a dredging moratorium from April 1 to November 15 to minimize impacts to nesting sea turtles and shorebirds (the WRC did indicate, however, that work could extend to April 15 if it is unavoidable and provided all equipment is off the beach by that date); and 2) That all precautions be implemented to ensure protection against incidental takings of sea turtles during dredging. The WRC also recommended that the applicant evaluate a better long-term solution to protecting beachfront such as establishing wider development and construction setbacks on all structures as they are rebuilt after being lost to the sea.

2. The NC Division of Marine Fisheries stated that it has no objection to the issuance of the modification in a letter memorandum dated January 13, 2004. This concurrence stands provided sampling and monitoring will be conducted such that only suitable material will be placed on the beach.

3. In a February 4, 2004 letter, the NC Division of Water Quality issued its approval for the 401 Water Quality Certification. Conditions to the 401 Certification will be incorporated as conditions to the CAMA permit.

C. Organization(s) and Individual(s):

1. The NC Coastal Federation (c/o: Mr. Jim Stephenson) stated its objections to the modification due to the incompatibility of Borrow Site A. In its February 13, 2004 letter, the Federation recommended evaluating the use of upland/mainland sources of beach quality material for the work.

2. In a February 13, 2004 letter, the Environmental Defense (c/o: Ms. Michelle Duvall) recommended denial of the modification based on the following issues: 1) Shell content in Borrow A, 2) Increasing the percentage of shell content from 35% to 39.5%, 3) The absence of additional monitoring and mitigation, 4) Reference their comments on the draft EIS (dated 3/13/01) for the definition of project success, and 5) Cumulative and long-term impacts.

3. Duke University (c/o: Mr. Andy Coburn) recommended denial of the modification request based on the inconsistency with NC Coastal Area Management Act, potential long-term cumulative impacts, and incompatible material. Also Mr. Coburn stated that the request should require a new permit, and that a public hearing is warranted.

4. Several individuals and citizens of Emerald Isle requested the denial of the permit or expressed concern over the percentage of shell content in the borrow source, and requested use of an alternative sand source. The commenters were BJ Mountford, Mr. George McLaughlin, Mr. and Mrs. John Ringwood, Mr. and Mrs. George Eggert, Mr. and Mrs. Cunningham, Mr. and Mrs. Hayne Yelverton, Ms. Emily Farmer, Ms. Doje Marks, Mr. and Mrs. William Cole, Mr. and Mrs. Walter Fuller, Mr. Dick Eckhardt, and Mr. Fred Machemer.

Comments from February 20, 2004 Public Notice:

A. Federal agencies:

1. In a March 2, 2004 letter, the U.S. Fish and Wildlife Service reemphasized the use of compatible material. The Service's minimum recommendations prior to the issuance of any modification must include the following: the original permit conditions relating to shell content remain in place, incorporation of all measures to minimize impacts to federally-listed species as stated in the October 26, 2001 permit, and that the material is shown to be compatible with native beach material.

2. The subsequent comments from NMFS, dated March 3, 2004, concurred that the material from the ODMDS area is more compatible than the Borrow Site A, and that the use of material from this site is preferable. However, NMFS remains concerned that the proposed action would contribute to the cumulative adverse effect of beach nourishment on EFH and associated species. Additionally, NMFS recommends that affected monitoring stations should be

reinitiated and the original monitoring requirements implemented.

Concerned Issues:

A. Shell Content or Percentage: In the Town's evaluation of an additional alternative, the Town is proposing to use ODMDS. The Corps has used this ocean disposal site when dredging the Federally maintained Morehead City Outer Harbor, which includes Beaufort Inlet channel to the ocean, since mid to late 1980's. The U.S. Environmental Protection Agency (EPA) has approved the site for ocean disposal, and has determined that the material is suitable for ocean disposal pursuant to the Marine Protection Research and Sanctuaries Act. Sediment characteristics of the material within this disposal area contain a mean grain size of 2.31 phi, visual calcium carbonate or shell content of 7.1 percent, and a mud or silt percentage of 3.9 percent. Native beach sediment of Emerald Isle has a mean grain size of 2.3 phi, visual shell content of 6.3 percent, and a mud or silt percentage of 2.6 percent. It should be noted that a Corps contractor is currently dredging the Morehead City Outer Harbor channel and placing the material on stretches of Indian Beach and Salter Path. This is the same type material that would otherwise be disposed of in the ODMDS.

With concerns expressed over the amount of shell content in previous borrow areas, our GeoTechnical staff, specifically Mr. Ben Lackey, reviewed the sediment analysis from the ODMDS to determine its compatibility for beach renourishment. In his March 1, 2004 evaluation report, Mr. Lackey stated that the material from the ODMDS is highly compatible and is more suitable for the renourishment than the previously authorized Borrow Site A. The use of ODMDS is expected to eliminate concerns about compatibility, specifically shell content. It should be noted that Mr. Lackey commented that the material from Borrow Site A is compatible for use of beach fill material; however, the ODMDS area provides a more comparable source to the native beaches.

B. Cumulative Impacts and EFH: As expressed by NMFS and others, cumulative impacts remain a concern due to the various beach nourishment and renourishment activities, both permitted and Federal Civil Works actions, taken place along Bogue Banks Beaches. The following are (re)nourishment activities that have been conducted or are being proposed along the 24-mile stretch of beaches on Bogue Banks:

1. In 2001/2002, approximately 7.0 miles of beaches from Pine Knoll Shores to Indian Beach/Emerald Isle limits were nourished pursuant to the October 26, 2001 permit. Approximately 2.5 miles of this same portion of Indian Beach, Salter Path, Pine Knoll Shores were renourished in February and March of 2004 pursuant to the COE Section 933 Project.

2. In January to March 2003, approximately 5.8-miles of Emerald Isle Beach was nourished pursuant to the October 26, 2001 and October 22, 2002 permits. Approximately 12,500 linear feet, or 2.3 miles, of this stretch will be renourished pursuant this March permit.

3. In the fall 2004/winter 2005, the Town of Emerald Isle is proposing to use dredge material from relocating Bogue Inlet Channel to nourish approximately 5.0- miles of Emerald Isle Beach. This stretch is the Phase III section of the October 26, 2001 permit.

4. In 2005, approximately 11 miles of beach from Fort Macon to Pine Knoll Shores are planned to be renourished pursuant to the COE Section 933 Project and the pump-out of the disposal site, Brandt Island. The Pine Knoll Shores section of this proposal includes approximately 5.0 miles of beach that was nourished in 2001/2002. These pending actions are based on the appropriation of funds.

Both spatial and temporal factors are considered in analyzing cumulative effects from these projects along Bogue Banks. In reviewing all the (re)nourishment activities on Bogue Banks, it first appears that all the beaches are being affected at once without any time for biological (benthic community) recovery. The recovery of the benthic community, such as Donax clam, mole crab, and polychaete worms, depends mainly on the compatibility of the beach fill material and the occurrence of the (re)nourishment activity. With the use of the compatible material in the ODMDS, it is expected that the benthic community will fully recover in a short period of time, which could be less than 6 months. To measure the recovery, the biological monitoring for this action will be extended two years for the affected monitoring stations, Transect #39 or Block # 1800, and Transect #40a or Block #1500. The project limits were modified to not impact the station located at transect 36, or Block #2400. With this anticipated short recovery time, it is expected that the effect on the EFH resources will be minimal (Reference the March 2004 Supplement to Essential Fish Habitat Assessment for additional discussions to EFH).

When incorporating spatial and temporal factors into the analysis of effects along Bogue Banks, only 10 percent, or 2.3 miles, of the entire 24-mile stretch has received beach fill more than once within a 1.0 year period, and that the entire 10 percent includes this proposed permit modification. For Pine Knoll Shore beach, there will be a minimal lag time of 2.0 years between the October 26 permitted nourishment activity and the COE Section 933/Brandt Island Pump-out Project. As the biological monitoring results are showing, the benthic community is expected to be fully recovered along Pine Knoll Shores prior to the next nourishment event. If the cumulative effects analysis includes the undeveloped State Park of Bear Island and the low developed Marine Corps Onslow Beach to the west/southwest and the undeveloped National Park of Shackelford Banks and Cape Lookout to the east/northeast, the percentage of beaches receiving sediment for beach (re)nourishment for any period of time within this 68 miles region of beaches is approximately 35 percent. The potential of this action cumulative impacting EFH, sea turtle nesting, and the benthic community has been determined to be minimal.

C. Threatened and Endangered Species: The 1997 Regional Biological Opinion and the conservation measures, dated December 20, 2001, will be implemented to reduce the potential of an incidental take of threatened and endangered sea turtles within the water column during dredging operations. The FWS had expressed that data collected in 2003 may be showing some impacts to nesting turtles in regards to the color of the material effecting temperature and the number of false crawls identified. With this information, FWS recommended that the Town of Emerald Isle extend their sea turtle contract an additional year with the NC WRC. The results that are referenced are the second year of an extensive 6-year monitoring plan. At this time, the data is inconclusive in determining that the previously used dredged material has affected nesting. The need for additional monitoring, when conclusive results are available, will be determined toward the end of the 6-year period. It should be noted that the original permit is conditioned to submit this data to our office by January 15 of each year. FWS has been informed that NC WRC has not provided this year's result to our office for review.

As stated in the FWS March 2 letter, the Service's goal is to have a sediment source that is compatible with the native beaches in terms of grain size, color, and shell content. Although the previously used Borrow Site A has been considered compatible, the ODMDS is more similar to the native beach in regards to color and shell content. This sand source is expected to reduce any potential impacts to nesting sea turtles.

Additionally, the permit will be conditioned to complete all dredging work by March 31 and all tilling and equipment removal off the beach must be done by April 15. No extension will be approved past the April 15th date in order to avoid any impact to nesting sea turtles.

In our review and evaluation of all appropriate information, our office has determined that, with the inclusion of appropriate special conditions, all concerns and comments from the responding agencies and public have been adequately satisfied and addressed; and that the proposed project will result in minimum adverse impacts to the water resources of the Atlantic Ocean. The Corps concurs that the issuance of a permit to the Town of Emerald Isle will not be contrary to the general public interest provided that it adheres to the conditions incorporated in the permit.

STATEMENT OF FINDINGS: All conditions of the October 26, 2001 permit remain applicable to this modification, unless specified in the modified special conditions.

1. Modified Special Conditions:

a. Special condition (5); No nourishment material will be obtained outside the designated ODMDS area (see attached map).

b. Special condition (6); During the dredge operation, the dredge will excavate at a depth of 3.0 feet in the ODMDS area with a 1.0-foot margin of error. Undisturbed or un-dredged strips of 25 to 50 feet wide will be left between each pass of the dredge. Dredge surveys will be submitted to our office on a daily basis to ensure strips remain and to confirm the dredging location within the approved boundaries.

c. Special condition (9) will remain unchanged for the implementation of the August 23, 2001 monitoring plan (for benthic and fish communities) except for the station at transect 40(a) or #1500 Block, and transect 39 or #1800 Block. These stations will be monitored for two years after the completion of the renourishment, or until benthic recovery has been determined.

d. Special condition (10d); Compaction test will be conducted immediately after or during the renourishment activity. This test, along with field observations, will be compared to pre-Phase II dredge conditions to determine the need for beach tilling. If needed, tilling must be completed by April 15.

e. Special condition (12); All dredging operation must be completed by March 31 and all beach activity, such as removal of pipeline, equipment, and tilling, must be completed and removed from the beach by April 15, 2004.

2. New Special Conditions:

a. During dredging operations, a sediment analysis of the material placed on the beach, including shell (calcium carbonate) percentage, shall be submitted to our office on a daily basis until the completion of the project.

b. If, at any time, an incidental take of a sea turtle occurs, the permittee must stop all dredging operations and immediately contact the District Engineer for consultation. During consultation, it will be determined what action the permittee must implement, which may include the attached December 20, 2001 conservation measures, to reduce the potential take of an additional threatened and endangered sea turtle.

c. The contractor shall install baskets or screening over the hopper inflow(s) and overflow(s) with no greater than 4" by 4" openings. The screening shall provide 100% screening of the hopper inflow(s) and overflow(s) and will remain in place during the dredging operation. These screens shall be maintained in operational condition throughout the period of their required use.

d. Hopper dredge drag heads shall be equipped with rigid sea turtle deflectors that are rigidly attached.

e. Project limit for this permit modification will be restricted to the attached site plan. Renourishment Area 2 will be terminated approximately 500 linear feet prior to 26th Street, or #2600 Block, to avoid the placement of material over the biological station at the point.

f. This project is considered a one-time event, and any future plans to renourish Phase II section will be processed under a new permit application. Permit modifications for Phase II, pursuant to the October 26, 2001 authorization, will not be available.

PREPARED BY______________ 3-12-04
Mickey Sugg, Project Manager
CESAW-RG-L
Date

REVIEWED BY______________ 3/12/04
Keith A. Harris, Chief for
CESAW-RG-L
Date

APPROVED BY______________ 3/12/04
Charles R. Alexander, Jr. for
Colonel, U.S. Army
District Engineer
Date

DEPARTMENT OF THE ARMY
Wilmington District, Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402

Action ID. SAW-2006-32753-016 7 November 2006

Applicants: Town of Emerald Isle
7500 Emerald Isle Drive
Emerald Isle, North Carolina 28494

Town of Pine Knoll Shores
100 Municipal Circle
Pine Know Shores, North Carolina 28512

Town of Indian Beach
P.O. Box 306
Salter Path, North Carolina 28475

AGENT: Coastal Science & Engineering (CSE).
P.O. Box 1643
Morehead City, North Carolina 28557

Waterways: The Atlantic Ocean

ENVIRONMENTAL ASSESSMENT, 404(B)(1) ANALYSIS, FINDING OF NO SIGNIFICANT IMPACT, AND STATEMENT OF FINDINGS

This document constitutes my Environmental Assessment, Finding of No Significant Impact, Statement of Findings, and review and compliance determination according to the 404(b)(1) guidelines for the proposed work.

This permit action is being taken under authority delegated to the Wilmington District Engineer by the Secretary of the Army and the Chief of Engineers by Title 33, Code of Federal Regulations, Part 325.8, pursuant to:

__X__ Section 10 of the Rivers and Harbors Act of 1899.
__X__ Section 404 of the Clean Water Act.
_____ Section 103 of the Marine Protection, Research and Sanctuaries Act.
_____ Section 4(e) of the Outer Continental Shelf Lands Act of 1953.

1. Proposed Project: The following description of the work is taken from data provided by the applicant. The proposed project consists of excavating by hydraulic dredge up to 1,107,560 cy of beach-quality sediment from the Offshore Dredged Material Disposal Site (ODMDS), located about 2 miles offshore of Atlantic Beach. Shallow excavations (2-5 ft deep, typical) would be made by hopper dredge and pumped via submerged pipe to the beach. The FEMA-approved renourishment area will consist of approximately five reaches totaling up to 54,658 ft (cumulative) along Bogue Banks. The reaches are listed in Table 1 below.

Sediment would be spread on the beach via land-based equipment and shaped into a recreational beach between the existing toe of the foredune and the low watermark. The beach fill will impact about 460 acres of beach above mean high water (MHW) and a portion of the lower foreshore area of the near shore zone. The main fill portions of the project will contain about 20 cubic yards per linear foot (cy/ft) of beach (1,107,560 cy total) and will include a flat berm at elevation +7.0 ft NGVD initially placed 85–145 feet (ft) wide and extend seaward to a depth of about –11 ft NGVD on a 1 to 15 slope. The proposed beach fill eastern and western project boundaries are the same area as that originally authorized for Bogue Banks but the total length of beach fill within this area is shorter since not all areas need to be re-nourished at this time. Total project length of the proposed project is 54,658 feet and the project originally authorized was 88,760 feet (62 % of the original project). The fill volume for each reach varies according to the site-specific erosion losses resulting from Hurricane *Ophelia*. Beach fill transition tapers that will be 1,000 ft long at the eastern ends of Reaches 2 and 5, and 500 ft long at all other reach terminuses will tie the main beach fill into the natural shoreline at the ends of each reach. Lengths and volumes for each reach include the planned tapered transition sections.

The beach fill material will be dredged from a borrow area in the ODMDS that has been identified by the US Army Corps of Engineers for disposal of dredged material from Beaufort Inlet and Morehead City Harbor. Material placed on the beach will be monitored continuously for sediment quality. Monitoring will include visual classification with confirmation by sieve analysis of representative samples collected on a daily basis. Pre-project sampling of the borrow area is being used to identify areas where sediment compatibility can be maximized.

I have reviewed and considered the document entitled "Final Environmental Assessment, Bogue Banks Beach Nourishment Project, Carteret County, North Carolina" dated October 19, 2001, prepared by the applicant and the applicants permit application dated June 9, 2006. This environmental document is hereby referred to as "Bogue Banks FEA". Portions of this document as identified are hereby incorporated by reference.

Table 1. Preliminary reach lengths and nourishment fill volumes for Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores.

Nourishment Reach	[1] Reach Length (ft)	Project Station	Locality	[2] Unit Fill Volume	Reach Volume
Emerald Isle					
1	13,604	10--20	Conch Court To Lee Avenue	20.00	262,080
2	14,059	33--45	Gregg Street to 6th Street	23.07	307,080
Total	27,663			21.75	569,160
Indian Beach					
3	13,389	48--58a	300 ft east of 1st Street to apartment complex at east town boundary	23.17	298,604
Total	13,389			23.17	298,604
Pine Knoll Shores					
4	3,478	62a--65	300 ft east of Murex Drive to 3,700 ft east of Murex Drive	20.00	59,560
5	10,128	66--73a	Bogue Shores Club to Middle of Pinewood Road	19.22	180,236
Total	13,606			19.41	239,796

NOTES:

[1] Reach lengths include 500 ft taper section at beginning and each end of reach. Reaches 2 and 5 have a 1,000 ft taper at west end of reach and a 500 ft taper at east end.

[2] Unit fill volume calculations include taper sections.

According to information provided by the applicant, the proposed fill will be placed by ocean-going, trailing suction hopper dredge(s) between the seaward crest of the existing dry beach and the outer bar. Only the profile above high water is controllable in nourishment construction. Intertidal and underwater portions of the profile will be subject to natural adjustment by waves following placement of the beach fill. The fill will be placed no higher than +7 ft NGVD (the natural elevation of the berm).

Work will progress in sections within the borrow area and along the beach. Fill placement along the beach will typically progress at a rate of 400-700 ft per day. Construction activities will involve movement of heavy equipment and pipe along approximately 1 mile long reaches over a period of 1–2 weeks. Once a section is complete, piping and heavy equipment will be shifted to a new section and the process repeated. As soon as practicable, sections will be graded and dressed to final slopes. Other than at equipment staging areas, beach residents along the project area will experience disruption due to construction for several days or less.

Land-based equipment will be brought to the site over public roads and will enter the beach at existing permanent beach access areas identified on the permit drawings. Any alteration of dune vegetation/topography necessary for equipment access will be repaired to pre-project conditions. Daily equipment staging will be on the constructed beach seaward of the dune line. Existing dunes and vegetation on the beach will be avoided and preserved. Construction contracts will provide for proper storage and disposal of oils, chemicals, and hydraulic fluids (etc) necessary for operation in accordance with state and federal regulations.

Hopper dredges will dredge material from the designated ocean borrow area (ODMDS). Hopper dredges typically require approximately 25 ft minimum operational depth and are efficient for excavating shallow cuts on the order of approximately 2–5 ft. Typical excavation depths in the ODMDS will be approximately 3 feet. During excavation and loading, the slurry drains overboard via scuppers, discharging fine materials in the borrow area and leaving coarser material in the hopper. When loaded, the dredge travels to a temporary mooring and submerged pipeline near the project site. It connects to the pipeline and pumps the material from the hopper to the beach where it is spread mechanically by bulldozers. This is the same type of dredging placement operation used for construction of Phase 1 and most of Phase 2 of the Bogue Banks beach nourishment projects completed in winter 2001-2002 and 2002-2003 (respectively).

2. <u>Project History:</u> On October 26, 2001, a Section 404 and Section 10 permit under Action ID 200000362 was issued to Carteret County, Pine Knoll Shores, Indian Beach, and Emerald Isle to place sand from an offshore site onto 17.5 miles of beach. The project encompasses three phases. All authorized work is limited to a November 16 to April 15 dredging window. Phases 1 and 2 were accomplished between December 2001 and April 2003) Phase II occurred in 2002/03 and Phase III is has not been authorized to date. Phase I nourishment was approximately 7 miles of beach, but stopped short due to the incidental take of a 7th Kemp Ridley sea turtle that ceased all hopper dredging in the SAD area.

According to information provided by the applicant, following completion of Phases 1 and 2, the applicant (2003a, b) documented nourishment volumes placed along the Towns of Emerald Isle, Pine Knoll Shores, and Indian Beach. Hurricane *Ophelia* impacted Bogue Banks in September 2005. Following the Hurricane *Ophelia*, the applicant resurveyed 43 profile lines and documented nourishment volume losses totaling 1,107,560 cy from the eastern town limit of Pine Knoll Shores to the western end of Emerald Isle (CSE 2005, letter dated September 28, Post-*Ophelia* Beach Changes). In addition, FEMA representatives inspected the damaged beach after Hurricane *Ophelia* and authorized a post-storm renourishment totaling 1,107,560 cy under project work sheets PW #38 (Emerald Isle), PW #39 (Pine Knoll Shores), and PW #40 (Indian Beach). The proposed fill profile and project dimensions are based on the FEMA authorization. This volume will restore the project area (Phases 1 and 2) to pre-storm conditions. The renourishment will be accomplished by adding sand from a non-littoral source (ODMDS) at generally 20 cubic yards per linear foot so as to replace the eroded material. The original project was formulated for longevity of 10 years. The proposed project is designed to maintain this longevity.

3. <u>Environmental Setting</u>. Bogue Banks is a 25-mile long barrier island that traverses east and west with a southward facing ocean shoreline. The island is between two major tidal inlets, Bogue Inlet to the west and Beaufort Inlet, a major commercial inlet, to the east. Bogue Inlet drains the White Oak River and western Bogue Sound while Beaufort Inlet drains the Newport River, eastern Bogue Sound and portions of the North River. Bogue Sound borders the north side of the island while Onslow Bay of the Atlantic Ocean flanks the south side. Of the 80 miles of Carteret County barrier island shoreline, Bogue Banks is the only developed area.

4. Environmental and Public Interest Factors Considered:

a. Purpose and need: The purpose and need of the proposed project is to restore the width of the protective berm to its pre-storm condition and to reestablish the storm protection of the beach that existed prior to Hurricane *Ophelia.*

b. Alternatives [33 CFR 320.4(b)(4), 40 CFR 230.10]: The Bogue Banks FEA (Section 2.0) describes the original alternatives for the Bogue Banks Beach Renourishment project. The FEA identified and discussed three primary alternatives including: (1) no action; (2) abandon property, retreat, and relocate; and (3) nourish the beach. The selected alternative was based on evaluations of the existing sand deficit, average long term erosion rate, density and value of the developed property at risk, proximity to suitable offshore borrow areas, storm protection, and beach recreation. Structural alternatives such as seawalls, revetments, and bulkheads were not considered since hard structures on ocean shorelines are prohibited by NC Coastal Area Management Act (CAMA) regulations. The FEA alternative analysis, updated to reflect the proposed project, is briefly summarized below:

(1) No action: According the FEA (Section 2.1), the no action alternative would not meet the project purpose and need for storm protection of the existing beach. The FEA states that continued erosion of the beaches in the area would result in increased beach scraping activities and that forty acres of vegetation and sea turtle habitat would be lost under this alternative. Thus, this alternative would likely result in impacts to sea turtles and existing sea turtle nesting habitat. In addition, the FEA states that cost to the applicant under this alternative would result from removal and demolition of storm damaged structures, rebuilding beach access structures, lost tax revenues, and lost rental income. In view of the long term erosion rates in the project area, I concur with the applicant that the no action alternative meets the project's purpose and need and is not a practicable alternative.

(2) Retreat and Relocation: According the FEA (Section 2.2), in March 2000 it was estimated that 173 properties in Emerald Isle and 36 properties in Pine Knoll Shores have been identified as threatened or condemned. In addition, relocations were evaluated in terms of feasibility and costs associated with relocation and loss of rental property. Based on this analysis, the FEA concludes that based on the cost and feasibility to relocated, this alternative would not meet the project purpose and of the proposed project and is not considered a practicable alternative. I concur with the applicant that the retreat and relocation alternative meets the project's purpose and need and is not a practicable alternative.

(3) Proposed Action: According to information provided by the applicant, the only practicable alternative is to restore the existing project beach to pre-*Ophelia* conditions, as

described above, to provide needed storm protection. The FEA described alternate methods of construction including borrow area options, methods of beach fill construction, beach fill profiles, and construction schedules. Several beach nourishment sources were also identified in the FEA and permit application including lagoon sediments, inlet shoals (both inshore and offshore), nearshore bars, offshore deposits, recycled spoil sediments, accreting spits/beach deposits, attached bar deposits, inland deposits, freshwater pond deposits, fillets at jetties, and imported material. Of these alternative beach fill sources, offshore deposits, inlet shoals (inshore and offshore), and recycled spoil sediments were more likely to provide the most compatible material to nourish the beach in the project area. Due to compatibility and other environmental concerns, the offshore deposits were selected as the most practicable alternative as a nourishment source (Section 2.0 of the FEA). This conclusion applies to the proposed project. The FEA did not include the ODMDS in the initial borrow source analysis. However, based on the analysis of borrow sources considered in the FEA and the analysis of the ODMDS described in the permit application we concur with the applicant that the ODMDS would provide suitable beach nourishment material for the proposed project.

I have reviewed the information provided by the applicant, as well as all information and comments made during the public interest review process. The applicant has presented a reasonable range of alternatives for my review. With the inclusion of appropriate special conditions, I concur that the proposed project is the least environmentally damaging practicable alternative (LEDPA).

(4) Pursuant to the February 6, 1990, Corps/EPA Memorandum of Agreement (MOA) that established procedures to determine the type and level of mitigation necessary to comply with the Clean Water Act Section 404(b)(1) Guidelines, avoidance and minimization were considered to the maximum practicable extent. The applicant has designed the project in order to avoid all wetland impacts (excavating and filling).

The project area environment and the ODMDS were evaluated for mitigation requirements. The ODMDS is designated for use as an ocean disposal area for dredging Beaufort Inlet to the Port of Morehead City. The area is frequently disturbed by the USACE during maintenance dredging events to Beaufort Inlet the Morehead City Harbor Port. Therefore, the impacts to the nearshore bottom areas of the ODMDS should be minimal, especially in view of the suitable alternative borrow areas (or lack thereof) in the project area. In addition, studies by the Wilmington District have shown that the area rapidly recovers following each event. Thus, the impacts to this are will likely be temporary. Since the impacts from the proposed project will be temporary and minimal, mitigation will not be required for either the dredging of the ODMDS or the placement of beach compatible sand above Mean High Water (MHW).

Based upon the above information, I find that the applicant has satisfied the requirements of the Corps/EPA Mitigation MOA.

c. Physical/chemical characteristics and anticipated changes (Check applicable blocks and provide concise description of impacts).

(X) Substrate: The substrate in the beach and dune project areas and ODMDS consist of fine to medium sand. No negative impacts will occur as a result of the nourishment activities as the beach nourishment material from the ODMDS since the material from this disposal site is beach compatible sand.

(X) Currents, circulation or drainage patterns: The primary energy source for littoral transport (sand movement) within the project area is surface wave action and ocean currents along the shoreline. On the beach or at the shoreline, the proposed project will have no affect on incoming or reflected waves. In the offshore zone, the excavation of about 3 feet in the ODMDS is not likely to influence wave diffraction processes in the project area and should not influence net sediment transport processes at the Bogue Banks shoreline. Thus, there will be minimal changes to littoral transport processes as a result of this project.

(X) Suspended particulates; turbidity: No appreciable effect. The project will produce temporary and localized turbidity increases which are normally associated with hopper dredging and beach nourishment operations. Because about 98 percent of the material in the proposed excavation zone of the ODMDS is in the sand size class or larger, it will settle almost immediately and not remain in suspension. However, silt and clay-sized material will not settle as quickly and could cause increases in turbidity during the hopper dredging process. In addition, the excess water pumped into the hopper during loading flows overboard, taking with it much of the silt and clay-sized material. This fine material will then be discharged into the ocean in the ODMDS location. The effect of turbidity levels in the surf zone is expected to fall within the natural range of background conditions.

In April 2002, Phase 1 of the Bogue Banks (NC) restoration project involved pumping 1.73 million cubic yards of sand to re-nourish Pine Knoll Shores and Indian Beach. During this stage of operations, turbidity was measured along two cross-shore transects (4,000 ft); one transect located inside the pumping zone and transect located away from the pumping zone. Turbidity was also measured alongshore in the surf zone (3.8 miles) within the project area before pumping started and during sand pumping (source: CSE, unpublished data, April 2002).

The longshore turbidity measured before pumping provides background data with which to compare changes in turbidity during excavation. The background turbidity measured between 13.0 and 94.0 NTU with an average turbidity of about 50.0 NTU. After pumping started, the turbidity in the surf zone showed a slight overall increase in the longshore direction (measurements averaged about 65 NTU) with a sharp increase at the point of sand discharge (>400 NTU). The sharp increase is seen only locally at the point of discharge and is drastically reduced within several hundred feet alongshore. The cross-shore turbidity was highest in the surf zone within the project area and quickly declined seaward of the outer bar to <10 NTU on average. Outside the project area, the cross-shore turbidity was similar to the turbidity inside the project area. Higher turbidity was noted in the shallow, turbulent surf zone (70–120 NTU) but quickly diminished within several hundred feet seaward of the outer bar (about 500 ft offshore).

Measurements during Phase 1 indicated that turbidity increases associated with dredging and beach construction tend to remain localized at the pump discharge area and remain at or near background levels within several hundred feet of the discharge. During a similar project in 2001–2002, the USACE dredged the lower portion of the Cape Fear River to re-nourish Bald Head Island, Caswell Beach, Oak Island, and Holden Beach (NC). Versar (2003) concluded that turbidity increases associated with beach renourishment tended to remain isolated close to shore.

(X) Water quality (temperature, salinity patterns and other parameters): The North Carolina Division of Water Quality authorized this activity under Water Quality Certification Number 3593 dated October 30, 2006.

(X) Storm, wave and erosion buffers: The construction of the project will provide storm and flood protection for the homes adjacent to the ocean front beaches. Storm damage reduction resulting from the project in project area will provide an economic benefit the community.

(X) Erosion and accretion patterns: The project will change the channel profile (deepen and widen the channel) and add beach compatible material on the beach.

( ) Aquifer recharge: No appreciable effect.

( ) Baseflow: No appreciable effect.

Additionally, for projects involving the discharge of dredged material into open water:

(X) Mixing zone, in light of the depth of water at the disposal site; current velocity, direction and variability at the disposal site; degree of turbulence; water column stratification; discharge vessel speed and direction; rate of discharge; dredged material characteristics; number of discharges per unit of time; and any other relevant factors affecting rates and patterns of mixing: The proposed project will place material in the intertidal zone and shoreward. The principle force for sediment transport within the project area is wave action and tidal currents at the shoreline. The mixing zone will be in the intertidal zone area and in the nearshore area of the ODMDS. Sand to be placed on the beach will be clean material, free of debris with little nutrient content. Unsuitable material will not be placed on the beach. The beach fill material will consist of beach compatible sand containing less than 5% silt. The source material will be obtained from the ODMDS. By using clean-source sand with suitable grain sizes, renourishment activities are not expected to discernibly alter adjacent water quality from its current, ambient conditions.

d. Biological characteristics and anticipated changes (Check applicable blocks and provide concise description of impacts).

(X) Special aquatic sites (wetlands, mudflats, coral reefs, pool and riffle areas, vegetated shallows, sanctuaries and refuges, as defined in 40 CFR 230.40-45): The proposed project will not impact any wetlands.

(X) Habitat for fish and other aquatic organisms: The National Marine Fisheries Service (NMFS) reviewed the essential fish habitat assessment for the proposed project. Through this review process they determined that if the project is constructed between November 15 and March 31 of any year it will have a minimal impact to fisheries resources. They stated that if this work window was made a permit condition they would not object to the proposed project. This work window is proposed is within in the window acceptable to the National Marine Fisheries Service. However, information provided by the Wilmington District, Technical Services Division, P&E indicates that hopper dredging in the Bogue Banks nearshore area should only be authorized between January 1st and March 31st in order to reduce risks of turtle takes in this area. In response to comments on the DA public notice, the applicant revised the proposed project to limit hopper dredging activity between January 1st and March 31st along with implementing the following turtle take minimization measures:

- Relocation trawling when sea surface temperatures are greater than 57 degrees.
- Implement a Silent Inspector program during dredging.
- Employ a full time endangered species monitor on the dredge.
- Till the completed beach project to a depth of 36 inches.
- Remove all beach escarpments greater than 18 inches.

Based on the review of these comments and the responses provided by the applicant, it has been determined, in coordination the USFWS and NMFS, to concur with the dredging window and turtle take minimization measures proposed by the applicant. Further requirements regarding sea turtles are described below.

(X) Wildlife habitat (breeding, cover, food, travel, general): The previously authorized permit for the project had special conditions to minimize impacts to wildlife. These conditions will apply to this modification. The impacts to wildlife habitat will be minimal.

(X) Endangered or threatened species: The previously authorized permit addressed impacts to manatees and nesting sea turtles through special conditions. The National Marine Fisheries Service and the US Fish and Wildlife Service helped to develop these conditions to minimize impacts to threatened and endangered species. The 1997 RBO requires that the Corps initiate consultation for any project in which more than one turtle is taken within 24 hours or once five or more turtles are taken. The Corps' own policies are more stringent than the RBO with regards to project shutdown after turtle takes. Comments received in response to the public notice for this project reflect concern for hopper dredging in the Morehead City area in that turtle takes are common for such projects. In order for the Regulatory Division to exercise appropriate supervision and control over potential turtle takes by hopper dredging projects in North Carolina, and in order to maintain consistency with all Corps regulatory offices in the South Atlantic Region, the proposed project will be conditioned to require immediate shut down of dredging operations after a turtle take until a risk assessment can be performed, and conditions evaluated to insure low risk of additional turtle takes. In addition, the proposed project will also be conditioned to require implementation of the Silent Inspector program to reduce the risk of turtle takes by the proposed project.

(X) Biological availability of possible contaminants in dredge or fill material, considering hydrography in relation to known or anticipated sources of contaminants; results of previous testing of material from the vicinity of the project; known significant sources of persistent pesticides from land runoff or percolation; spill records for petroleum products or designated (Section 311 of the CWA) hazardous substances; other public records of significant introduction of contaminants from industries, municipalities or other sources: No appreciable effect.

e. Human use characteristics and impacts: (Check applicable blocks and provide concise description of impacts):

( ) Existing and potential water supplies; water conservation: N/A.

(X) Recreational or commercial fisheries: During project construction there will be an increase in the turbidity of the surf zone in the immediate area of sand deposition. Most of the fine material in the beach fill would be expected to wash seaward into the surf zone during construction. This increase in fine material may cause the temporary displacement of various species of fish, causing a negative impact to surf fishing and beach seining in the area of deposition. A study done by the National Maine Fisheries Service (NMFS) on the effects of beach nourishment on near shore macro infauna concluded that beach nourishment projects have no harmful effects provided that the sediments are similar to those where they are placed (Saloman and Naughton 1984). The material that would be used for beach fill is similar in composition to the native beach material, therefore the amount of fine material expected to wash out of the beach fill should not be too great. With the expected short-term impacts to the benthic communities, it is anticipated this will result in some effects to demersal organisms since benthos organisms are a predominant food source, and, in turn, affect pelagic species that feed on demersal species. These organisms, specifically post-larval, juvenile, and adult red drum, spot, croaker, striped mullet, summer flounder, juvenile and adult bluefish, Florida pompano, southern kingfish, Atlantic menhaden, and shrimp species, contain an important commercial value for the fishing industry. However, these impacts are expected to be short lived due to the fact that the project activities will occur during periods of decreased biological activity and outside the peak periods of larval recruitment and will minimize impacts to fauna of the intertidal and subtidal bottom habitats. Impacts to recreational and commercial fisheries are anticipated to be short-term and not cumulatively significant.

(X) Other water related recreation: Water related recreational activities (including boating, skiing, swimming, and sailing) would be minimally impacted by the project as these activities are routinely conducted wherever suitable conditions exist. Suitable conditions vary as a result of the dynamic nature of barrier islands. The public will benefit from the project by the construction of a larger recreational ocean beach that also provides storm protection to the adjacent coastline.

(X) Aesthetics of the aquatic ecosystem: Anticipated impacts would be minor as a result of the constantly changing conditions associated with the dynamic nature of barrier islands.

(X) Parks, national and historic monuments, national seashores, wild and scenic rivers, wilderness areas, research sites, etc.: N/A

(X) Traffic/transportation patterns: During the construction of the proposed project navigation may be impacted by dredging activities. In addition, the project may create conflicts with the dredge operations of the Corps Section 933 project. The permit will be condition to require appropriate safety measures to protect the boating public and to prohibit any interference with the Corps Section 933 project.

( ) Energy consumption or generation: N/A

(X) Navigation: The dredge and dredge pipe may cause some minimal obstruction to navigation in the offshore areas between the ODMDS and the beach disposal area. Once the dredge operation is complete there will be no obstructions to navigation from this project.

(X) Safety: During the construction of the proposed project navigation may be impacted by dredging activities. The permit will be conditioned to require appropriate safety measures to protect the boating public.

(X) Air quality: The emissions from the portion of the project authorized by this permit fall below prescribed deminimus levels, and therefore, no Clean Air Act conformity determination is required.

(X) Noise: There will be some increase in noise (dredge plant operation) during construction of the project, but this increase in sound will stop at the completing of the project.

(X) Historic Properties (Section 301(5) National Historic Preservation Act): The proposed project may impact submerged historic or archeological resources. If submerged cultural resources are encountered during the operation, the permit will be conditioned to require that the District Engineer be immediately notified so that coordination can be initiated with the Underwater Archeology Unit (UAU) of the Department of Cultural Resources.

(X) Land use classification: The proposed project is will not change the land use of the project area.

(X) Economics: The propose project will ensure that town's overall economy and tax base is preserved. In addition, there will be temporary economic benefits to the local economy with the employment of contractors.

( ) Property values: Property values on the Bogue Banks Barrrier island will likely benefit because of regional storm protection and recreation benefits provided by the proposed project.

(X) Regional growth: No appreciable affect.

(X) Tax revenues: The beach nourishment activities will provide some protection to ocean front homes and help maintain existing tax base in those areas.

(X) Employment: There will be temporary benefits from the project with the employment of contractors.

(X) Public facilities and services: The proposed project will provide a wider recreational beach.

(X) Business activity: No appreciable affect.

( ) Prime and unique farmland (7 CFR Part 658): N/A

( ) Food and fiber production: N/A

(X) Water quality: The North Carolina Division of Water Quality authorized this activity under Water Quality Certification Number 3593 dated October 30, 2006.

(X) Mineral Needs: The project involves dredging material from the ODMDS and placing beach compatible sand on the ocean shore on the Bogue Banks Barrier Island. Renourishment of beach-compatible sand into the littoral zone will help negate these effects.

(X) Consideration of private property: The proposed project will provide beach nourishment material to the ocean front and provide increase storm and floodwater protection to the adjacent homes.

( ) Community cohesion: No appreciable affect.

( ) Community growth and development: No appreciable affect.

( ) Relocation (business, home, etc.): N/A

( ) Other: N/A

5. Summary of secondary and cumulative effects:

Secondary impacts associated with this project have been evaluated as part of the public interest review. The proposed project will excavate by hydraulic dredge up to 1,107,560 cy of beach-quality sediment from the Offshore Dredged Material Disposal Site (ODMDS), situated about 2 miles offshore of Atlantic Beach. Shallow excavations (about 2-5 ft deep, typical) would be made by hopper dredge and pumped via submerged pipe to the beach. The FEMA-approved renourishment area will consist of approximately five reaches totaling up to 54,658 ft along Bogue Banks. This will provide enhanced storm protection by restoring the beach to pre-*Ophelia* conditions. The main negative secondary impacts of the proposed project are impacts to the habitat for fish and other aquatic organisms, shorebirds, recreational and commercial fishing.

As discussed above, the negative impacts associated with the disposal of sand on the beach are temporary in nature and with the appropriate special conditions and conservation measures the proposed project should not have any long-term negative effects and I do not consider those impacts to be significant.

We have considered the cumulative impact of the proposed project and also considered the past and proposed future projects similar in nature in North Carolina. The Wilmington District performed a cumulative impact analysis of beach renourishment/disposal activities within the state of North Carolina in the Final Environmental Impact Statement on Hurricane Protection and Beach Erosion Control, Dare County Beaches (Bodie Island Portion), pages 6-31 through 6-39. The following discussion is an update of that analysis.

The State of North Carolina has approximately 320 miles of ocean shoreline. There are numerous completed and proposed projects involving beach renourishment, similar to the completed and proposed renourishment activity on Bogue Banks. These projects are typically authorized as one-time beach nourishment events and do not include long term maintenance, except for the Mason Inlet project. In addition to the permitted projects, there are four Corps congressionally authorized beach nourishment projects and several beach nourishment projects. Federal projects are authorized for 50 years of long-term periodic maintenance following initial beach fill construction. All Corps projects utilize offshore borrow sources.

The authorized project of the relocation of Mason Inlet was not included in the Final Environmental Impact Statement, but it does include Figure 8 Island where private beach nourishment has occurred on about two miles of beach (including the area to be renourished as a part of the Mason Inlet project) on four occasions between 1985 and 1999. In 2001, the Figure 8 Island Homeowners Association completed renourishment of the northern part of the island, using sandy material dredged from Nixon Channel, a tributary of Rich Inlet. Figure Eight Island also performed this same project along with the dredging of Banks Channels renourishing the entire shoreline along the ocean front of Figure Eight Island.

The Marine Corps is currently authorized for beach nourishment on about one mile of West Onslow Beach. Carteret County recently renourished approximately 18 miles of Bogue Banks, from Emerald Isle to Atlantic Beach, using material dredged from offshore borrow sites. In the spring of 2006, the Town of Holden Beach completed a beach nourishment project on its beaches using material from upland borrow site. Topsail Island (composed of the Towns of North Topsail Beach, Surf City, and Topsail Beach) in Pender and Onslow Counties is presently studying beach nourishment options of its oceanfront beaches. Figure Eight Island is also studying its beach nourishment options for its island. The Town of Nags Head located in Dare County has applied for Corps permit to nourish eleven miles of its beaches using beach fill from offshore borrow sites. Many of these communities have either received state or Federal permit authorization to conduct community-wide emergency beach work, or are preparing official requests.

The Corps currently renourishes Wrightsville, Carolina, and Kure beaches every three to five years. The Corps has also nourished Atlantic Beach under Section 933. The Corps recently established sea turtle habitat at Oak Island, using sand dredged from the Yellow Banks Disposal

Area, a large sand source on the mainland adjacent to the AIWW, and placing it waterward of the Atlantic Ocean's MHW. In association with its ongoing Cape Fear River/Wilmington Harbor deepening project, the USACE has placed and is going to place additional dredged sand on Bald Head Island, Caswell Beach, and Holden Beach. In March 2001, the USACE renourished approximately 3 miles of beach at Ocean Isle, and expects to renourish it every three years. In addition, the Corps is in the process of studying the feasibility of Federal renourishment project to include undetermined reaches of beach at Holden Beach and Oak Island/Caswell Beach in Brunswick County. In addition, the Corps has obtained approval for the renourishment Dare County Beaches of Kitty Hawk, Kill Devil Hills, and Nags Head. The Corps is currently studying beach nourishment projects at Topsail, Surf City, and North Topsail. Lastly, the Corps also performs beach disposal of sediments on the AIWW as part of the maintenance program for the AIWW

The following summaries are statewide impacts related to Wilmington District activities:

<u>Disposal Activities</u>:

Avg/year – 8.0 miles or 2.5% of total NC ocean beach (320 miles)
Minimum for any year is 3.5 miles or 1.1 % of total NC ocean beach
Total beach affected is 22.4 miles or 7.0 % of total NC ocean beach

Given the small percentage of the total shoreline impacted, the fact that each project is not conducted on an annual basis but every two or more years (thereby allowing biological recovery), the dynamic nature of the systems, and the minimal and/or short-term environmental impacts associated with each project, the cumulative environmental impacts of these combined beach disposal and renourishment projects (including the proposed project) are not considered to be significant.

<u>Resource Threshold Levels:</u> We are aware of no established thresholds regarding the extent of ocean beach that can be disturbed by beach disposal/nourishment without significant population level impacts on birds and fisheries that rely on the beach invertebrates for food. Therefore a comparison of cumulative impacts to established thresholds is not made. A relatively small portion of North Carolina beaches is presently affected by these activities, about 15%. It is unlikely that cumulative impacts from space crowded perturbation are occurring or will occur with the construction of this project. The analysis suggests that the potential impact area from the proposed and existing actions is small relative to the area of available similar habitat on a vicinity and statewide basis. These areas are expected to recover food resources, which should continue to be available. It is expected that the direct and cumulative impacts of the proposed action and other existing similar activities would reach a threshold with high potential for population level impacts on important commercial fish stocks and birds is low. The following discussion provides support for this conclusion.

(DOI 1999) reports that: *As with benthic organisms living in borrow areas, benthic organisms are significantly impacted by beach nourishment activities (Nelson 1985; Van Dolah et al. 1992). These impacts, however, are considerably shorter in duration than the impacts observed in offshore borrow areas. Because benthic organisms living in beach habitats are adapted to* *living in high energy environments, they are able to quickly recover to original levels following beach nourishment events; sometimes in as little as three months (Van Dolah et al. 1994; Levison and Van Dolah 1996). This is again attributed to the fact that intertidal organisms are living in high energy habitats where disturbances are more common. Because of a lower diversity of species compared to other intertidal and shallow subtidal habitats (Hackney et al. 1996), the vast majority of beach habitats are recolonized by the same species that existed before nourishment (Van Dolah et al. 1992; Nelson 1985; Levison and Van Dolah 1996; Hackney et al. 1996). Rakocinski et al.I*

The Corps has considered the cumulative impacts of this project along with other similar projects in North Carolina. All the authorized nourishment projects have been individually conditioned to minimize environmental impacts. These conditions include allowing work only in time frames when oceanfront and aquatic organisms are least active and requiring conservation measures to further minimize impacts to the coastal environment. Because of the dynamic nature of the systems, the minimal and/or short-term environmental impacts, limiting the time frame of work, and incorporating special conditions and conservation measures, the cumulative environmental impacts are not considered significant.

With respect the proposed project, the applicant has provided extensive data regarding monitoring results from data collected during construction of Phase 1 and Phase 2 of the Bogue Banks Renourishment Project. The applicant's analysis is summarized below.

The biological monitoring plan for Phases 1 and 2 of the Bogue Banks beach nourishment project has fulfilled the permit requirements set forth by federal and state governments. Monitoring was implemented to document the impact on invertebrates, fish, and endangered plants. The borrow areas for Phases 1 and 2 were left to adjust naturally and to re-colonize while other areas are being excavated. Fill sections were left to adjust naturally as soon as the required volumes were pumped into place and confirmed by surveys. The monitoring plan scope (2001–2005) was as follows:

- Quantify the changes in benthic (bottom dwelling) populations in the borrow areas
- Quantify the changes in benthic populations along the beach
- Compare impacted areas of the beach with unrestored areas
- Obtain semi-quantitative data on fish populations and foraging habitats in the surf zone
- Monitor the recovery and population of ghost crabs and turtle nests in the project area
- Monitor the occurrence of seabeach amaranth (threatened plant species) in project area

Sampling was conducted twice annually every June and November for five years following the end of the Phase 2 project in Emerald Isle or until organisms recovered to near or above baseline conditions. Two monitoring events were conducted by 2001 (June and November) to set baseline conditions for post dredge monitoring. The applicant's agent, Coastal Science Associates Inc, used five quantitative analyses to generate relevant statistical data based on taxonomic information gathered from the offshore and beach samples:

1) Species abundance – as total number of individuals.
2) Number of species – as total number of species.

3) Mean number of species.
4) Shannon-Wiener species diversity.
5) Evenness – the distribution of individuals among the species.

The seventh and final spring biological monitoring event for Phases 1 and 2 took place in June 2005. For this monitoring event, comparisons were made between dominate benthic invertebrates *Emerita talpoida*, *Donax variabilis, Amphiporeia virginiana, and Scolelepis squamata*. Results of biological monitoring through June 2005 are summarized as follows.

Pine Knoll Shores – After the seventh monitoring event species diversity and evenness returned to or above pre dredge (baseline) levels. Numbers of *Emerita talpoida* and *Scolelepis squamata* recovered to near or above baseline levels. Data shows that *Donax variabillis* and *Amphiporeia virginiana* are still below baseline, but are recovering well.

Indian Beach – Species diversity and evenness decreased slightly since the fifth post dredging monitoring event, but increased to near baseline levels. Species abundance are approaching baseline conditions.

Emerald Isle – Compared to previous pre-nourishment surveys, species diversity and evenness have increased to close to baseline levels. *Amphiporeia virginiana* and *Emerita talpoida* are still below predredge levels; however, the abundances are still increasing. The numbers for *Donax variabillis* and *Scolelepis squamata* have surpassed the baseline showing that recovery is almost complete.

Control Sites – There are six control sites for Bogue Banks. Three control sites are located in Emerald Isle (stations 1–3). The other three control stations are located in Atlantic Beach (stations 1–3). Three control sites were monitored for the seventh monitoring event, two from Emerald Isle (Fairfax & Ocean, control station # 4), and one from Atlantic Beach (control station # 3). At station 3, data revealed a decrease in species diversity and evenness since the fifth sampling event. Total number of organisms increased since the last sampling event due to a spike in the *Scolelepis squamata* population. Abundances in the other species have remained fairly constant throughout the study.

Both Emerald Isle control stations showed a decrease in species diversity and evenness since survey five. There was an increase in number of organisms at the three stations due to spikes in populations from all four dominate species.
Although species diversity, evenness, and organism numbers were below baseline levels, data suggests that recovery of organisms is continually moving in a positive direction. Biological monitoring for Phases 1 and 2 confirmed that all species present before nourishment has repopulated the nourished beach by varying degrees depending on the species.

According to CSA's fifth post dredge sampling event and report, populations in the offshore borrow area indicated increases in the number of organisms, species diversity, and evenness. Nearshore demersal fish species and numbers varied from station to station, but still remain at or above pre-project numbers.

On the beach, ghost crabs have returned to similar or higher levels than pre-project conditions and the seabeach amaranth have expanded over 100-fold compared with pre-project numbers. Post project turtle nesting and numbers of hatchlings exceed pre-project numbers.

The proposed renourishment will impact about 54,658 linear feet of the total length of Bogue Banks. It will consist of five reaches along about 10.3 miles of shoreline length, leaving undisturbed sections from which recruitment of benthic organisms can occur.

The applicant has proposed the following mitigation measures:

- Construction only during permitted time periods
- Implementation of endangered species monitoring onboard hopper dredges
- Implementation of turtle trawling and relocation measures during periods when water temperature exceeds 57º Fahrenheit
- Continuation of semi-annual biological monitoring of the borrow areas and beach along Bogue Banks
- Daily monitoring of construction
- Daily sediment sampling and testing
- Dredging from ODMDS, the ocean disposal site for dredging of Morehead City Harbor channel; this site is not an undisturbed bottom area

6. Agency Coordination:

a. Other authorizations:

(1) 401 Certification (North Carolina Department of Environmental Management):
Date _October 30, 2006_ issued _X_ (Water Quality Certification #3593)
denied __ waived __ not required
Special Conditions Yes _X_ No

(2) Coastal Zone Management Consistency Determination:
Date _November 2, 2006_ issued _X_ denied __ waived ___ not required
Special Conditions Yes _X_ No

(3) State and/or local authorizations (if issued)

b. Summary of comments received: All comments received on this action have been reviewed and are summarized below.

(1) Federal agencies:

(a) U.S. Fish and Wildlife Service (USFWS): In a September 20, 2006 letter, the USFWS stated that the proposed project might impact threatened or endangered species (loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), Kemp's ridley (*Lepidochlelys kempi*), hawksbill (*Eremochelys imbricata*) , green sea turtles (*Chelonia mydas*) and Seabeach amaranth (*Amaranthus pumilus*). The USFWS stated the formal consultation with the Federal agency and the preparation of a biological opinion will be required if conditions, summarized below, are not implemented. The recommended conditions are summarized below:

- Project activities on the beach must be limited to November 16 thru April 30th.
- All fill material must be beach compatible and free of construction debris, rocks,
- organic materials, or other foreign matter and shall not contain greater than 10 percent fines or 5 percent coarse gravel or cobble.
- A sea turtle nest monitoring program of the Bogue Banks beach nourishment
- project must continue after completion of the beach disposal work and prior to April
- 1 for three subsequent years or until the nourishment material is "washed off the beach".
- Sand compaction must be monitored following beach fill placement for each reach and if required the nourished beach must be tilled to a depth of 36 inches.
- Escarpments exceeding 18 inches must be removed immediately.
- No construction equipment will be stored on the beach from May 1 through November 15.

Resolutions of USFWS concerns:

In response to the USFWS comments, the application has revised its proposal to conducting dredging operations to between January 1st and March 31st and the implementation of the following turtle take measures:

- Construction only during permitted time periods
- Implementation of endangered species monitoring onboard hopper dredges
- Implementation of turtle trawling and relocation measures during periods when water temperature exceeds 57° Fahrenheit
- Continuation of semi-annual biological monitoring of the borrow areas and beach along Bogue Banks
- Daily monitoring of construction
- Daily sediment sampling and testing
- Dredging from ODMDS, the ocean disposal site for dredging of Morehead City
- Harbor Channel; this site is not an undisturbed bottom area

The applicant has stated that a request for an extension of time to April 15th may be needed to complete the proposed project. The applicant's proposal does not include a project completion date nor does it indicate when all construction equipment will be removed from the beach. In response to USFWS comments, a special permit condition to the proposed project will require that all beach work shall be completed by March 31st including demobilizing all equipment and beach tilling.

In response to the USFWS comment, the applicant stated that there has been over 5 million cubic yards successfully placed along Bogue Banks project area since 2002. The applicant also stated that extensive ODMDS sediment analyses have been performed to ensure these materials are beach compatible. The applicant did not propose any sediment analyses during construction to ensure that what is placed on the beach is beach compatible sand. Only beach quality sand will be used for the proposed project. Since sediment compatibility problems were encountered during Phase 1 and Phase 2 of the Bogue Banks Renourishment project, it has been determined that DAILY sediment samples will be collected and grain size analyses of these samples provided daily to ensure that only beach compatible sand is discharged onto the beaches of the Bogue Banks project area.

In response to the USFWS comment regarding sea turtle nest monitoring, the applicant stated that sea turtle nest monitoring is not warranted beyond 2007 and that Carteret County, through the County Shore Protection Office, has been funding turtle monitoring since 2002 with the agreement between the Carteret County and NCWRC to end all monitoring in 2007. The sea turtle nest monitoring program for the Bogue Banks beach nourishment project is ongoing and scheduled to end in 2007. It has been determined that data from the current program will be evaluated near the completion of the proposed project to determine if the monitoring program should be continued.

In response to the USFWS comment regarding sand compaction and sand compaction monitoring, the applicant stated that the completed beach will be tilled from the high water mark to the landward extent of the beach fill or areas disturbed by heavy construction equipment and that tilling will be performed to a depth of 36 inches. The applicant did not address the recommendation to collect and analyze sand compaction data for each reach. It has been determined compaction monitoring in accordance with the USFWS recommendations will be required. This includes compaction testing of each reach upon completion of that reach. This data will be evaluated and coordinated with the USFWS to determine if tilling of the beach is needed.

In response the USFWS comment regarding the formation of beach escarpments during and after construction, the applicant has revised the proposed project to grade all escarpments greater than 18 inches to match the existing grade. This will also be required by special condition for the life to the project to ensure all escarpments are graded promptly by the applicant.

In response the USFWS recommendation for sea beach amaranth surveys for three years, the applicant stated that no further monitoring of sea beach amaranth is warranted. The applicant stated that sea beach amaranth has been monitored since 2000 and feel that as long as suitable habitat is maintained the plant will continue to flourish on Bogue Banks and no further monitoring is required. Based on the USFWS recommendation, it is felt that surveys should not be required.

The applicant did not respond to the USFWS comment recommending no equipment or pipes shall be stored on the beach from May 1 through November 15. We believe this was an oversight by the applicant and agree with the USFWS. It has been determined that this requirement shall be made be special condition to the permit to restrict all beach disposal work to between January 1 and March 31st.

(b) **National Marine Fisheries Service (NMFS)**: In a letter dated August 1, 2006 the NMFS stated that potential impacts to ESA-listed humpback and right whales, sea turtles, and shortnose sturgeon stemming from the use of pipeline and hopper dredges are encompassed by the September 27, 1997 regional biological opinion (RBO) to the COE's South Atlantic Division on the continued hopper dredging of channels and borrow areas in the southeastern united states. The NMFS stated that there are no new species listed under the ESA since the RBO was issued that will be affected by the proposed action and since the effects of the proposed action are included in the RBO and there is no new information that would change the basis of the RBO's findings, consultation with the NMFS on the proposed action is not necessary.

Resolutions to NMFS concerns. The NMFS does not object to the proposed project.

(2) State and local agencies:

(a) **North Carolina Wildlife Resources Commission (NCWRC)**: In an August 7, 2006 letter, the NCWRC stated that they had no objections to the proposed dredging but stated it had concerns regarding the ability of invertebrate populations to fully recover due to the frequency of nourishment events, that more time will be needed to construct the project than what was proposed, and safeguards to ensure beach compatible material is placed on the beach.

Resolutions to NCWRC concerns.

In response the NCWRC comment, the applicant has stated that since 2000 there have been extensive studies of recovery of invertebrates in the surf zone of nourished beached on Bogue Banks and provided the results of these studies. This report states that the recovery of organisms is continually moving a positive direction and that all species present prior to nourishment re-populated the nourished beach. Based on this report, it has been determined that invertebrate recovery could potentially be impacted by the proposed project and that this monitoring should continue.

The applicant did not respond to the NCWRC comment regarding construction time.

The applicant previously responded to comments regarding beach compatibility by the USFWS.

5. **Organizations:** None.

6. **Individuals:** None.

7. **Complete Application and Public Notice:** The Corps received the application on June 14, 2006. The Corps considered the application complete on June 14, 2006. The Corps issued a public notice on July 5, 2006 and sent this notice to all interested parties including appropriate

State and Federal agencies.

8. Evaluations:

I have reviewed and evaluated, in light of the overall public interest, the documents and factors concerning this permit application as well as the stated views of other interested agencies and the concerned public. In doing so, I have considered the possible consequences of this proposed work in accordance with regulations published in 33 CFR Part 320 to 330 and 40 CFR Part 230. The following paragraphs include my evaluation of comments received and how the project complies with the above cited regulations.

a. Consideration of Comments: In accordance with policy guidance from the office, Chief of Engineers, Regulatory Guidance Letter 92-1, Federal Agencies Roles and Responsibilities, I have fully considered all agency comments. The proposed project, with the inclusion of special conditions, will result in minimum adverse impacts to the waters of the Atlantic Ocean and the shoreline adjacent to Bogue Banks.

b. Evaluation of Compliance with 404(b)(1) Guidelines (Restrictions on discharge, 40 CFR 230.10): (An * is marked above the answer that would indicate noncompliance with the guidelines. No * marked signifies the question does not relate to compliance or noncompliance with the guidelines. An "X" simply marks the answer to the question posed.)

1. Alternatives test:

	Yes	No
a. Based on the discussion in 4b, are there available, practicable alternatives having less adverse impact on the aquatic ecosystem and without other significant adverse environmental consequences that do not involve discharges into "waters of the United States" or at other locations within these waters?	*	X
b. Based on 4d, if the project is in a special aquatic site and is not water-dependent, has the applicant clearly demonstrated that there are no practicable alternative sites available?	X	*

2. Special restriction. Will the discharge:

a. violate state water quality standards?	*	X

Yes No

b. violate toxic effluent standards (under Section 307 of the Act)?

* ___ _X_ Yes No

c. jeopardize endangered or threatened species or their critical habitat?

* ___ _X_ Yes No

d. violate standards set by the Department of Commerce to protect marine sanctuaries?

* ___ _X_ Yes No

e. Evaluation of the information in 4 c and d above indicates that the proposed discharge material meets testing exclusion criteria for the following reason(s):

_X_ Yes No

(X) based on the above information, the material is not a carrier of contaminants.

( ) the levels of contaminants are substantially similar at the extraction and disposal sites and the discharge is not likely to result in degradation of the disposal site and pollutants will not be transported to less contaminated areas.

( ) acceptable constraints are available and will be implemented to reduce contamination to acceptable levels within the disposal site and prevent contaminants from being transported beyond the boundaries of the disposal site.

3. Other restrictions. Will the discharge contribute to significant degradation of "waters of the United States" through adverse impacts to:

a. human health or welfare, through pollution of municipal water supplies, fish, shellfish, wildlife

* ___ _X_ Yes No

and special aquatic sites?

b. life stages of aquatic life and other wildlife?	* ___ _X Yes No
c. diversity, productivity and stability of the aquatic life and other wildlife or wildlife habitat or loss of the capacity of wetland to assimilate nutrients, purify water or reduce wave energy?	* ___ _X Yes No
d. recreational, aesthetic and economic values?	* ___ _X Yes No
4. Actions to minimize potential adverse impacts (mitigation). Will all appropriate and practicable steps (40 CFR 230.70-77) be taken to minimize the potential adverse impacts of the discharge on the aquatic ecosystem?	* _X Yes No

In accordance with 33 U.S.C. 1341(d), all conditions of the North Carolina Division of Coastal Consistency Determination dated November 2, 2006 and the North Carolina Division of Water Quality 401 Water Quality Certification #3593 dated October 30,2006 are incorporated as part of the Department of the Army permit.

c. General Evaluation [33 CFR 320.4(a)]:

(1) The relative extent of the public and private need for the proposed work has been fully documented. The project complies with all requirements of National Environmental Policy Act and the 404(b)(1) Guidelines of the Clean Water Act.

(2) The practicability of using reasonable alternative locations and methods to accomplish the objective of the proposed structure or work: See III.B. above.

(3) The extent and permanence of the beneficial and/or detrimental effects that the proposed work may have on the public and private uses to which the area is suited have been clearly documented by the applicant. Provided that the work is undertaken in accordance with all permit conditions, no appreciable adverse effects are anticipated.

9. Statement of Findings:

a. Finding of No Significant Impact (FONSI) (33 CFR Part 325): Having reviewed the information provided by the applicant, all interested parties and the assessment of environmental impacts contained in Part III of this document, I find that this permit action will not have a significant impact on the quality of the human environment. Therefore, the preparation of a detailed Environmental Impact Statement pursuant to Section 102(2)(c) of the National Environment Policy Act of 1969 is not required.

b. 404(b)(1) Compliance/Non-compliance Review (40 CFR 230.12):

( ) The discharge complies with the guidelines.

(X) The discharge complies with the guidelines, with the inclusion of the appropriate and practicable conditions listed in V.B.4. above to minimize pollution or adverse impacts to the effected ecosystem.

( ) The discharge fails to comply with the requirements of these guidelines because:

( ) There is a practicable alternative to the proposed discharge that would have less adverse effect on the aquatic ecosystem and that alternative does not have other significant adverse environmental consequences.

( ) The proposed discharge will result in significant degradation of the aquatic ecosystem under 40 CFR 230.10(b) or (c).

( ) The discharge does not include all appropriate and practicable measures to minimize potential harm to the aquatic ecosystem, namely...

( ) There is not sufficient information to make a reasonable judgement as to whether the proposed discharge will comply with the guidelines.

c. Public Interest Evaluation and Statement of Findings:

I have given full consideration to this application, weighing the favorable and unfavorable aspects. My evaluation has included the impact of the activity on the public interest, including application of the 404(b)(1) guidelines, and I find that issuance of a Department of the Army permit, as prescribed by regulations published in 33 CFR Parts 320 to 330, and 40 CFR Part 230, is not contrary to the general public interest provided that the permittee adheres to the attached conditions incorporated in the permit. Accordingly, I am hereby issuing (or intend to issue) the requested permit.

PREPARED BY:

________________________ ______________

Dave Timpy Date
Regulatory Project Manager

REVIEWED BY:

Keith A. Harris Date
Chief, Wilmington Field Office
Regulatory Division

APPROVED BY:

John E. Pulliam, Jr. Date
Colonel, U.S. Army
District Engineer

ATTACHMENT 1

SEDIMENT COMPATIBILITY ANALYSIS AND BACKUP INFORMATION

Sediment Compatibility Analysis
Geophysical Seafloor Imaging – Backscatter
Geophysical Seafloor Imaging – Bathymetry
Geophysical Subsurface Imaging – Isopach (Sediment Thickness) Map
Geophysical Subsurface Imaging – Profile Maps
Vibracore Photos
Vibracore Geological Logs
Vibracore Sediment Sieve Analyses
Vibracore Penetration Graphs

Bogue Banks Sediment Compatibility

Native Sediment Characteristics

Reference - (CSE, 2001 - EA for Phases 1 & 2 and CAMA Permit #124-01)

Mean	1.76 phi	0.30 mm
Standard Deviation	0.77 phi	0.59 mm

Borrow Area Sediment Characteristics ODMDS

Reference - (Alpine, February 2012)

Mean	1.71 phi	0.31 mm
Standard Deviation	1.09 phi	0.81 mm

Percent Fines	0.5%
Percent Sand	98.0%
Precent Gravel	1.5%

Overfill Factor

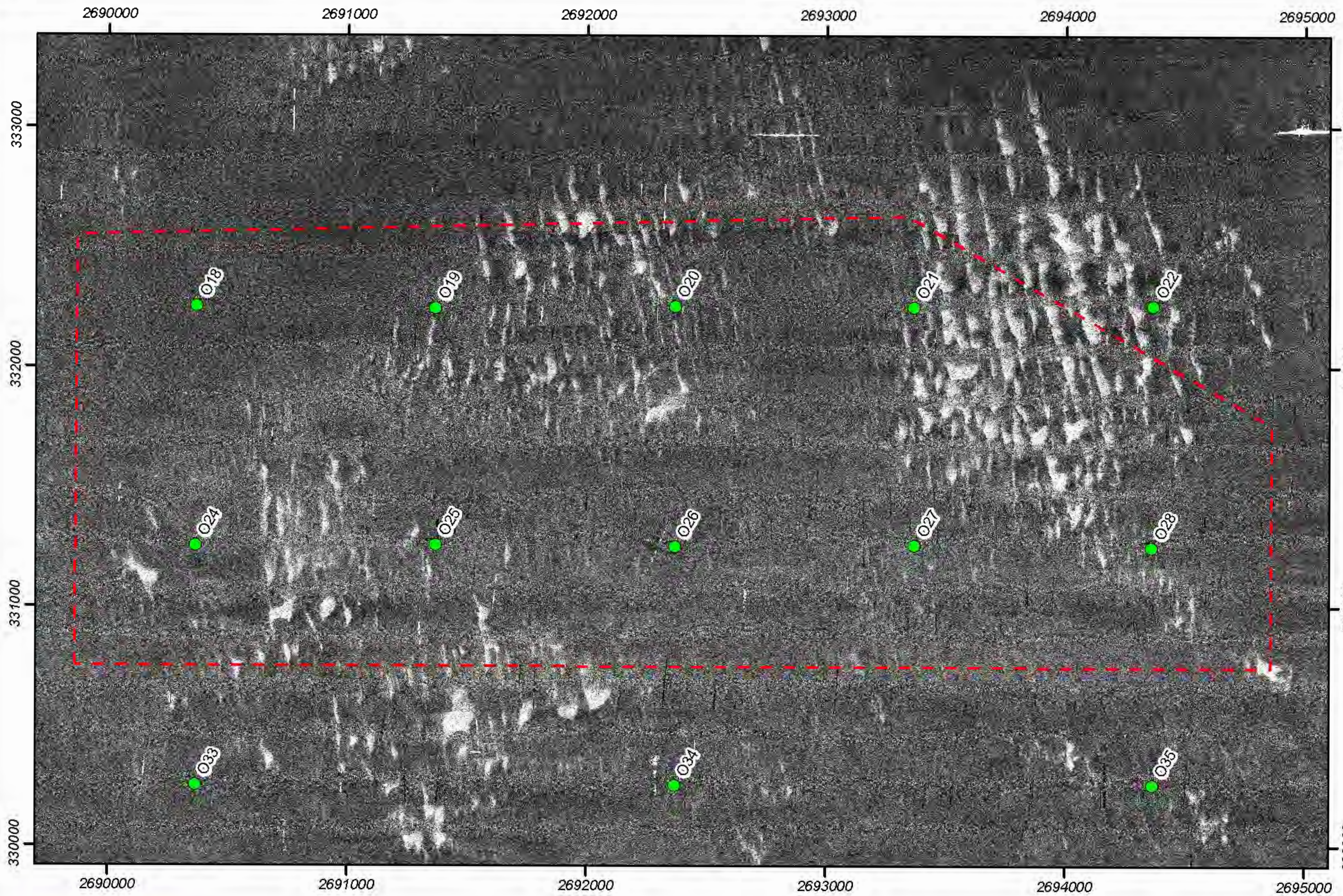
Mean Difference	Sorting Ratio	Overfill Ratio ACES & CEM
-0.06	1.42	1.14

Summary of ODMDS Borrow Area Sediment Characteristics

Vibracore	Sample Number	Depth (ft)	Bed Elevation (ft NAVD)	Sample Elevation (ft NAVD)			Sample Depth (ft)	Gravel	Sand	<#200	<#230	Carbonate	Mean (mm)	Mean (phi)	S.D. (phi)	USC
O18	1	0-6	-44.1	-44.1	-	-50.1	6.0	1.22	98.07	0.71	0.53	12.1	0.28	1.84	1.1	SW
O18	2	6-12	-44.1	-50.1	-	-56.1	6.0	0.21	99.39	0.4	0.29	12.6	0.28	1.84	1.02	SW
O19	1	0-6	-36.1	-36.1	-	-42.1	6.0	0	99.82	0.18	0.08	10.6	0.25	2.00	0.86	SW
O19	2	6-12	-36.1	-42.1	-	-48.1	6.0	1.69	98.27	0.04	0	13.5	0.29	1.79	1.07	SW
O19	3	12-17	-36.1	-48.1	-	-53.1	5.0	1.63	98.19	0.18	0.12	12.8	0.32	1.64	1.1	SW
O19	4	17-19.3	-36.1	-53.1	-	-55.4	2.3	0	99.3	0.7	0.49	9.5	0.24	2.06	0.73	SP
O20	1	0-5	-36.4	-36.4	-	-41.4	5.0	2.55	97.31	0.14	0.12	17.8	0.35	1.51	1.29	SW
O20	2	5-10	-36.4	-41.4	-	-46.4	5.0	1.28	97.83	0.89	0.72	21.2	0.31	1.69	1.18	SW
O20	3	10-13.9	-36.4	-46.4	-	-50.3	3.9	2.31	97.24	0.45	0.39	9.3	0.3	1.74	1.21	SW
O21	1	0-5	-37	-37.0	-	-42.0	5.0	0.36	99.34	0.3	0.28	16.2	0.3	1.74	0.92	SW
O21	2	5-10	-37	-42.0	-	-47.0	5.0	1.77	97.72	0.51	0.46	11.7	0.36	1.47	1.24	SW
O21	3	10-15	-37	-47.0	-	-52.0	5.0	1.66	98.11	0.23	0.16	12.3	0.31	1.69	1.08	SW
O22	1	0-5	-32.7	-32.7	-	-37.7	5.0	2.14	97.72	0.14	0.13	16.2	0.34	1.56	1.2	SW
O22	2	5-10	-32.7	-37.7	-	-42.7	5.0	2.12	97.68	0.2	0.14	12.3	0.31	1.69	1.18	SW
O22	3	10-15	-32.7	-42.7	-	-47.7	5.0	1.58	98.04	0.38	0.37	11.7	0.29	1.79	1.03	SW
O22	4	15-20	-32.7	-47.7	-	-52.7	5.0	1.06	98.53	0.41	0.4	14.7	0.34	1.56	1.02	SW
O24	1	0-4.9	-49.3	-49.3	-	-54.2	4.9	4.78	90.03	5.19	4.81	13	0.24	2.06	1.59	SW-SM
O24	2	4.9-6.8	-49.3	-54.2	-	-56.1	1.9	0.32	99.38	0.3	0.2	10.4	0.26	1.94	0.85	SP
O25	1	0-6	-42	-42.0	-	-48.0	6.0	0.9	98.65	0.45	0.36	13.6	0.33	1.60	1.1	SW
O25	2	6-12	-42	-48.0	-	-54.0	6.0	2.05	96.99	0.96	0.83	18	0.33	1.60	1.21	SW
O25	3	12-17.9	-42	-54.0	-	-59.9	5.9	1.79	98.06	0.15	0.12	19.2	0.32	1.64	1.17	SW
O26	1	0-5	-45.7	-45.7	-	-50.7	5.0	5.01	94.52	0.47	0.37	12.7	0.36	1.47	1.62	SW
O26	2	5-9.3	-45.7	-50.7	-	-55.0	4.3	0.97	98.79	0.24	0.21	11.9	0.3	1.74	0.97	SW
O27	1	0-4	-43.6	-43.6	-	-47.6	4.0	0.56	99.24	0.2	0.2	16.7	0.4	1.32	1.06	SW
O27	2	4-8	-43.6	-47.6	-	-51.6	4.0	0.67	98.95	0.38	0.35	12	0.32	1.64	1	SW
O27	3	8-12.9	-43.6	-51.6	-	-56.5	4.9	0.16	99.35	0.49	0.41	11.8	0.29	1.79	0.88	SW
O28	1	0-6	-42.7	-42.7	-	-48.7	6.0	0.59	99.29	0.12	0.09	12.8	0.28	1.84	0.93	SW
O28	2	6-11.6	-42.7	-48.7	-	-54.3	5.6	0.41	99.34	0.25	0.16	13.4	0.3	1.74	0.95	SW
							average	1.42	98.04	0.54	0.46	13.57	0.31	1.71	1.09	
							median	1.25	98.23	0.34	0.29	12.75	0.31	1.71	1.08	

Notes:

1. Only samples for depths above which may be dredged are included.
2. Elevations in ft NAVD 88; MLLW = - 2.09 ft NAVD88 (e.g. -50 ft MLLW = -52.09 ft NAVD88)



Geophysical Seafloor Imaging (Backscattter with Vibracore Locations)

Legend

- Core Locations
- Permit Borrow Area

Backscatter Value

High : -0.1

Low : -50

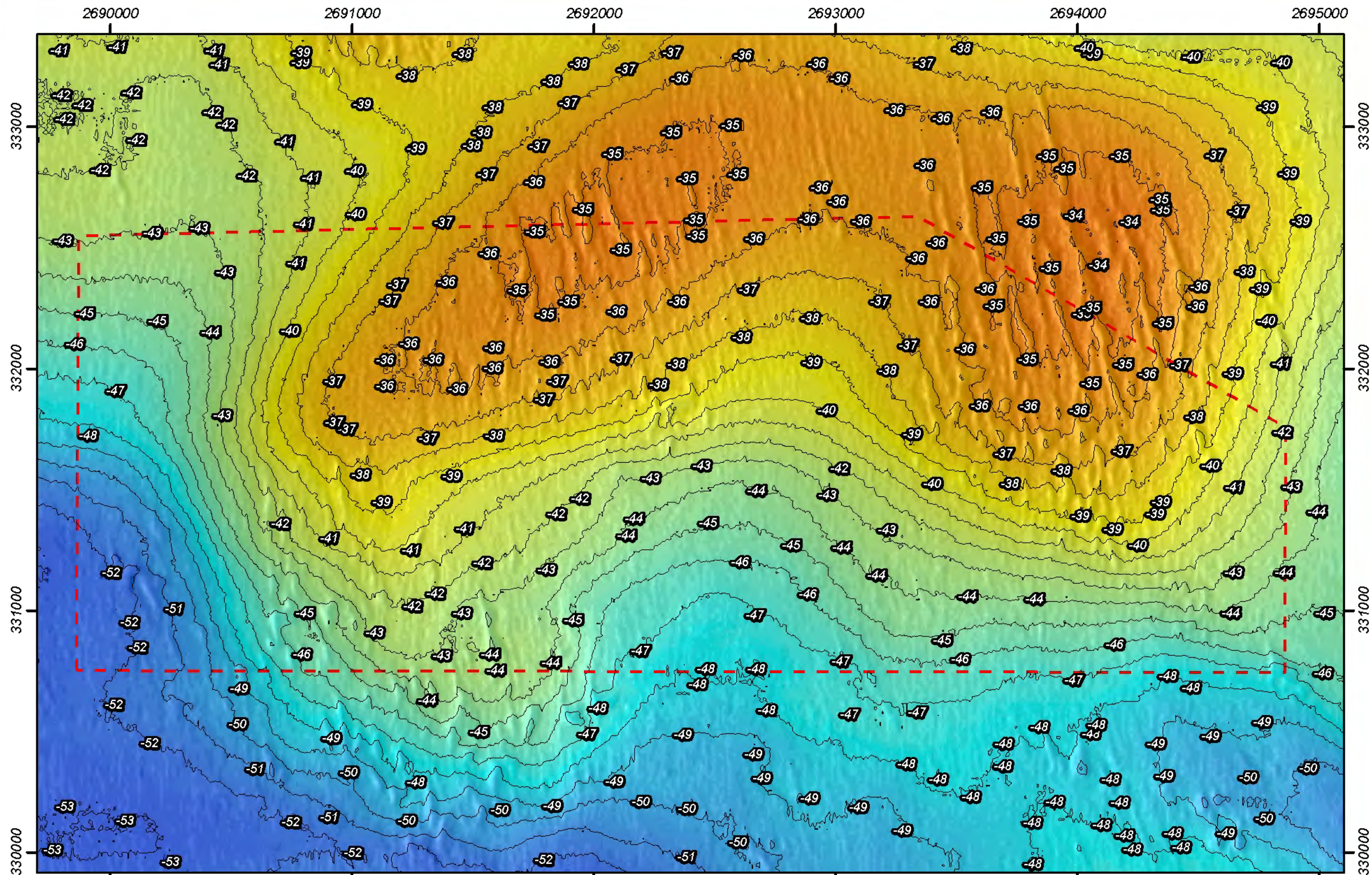
Notes:

Backscatter dataset from EM3002D multi-beam acoustic intensity data. More positive values (white) represent harder returns. Backscatter was only processed for ODMDS data, not the 2009 Beaufort Inlet survey.

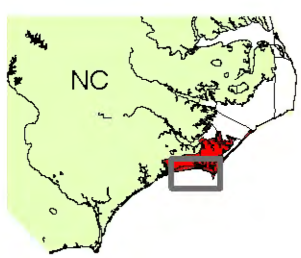
POST IRENE RENOURISHMENT PROJECT	
Sheet No:	Drawn By: Dave Bernstein	Date: Feb. 28, 2012
Stamp:	Reviewed By: Chris Freeman	Revision: 1.1

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

Geodynamics
310 A Greenfield Drive
Newport, NC 28570
252-247-5782
www.geodynamicsgroup.com



Geophysical Seafloor Imaging (Bathymetry with 1ft Contours)



Legend

1ft Contours

Permit Borrow Area

Elevation (feet, navd88)

High : -31

Low : -56

Notes:

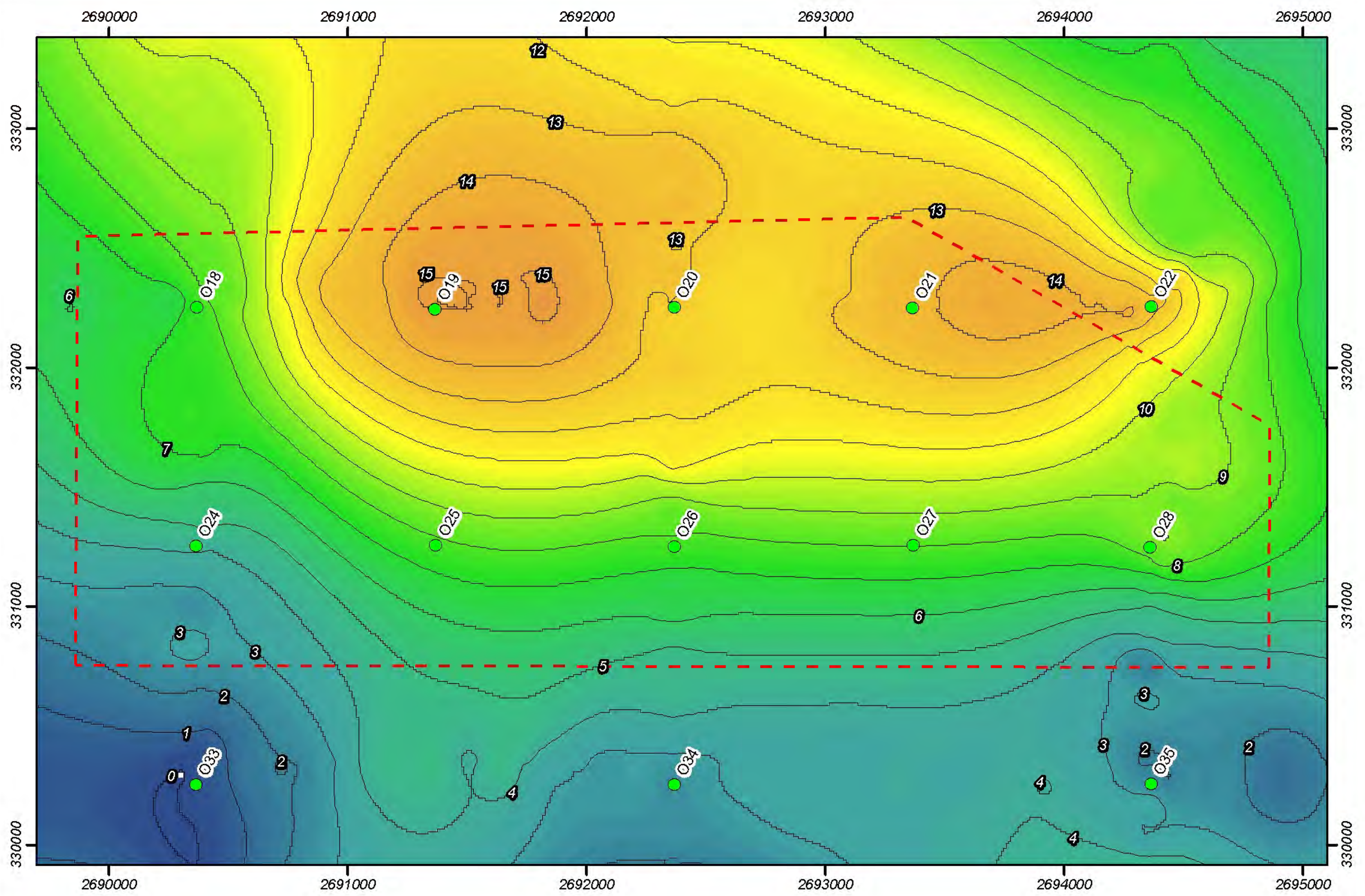
Bathymetry elevation is comprised of bathymetry collected at the ODMDS site in 2011 and bathymetry collected across Beaufort Inlet for the USACE in 2009.

POST IRENE RENOURISHMENT PROJECT

Sheet No:	Drawn By: Dave Bernstein	Date: Feb. 28, 2012
Stamp:	Reviewed By: Chris Freeman	Revison: 1.1

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

Geodynamics
310 A Greenfield Drive
Newport, NC 28570
252-247-5782
www.geodynamicsgroup.com



Geophysical Subsurface Imaging (Isopach Map with Vibracore Locations)

Legend

- Core Locations
- Permit Borrow Area
- Sed. Thickness Contours (ft)

Sediment Thickness (Feet)

High : 18

Low : 0

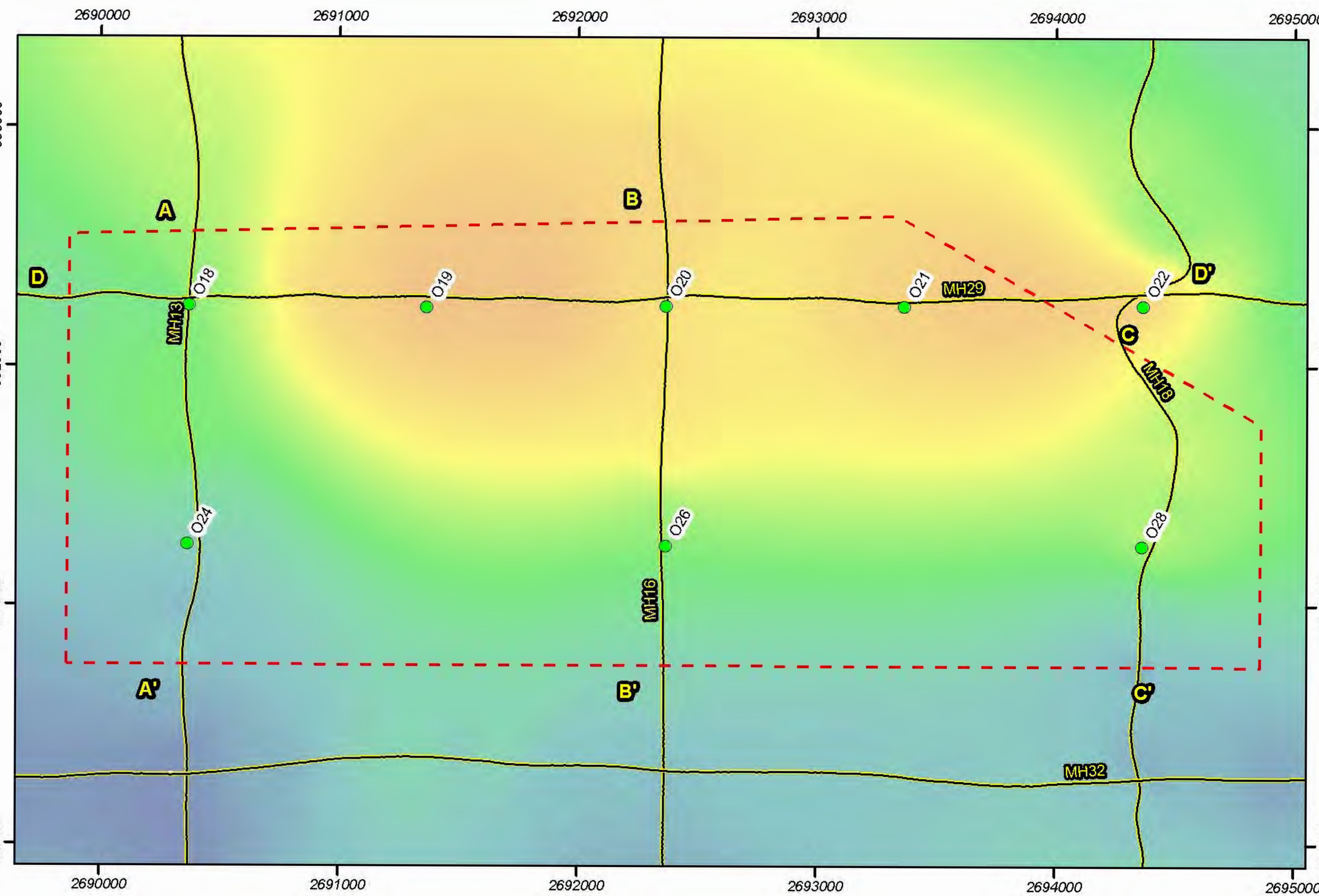
Notes:

Isopach surface and contours created from sub-bottom profile data collected with an EdgeTech sb512i CHIRP sub-bottom reflection sonar.

POST IRENE RENOURISHMENT PROJECT

Sheet No:	Drawn By: Dave Bernstein	Date: Feb. 28, 2012
Stamp:	Reviewed By: Chris Freeman	Revison: 1.1

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR
Geodynamics
310 A Greenfield Drive
Newport, NC 28570
252-247-5782
www.geodynamicsgroup.com



Geophysical Subsurface Profiles (Key Map)

Legend

- Subsurface Profiles
- Permit_Area_Core_Locations
- Permit Borrow Area

Sediment Thickness (Feet)

High : 18

Low : 0

Notes:

Geophysical subsurface profile graph extents for each slice are only within the permitted borrow area.

POST IRENE RENOURISHMENT PROJECT

Sheet No:	Drawn By: Dave Bernstein	Date: Feb. 28, 2012
Stamp:	Reviewed By: Chris Freeman	Revison: 1.1

geodynamics — COMPLEX COASTAL CHANGE MADE CLEAR

Geodynamics
310 A Greenfield Drive
Newport, NC 28570
252-247-5782
www.geodynamicsgroup.com

INSERT PROFILE MAPS HERE

Core Photographs
ODMDS Core 18 – ODMDS Core 28

Prepared for:

Moffatt & Nichol
1616 East Millbrook Road, Suite 160
Raleigh, NC 27609

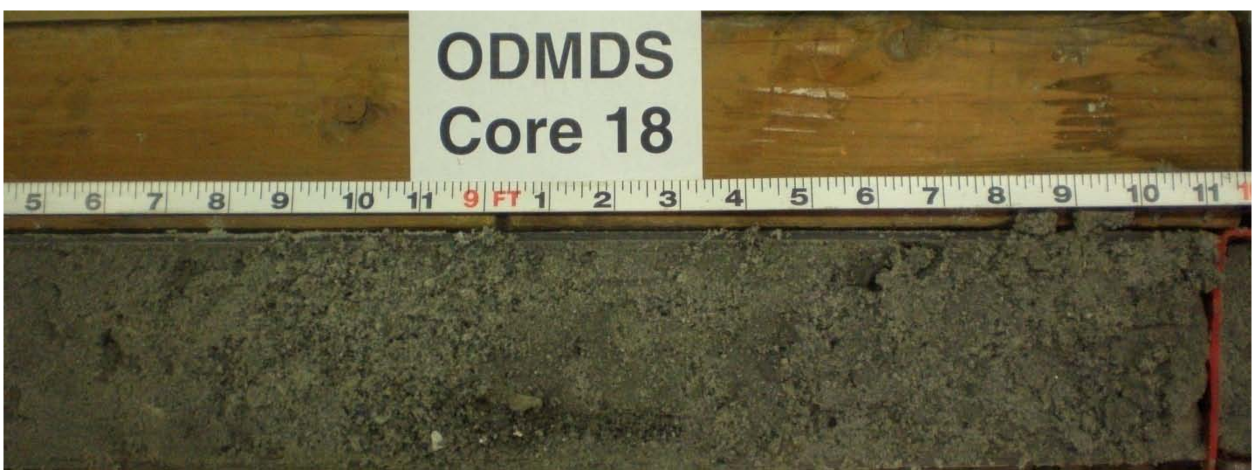
Submitted by:

Alpine Ocean Seismic Survey, Inc.
155 Hudson Avenue
Norwood, NJ 07648

February 9, 2012

ODMDS Core 18
0 – 5 feet

ODMDS Core 18
5 – 10 feet

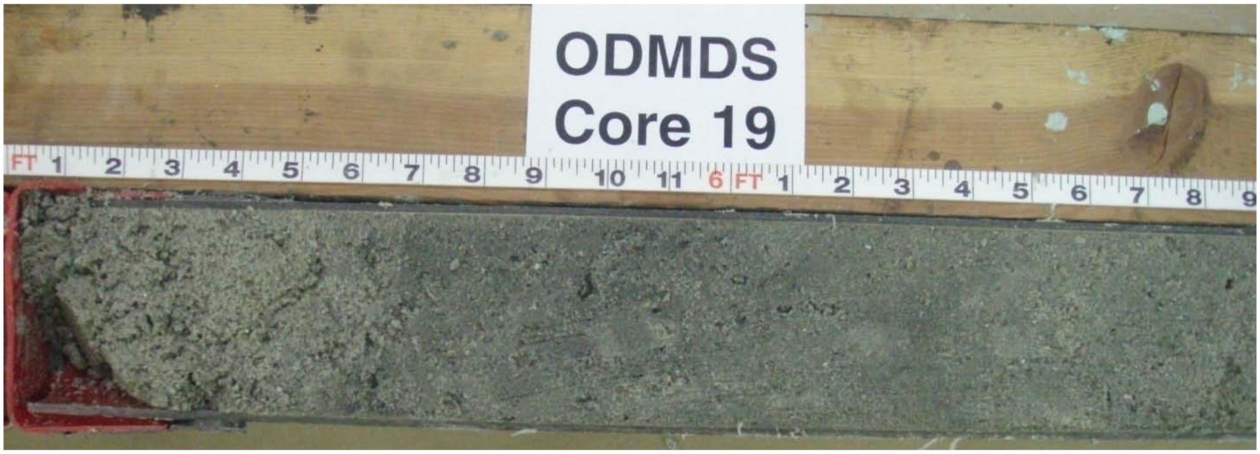


ODMDS Core 18
10 – 15 feet

ODMDS Core 18
15 – 17.83 feet

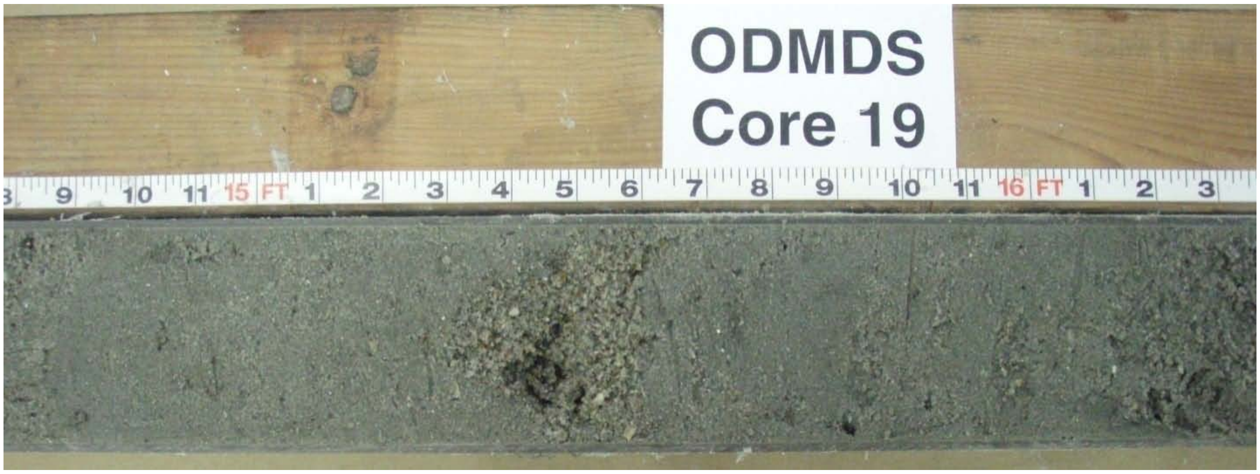
ODMDS Core 19
0 – 5 feet

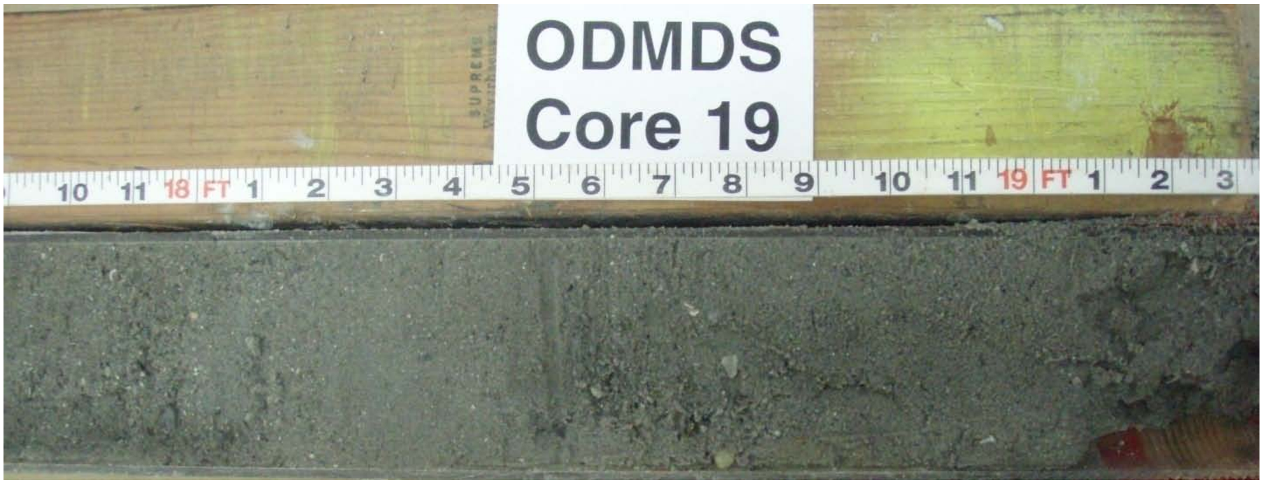
ODMDS Core 19
5 – 10 feet



ODMDS Core 19
10 – 15 feet

ODMDS Core 19
15 – 19.25 feet





ODMDS Core 20
0 – 5 feet

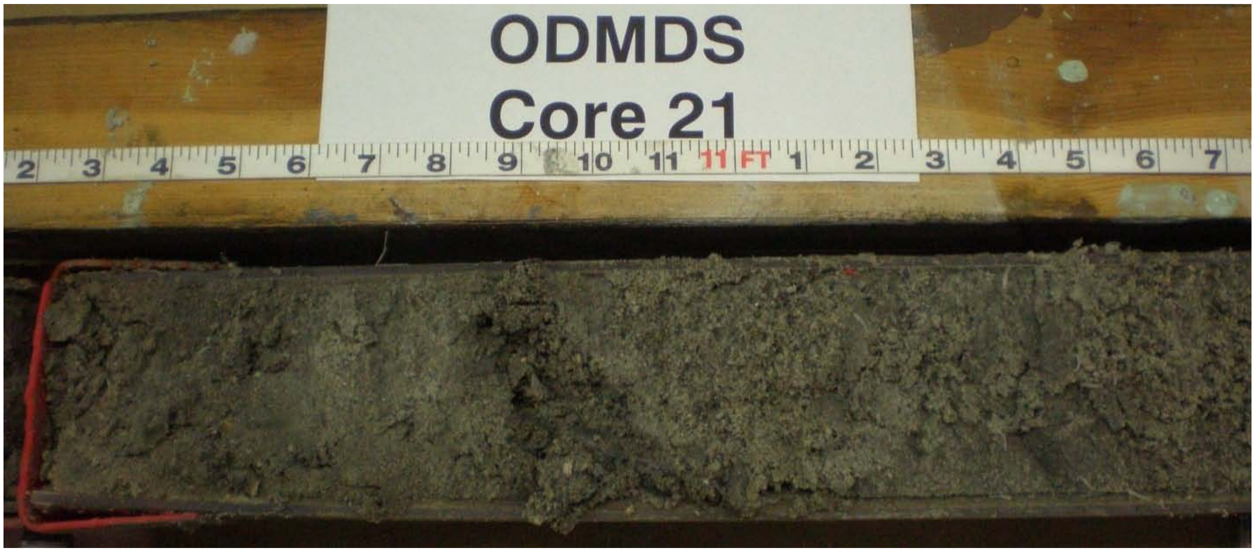
ODMDS Core 20
5 – 10 feet

ODMDS Core 20
10 – 13.83 feet

ODMDS Core 21
0 – 5 feet

ODMDS Core 21
5 – 10 feet

ODMDS Core 21
10 – 15.92 feet



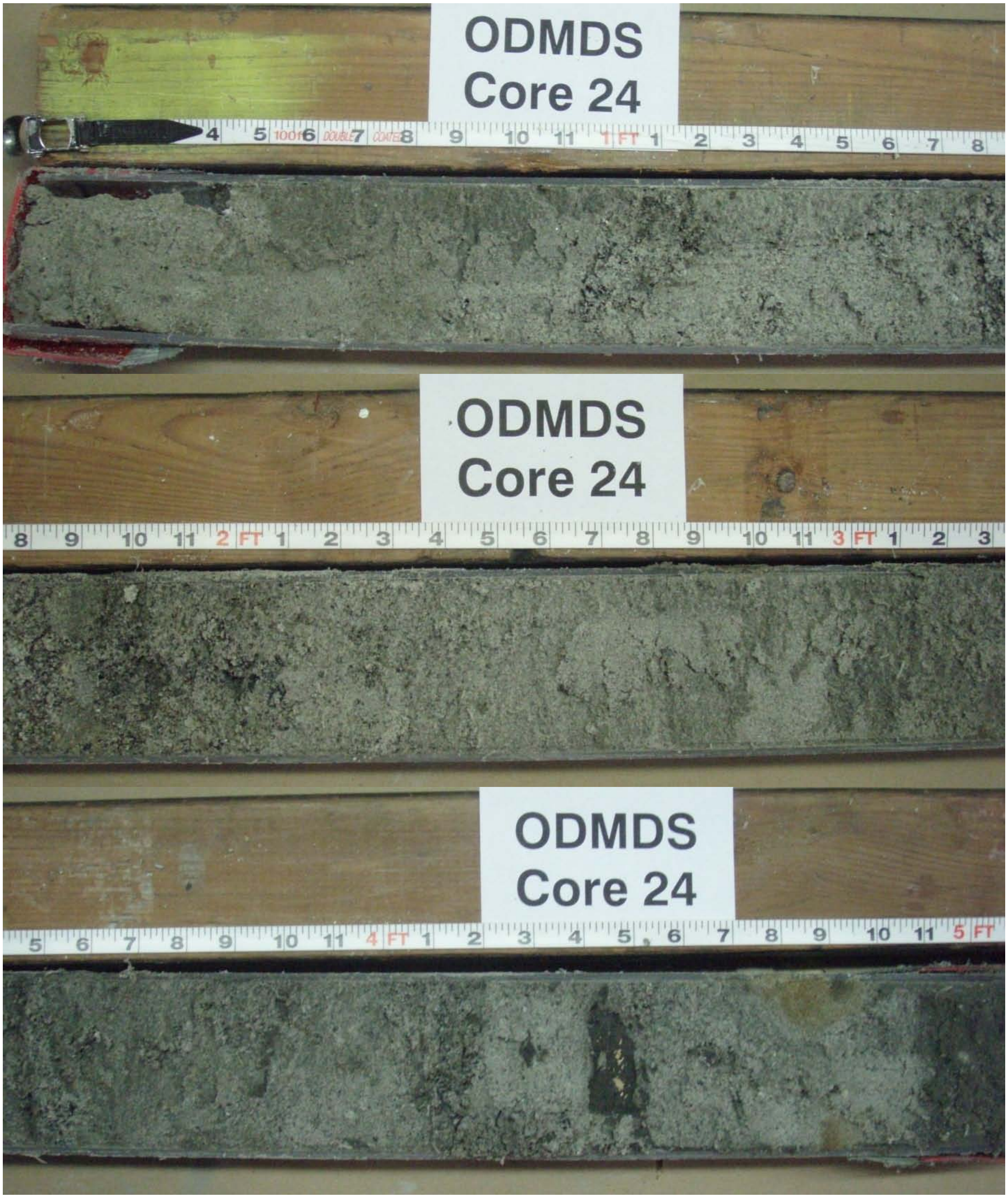
ODMDS Core 22
0 – 5 feet

ODMDS Core 22
5 – 10 feet

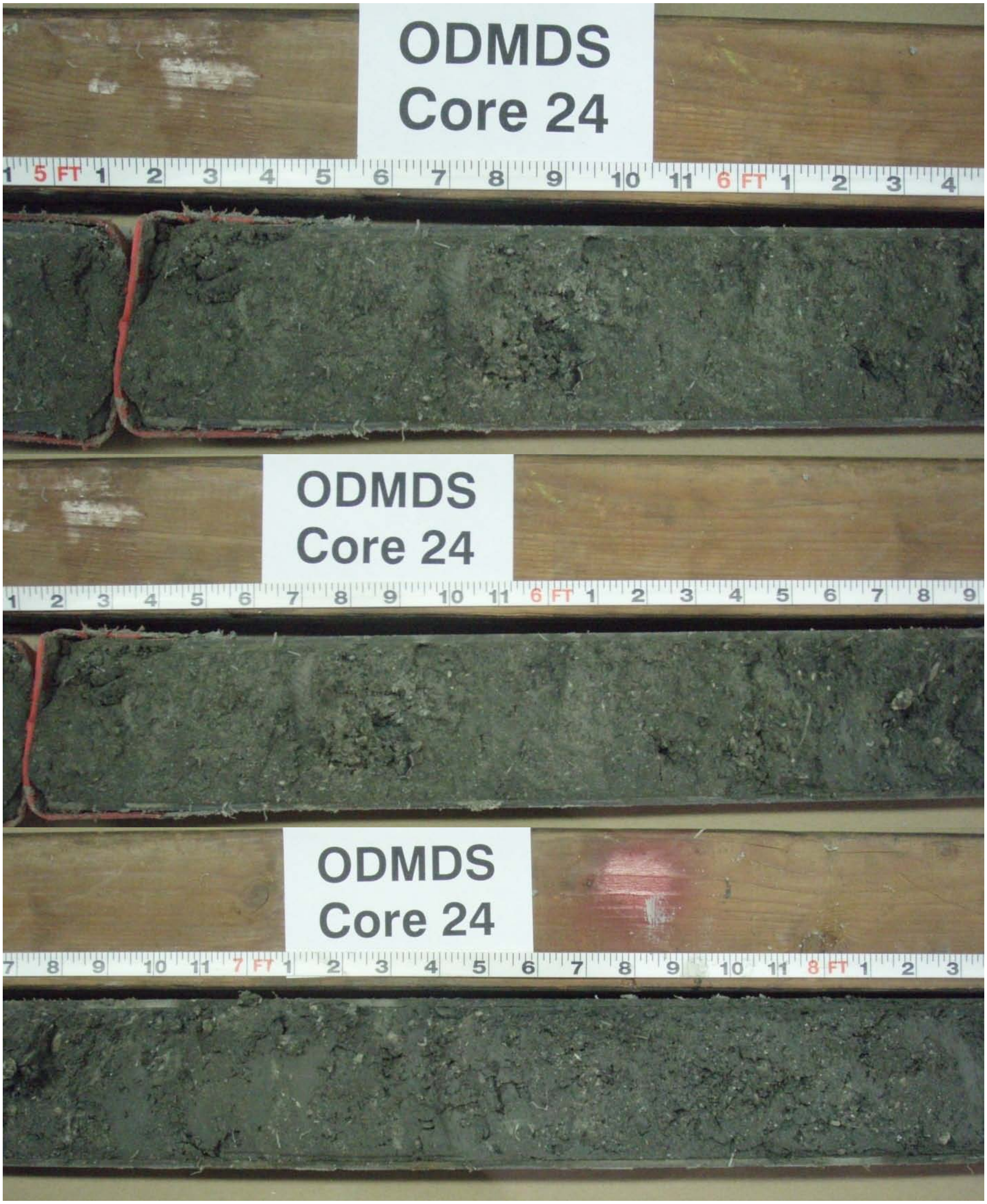
ODMDS Core 22
10 – 15 feet

ODMDS Core 22
15 – 19 feet

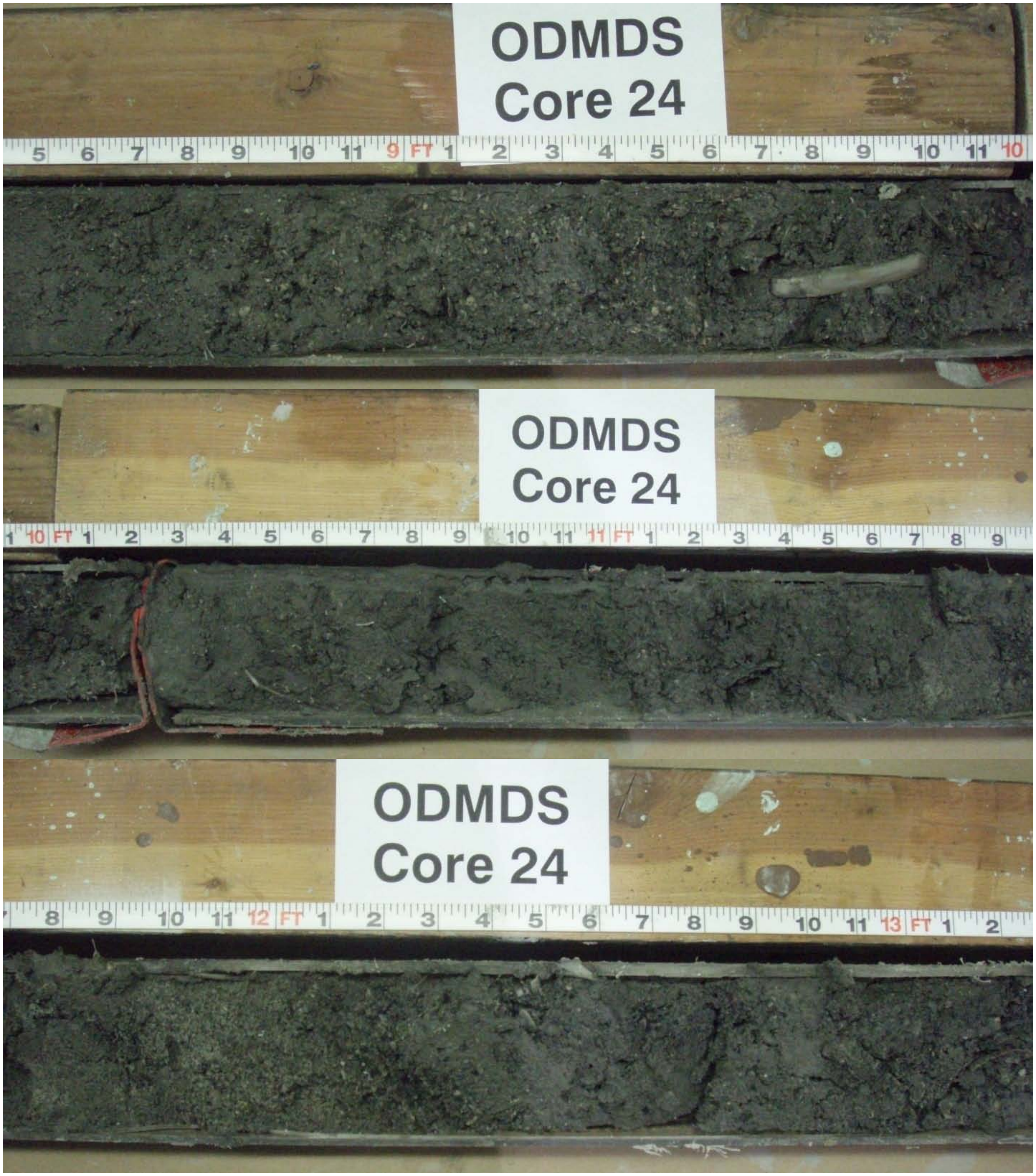
ODMDS Core 24
0 – 5 feet



ODMDS Core 24
5 – 8 feet



ODMDS Core 24
8 – 13 feet



ODMDS Core 24
12.42 – 13.75 feet

ODMDS Core 25
0 – 5 feet

ODMDS Core 25
5 – 10 feet

ODMDS Core 25
10 – 15 feet

ODMDS Core 25
15 – 19.42 feet

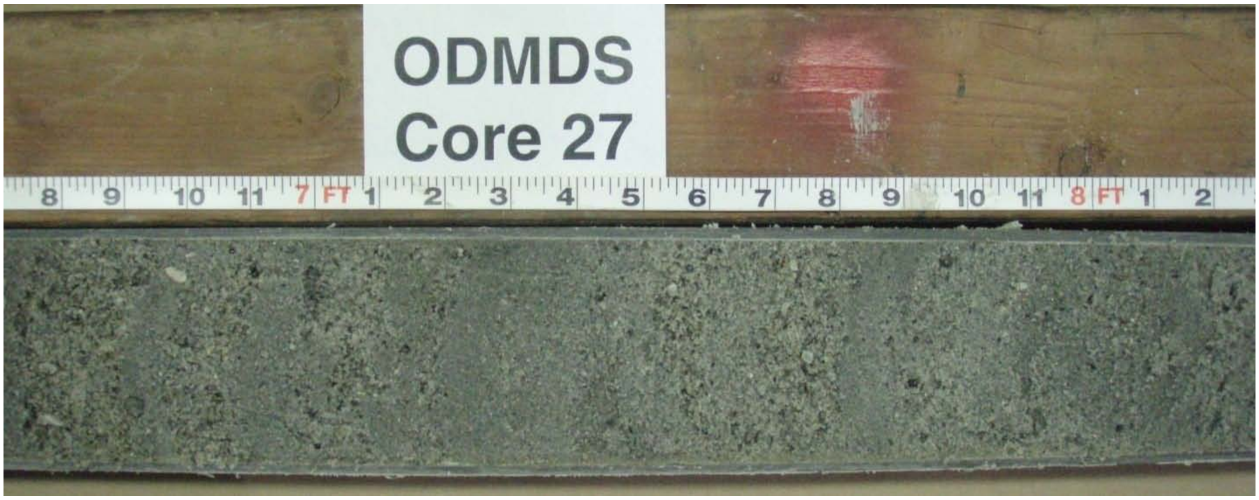
ODMDS Core 26
0 – 5 feet

ODMDS Core 26
5 – 10 feet

ODMDS Core 26
10 – 13.75 feet

ODMDS Core 27
0 – 5 feet

ODMDS Core 27
5 – 10 feet



ODMDS Core 27
10 – 15 feet

ODMDS Core 27
15 – 16.75 feet

ODMDS Core 28
0 – 5 feet

ODMDS Core 28
5 – 10 feet

ODMDS Core 28
10 – 12.58 feet

Core Geological Logs
ODMDS Core 18 – ODMDS Core 28

Prepared for:

Moffatt & Nichol
1616 East Millbrook Road, Suite 160
Raleigh, NC 27609

Submitted by:

Alpine Ocean Seismic Survey, Inc.
155 Hudson Avenue
Norwood, NJ 07648

February 9, 2012

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT 3.5 in
2. LOCATION (Coordinates or Station) N 332,252.6 E 2,690,367.3	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NAVD 88
3. DRILLING AGENCY Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore
4. HOLE NO. *(As shown on drawing title and file number)* O-18	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED 3 — UNDISTURBED
5. NAME OF DRILLER C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 12/12/2011 — COMPLETED 12/12/2011
7. Penetration, ft 20.2	17. ELEVATION TOP OF HOLE -44.1
8. Recovery, ft 17.9	18. TOTAL CORE RECOVERY FOR BORING 90 %
9. Total Recovery, % 90.0	19. GEOLOGIST C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth weathering, etc., if significant)* g
-44.1	0.0		Gray fine to medium Well-graded Sand, rare shells and shell hash (5%)	100	1 0.0 6.0	
				100	2 6.0 12.0	
-56.1	12.0					
			Sharp break at 12 ft to Dark gray fine Silty Sand and shell hash (80%)	100	3 12.0 18.0	
-61.9	17.8					

Hole No. O-19

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT 3.5 in
2. LOCATION (Coordinates or Station) N 332,250.3 E 2,691,366.5	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NAVD 88
3. DRILLING AGENCY Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore
4. HOLE NO. *(As shown on drawing title and file number)* O-19	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED 4 — UNDISTURBED
5. NAME OF DRILLER C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 12/12/2011 — COMPLETED 12/12/2011
7. Penetration, ft 20.0	17. ELEVATION TOP OF HOLE -36.1
8. Recovery, ft 21.5	18. TOTAL CORE RECOVERY FOR BORING 107 %
9. Total Recovery, % 107.0	19. GEOLOGIST C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth weathering, etc., if significant)* g
-36.1	0.0		Gray to dark gray fine to medium Well-graded Sand; lenses of shell fragments at 4'-5-5' and 6.9-7.5'	100	1 0.0 6.0	
				100	2 6.0 12.0	
				100	3 12.0 17.0	
-49.1	13.0					
-49.2	13.1		Dark gray Clay lens			
			Dark gray fine to medium Well-graded Sand, rare shell fragments (5%)			
-53.1	17.0					
			Gray fine Poorly-graded Sand, few shells, little dark gray silt-clay in thin laminae	100	4 17.0 19.3	
-55.4	19.3					

Hole No. O-20

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT 3.5 in
2. LOCATION (Coordinates or Station) N 332,250.4 E 2,692,364.7	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NAVD 88
3. DRILLING AGENCY Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore
4. HOLE NO. *(As shown on drawing title and file number)* O-20	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED 3 — UNDISTURBED
5. NAME OF DRILLER C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 12/11/2011 — COMPLETED 12/11/2011
7. Penetration, ft 15.7	17. ELEVATION TOP OF HOLE -36.4
8. Recovery, ft 13.8	18. TOTAL CORE RECOVERY FOR BORING 86 %
9. Total Recovery, % 86.0	19. GEOLOGIST C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth weathering, etc., if significant)* g
-36.4	0.0		Gray fine to medium Well-graded Sand with rare (5%) shells and shell hash; sand color is brown-gray for two inches at 5 ft.; coarse shell layer (90%) at 13-13.4 ft.	100	1 0.0 5.0	
				100	2 5.0 10.0	
				100	3 10.0 13.9	
-50.2	13.8					

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT: Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT: 3.5 in
2. LOCATION (Coordinates or Station): N 332,249.3 E 2,693,363.5	11. DATUM FOR ELEVATION SHOWN (*TBM or MSL*): NAVD 88
3. DRILLING AGENCY: Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL: Vibracore
4. HOLE NO. (*As shown on drawing title and file number*): O-21	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 3; UNDISTURBED
5. NAME OF DRILLER: C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 12/12/2011; COMPLETED 12/12/2011
7. Penetration, ft: 17.6	17. ELEVATION TOP OF HOLE: -37.0
8. Recovery, ft: 15.9	18. TOTAL CORE RECOVERY FOR BORING: 85 %
9. Total Recovery, %: 85.0	19. GEOLOGIST: C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (*Drilling time, water loss, depth weathering, etc., if significant*) g
-37.0	0.0		Gray-brown fine to medium Well-graded Sand, with some scattered shells	100	1 0.0 5.0	
-42.0	5.0		Gray fine to medium Well-graded Sand, some rare shell pieces; lens of dark gray clay 1" thick at 9.9'	100	2 5.0 10.0	
				100	3 10.0 15.0	
-52.9	15.9					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT 3.5 in
2. LOCATION (Coordinates or Station) N 332,253.7 E 2,694,363.6	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NAVD 88
3. DRILLING AGENCY Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore
4. HOLE NO. *(As shown on drawing title and file number)* O-22	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED 4 — UNDISTURBED
5. NAME OF DRILLER C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 12/10/2011 — COMPLETED 12/10/2011
7. Penetration, ft 20.0	17. ELEVATION TOP OF HOLE -32.7
8. Recovery, ft 20.0	18. TOTAL CORE RECOVERY FOR BORING 100 %
9. Total Recovery, % 100.0	19. GEOLOGIST C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth weathering, etc., if significant)* g
-32.7	0.0		Gray to brown fine to medium Well-graded Sand, intermittent shells and shell hash (20%); some shells to 2 inches in size at 8" and 1'3" below sea floor and between 8'10 and 10'	100	1 0.0 5.0	
				100	2 5.0 10.0	
				100	3 10.0 15.0	
				100	4 15.0 20.0	
-51.7	19.0					

Hole No. O-24

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT: Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT: 3.5 in
2. LOCATION (Coordinates or Station): N 331,252.2 E 2,690,362.0	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: NAVD 88
3. DRILLING AGENCY: Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL: Vibracore
4. HOLE NO. *(As shown on drawing title and file number)*: O-24	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 4; UNDISTURBED
5. NAME OF DRILLER: C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 12/12/2011; COMPLETED 12/12/2011
7. Penetration, ft: 18.5	17. ELEVATION TOP OF HOLE: -49.3
8. Recovery, ft: 13.8	18. TOTAL CORE RECOVERY FOR BORING: 73 %
9. Total Recovery, %: 73.0	19. GEOLOGIST: C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth weathering, etc., if significant)* g
-49.3	0.0		Gray fine to medium Well-graded Sand with Silt, few shells (15-20%); dark gray clay lens at 4'4"	100	1 0.0 4.9	
-54.2	4.9					
			Sharp change to 4.9 feet to dark gray fine Poorly-graded Sand, some shell fragments (20-30%)	101	2 4.9 6.8	
-56.1	6.8					
			Soft dark gray organic Silty Sand, some shells (30-40%)	100	3 6.8 13.9	
-63.1	13.8					

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT 3.5 in
2. LOCATION (Coordinates or Station) N 331,253.1 E 2,691,364.5	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NAVD 88
3. DRILLING AGENCY Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore
4. HOLE NO. *(As shown on drawing title and file number)* O-25	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 4; UNDISTURBED
5. NAME OF DRILLER C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 12/11/2011; COMPLETED 12/11/2011
7. Penetration, ft 20.0	17. ELEVATION TOP OF HOLE -42.0
8. Recovery, ft 19.5	18. TOTAL CORE RECOVERY FOR BORING 95 %
9. Total Recovery, % 95.0	19. GEOLOGIST C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth weathering, etc., if significant)* g
-42.0	0.0		Light gray fine to medium Well-graded Sand, trace shells and shell fragments (10-15%)	100	1 0.0 6.0	
				100	2 6.0 12.0	
				100	3 12.0 17.9	
-59.9	17.9					
			Dark gray fine Poorly-graded Sand with Silt, some shells and shell fragments (15-25%)	100	4 17.9 19.5	
-61.5	19.5					

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT 3.5 in
2. LOCATION (Coordinates or Station) N 331,247.3 E 2,692,365.1	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NAVD 88
3. DRILLING AGENCY Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore
4. HOLE NO. *(As shown on drawing title and file number)* O-26	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 3; UNDISTURBED
5. NAME OF DRILLER C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 12/11/2011; COMPLETED 12/11/2011
7. Penetration, ft 20.4	17. ELEVATION TOP OF HOLE -45.7
8. Recovery, ft 13.8	18. TOTAL CORE RECOVERY FOR BORING 68 %
9. Total Recovery, % 68.0	19. GEOLOGIST C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth weathering, etc., if significant)* g
-45.7	0.0		Gray fine to medium Well-graded Sand, some small shell fragments (10-20%); Very rare 1" clay balls	100	1 0.0 5.0	
				100	2 5.0 9.3	
-55.0	9.3					
			Dark gray fine Silty Sand with some clay lenses and shells (30-50%)	100	3 9.3 13.8	
-59.5	13.8					

Hole No. O-27

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT 3.5 in
2. LOCATION (Coordinates or Station) N 331,253.5 E 2,693,366.3	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NAVD 88
3. DRILLING AGENCY Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore
4. HOLE NO. *(As shown on drawing title and file number)* O-27	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 4; UNDISTURBED
5. NAME OF DRILLER C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE STARTED 12/11/2011 COMPLETED 12/11/2011
7. Penetration, ft 19.4	17. ELEVATION TOP OF HOLE -43.6
8. Recovery, ft 16.8	18. TOTAL CORE RECOVERY FOR BORING 86 %
9. Total Recovery, % 86.0	19. GEOLOGIST C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth weathering, etc., if significant)* g
-43.6	0.0		Gray fine to medium Well-graded Sand, rare shells (5%) in lenses	100	1 0.0 4.0	
				100	2 4.0 8.0	
				100	3 8.0 12.9	
-56.5	12.9		Dark gray fine Silty Sand with shell fragments (20%) and rare clay lenses to1/2" thick	100	4 12.9 16.8	
-60.4	16.8					

Hole No. O-28

DRILLING LOG	DIVISION	INSTALLATION ODMDS	SHEET 1 OF 1 SHEETS

1. PROJECT: Bogue Banks Master Beach Nourishment Plan	10. SIZE AND TYPE OF BIT: 3.5 in
2. LOCATION (Coordinates or Station): N 331,246.1 E 2,694,358.6	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NAVD 88
3. DRILLING AGENCY: Alpine Ocean Seismic Survey	12. MANUFACTURER'S DESIGNATION OF DRILL: Vibracore
4. HOLE NO. (As shown on drawing title and file number): O-28	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 3; UNDISTURBED
5. NAME OF DRILLER: C. Dill	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 12/10/2011; COMPLETED 12/10/2011
7. Penetration, ft: 19.2	17. ELEVATION TOP OF HOLE: -42.7
8. Recovery, ft: 12.9	18. TOTAL CORE RECOVERY FOR BORING: 63 %
9. Total Recovery, %: 63.0	19. GEOLOGIST: C. Dill

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth weathering, etc., if significant) g
-42.7	0.0		Gray fine to medium Well-graded Sand, few shell fragments (15-20%)	100	1 0.0 6.0	
				100	2 6.0 11.6	
-54.3	11.6					
			Sharp change at 11.6 ft to dark gray soft Silty Sand and clay, few shells (20%)	100	3 11.6 12.6	
-55.3	12.6					

Carteret County, NC
Sediment Analysis
For Vibracores O18-O28

Submitted to:

Alpine Ocean Seismic Survey, Inc.
Norwood, NJ

Submitted by:

Coastal Tech
Melbourne, Florida

February 7, 2012

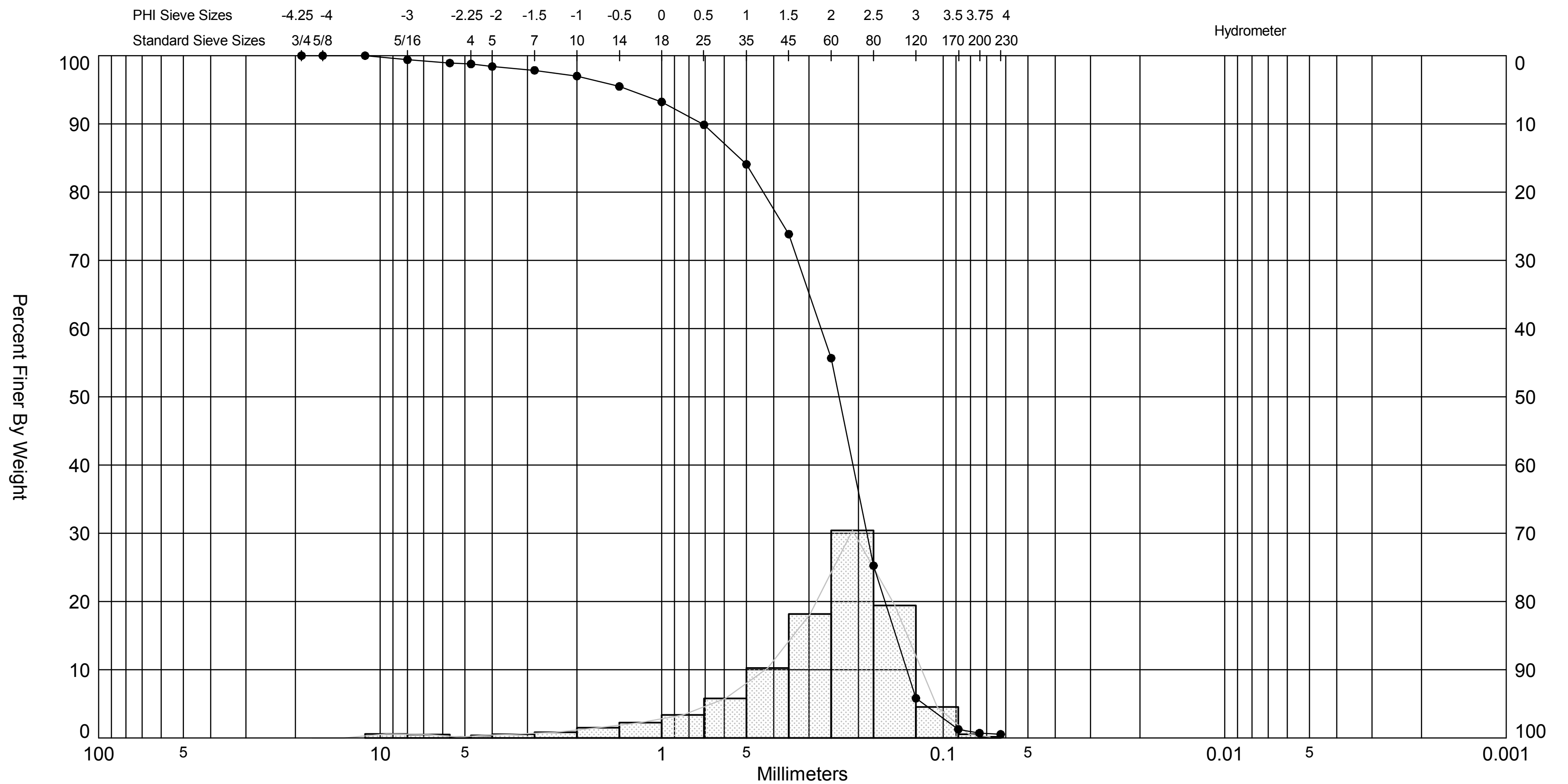
Coastal Technology Corporation

Table of Contents

1.0 Sedimentologic Summary Table

Vibracore	Sample Interval	Sample Number	**gINT Granularmetrics**							USC	**Composition (wt%)**			Sieve Treatment
			Size Class (wt%)				Descriptive Statistics							
			Gravel	*Sand*	*<#200*	*<#230*	*Mean (mm)*	*Verbal*	*Std. Dev.(phi)*		*Organic*	*Carbonate*	*Siliciclastic*	
O18	0-6	1	1.22	98.07	0.71	0.53	0.28	F	1.10	SW	0.9	12.1	87.0	DRY
	6-12	2	0.21	99.39	0.40	0.29	0.28	F	1.02	SW	0.6	12.6	86.8	DRY
	12-18	3	0.09	80.56	19.35	18.62	0.20	F	1.05	SM	2.0	23.2	74.8	WET
O19	0-6	1	0.00	99.82	0.18	0.08	0.25	F	0.86	SW	0.6	10.6	88.8	DRY
	6-12	2	1.69	98.27	0.04	0.00	0.29	F	1.07	SW	0.6	13.5	85.9	DRY
	12-17	3	1.63	98.19	0.18	0.12	0.32	F	1.10	SW	0.7	12.8	86.5	DRY
	17-19.3	4	0.00	99.30	0.70	0.49	0.24	F	0.73	SP	0.7	9.5	89.8	DRY
O20	0-5	1	2.55	97.31	0.14	0.12	0.35	F	1.29	SW	0.6	17.8	81.6	DRY
	5-10	2	1.28	97.83	0.89	0.72	0.31	F	1.18	SW	0.8	21.2	78.0	DRY
	10-13.9	3	2.31	97.24	0.45	0.39	0.30	F	1.21	SW	0.6	9.3	90.1	DRY
O21	0-5	1	0.36	99.34	0.30	0.28	0.30	F	0.92	SW	0.6	16.2	83.2	DRY
	5-10	2	1.77	97.72	0.51	0.46	0.36	F	1.24	SW	0.6	11.7	87.7	DRY
	10-15	3	1.66	98.11	0.23	0.16	0.31	F	1.08	SW	0.7	12.3	87.0	DRY
O22	0-5	1	2.14	97.72	0.14	0.13	0.34	F	1.20	SW	0.6	16.2	83.2	DRY
	5-10	2	2.12	97.68	0.20	0.14	0.31	F	1.18	SW	0.4	12.3	87.3	DRY
	10-15	3	1.58	98.04	0.38	0.37	0.29	F	1.03	SW	0.4	11.7	87.9	DRY
	15-20	4	1.06	98.53	0.41	0.40	0.34	F	1.02	SW	0.5	14.7	84.8	DRY
O23	0-6	1	1.88	97.98	0.14	0.11	0.36	F	1.25	SW	0.6	13.3	86.1	WET
	6-10	2	0.08	91.77	8.15	7.82	0.19	F	0.71	SP-SM	1.0	8.0	91.0	WET
	10-15	3	0.71	82.41	16.88	16.64	0.27	F	1.06	SM	1.2	24.2	74.6	WET
	15-17.2	4	9.13	81.15	9.72	9.42	0.81	M	1.90	SW-SM	1.9	53.3	44.8	WET
O24	0-4.9	1	4.78	90.03	5.19	4.81	0.24	F	1.59	SW-SM	1.5	13.0	85.5	WET
	4.9-6.8	2	0.32	99.38	0.30	0.20	0.26	F	0.85	SP	0.5	10.4	89.1	DRY
	6.8-13.9	3	1.85	78.09	20.06	18.63	0.38	F	1.63	SM	2.3	32.9	64.8	WET
O25	0-6	1	0.90	98.65	0.45	0.36	0.33	F	1.10	SW	0.5	13.6	85.9	DRY
	6-12	2	2.05	96.99	0.96	0.83	0.33	F	1.21	SW	0.5	18.0	81.5	DRY
	12-17.9	3	1.79	98.06	0.15	0.12	0.32	F	1.17	SW	0.9	19.2	79.9	DRY
	17.9-19.5	4	0.00	93.03	6.97	6.63	0.18	F	0.80	SP-SM	1.6	9.7	88.7	WET
O26	0-5	1	5.01	94.52	0.47	0.37	0.36	F	1.62	SW	0.6	12.7	86.7	DRY
	5-9.3	2	0.97	98.79	0.24	0.21	0.30	F	0.97	SW	0.4	11.9	87.7	DRY
	9.3-13.8	3	0.35	77.82	21.83	20.37	0.23	F	1.33	SM	1.5	10.7	87.8	WET
O27	0-4	1	0.56	99.24	0.20	0.20	0.40	F	1.06	SW	0.5	16.7	82.8	DRY
	4-8	2	0.67	98.95	0.38	0.35	0.32	F	1.00	SW	0.5	12.0	87.5	DRY
	8-12.9	3	0.16	99.35	0.49	0.41	0.29	F	0.88	SW	0.5	11.8	87.7	DRY
	12.9-16.8	4	0.40	86.13	13.47	12.72	0.21	F	1.15	SM	1.8	20.3	77.9	WET
O28	0-6	1	0.59	99.29	0.12	0.09	0.28	F	0.93	SW	0.5	12.8	86.7	DRY
	6-11.6	2	0.41	99.34	0.25	0.16	0.30	F	0.95	SW	0.5	13.4	86.1	DRY
	11.6-12.9	3	0.35	76.30	23.35	22.80	0.27	F	1.13	SM	1.7	13.9	84.4	WET

2.0 Granularmetric Curves



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O18 #1	—●—		SW	#200 - 0.71 #230 - 0.53	0.90	12.10	2.09	1.82	-1.78	7.36	1.1

Comments:

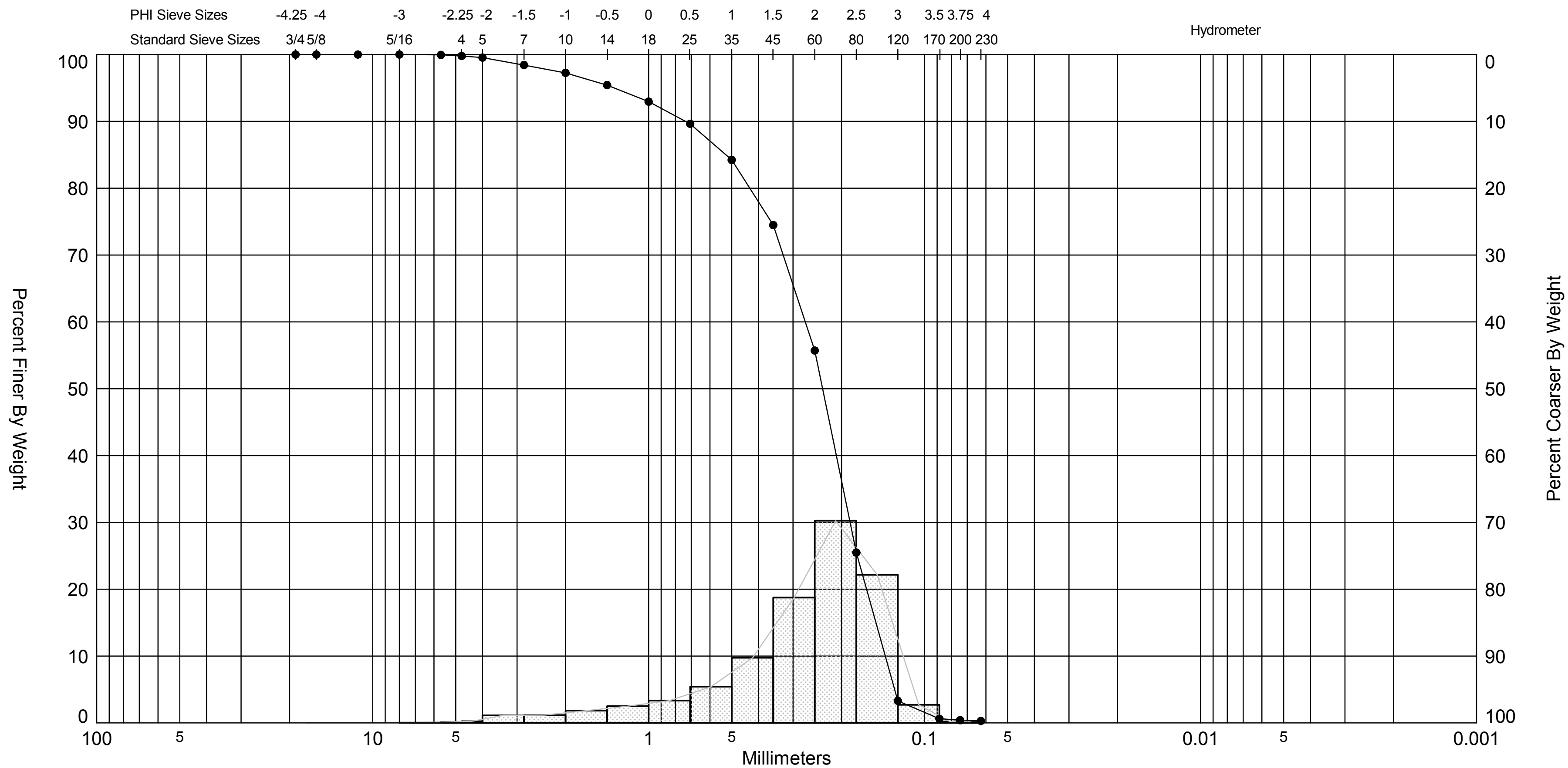
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O18 #2	—●—		SW	#200 - 0.40 #230 - 0.29	0.60	12.60	2.09	1.83	-1.52	5.54	1.02

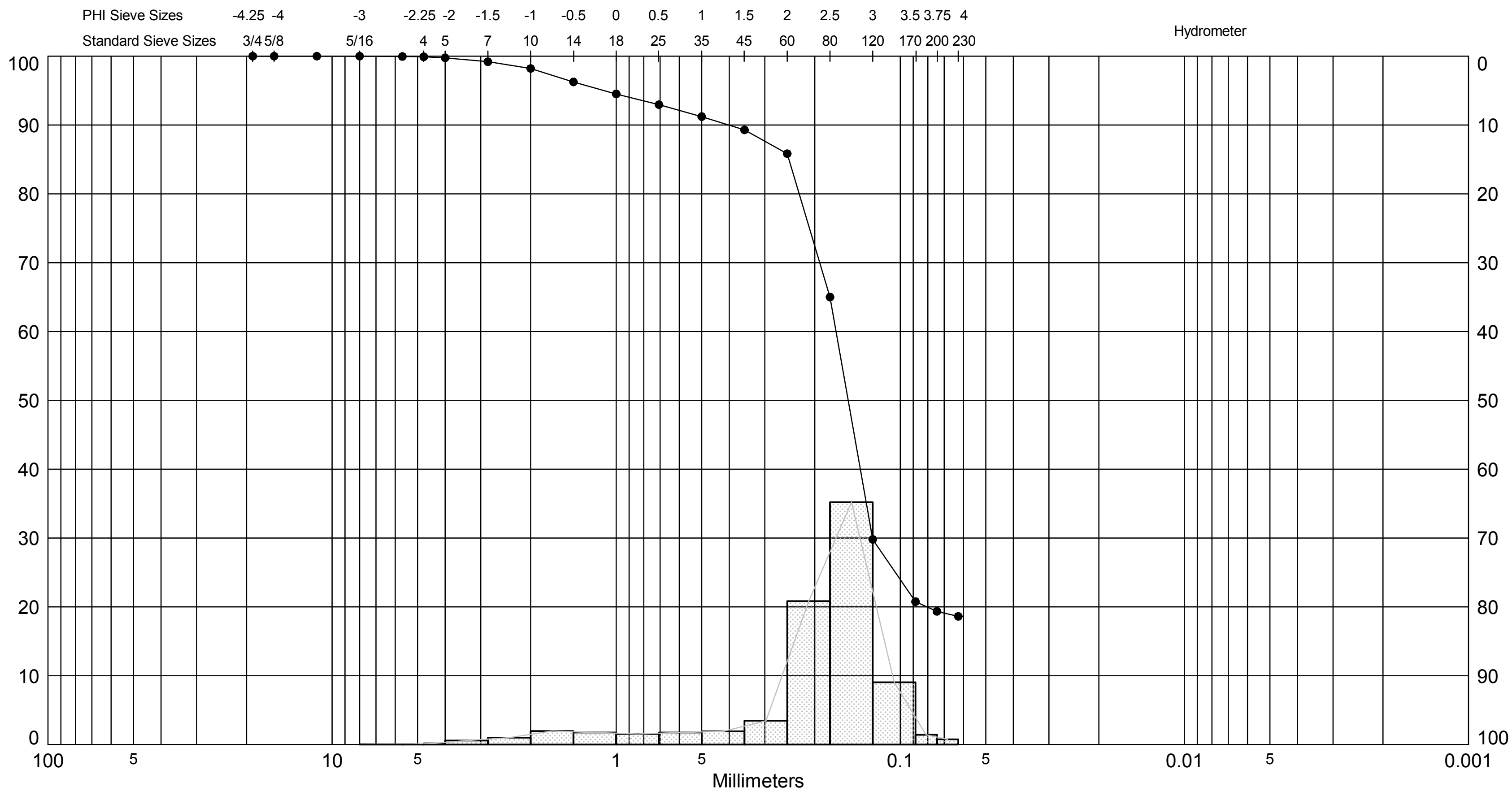
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O18 #3	—●—		SM	#200 - 19.35 #230 - 18.62	2.00	23.20	2.71	2.29	-2.05	7.19	1.05

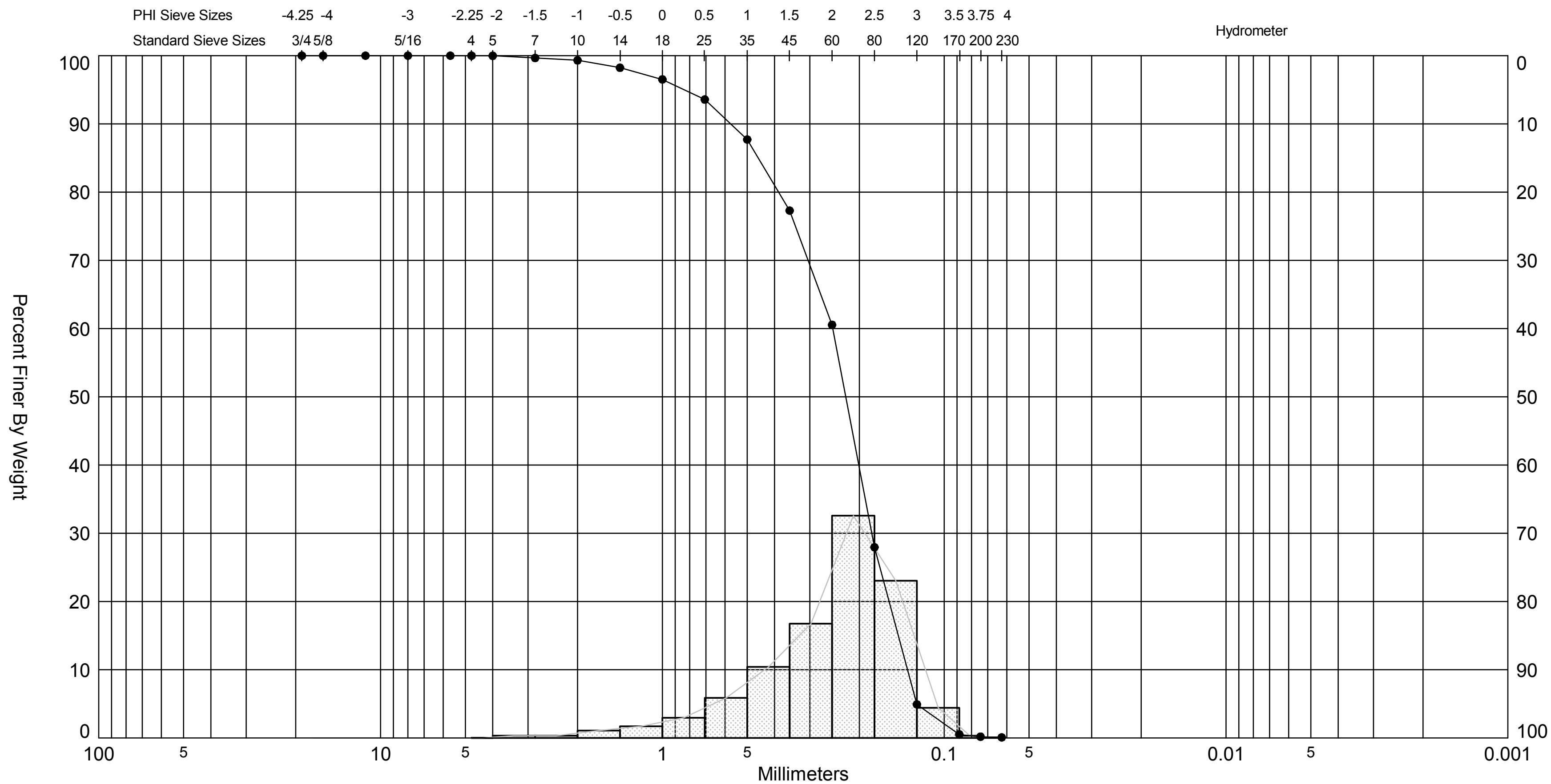
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O19 #1	—●—		SW	#200 - 0.18 #230 - 0.08	0.60	10.60	2.16	1.98	-1.25	5.07	0.86

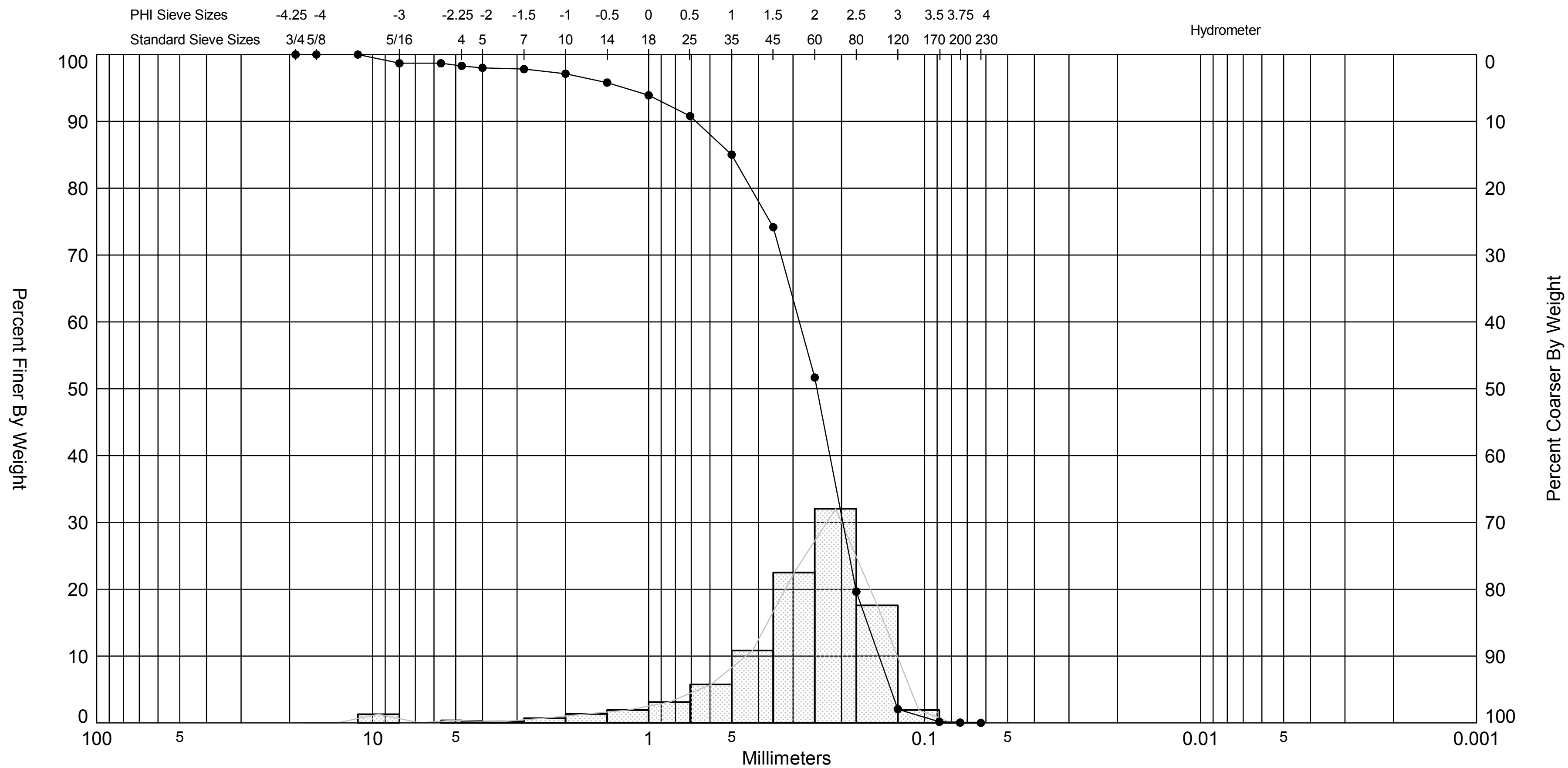
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O19 #2	—●—		SW	#200 - 0.04 #230 - 0.00	0.60	13.50	2.03	1.77	-2.18	9.5	1.07

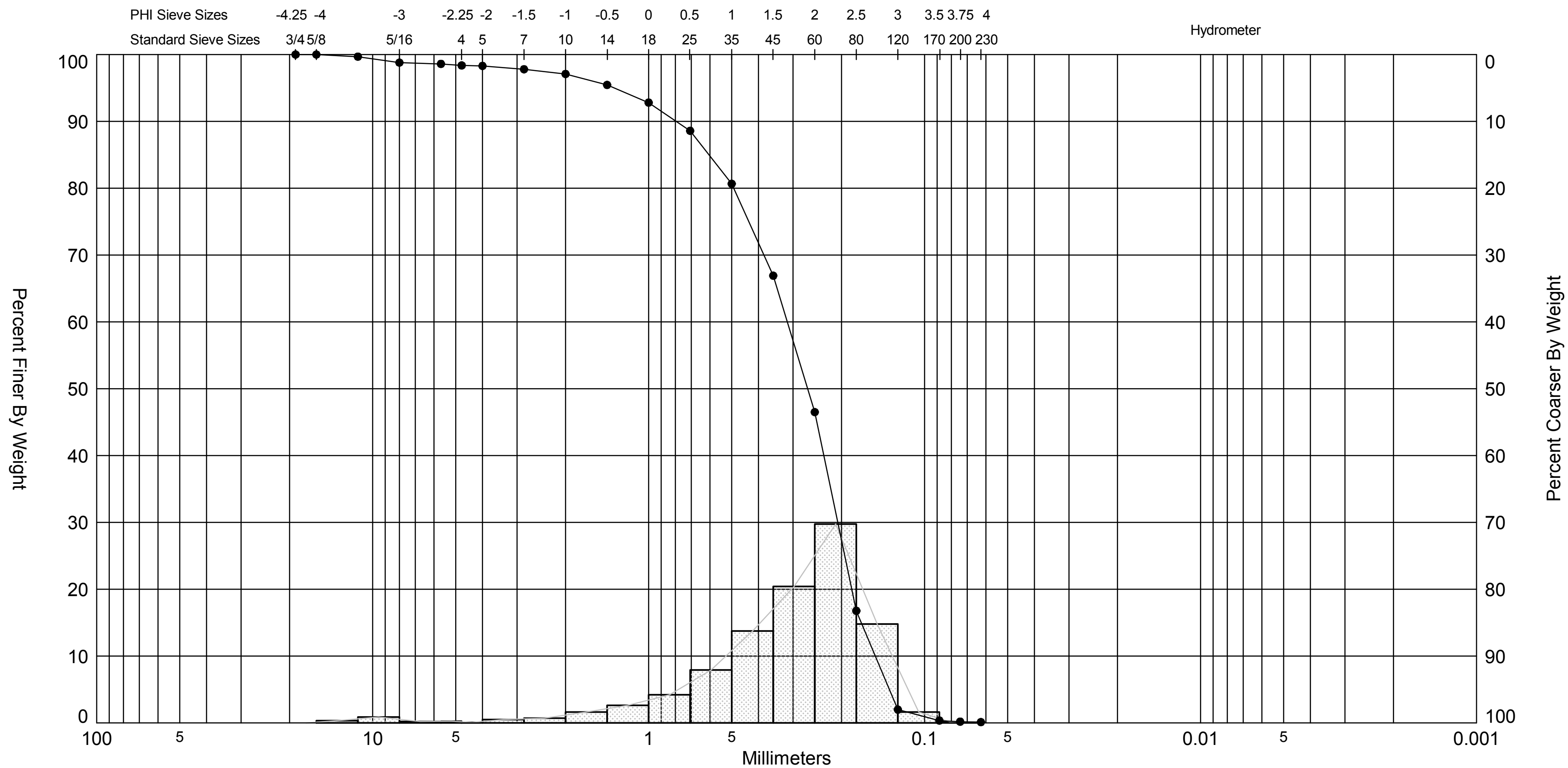
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O19 #3	—●—		SW	#200 - 0.18 #230 - 0.12	0.70	12.80	1.91	1.65	-1.89	8.21	1.1

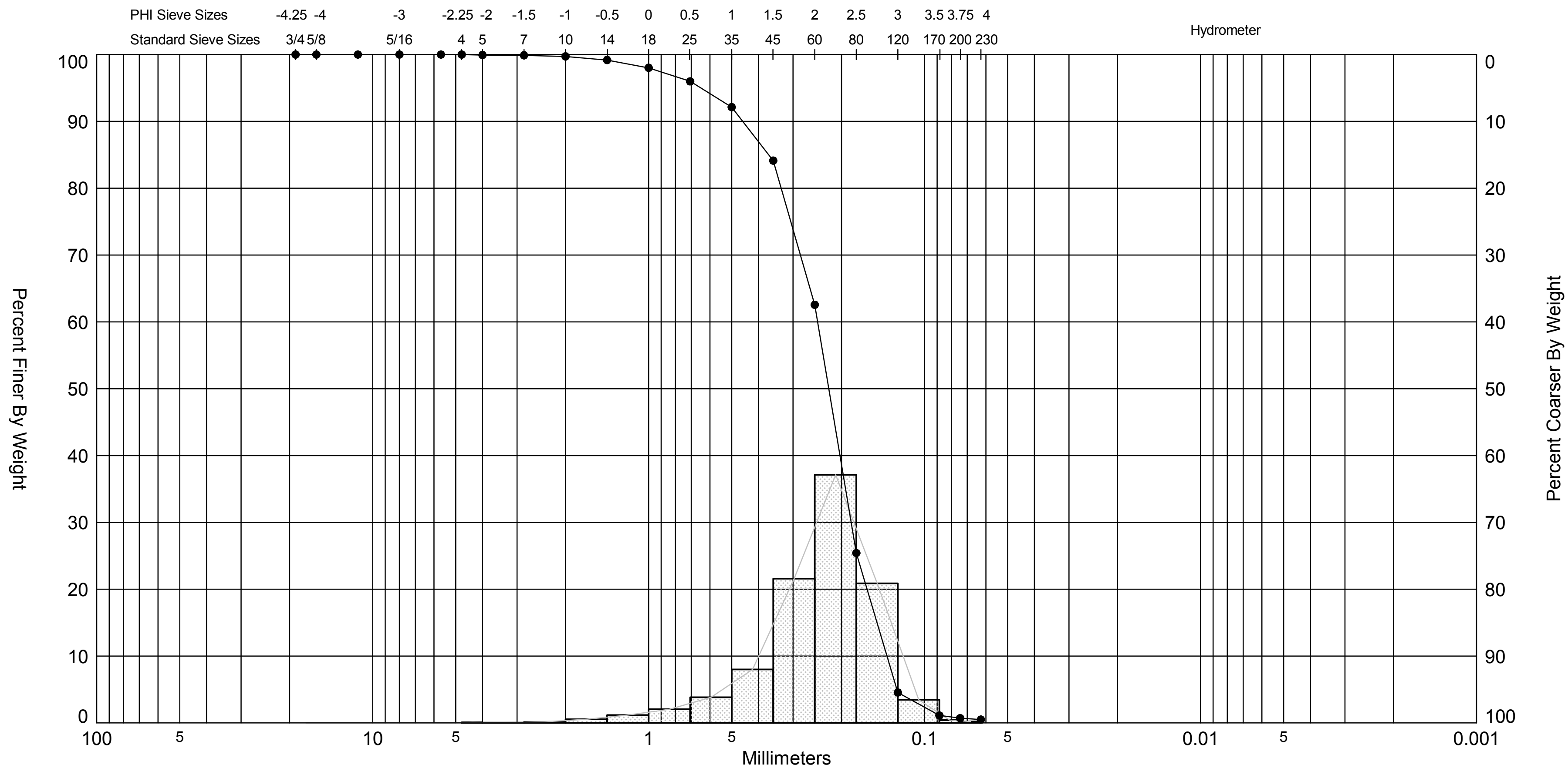
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O19 #4	—●—		SP	#200 - 0.70 #230 - 0.49	0.70	9.50	2.17	2.05	-1.28	6.1	0.73

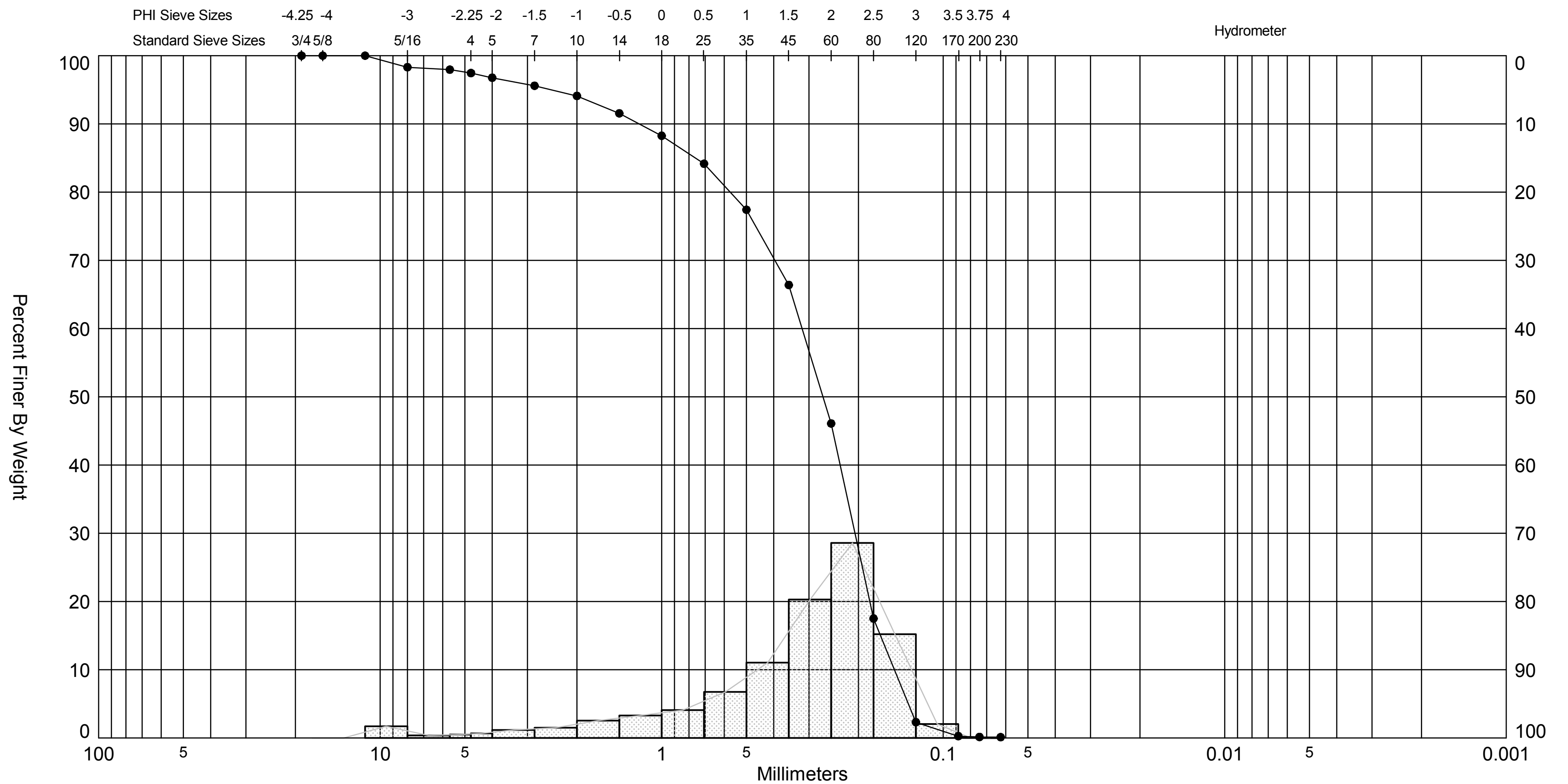
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O20 #1	—●—		SW	#200 - 0.14 #230 - 0.12	0.60	17.80	1.9	1.53	-1.67	5.92	1.29

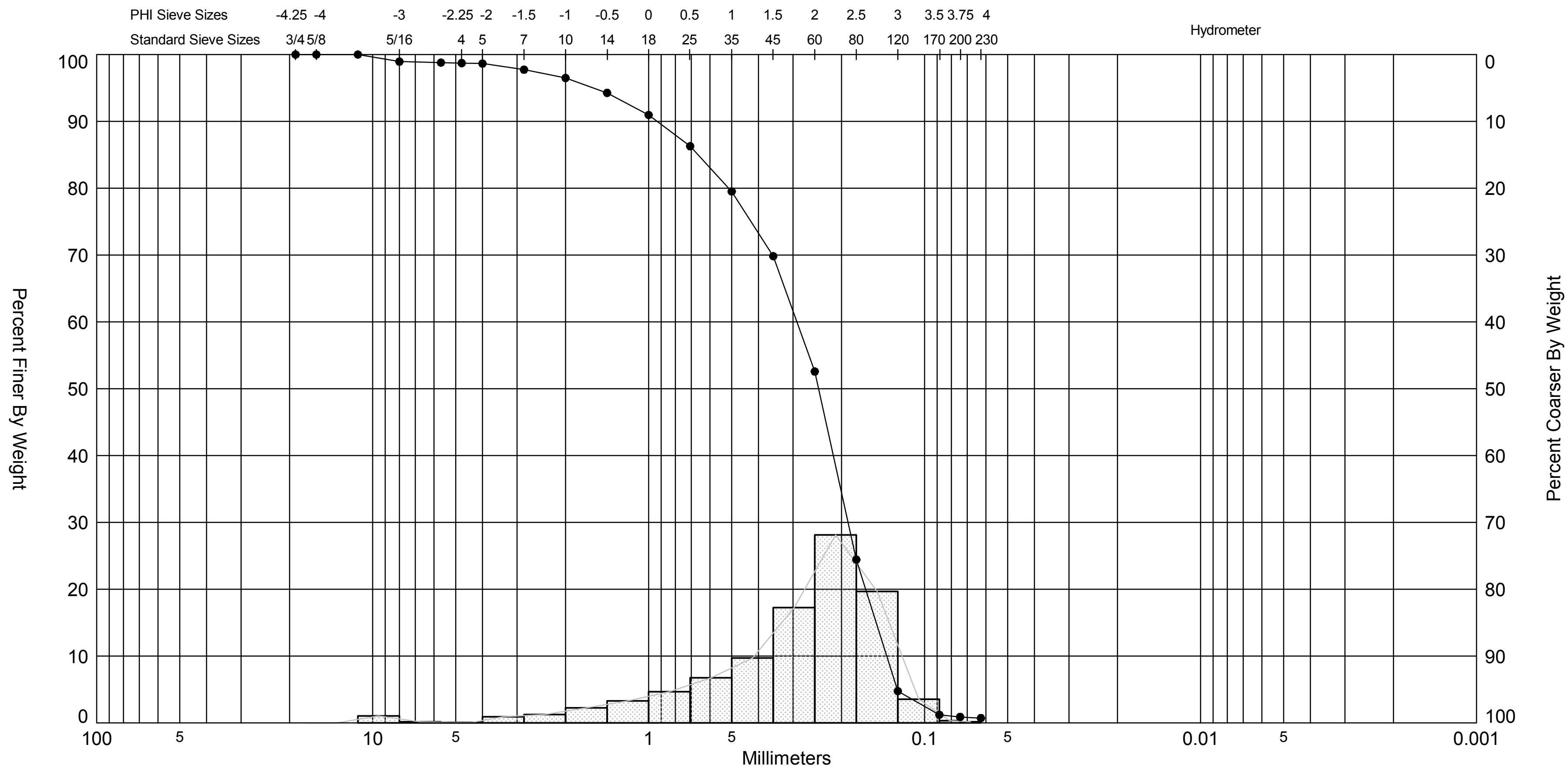
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O20 #2	—●—		SW	#200 - 0.89 #230 - 0.72	0.80	21.20	2.05	1.71	-1.59	6.15	1.18

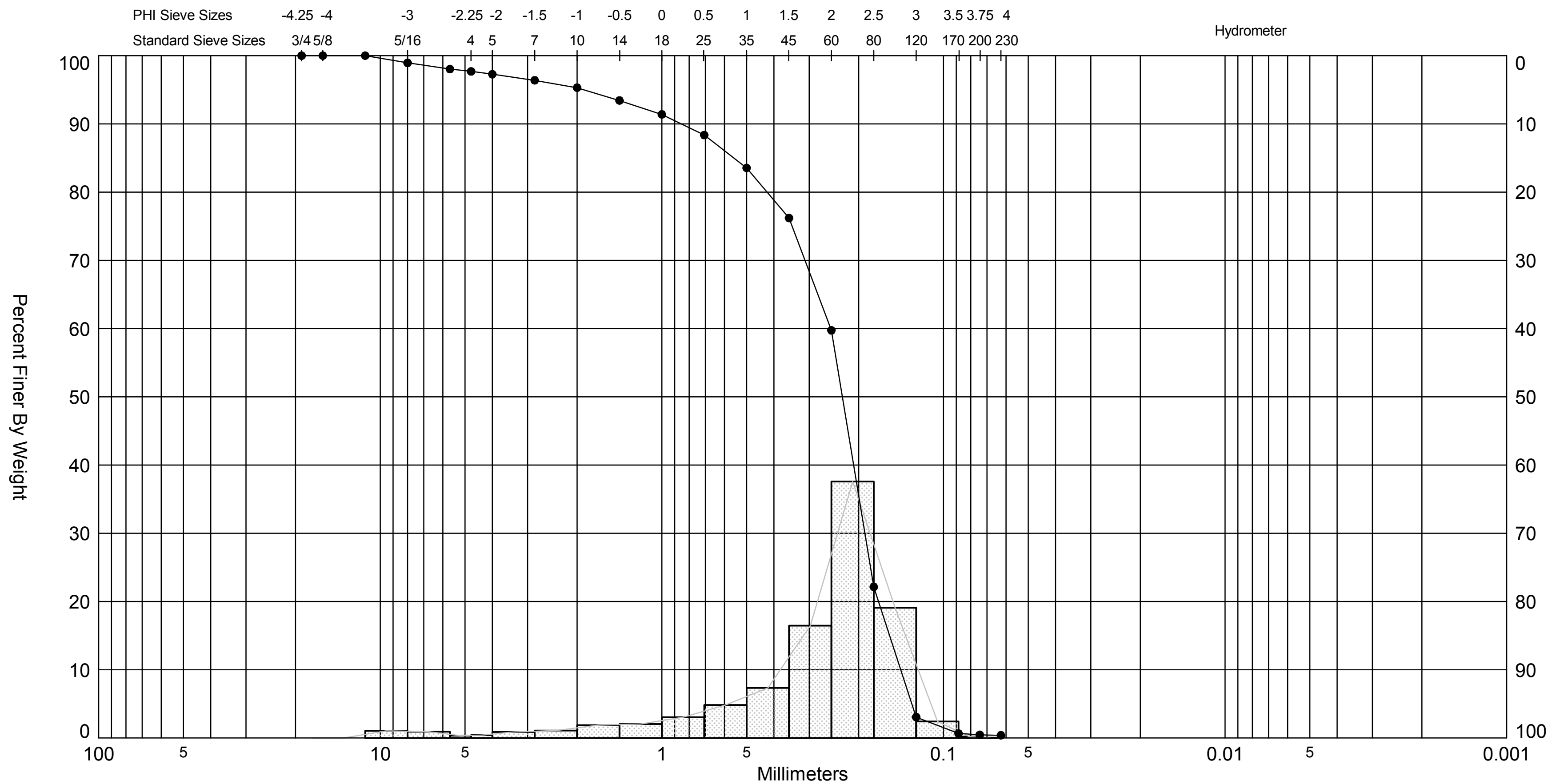
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O20 #3	—●—		SW	#200 - 0.45 #230 - 0.39	0.60	9.30	2.13	1.76	-2.07	7.65	1.21

Comments:

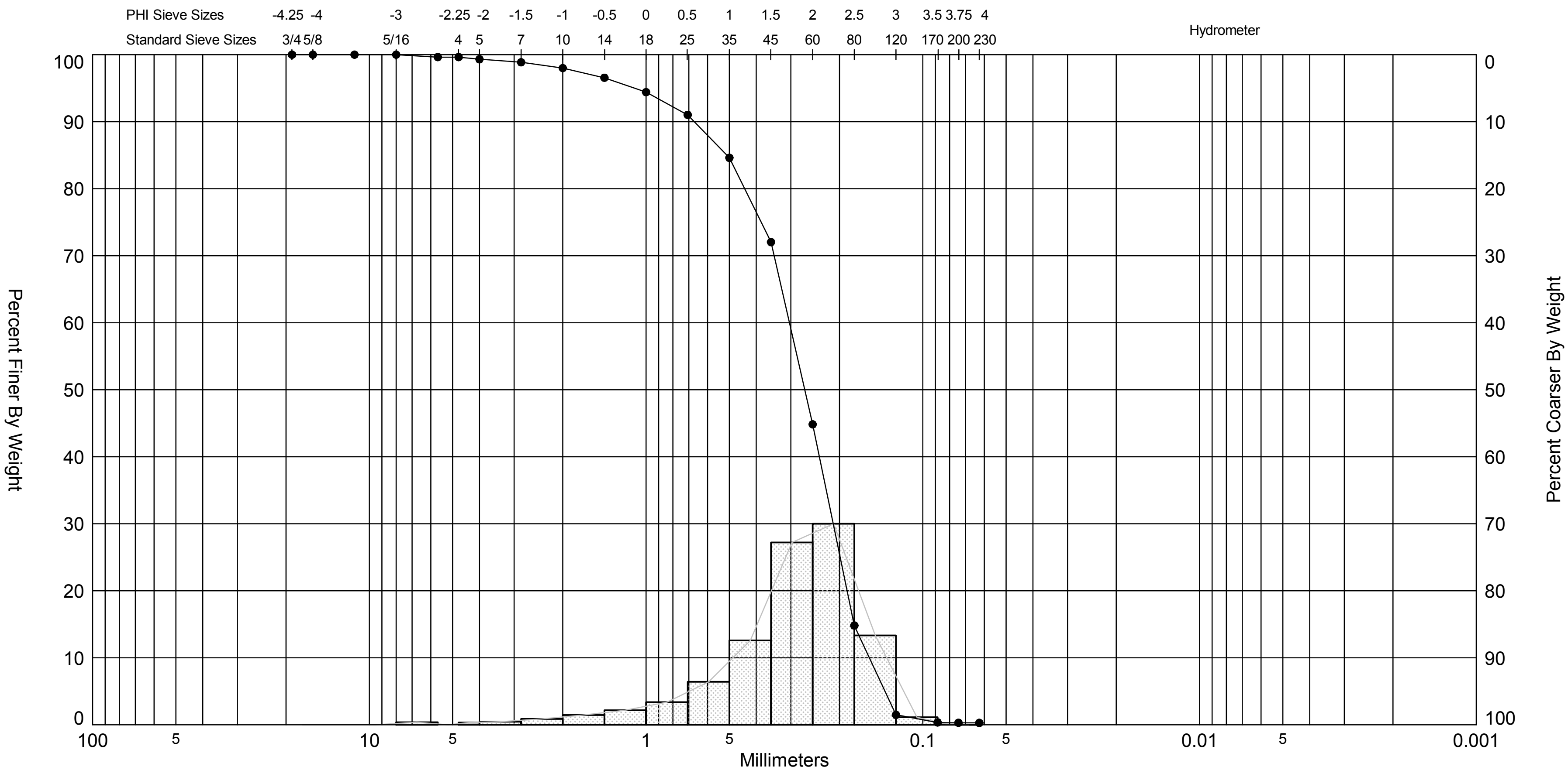
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O21 #1	—●—		SW	#200 - 0.30 #230 - 0.28	0.60	16.20	1.9	1.72	-1.63	6.83	0.92

Comments:

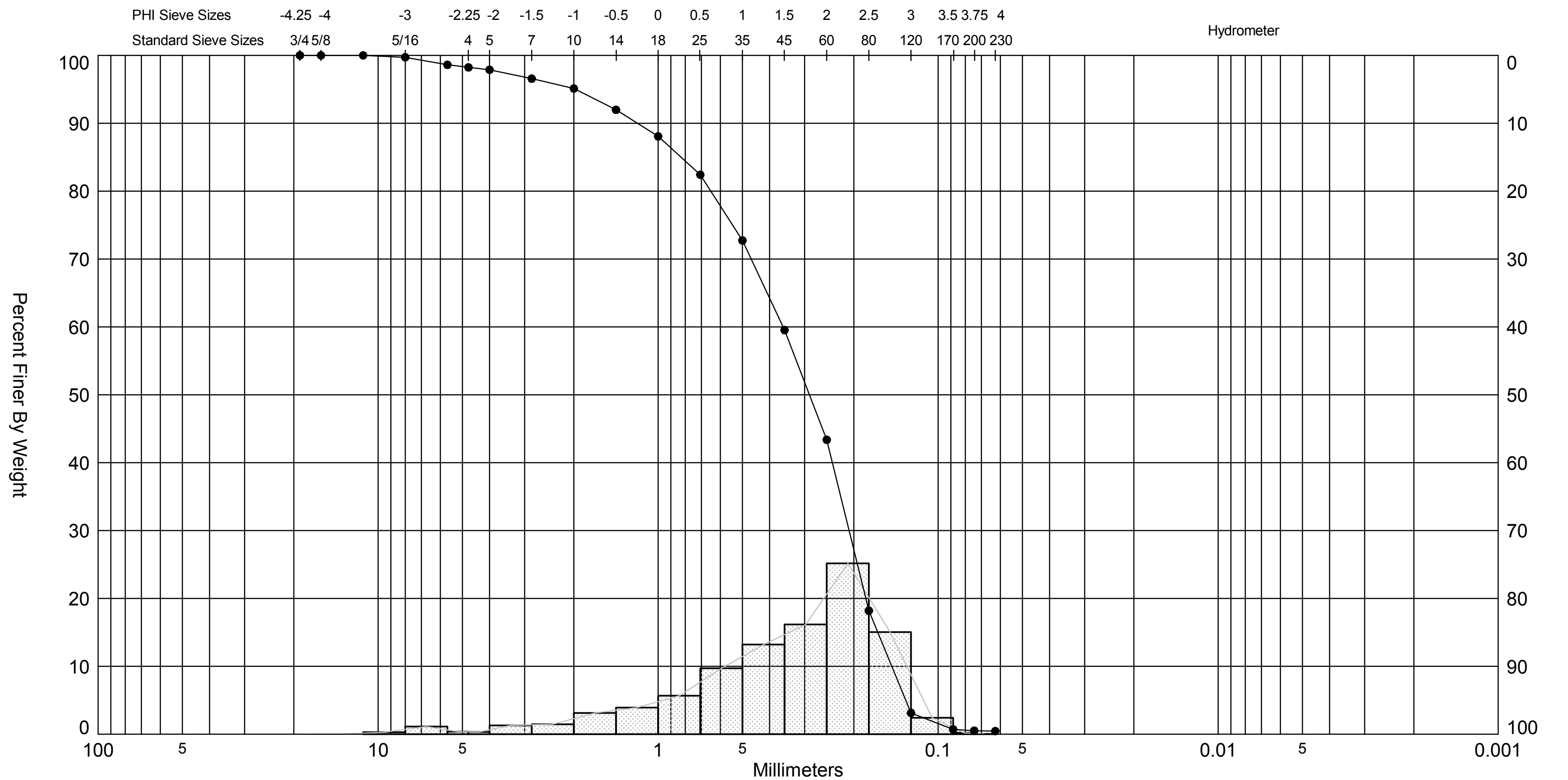
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O21 #2	—●—		SW	#200 - 0.51 #230 - 0.46	0.60	11.70	1.79	1.48	-1.26	4.62	1.24

Comments:

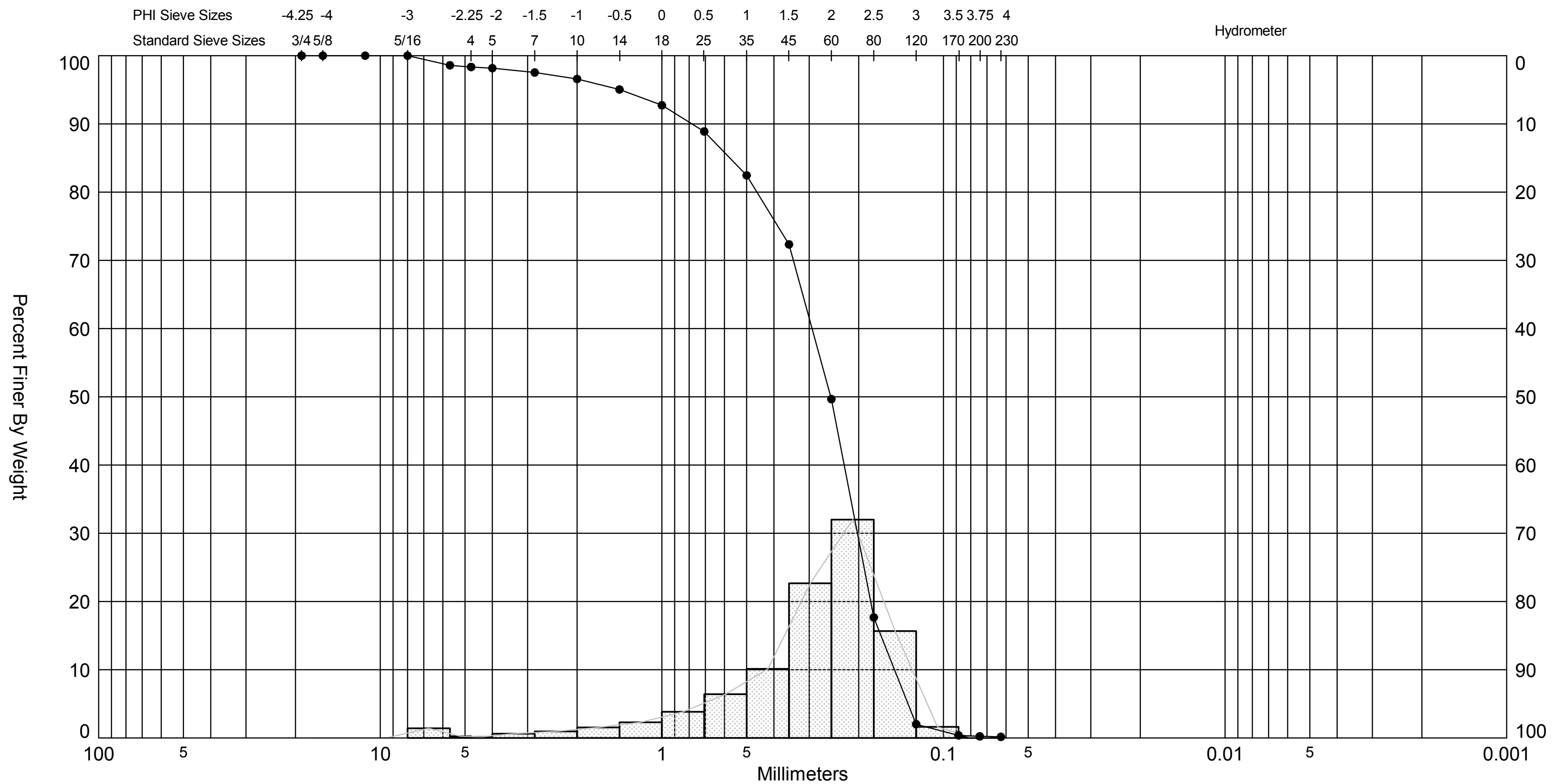
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O21 #3	—●—		SW	#200 - 0.23 #230 - 0.16	0.70	12.30	1.99	1.71	-1.84	7.2	1.08

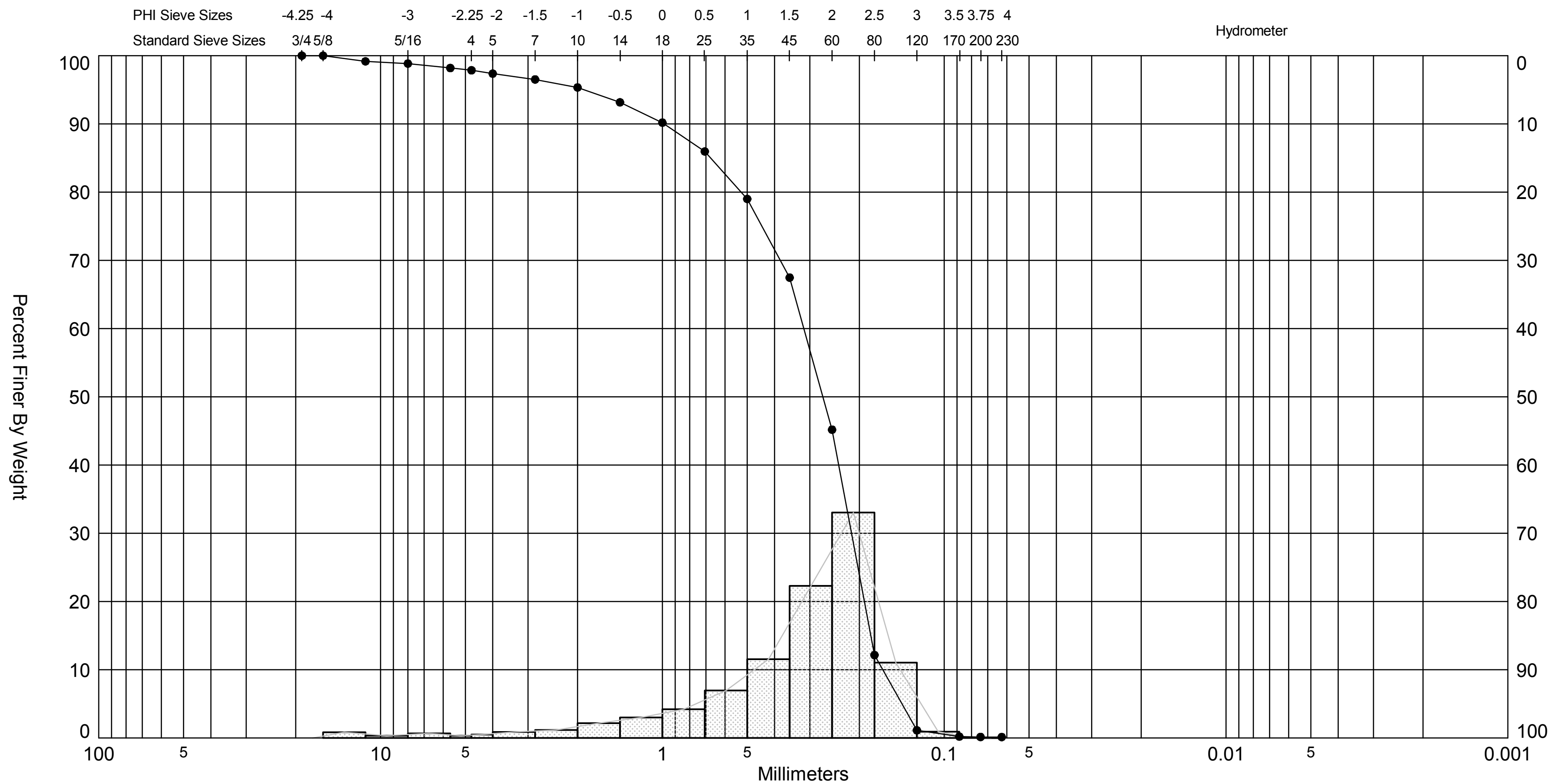
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O22 #1	—●—		SW	#200 - 0.14 #230 - 0.13	0.60	16.20	1.89	1.55	-1.95	7.52	1.2

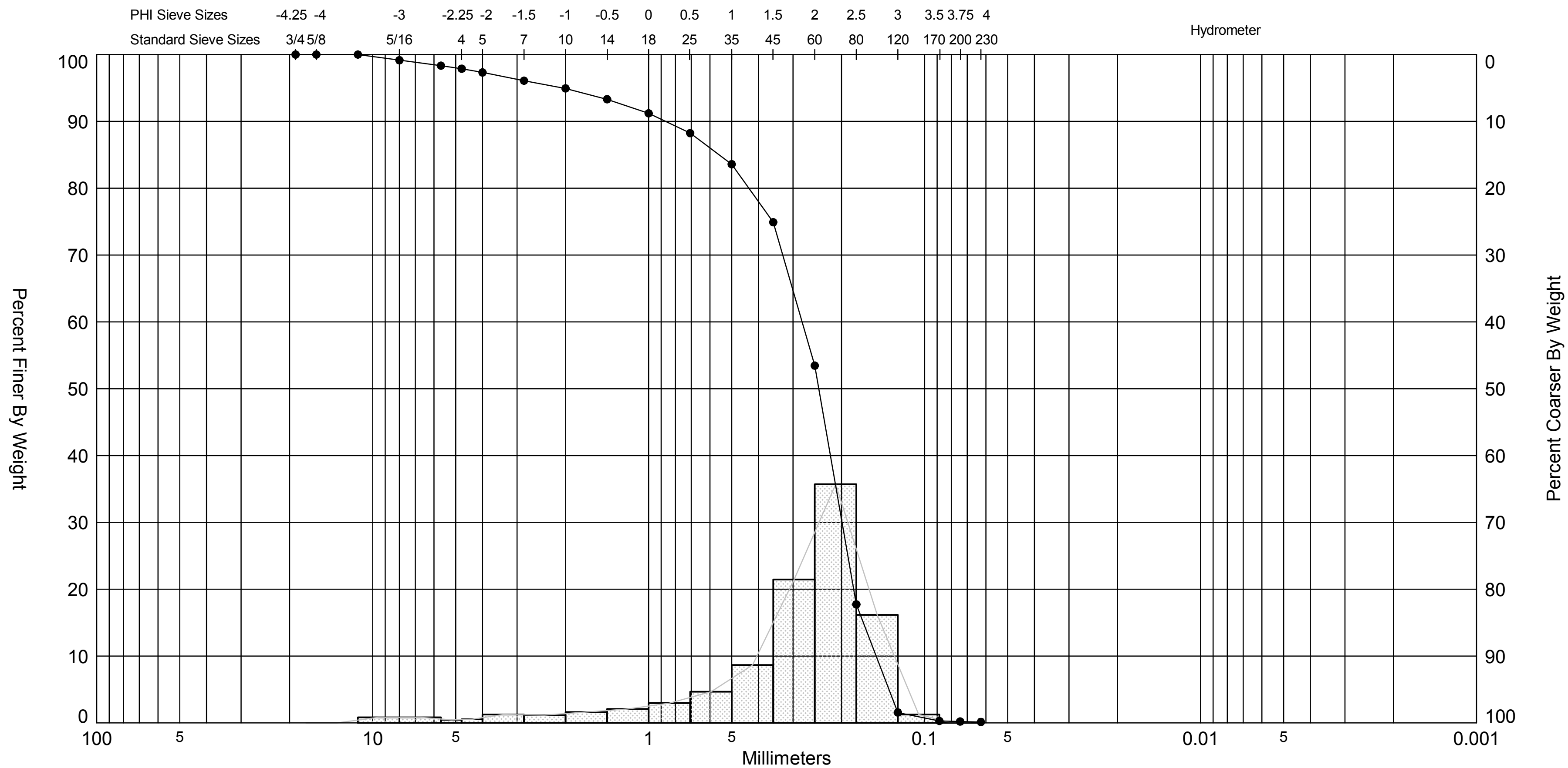
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O22 #2	—●—		SW	#200 - 0.20 #230 - 0.14	0.40	12.30	2.05	1.7	-2.05	7.54	1.18

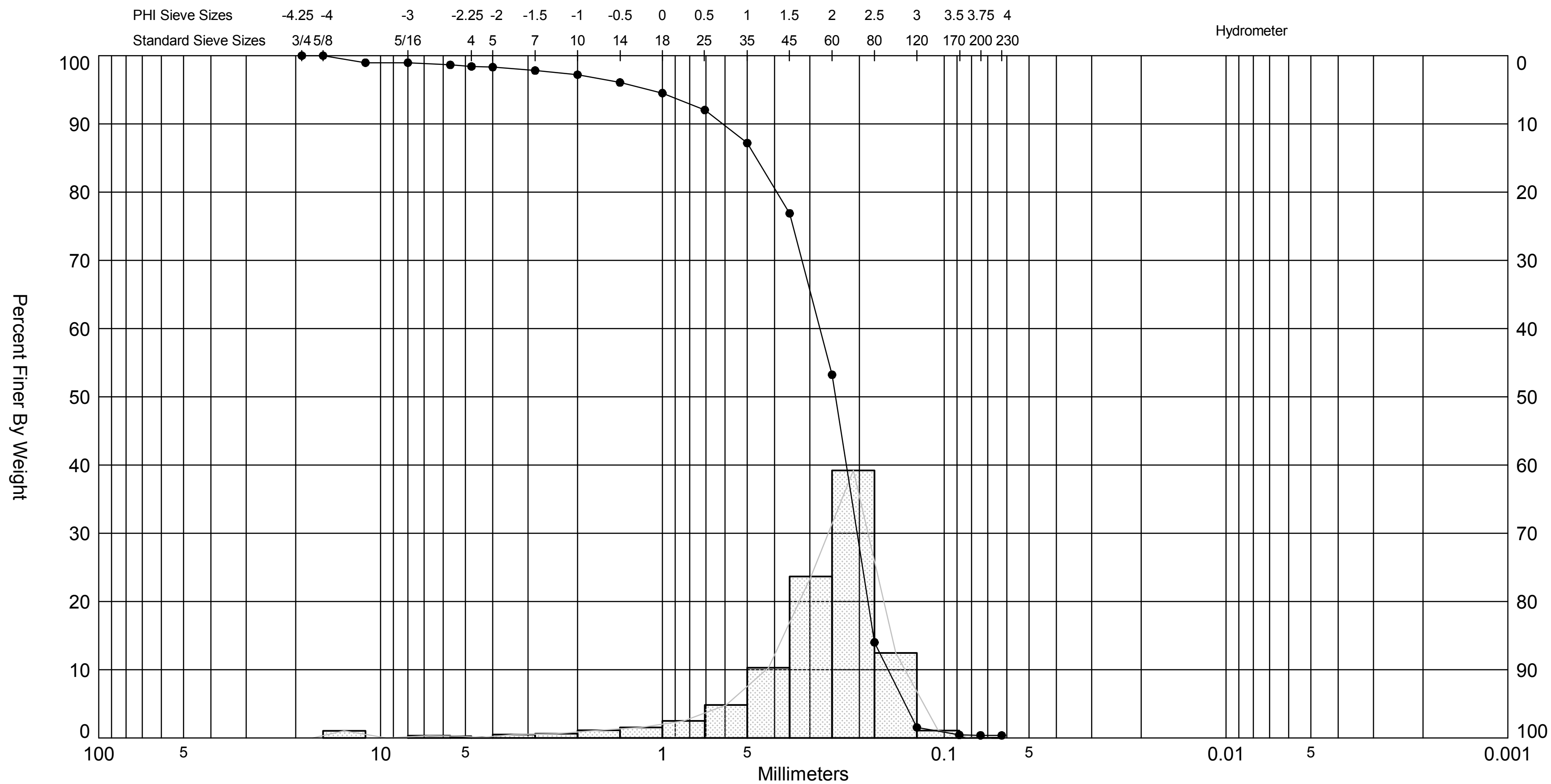
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O22 #3	—●—		SW	#200 - 0.38 #230 - 0.37	0.40	11.70	2.04	1.77	-2.66	12.61	1.03

Comments:

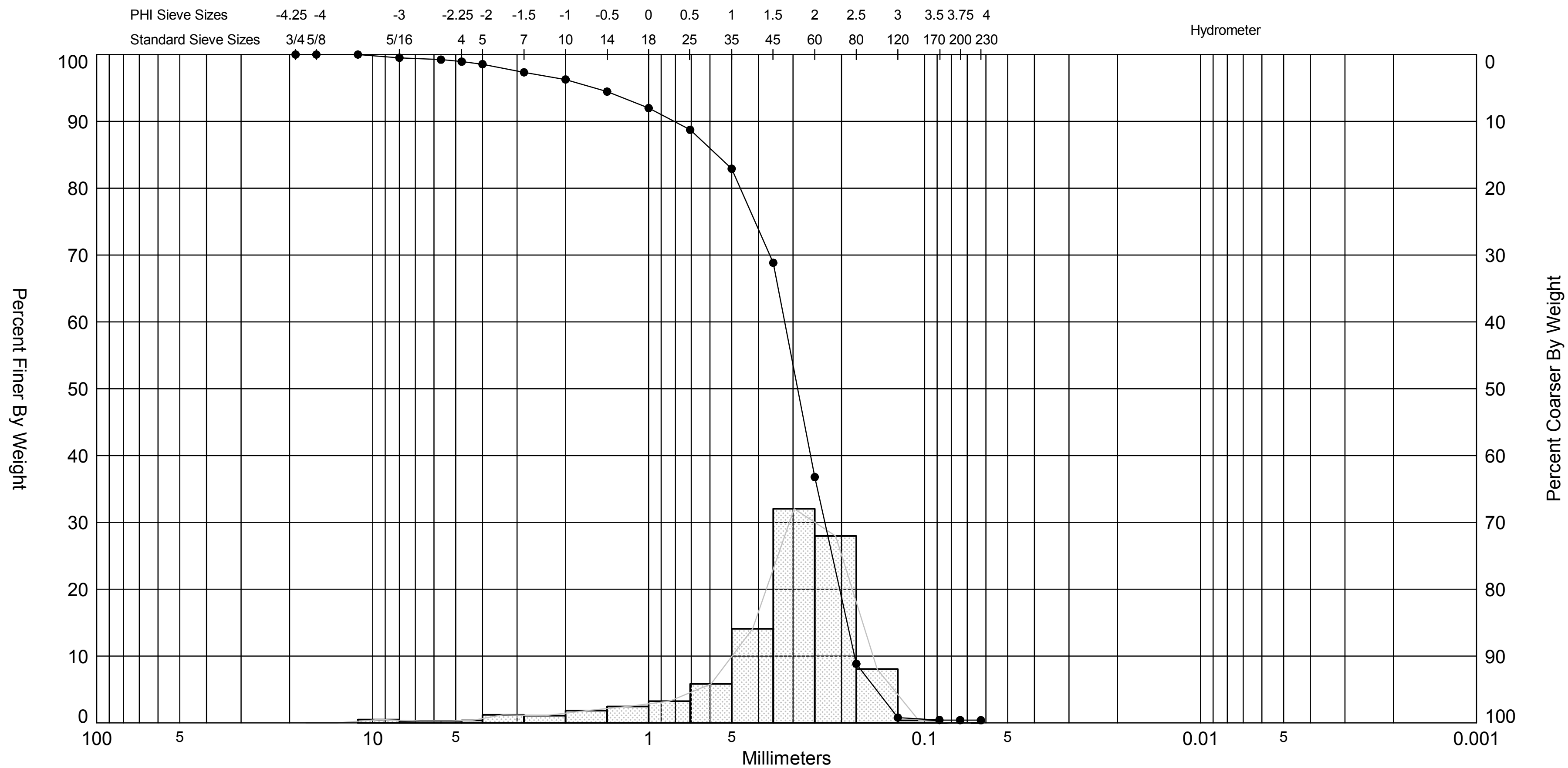
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O22 #4	—●—		SW	#200 - 0.41 #230 - 0.40	0.50	14.70	1.79	1.57	-1.95	7.72	1.02

Comments:

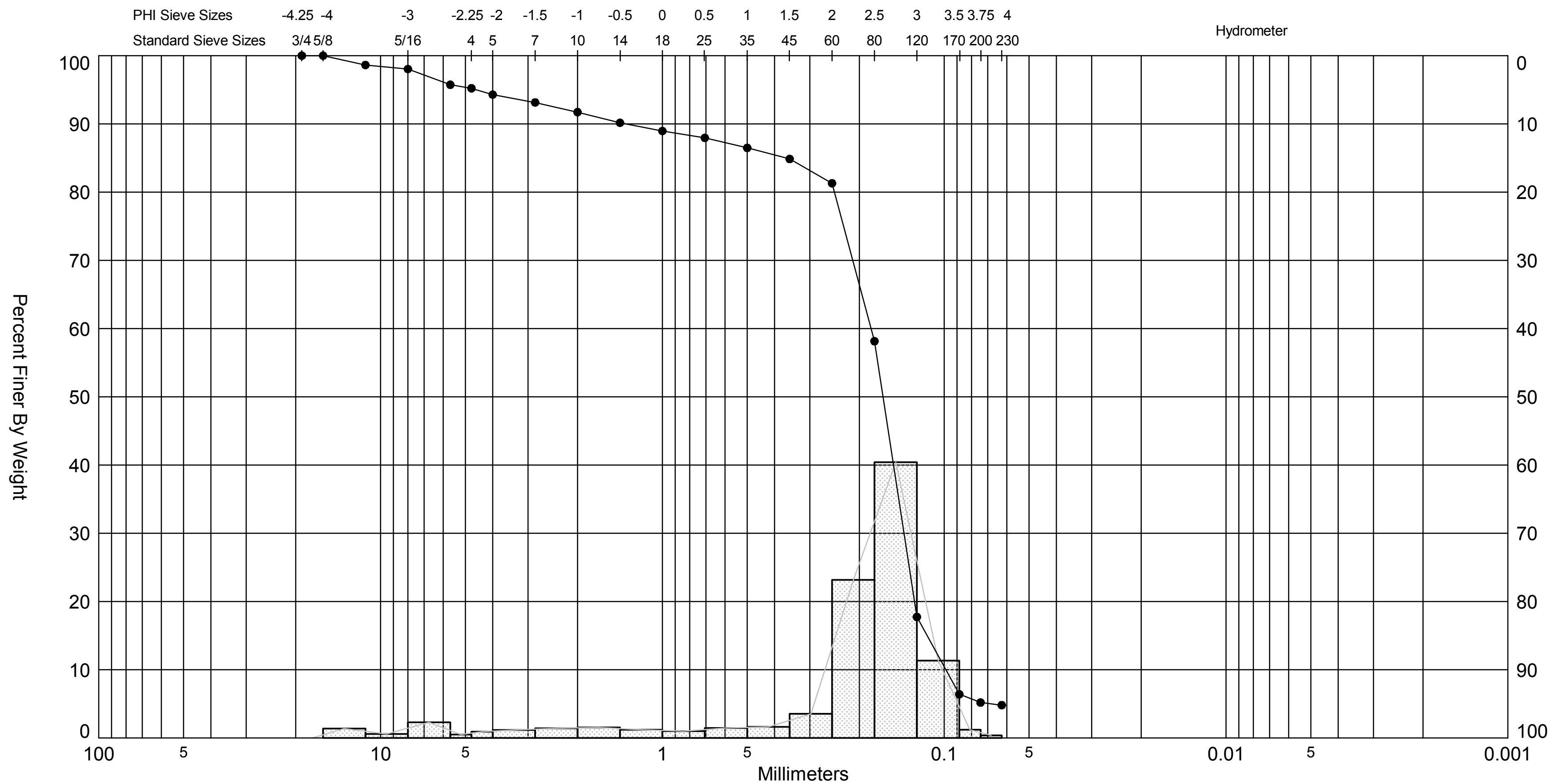
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-15-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O24 #1	—●—		SW-SM	#200 - 5.19 #230 - 4.81	1.50	13.00	2.6	2.03	-2.2	6.99	1.59

Comments:

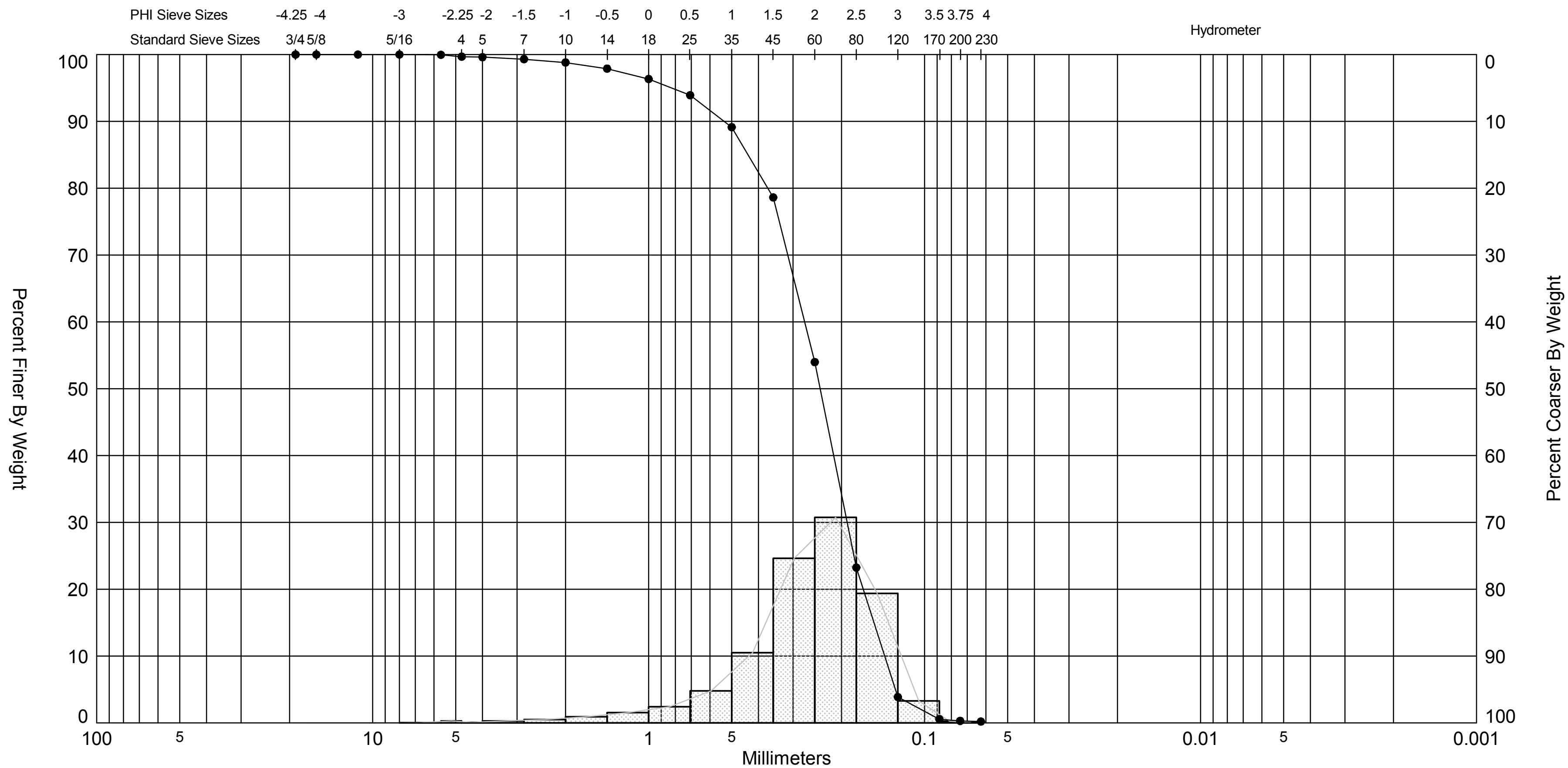
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O24 #2	—●—		SP	#200 - 0.30 #230 - 0.20	0.50	10.40	2.06	1.92	-1.55	7.11	0.85

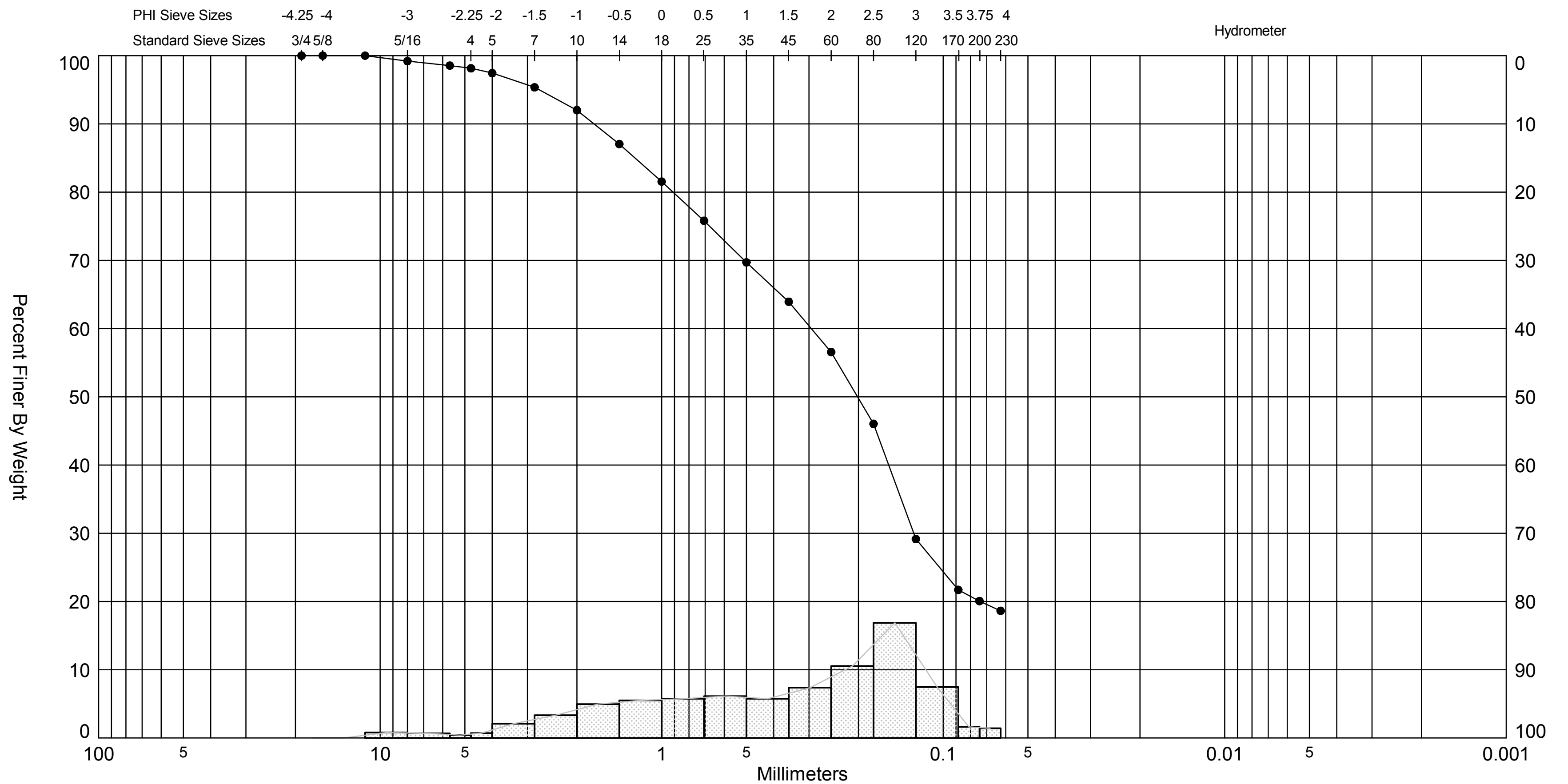
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O24 #3	—●—		SM	#200 - 20.06 #230 - 18.63	2.30	32.90	2.31	1.38	-0.68	2.61	1.63

Comments:

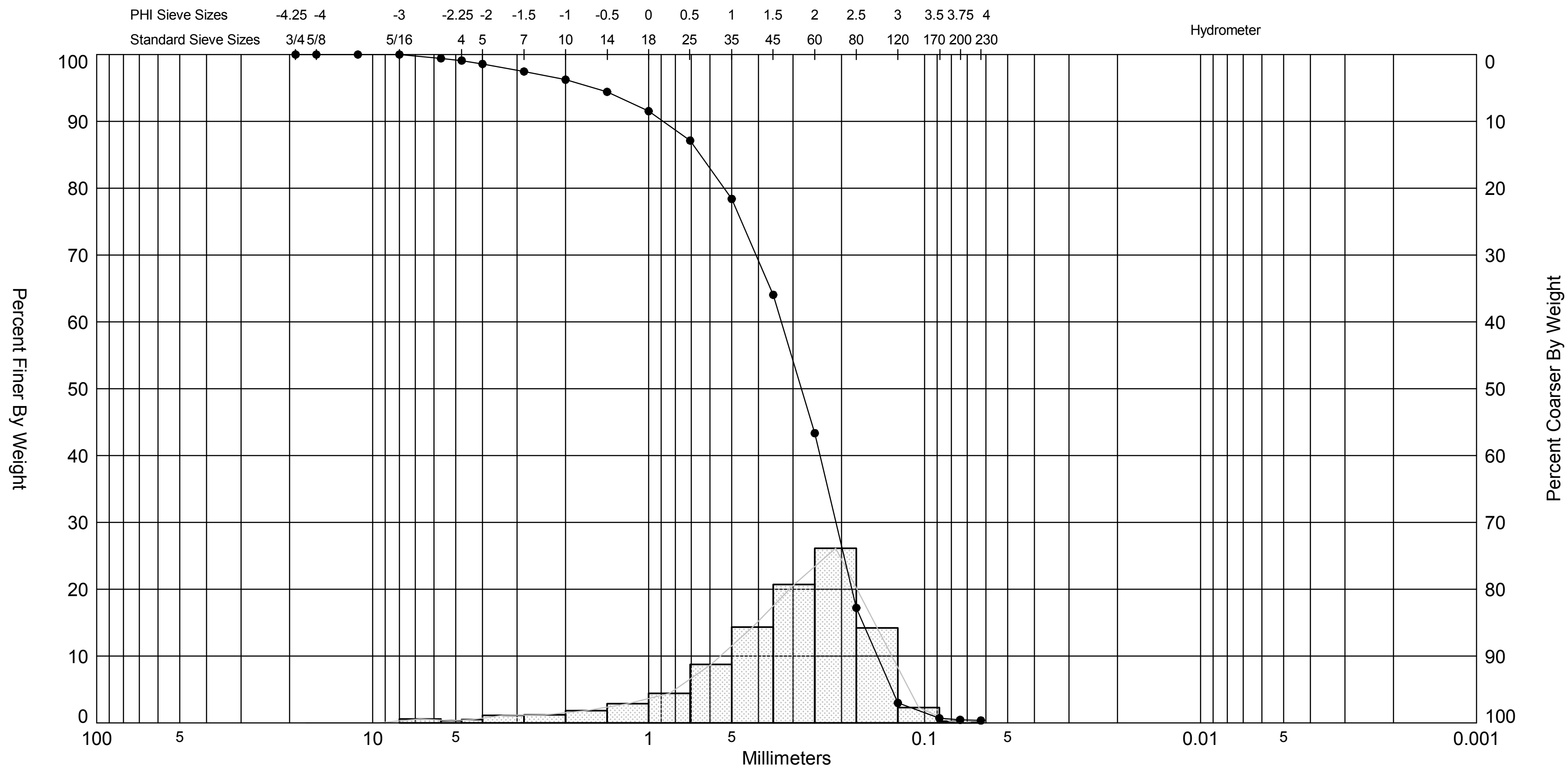
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O25 #1	—●—		SW	#200 - 0.45 #230 - 0.36	0.50	13.60	1.84	1.6	-1.38	5.35	1.1

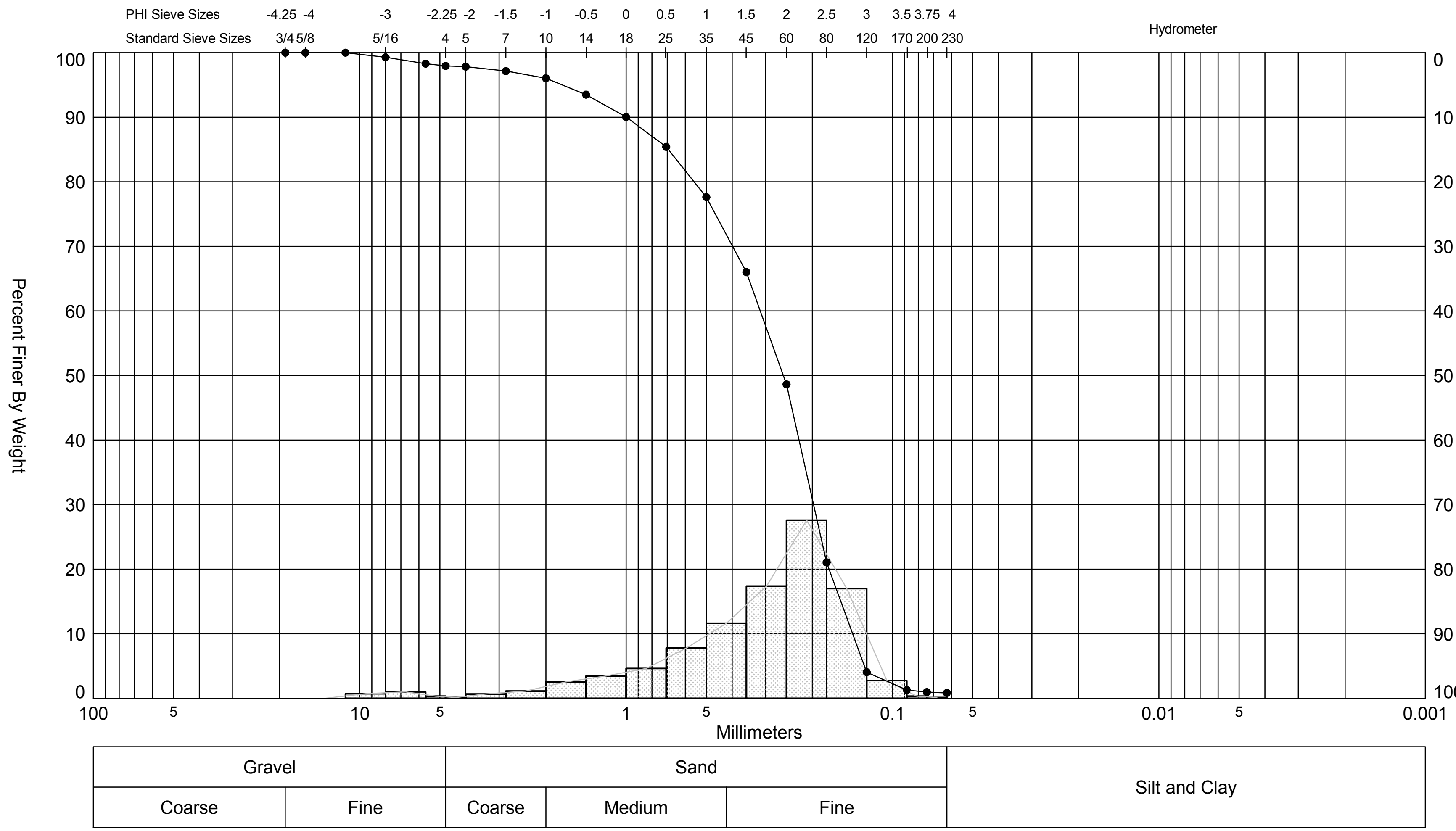
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O25 #2	—●—		SW	#200 - 0.96 #230 - 0.83	0.50	18.00	1.96	1.61	-1.54	5.84	1.21

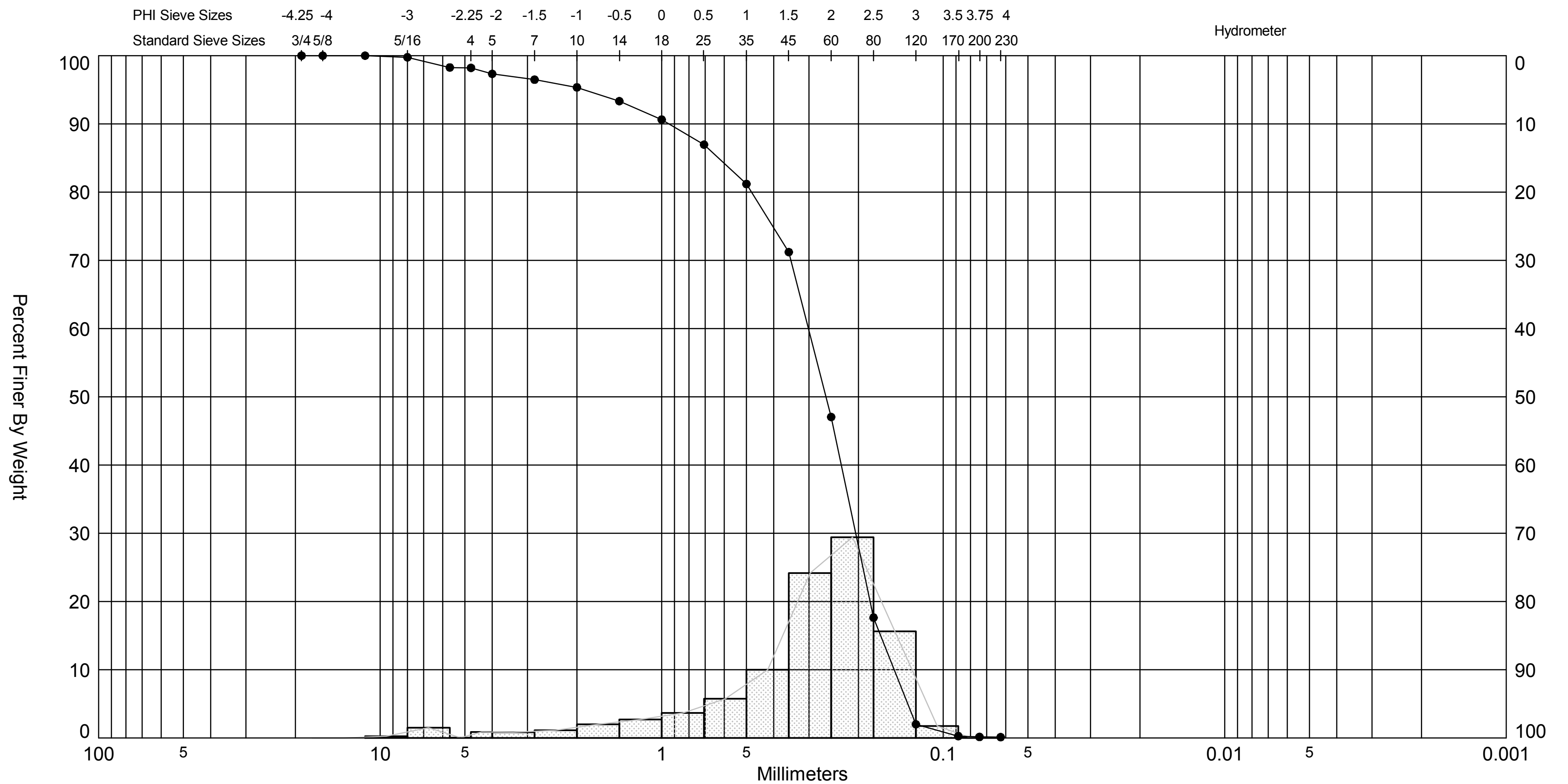
Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

Comments:

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O25 #3	—●—		SW	#200 - 0.15 #230 - 0.12	0.90	19.20	1.94	1.64	-1.79	6.54	1.17

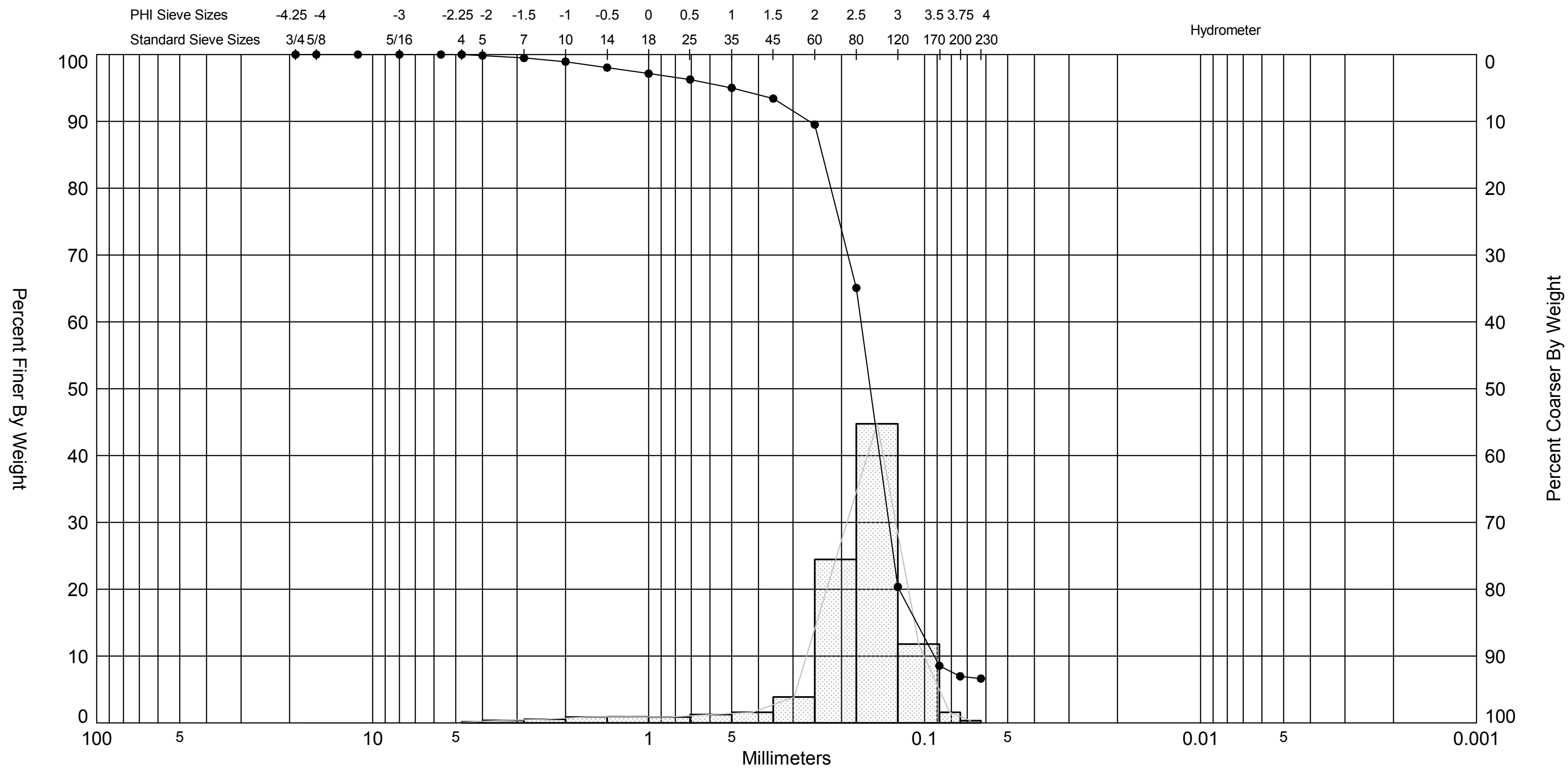
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O25 #4	—●—		SP-SM	#200 - 6.97 #230 - 6.63	1.60	9.70	2.67	2.47	-2.67	12.34	0.8

Comments:

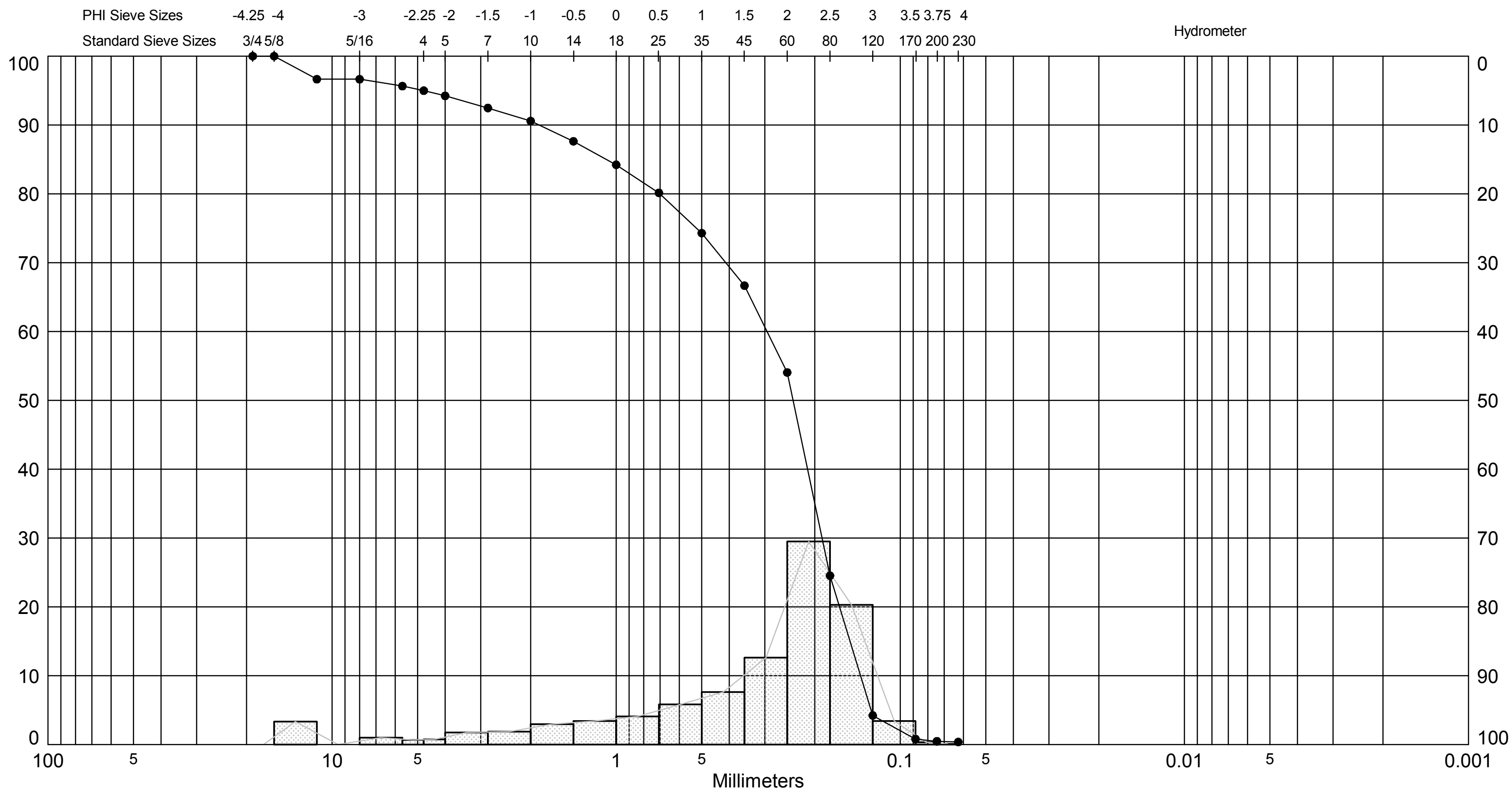
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O26 #1	—●—		SW	#200 - 0.47 #230 - 0.37	0.60	12.70	2.07	1.46	-1.64	5.22	1.62

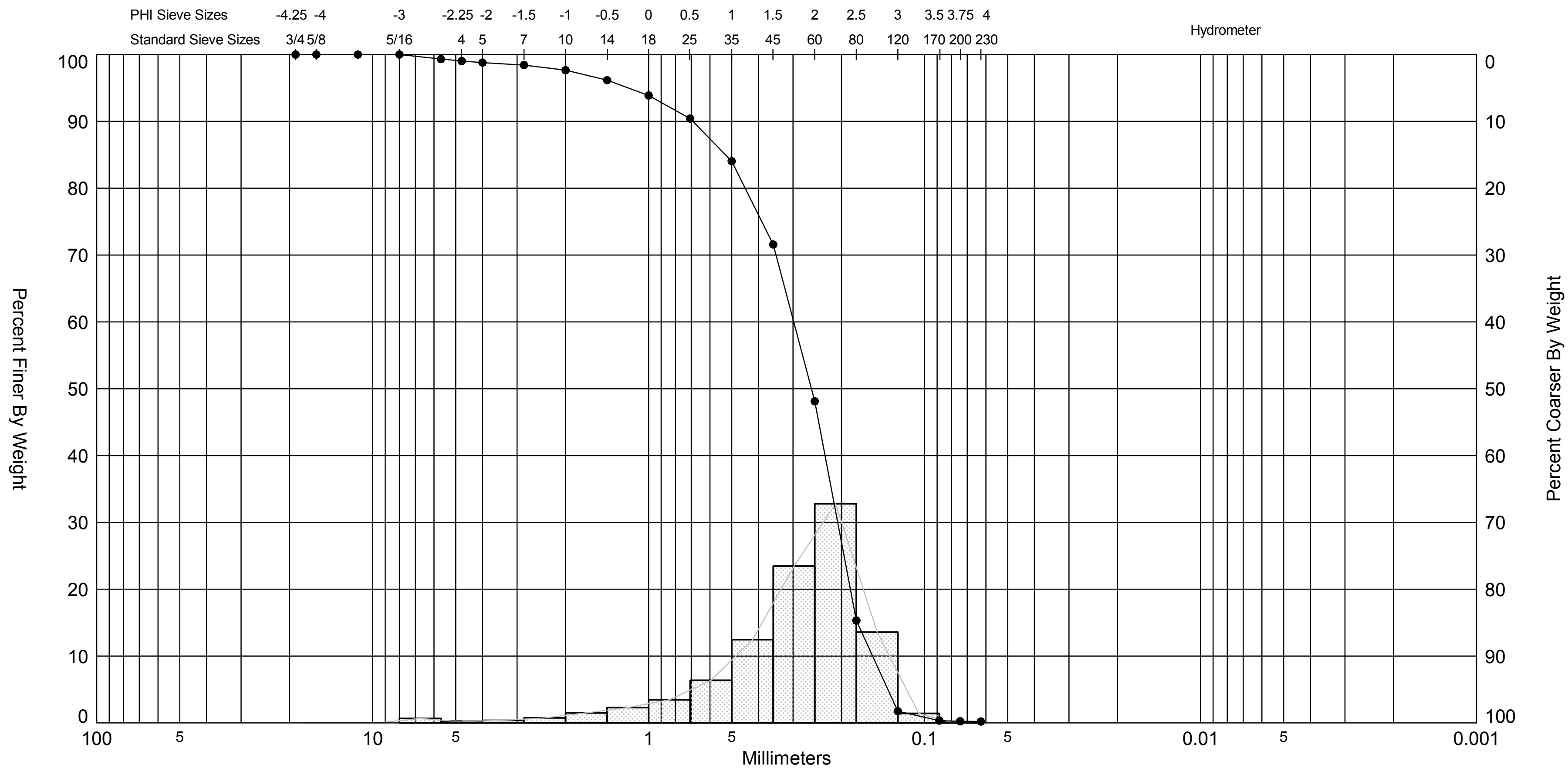
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O26 #2	—●—		SW	#200 - 0.24 #230 - 0.21	0.40	11.90	1.96	1.72	-1.77	7.34	0.97

Comments:

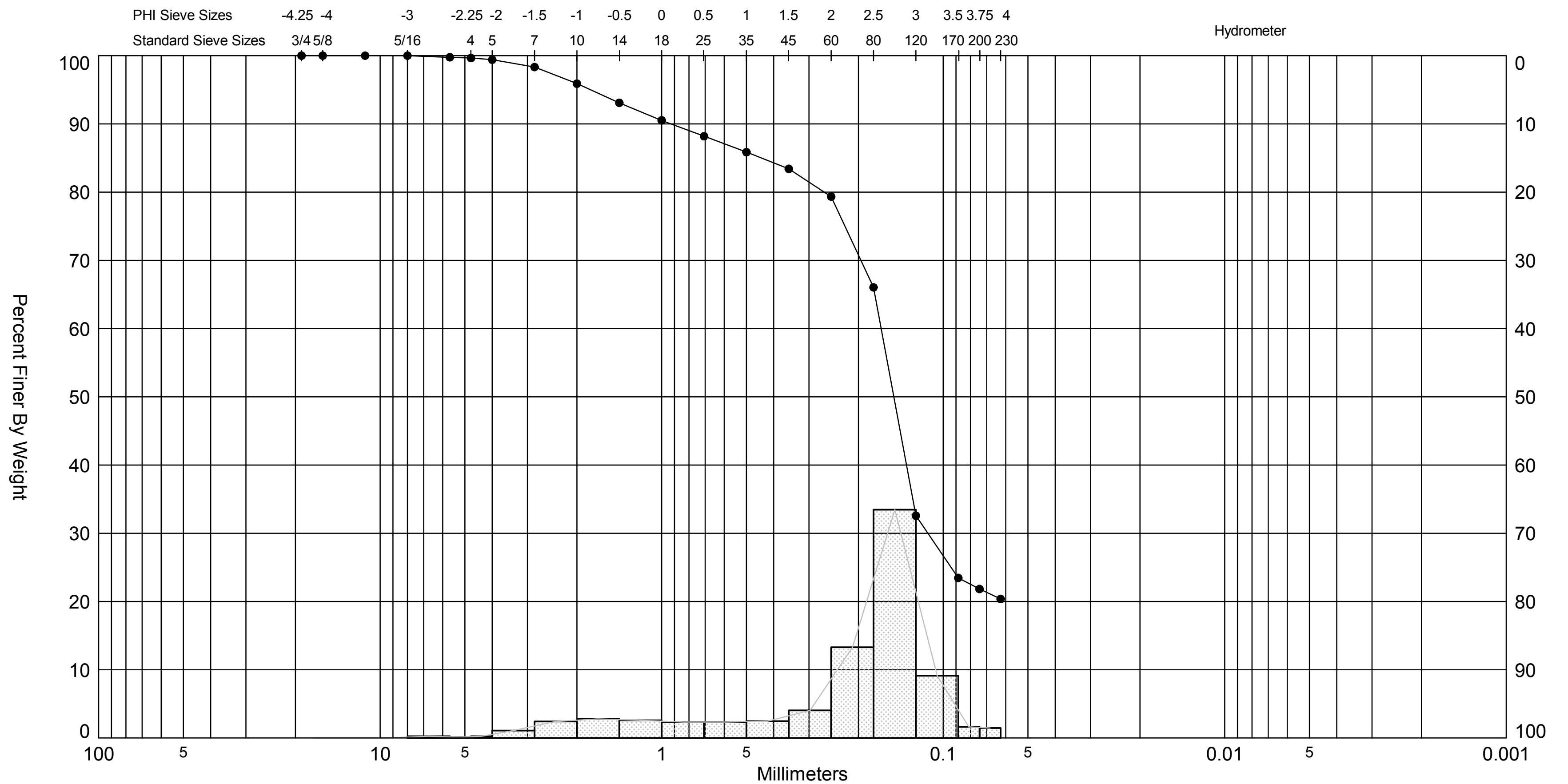
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O26 #3	—●—		SM	#200 - 21.83 #230 - 20.37	1.50	10.70	2.74	2.09	-1.52	4.48	1.33

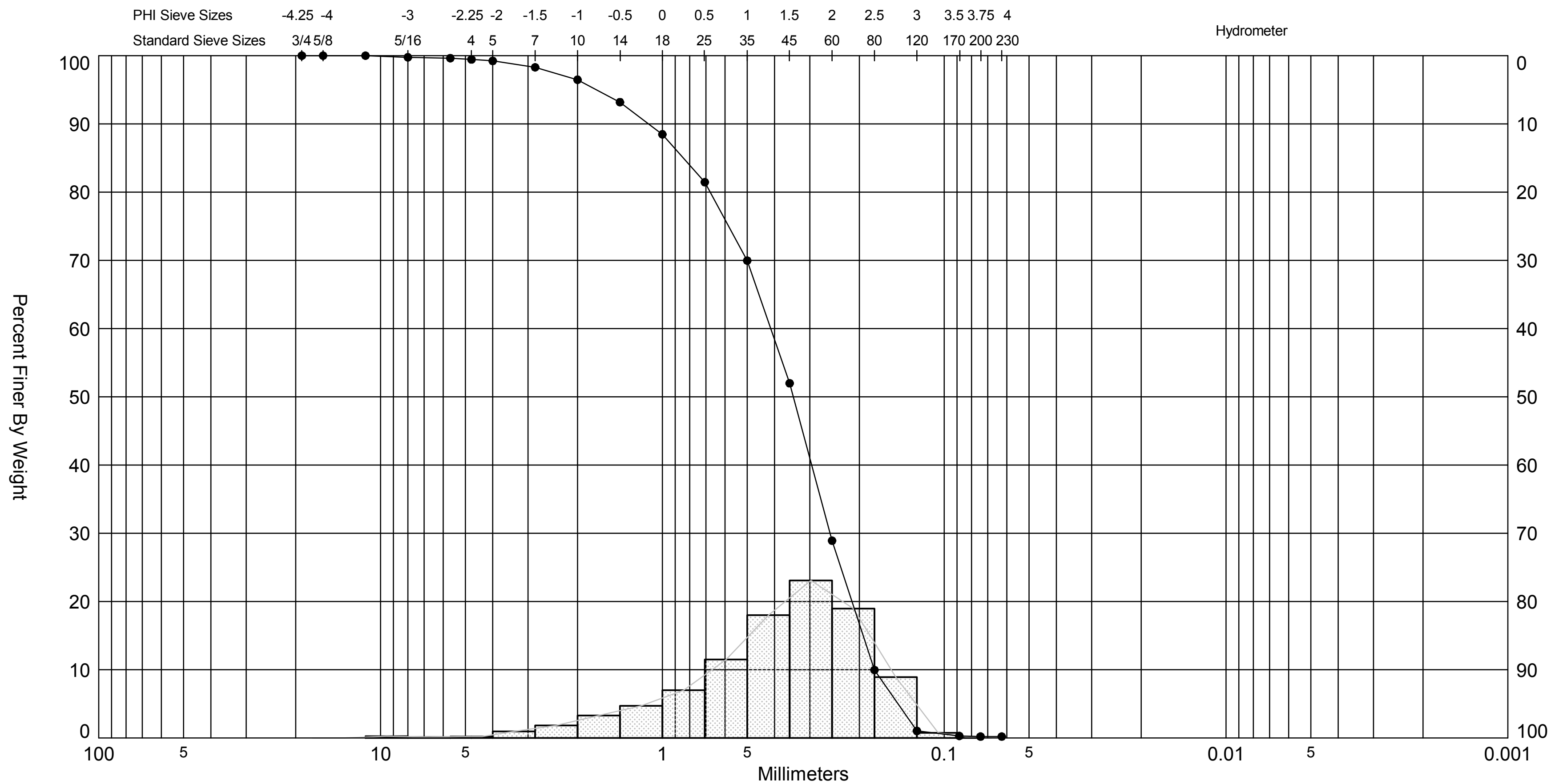
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-16-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O27 #1	—●—		SW	#200 - 0.20 #230 - 0.20	0.50	16.70	1.54	1.34	-1.02	4.24	1.06

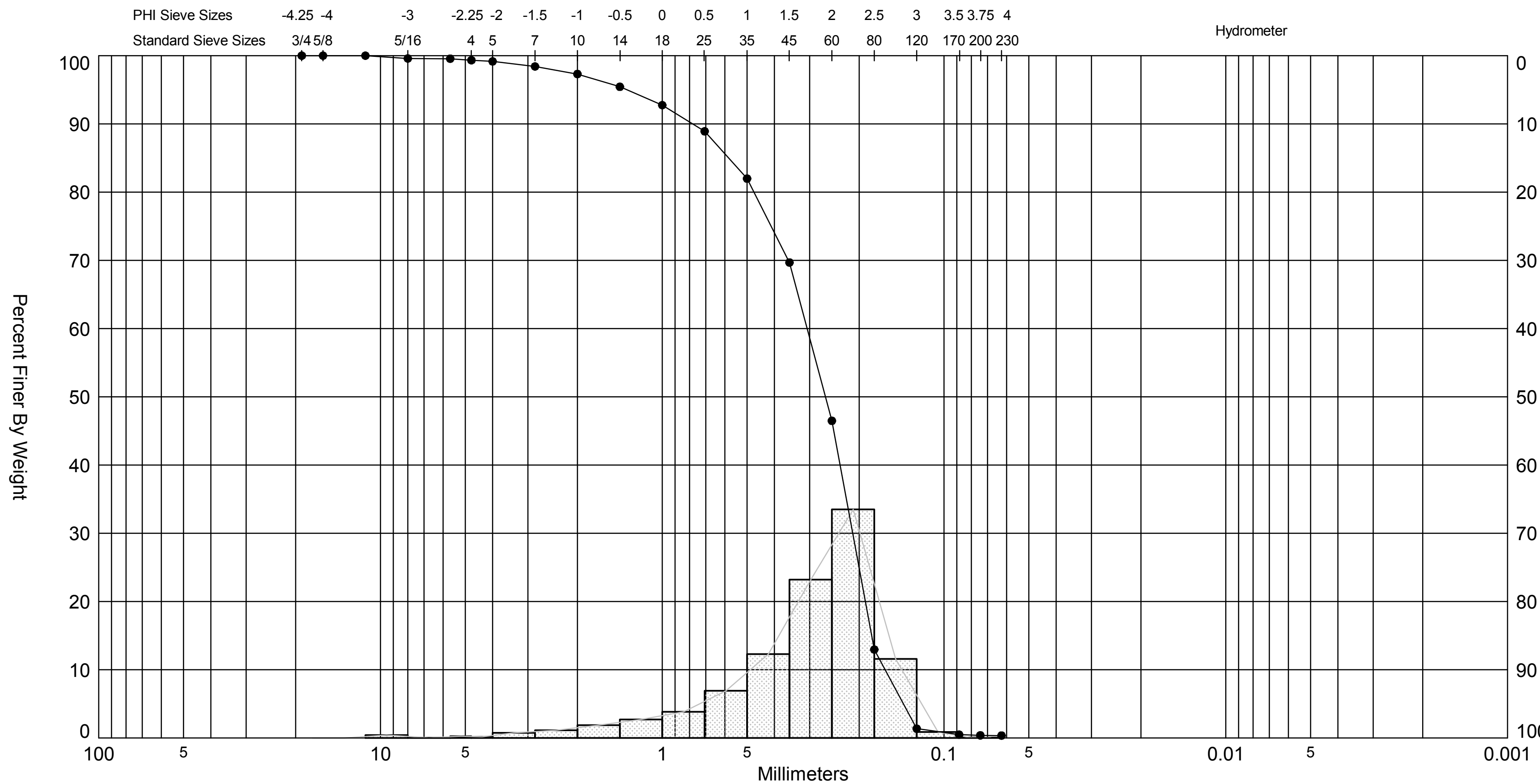
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-17-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O27 #2	—●—		SW	#200 - 0.38 #230 - 0.35	0.50	12.00	1.92	1.66	-1.7	6.84	1

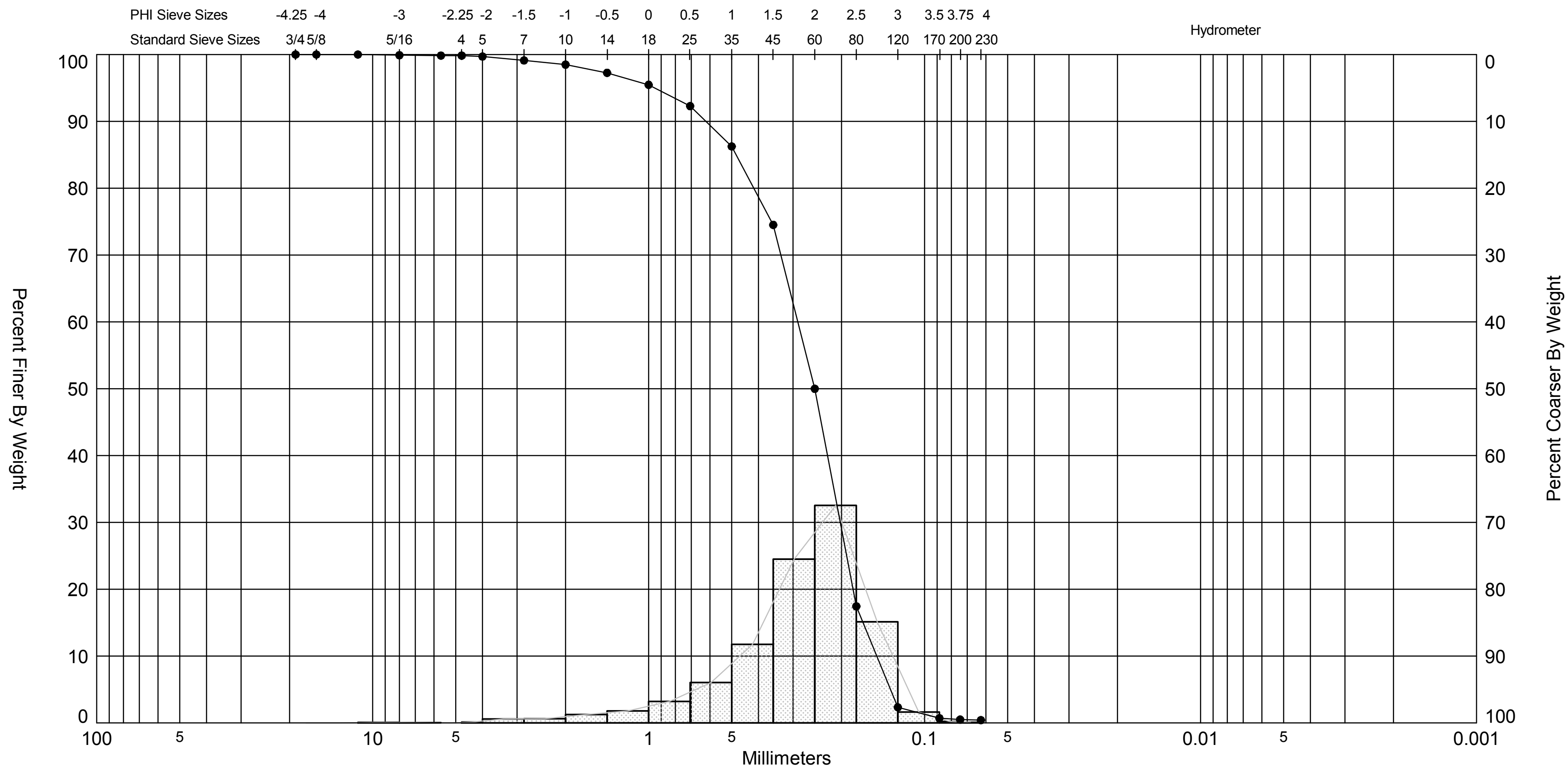
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-17-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O27 #3	—●—		SW	#200 - 0.49 #230 - 0.41	0.50	11.80	2	1.81	-1.56	6.8	0.88

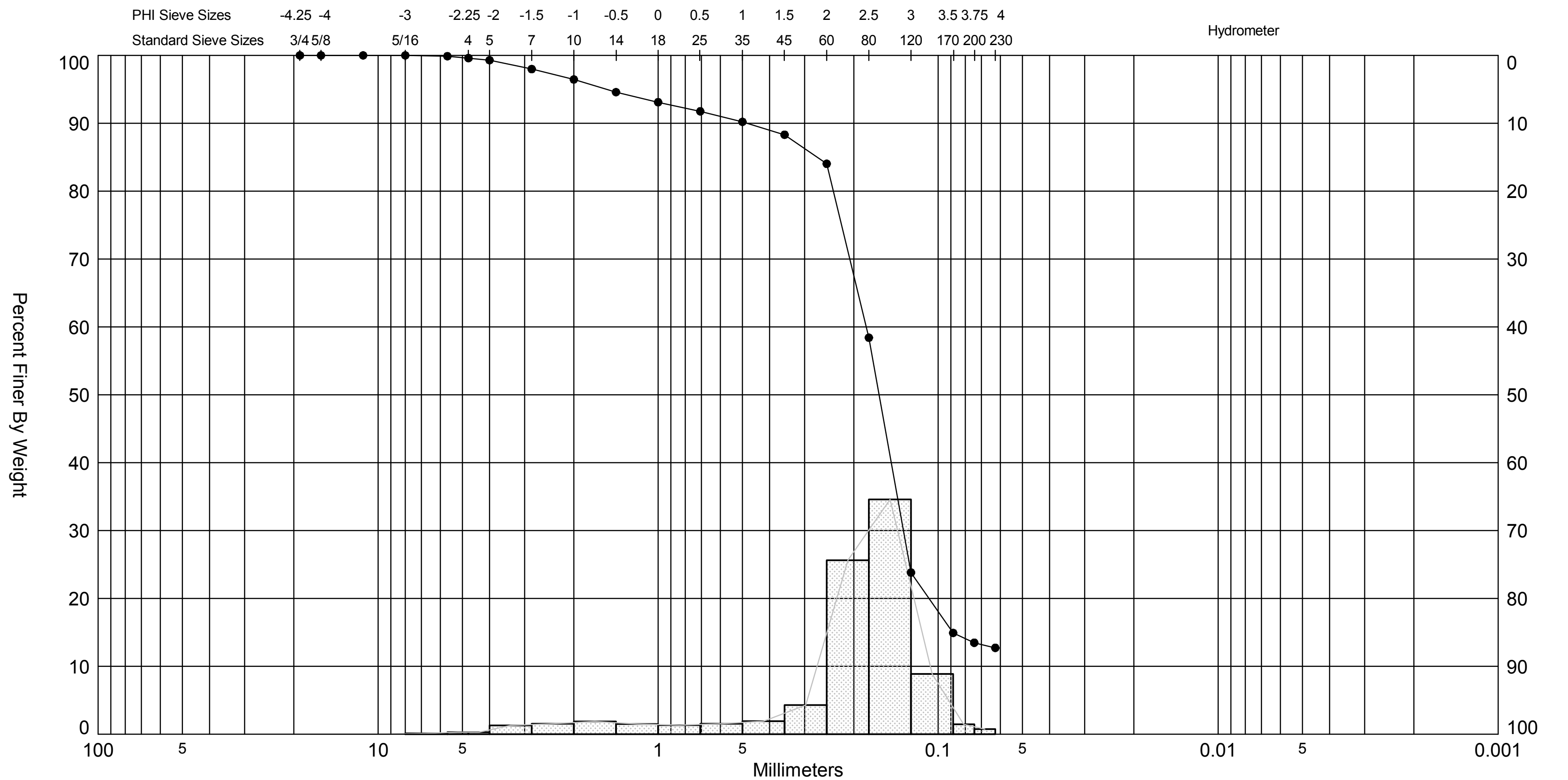
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-17-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O27 #4	—●—		SM	#200 - 13.47 #230 - 12.72	1.80	20.30	2.62	2.22	-2.12	7.34	1.15

Comments:

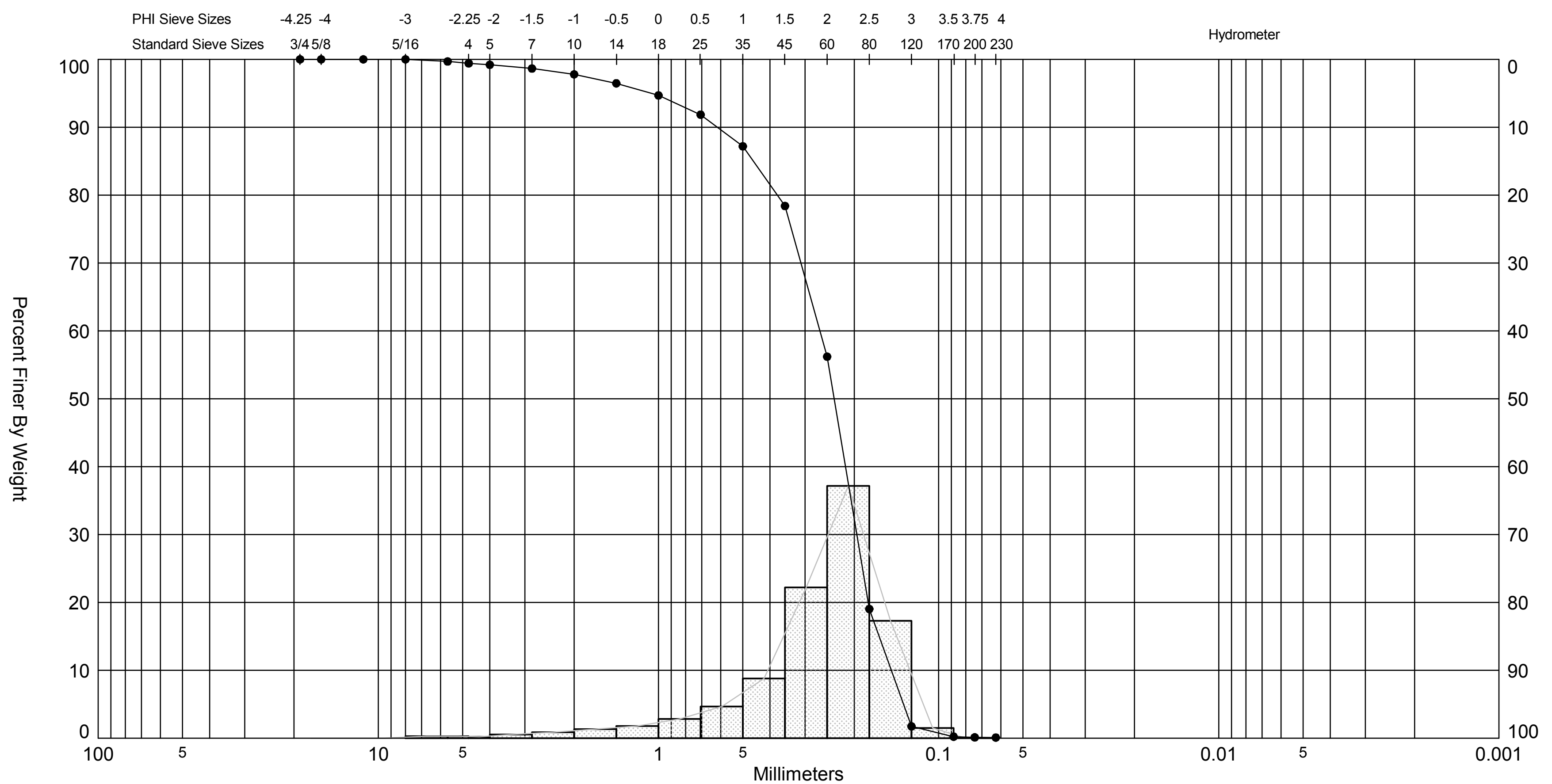
Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-17-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O28 #1	——●——		SW	#200 - 0.12 #230 - 0.09	0.50	12.80	2.08	1.85	-1.93	7.91	0.93

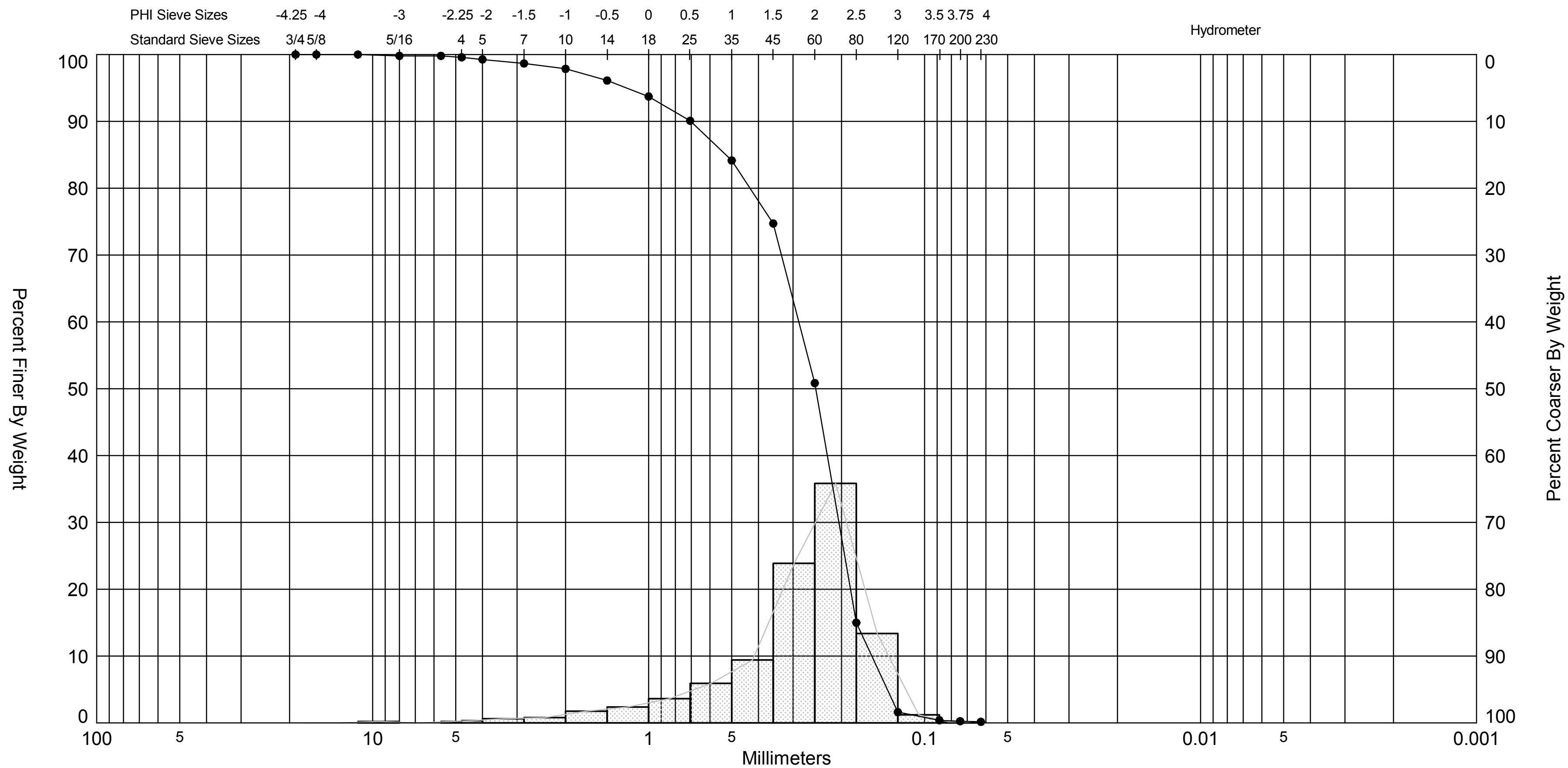
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-17-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O28 #2	—●—		SW	#200 - 0.25 #230 - 0.16	0.50	13.40	2.01	1.76	-1.73	6.93	0.95

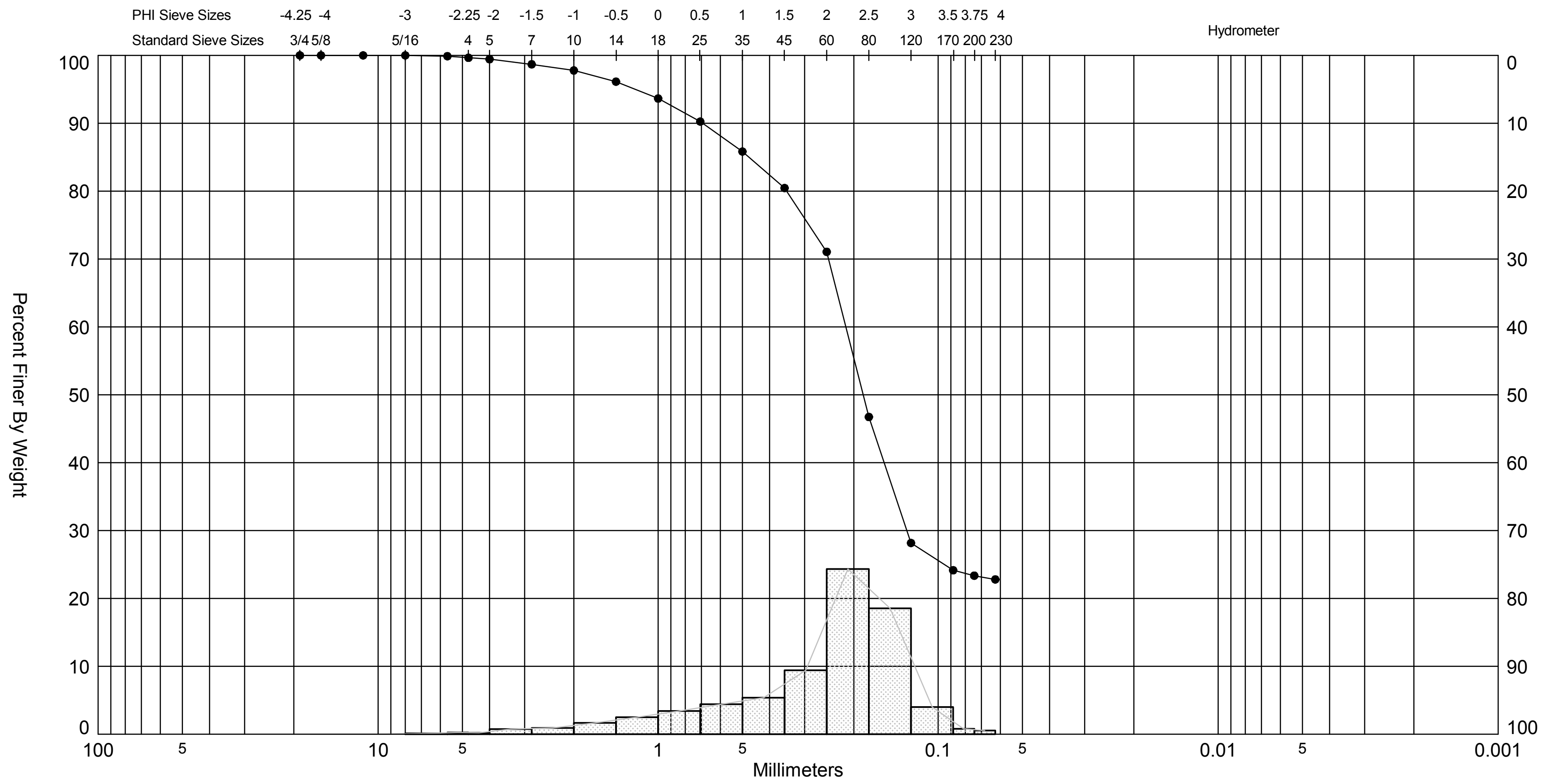
Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-17-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Sample	Symbol	Elev. (ft)	USCS	% Fines	% Organics	% Carbonates	Median	Mean	Skew	Kurt	Sort
O28 #3	—●—		SM	#200 - 23.35 #230 - 22.80	1.70	13.90	2.43	1.89	-1.38	4.89	1.13

Comments:

Depths and elevations based on measured values

Sample Information	
Project Name:	Carteret County
Analysis Date:	01-17-12
Analyzed By:	LA
Easting (X, ft):	
Northing (Y, ft):	
Horizontal System:	
Vertical System:	

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

SIEVE ANALYSIS CARTERET WITH ALPINE.GPJ FL DEP ROSS.GDT 2/7/12

3.0 Granularmetric Tables

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O18 #1
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
131.28	131.28	0.52	0.13	#200 - 0.71 #230 - 0.53	0.90	12.10	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.79	0.60	0.79	0.60
3.5	-2.50	5.66	0.63	0.48	1.42	1.08
4	-2.25	4.76	0.18	0.14	1.60	1.22
5	-2.00	4.00	0.49	0.37	2.09	1.59
7	-1.50	2.83	0.74	0.56	2.83	2.15
10	-1.00	2.00	1.10	0.84	3.93	2.99
14	-0.50	1.41	2.00	1.52	5.93	4.51
18	0.00	1.00	2.98	2.27	8.91	6.78
25	0.50	0.71	4.41	3.36	13.32	10.14
35	1.00	0.50	7.60	5.79	20.92	15.93
45	1.50	0.35	13.43	10.23	34.35	26.16
60	2.00	0.25	23.85	18.17	58.20	44.33
80	2.50	0.18	39.94	30.42	98.14	74.75
120	3.00	0.13	25.51	19.43	123.65	94.18
170	3.50	0.09	5.97	4.55	129.62	98.73
200	3.75	0.07	0.73	0.56	130.35	99.29
230	4.00	0.06	0.24	0.18	130.59	99.47

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
3.09	2.74	2.51	2.09	1.44	1.00	-0.39

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.82	0.28	1.1	-1.78	7.36

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O18 #2
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
135.32	135.32	0.28	0.08	#200 - 0.40 #230 - 0.29	0.60	12.60	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.08	0.06	0.08	0.06
4	-2.25	4.76	0.20	0.15	0.28	0.21
5	-2.00	4.00	0.33	0.24	0.61	0.45
7	-1.50	2.83	1.51	1.12	2.12	1.57
10	-1.00	2.00	1.59	1.17	3.71	2.74
14	-0.50	1.41	2.48	1.83	6.19	4.57
18	0.00	1.00	3.35	2.48	9.54	7.05
25	0.50	0.71	4.49	3.32	14.03	10.37
35	1.00	0.50	7.31	5.40	21.34	15.77
45	1.50	0.35	13.20	9.75	34.54	25.52
60	2.00	0.25	25.40	18.77	59.94	44.29
80	2.50	0.18	40.91	30.23	100.85	74.52
120	3.00	0.13	30.01	22.18	130.86	96.70
170	3.50	0.09	3.64	2.69	134.50	99.39
200	3.75	0.07	0.28	0.21	134.78	99.60
230	4.00	0.06	0.15	0.11	134.93	99.71

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.96	2.71	2.51	2.09	1.47	1.01	-0.41

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.83	0.28	1.02	-1.52	5.54

Granularmetric Report
Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O18 #3
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SM		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
135.18	110.62	0.46	0.12	#200 - 19.35 #230 - 18.62	2.00	23.20	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.07	0.05	0.07	0.05
4	-2.25	4.76	0.05	0.04	0.12	0.09
5	-2.00	4.00	0.20	0.15	0.32	0.24
7	-1.50	2.83	0.77	0.57	1.09	0.81
10	-1.00	2.00	1.33	0.98	2.42	1.79
14	-0.50	1.41	2.63	1.95	5.05	3.74
18	0.00	1.00	2.35	1.74	7.40	5.48
25	0.50	0.71	2.11	1.56	9.51	7.04
35	1.00	0.50	2.35	1.74	11.86	8.78
45	1.50	0.35	2.61	1.93	14.47	10.71
60	2.00	0.25	4.66	3.45	19.13	14.16
80	2.50	0.18	28.16	20.83	47.29	34.99
120	3.00	0.13	47.60	35.21	94.89	70.20
170	3.50	0.09	12.22	9.04	107.11	79.24
200	3.75	0.07	1.90	1.41	109.01	80.65
230	4.00	0.06	0.99	0.73	110.00	81.38

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
		3.27	2.71	2.26	2.04	-0.14

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	2.29	0.20	1.05	-2.05	7.19

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O19 #1
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
127.68	127.68	0.11	0.00	#200 - 0.18 #230 - 0.08	0.60	10.60	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.00	0.00	0.00	0.00
4	-2.25	4.76	0.00	0.00	0.00	0.00
5	-2.00	4.00	0.03	0.02	0.03	0.02
7	-1.50	2.83	0.41	0.32	0.44	0.34
10	-1.00	2.00	0.43	0.34	0.87	0.68
14	-0.50	1.41	1.39	1.09	2.26	1.77
18	0.00	1.00	2.18	1.71	4.44	3.48
25	0.50	0.71	3.77	2.95	8.21	6.43
35	1.00	0.50	7.48	5.86	15.69	12.29
45	1.50	0.35	13.31	10.42	29.00	22.71
60	2.00	0.25	21.37	16.74	50.37	39.45
80	2.50	0.18	41.62	32.60	91.99	72.05
120	3.00	0.13	29.40	23.03	121.39	95.08
170	3.50	0.09	5.62	4.40	127.01	99.48
200	3.75	0.07	0.43	0.34	127.44	99.82
230	4.00	0.06	0.13	0.10	127.57	99.92

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
3.00	2.76	2.56	2.16	1.57	1.18	0.26

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.98	0.25	0.86	-1.25	5.07

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O19 #2
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
129.43	129.43	0.01	0.01	#200 - 0.04 #230 - 0.00	0.60	13.50	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	1.70	1.31	1.70	1.31
3.5	-2.50	5.66	0.00	0.00	1.70	1.31
4	-2.25	4.76	0.49	0.38	2.19	1.69
5	-2.00	4.00	0.39	0.30	2.58	1.99
7	-1.50	2.83	0.24	0.19	2.82	2.18
10	-1.00	2.00	0.89	0.69	3.71	2.87
14	-0.50	1.41	1.71	1.32	5.42	4.19
18	0.00	1.00	2.47	1.91	7.89	6.10
25	0.50	0.71	4.03	3.11	11.92	9.21
35	1.00	0.50	7.47	5.77	19.39	14.98
45	1.50	0.35	14.04	10.85	33.43	25.83
60	2.00	0.25	29.12	22.50	62.55	48.33
80	2.50	0.18	41.45	32.03	104.00	80.36
120	3.00	0.13	22.75	17.58	126.75	97.94
170	3.50	0.09	2.46	1.90	129.21	99.84
200	3.75	0.07	0.15	0.12	129.36	99.96
230	4.00	0.06	0.05	0.04	129.41	100.00

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.92	2.60	2.42	2.03	1.46	1.05	-0.29

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.77	0.29	1.07	-2.18	9.5

Granularmetric Report
Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O19 #3
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
133.18	133.18	0.06	0.10	#200 - 0.18 #230 - 0.12	0.70	12.80	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.42	0.32	0.42	0.32
5/16"	-3.00	8.00	1.19	0.89	1.61	1.21
3.5	-2.50	5.66	0.25	0.19	1.86	1.40
4	-2.25	4.76	0.31	0.23	2.17	1.63
5	-2.00	4.00	0.09	0.07	2.26	1.70
7	-1.50	2.83	0.66	0.50	2.92	2.20
10	-1.00	2.00	0.95	0.71	3.87	2.91
14	-0.50	1.41	2.18	1.64	6.05	4.55
18	0.00	1.00	3.51	2.64	9.56	7.19
25	0.50	0.71	5.62	4.22	15.18	11.41
35	1.00	0.50	10.56	7.93	25.74	19.34
45	1.50	0.35	18.31	13.75	44.05	33.09
60	2.00	0.25	27.18	20.41	71.23	53.50
80	2.50	0.18	39.59	29.73	110.82	83.23
120	3.00	0.13	19.68	14.78	130.50	98.01
170	3.50	0.09	2.18	1.64	132.68	99.65
200	3.75	0.07	0.23	0.17	132.91	99.82
230	4.00	0.06	0.08	0.06	132.99	99.88

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.90	2.53	2.36	1.91	1.21	0.79	-0.41

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.65	0.32	1.1	-1.89	8.21

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County

Sample Name: O19 #4

Analysis Date: 01-15-12

Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SP		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
124.56	124.56	0.42	0.15	#200 - 0.70 #230 - 0.49	0.70	9.50	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.00	0.00	0.00	0.00
4	-2.25	4.76	0.00	0.00	0.00	0.00
5	-2.00	4.00	0.09	0.07	0.09	0.07
7	-1.50	2.83	0.05	0.04	0.14	0.11
10	-1.00	2.00	0.21	0.17	0.35	0.28
14	-0.50	1.41	0.67	0.54	1.02	0.82
18	0.00	1.00	1.45	1.16	2.47	1.98
25	0.50	0.71	2.54	2.04	5.01	4.02
35	1.00	0.50	4.79	3.85	9.80	7.87
45	1.50	0.35	9.97	8.00	19.77	15.87
60	2.00	0.25	26.87	21.57	46.64	37.44
80	2.50	0.18	46.26	37.14	92.90	74.58
120	3.00	0.13	25.99	20.87	118.89	95.45
170	3.50	0.09	4.29	3.44	123.18	98.89
200	3.75	0.07	0.51	0.41	123.69	99.30
230	4.00	0.06	0.26	0.21	123.95	99.51

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.99	2.73	2.51	2.17	1.71	1.50	0.63

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	2.05	0.24	0.73	-1.28	6.1

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County

Sample Name: O20 #1

Analysis Date: 01-15-12

Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
126.68	126.68	0.01	0.11	#200 - 0.14 #230 - 0.12	0.60	17.80	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	2.14	1.69	2.14	1.69
3.5	-2.50	5.66	0.45	0.36	2.59	2.05
4	-2.25	4.76	0.63	0.50	3.22	2.55
5	-2.00	4.00	0.86	0.68	4.08	3.23
7	-1.50	2.83	1.49	1.18	5.57	4.41
10	-1.00	2.00	1.89	1.49	7.46	5.90
14	-0.50	1.41	3.23	2.55	10.69	8.45
18	0.00	1.00	4.17	3.29	14.86	11.74
25	0.50	0.71	5.19	4.10	20.05	15.84
35	1.00	0.50	8.54	6.74	28.59	22.58
45	1.50	0.35	13.97	11.03	42.56	33.61
60	2.00	0.25	25.72	20.30	68.28	53.91
80	2.50	0.18	36.20	28.58	104.48	82.49
120	3.00	0.13	19.26	15.20	123.74	97.69
170	3.50	0.09	2.59	2.04	126.33	99.73
200	3.75	0.07	0.17	0.13	126.50	99.86
230	4.00	0.06	0.03	0.02	126.53	99.88

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.91	2.55	2.37	1.90	1.11	0.51	-1.30

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.53	0.35	1.29	-1.67	5.92

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O20 #2
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
126.80	126.80	0.49	0.34	#200 - 0.89 #230 - 0.72	0.80	21.20	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	1.35	1.06	1.35	1.06
3.5	-2.50	5.66	0.19	0.15	1.54	1.21
4	-2.25	4.76	0.09	0.07	1.63	1.28
5	-2.00	4.00	0.09	0.07	1.72	1.35
7	-1.50	2.83	1.17	0.92	2.89	2.27
10	-1.00	2.00	1.57	1.24	4.46	3.51
14	-0.50	1.41	2.83	2.23	7.29	5.74
18	0.00	1.00	4.19	3.30	11.48	9.04
25	0.50	0.71	5.93	4.68	17.41	13.72
35	1.00	0.50	8.57	6.76	25.98	20.48
45	1.50	0.35	12.29	9.69	38.27	30.17
60	2.00	0.25	21.88	17.26	60.15	47.43
80	2.50	0.18	35.68	28.14	95.83	75.57
120	3.00	0.13	24.95	19.68	120.78	95.25
170	3.50	0.09	4.49	3.54	125.27	98.79
200	3.75	0.07	0.40	0.32	125.67	99.11
230	4.00	0.06	0.21	0.17	125.88	99.28

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.99	2.71	2.49	2.05	1.23	0.67	-0.67

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.71	0.31	1.18	-1.59	6.15

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O20 #3
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
134.32	134.32	0.22	0.20	#200 - 0.45 #230 - 0.39	0.60	9.30	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	1.43	1.06	1.43	1.06
3.5	-2.50	5.66	1.22	0.91	2.65	1.97
4	-2.25	4.76	0.46	0.34	3.11	2.31
5	-2.00	4.00	0.55	0.41	3.66	2.72
7	-1.50	2.83	1.20	0.89	4.86	3.61
10	-1.00	2.00	1.45	1.08	6.31	4.69
14	-0.50	1.41	2.53	1.88	8.84	6.57
18	0.00	1.00	2.74	2.04	11.58	8.61
25	0.50	0.71	4.07	3.03	15.65	11.64
35	1.00	0.50	6.48	4.82	22.13	16.46
45	1.50	0.35	9.86	7.34	31.99	23.80
60	2.00	0.25	22.11	16.46	54.10	40.26
80	2.50	0.18	50.51	37.60	104.61	77.86
120	3.00	0.13	25.63	19.08	130.24	96.94
170	3.50	0.09	3.24	2.41	133.48	99.35
200	3.75	0.07	0.27	0.20	133.75	99.55
230	4.00	0.06	0.08	0.06	133.83	99.61

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.95	2.66	2.46	2.13	1.54	0.95	-0.92

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.76	0.30	1.21	-2.07	7.65

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O21 #1
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
114.49	114.49	0.01	0.28	#200 - 0.30 #230 - 0.28	0.60	16.20	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.41	0.36	0.41	0.36
4	-2.25	4.76	0.00	0.00	0.41	0.36
5	-2.00	4.00	0.37	0.32	0.78	0.68
7	-1.50	2.83	0.51	0.45	1.29	1.13
10	-1.00	2.00	1.00	0.87	2.29	2.00
14	-0.50	1.41	1.65	1.44	3.94	3.44
18	0.00	1.00	2.46	2.15	6.40	5.59
25	0.50	0.71	3.88	3.39	10.28	8.98
35	1.00	0.50	7.34	6.41	17.62	15.39
45	1.50	0.35	14.40	12.58	32.02	27.97
60	2.00	0.25	31.14	27.20	63.16	55.17
80	2.50	0.18	34.37	30.02	97.53	85.19
120	3.00	0.13	15.26	13.33	112.79	98.52
170	3.50	0.09	1.29	1.13	114.08	99.65
200	3.75	0.07	0.06	0.05	114.14	99.70
230	4.00	0.06	0.02	0.02	114.16	99.72

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.87	2.48	2.33	1.90	1.38	1.02	-0.14

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.72	0.30	0.92	-1.63	6.83

Granularmetric Report
Depths and elevations based on measured values

Project Name: Carteret County	COASTAL TECH Coastal Geology & Sediments Laboratory
Sample Name: O21 #2	
Analysis Date: 01-15-12	
Analyzed By: LA	

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
130.07	130.07	0.16	0.32	#200 - 0.51 #230 - 0.46	0.60	11.70	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.37	0.28	0.37	0.28
3.5	-2.50	5.66	1.45	1.11	1.82	1.39
4	-2.25	4.76	0.50	0.38	2.32	1.77
5	-2.00	4.00	0.46	0.35	2.78	2.12
7	-1.50	2.83	1.71	1.31	4.49	3.43
10	-1.00	2.00	1.88	1.45	6.37	4.88
14	-0.50	1.41	4.08	3.14	10.45	8.02
18	0.00	1.00	5.09	3.91	15.54	11.93
25	0.50	0.71	7.35	5.65	22.89	17.58
35	1.00	0.50	12.61	9.69	35.50	27.27
45	1.50	0.35	17.17	13.20	52.67	40.47
60	2.00	0.25	21.02	16.16	73.69	56.63
80	2.50	0.18	32.75	25.18	106.44	81.81
120	3.00	0.13	19.57	15.05	126.01	96.86
170	3.50	0.09	3.16	2.43	129.17	99.29
200	3.75	0.07	0.26	0.20	129.43	99.49
230	4.00	0.06	0.07	0.05	129.50	99.54

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.94	2.57	2.36	1.79	0.88	0.36	-0.98

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.48	0.36	1.24	-1.26	4.62

Granularmetric Report
Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O21 #3
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
133.66	133.66	0.12	0.07	#200 - 0.23 #230 - 0.16	0.70	12.30	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	1.88	1.41	1.88	1.41
4	-2.25	4.76	0.34	0.25	2.22	1.66
5	-2.00	4.00	0.23	0.17	2.45	1.83
7	-1.50	2.83	0.85	0.64	3.30	2.47
10	-1.00	2.00	1.27	0.95	4.57	3.42
14	-0.50	1.41	2.06	1.54	6.63	4.96
18	0.00	1.00	3.09	2.31	9.72	7.27
25	0.50	0.71	5.13	3.84	14.85	11.11
35	1.00	0.50	8.60	6.43	23.45	17.54
45	1.50	0.35	13.52	10.12	36.97	27.66
60	2.00	0.25	30.32	22.68	67.29	50.34
80	2.50	0.18	42.76	31.99	110.05	82.33
120	3.00	0.13	20.92	15.65	130.97	97.98
170	3.50	0.09	2.19	1.64	133.16	99.62
200	3.75	0.07	0.20	0.15	133.36	99.77
230	4.00	0.06	0.09	0.07	133.45	99.84

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.90	2.55	2.39	1.99	1.37	0.88	-0.49

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.71	0.31	1.08	-1.84	7.2

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O22 #1
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
116.26	116.26	0.00	0.13	#200 - 0.14 #230 - 0.13	0.60	16.20	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.97	0.83	0.97	0.83
5/16"	-3.00	8.00	0.38	0.33	1.35	1.16
3.5	-2.50	5.66	0.76	0.65	2.11	1.81
4	-2.25	4.76	0.38	0.33	2.49	2.14
5	-2.00	4.00	0.57	0.49	3.06	2.63
7	-1.50	2.83	1.00	0.86	4.06	3.49
10	-1.00	2.00	1.36	1.17	5.42	4.66
14	-0.50	1.41	2.53	2.18	7.95	6.84
18	0.00	1.00	3.46	2.98	11.41	9.82
25	0.50	0.71	4.91	4.22	16.32	14.04
35	1.00	0.50	8.09	6.96	24.41	21.00
45	1.50	0.35	13.41	11.53	37.82	32.53
60	2.00	0.25	25.92	22.29	63.74	54.82
80	2.50	0.18	38.40	33.03	102.14	87.85
120	3.00	0.13	12.82	11.03	114.96	98.88
170	3.50	0.09	1.07	0.92	116.03	99.80
200	3.75	0.07	0.07	0.06	116.10	99.86
230	4.00	0.06	0.01	0.01	116.11	99.87

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.82	2.44	2.31	1.89	1.17	0.64	-0.92

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.55	0.34	1.2	-1.95	7.52

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County

Sample Name: O22 #2

Analysis Date: 01-15-12

Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
133.58	133.58	0.07	0.10	#200 - 0.20 #230 - 0.14	0.40	12.30	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	1.14	0.85	1.14	0.85
3.5	-2.50	5.66	1.09	0.82	2.23	1.67
4	-2.25	4.76	0.60	0.45	2.83	2.12
5	-2.00	4.00	0.75	0.56	3.58	2.68
7	-1.50	2.83	1.66	1.24	5.24	3.92
10	-1.00	2.00	1.53	1.15	6.77	5.07
14	-0.50	1.41	2.16	1.62	8.93	6.69
18	0.00	1.00	2.80	2.10	11.73	8.79
25	0.50	0.71	3.97	2.97	15.70	11.76
35	1.00	0.50	6.21	4.65	21.91	16.41
45	1.50	0.35	11.59	8.68	33.50	25.09
60	2.00	0.25	28.67	21.46	62.17	46.55
80	2.50	0.18	47.72	35.72	109.89	82.27
120	3.00	0.13	21.60	16.17	131.49	98.44
170	3.50	0.09	1.69	1.27	133.18	99.71
200	3.75	0.07	0.12	0.09	133.30	99.80
230	4.00	0.06	0.08	0.06	133.38	99.86

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.89	2.55	2.40	2.05	1.49	0.96	-1.03

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.7	0.31	1.18	-2.05	7.54

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County

Sample Name: O22 #3

Analysis Date: 01-15-12

Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
142.11	142.11	0.02	0.36	#200 - 0.38 #230 - 0.37	0.40	11.70	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	1.46	1.03	1.46	1.03
5/16"	-3.00	8.00	0.00	0.00	1.46	1.03
3.5	-2.50	5.66	0.46	0.32	1.92	1.35
4	-2.25	4.76	0.32	0.23	2.24	1.58
5	-2.00	4.00	0.14	0.10	2.38	1.68
7	-1.50	2.83	0.71	0.50	3.09	2.18
10	-1.00	2.00	0.86	0.61	3.95	2.79
14	-0.50	1.41	1.62	1.14	5.57	3.93
18	0.00	1.00	2.22	1.56	7.79	5.49
25	0.50	0.71	3.53	2.48	11.32	7.97
35	1.00	0.50	6.88	4.84	18.20	12.81
45	1.50	0.35	14.64	10.30	32.84	23.11
60	2.00	0.25	33.62	23.66	66.46	46.77
80	2.50	0.18	55.74	39.22	122.20	85.99
120	3.00	0.13	17.72	12.47	139.92	98.46
170	3.50	0.09	1.56	1.10	141.48	99.56
200	3.75	0.07	0.09	0.06	141.57	99.62
230	4.00	0.06	0.01	0.01	141.58	99.63

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.86	2.47	2.36	2.04	1.54	1.15	-0.16

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.77	0.29	1.03	-2.66	12.61

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O22 #4
Analysis Date: 01-15-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
132.33	132.33	0.01	0.39	#200 - 0.41 #230 - 0.40	0.50	14.70	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.64	0.48	0.64	0.48
3.5	-2.50	5.66	0.38	0.29	1.02	0.77
4	-2.25	4.76	0.38	0.29	1.40	1.06
5	-2.00	4.00	0.50	0.38	1.90	1.44
7	-1.50	2.83	1.61	1.22	3.51	2.66
10	-1.00	2.00	1.41	1.07	4.92	3.73
14	-0.50	1.41	2.41	1.82	7.33	5.55
18	0.00	1.00	3.26	2.46	10.59	8.01
25	0.50	0.71	4.32	3.26	14.91	11.27
35	1.00	0.50	7.70	5.82	22.61	17.09
45	1.50	0.35	18.62	14.07	41.23	31.16
60	2.00	0.25	42.43	32.06	83.66	63.22
80	2.50	0.18	36.97	27.94	120.63	91.16
120	3.00	0.13	10.65	8.05	131.28	99.21
170	3.50	0.09	0.48	0.36	131.76	99.57
200	3.75	0.07	0.03	0.02	131.79	99.59
230	4.00	0.06	0.01	0.01	131.80	99.60

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.74	2.37	2.21	1.79	1.28	0.91	-0.65

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.57	0.34	1.02	-1.95	7.72

Granularmetric Report
Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County

Sample Name: O24 #1

Analysis Date: 01-16-12

Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW-SM		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
118.65	113.17	0.24	0.00	#200 - 5.19 #230 - 4.81	1.50	13.00	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	1.62	1.37	1.62	1.37
5/16"	-3.00	8.00	0.70	0.59	2.32	1.96
3.5	-2.50	5.66	2.73	2.30	5.05	4.26
4	-2.25	4.76	0.62	0.52	5.67	4.78
5	-2.00	4.00	1.10	0.93	6.77	5.71
7	-1.50	2.83	1.37	1.15	8.14	6.86
10	-1.00	2.00	1.68	1.42	9.82	8.28
14	-0.50	1.41	1.84	1.55	11.66	9.83
18	0.00	1.00	1.43	1.21	13.09	11.04
25	0.50	0.71	1.20	1.01	14.29	12.05
35	1.00	0.50	1.75	1.47	16.04	13.52
45	1.50	0.35	1.92	1.62	17.96	15.14
60	2.00	0.25	4.22	3.56	22.18	18.70
80	2.50	0.18	27.47	23.15	49.65	41.85
120	3.00	0.13	47.96	40.42	97.61	82.27
170	3.50	0.09	13.44	11.33	111.05	93.60
200	3.75	0.07	1.43	1.21	112.48	94.81
230	4.00	0.06	0.45	0.38	112.93	95.19

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
3.88	3.08	2.91	2.60	2.14	1.62	-2.19

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	2.03	0.24	1.59	-2.2	6.99

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory
715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O24 #2
Analysis Date: 01-16-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SP		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
137.36	137.36	0.22	0.04	#200 - 0.30 #230 - 0.20	0.50	10.40	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.06	0.04	0.06	0.04
4	-2.25	4.76	0.39	0.28	0.45	0.32
5	-2.00	4.00	0.10	0.07	0.55	0.39
7	-1.50	2.83	0.41	0.30	0.96	0.69
10	-1.00	2.00	0.68	0.50	1.64	1.19
14	-0.50	1.41	1.27	0.92	2.91	2.11
18	0.00	1.00	2.13	1.55	5.04	3.66
25	0.50	0.71	3.34	2.43	8.38	6.09
35	1.00	0.50	6.56	4.78	14.94	10.87
45	1.50	0.35	14.44	10.51	29.38	21.38
60	2.00	0.25	33.84	24.64	63.22	46.02
80	2.50	0.18	42.22	30.74	105.44	76.76
120	3.00	0.13	26.61	19.37	132.05	96.13
170	3.50	0.09	4.54	3.31	136.59	99.44
200	3.75	0.07	0.36	0.26	136.95	99.70
230	4.00	0.06	0.14	0.10	137.09	99.80

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.97	2.69	2.47	2.06	1.57	1.24	0.28

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.92	0.26	0.85	-1.55	7.11

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County

Sample Name: O24 #3

Analysis Date: 01-16-12

Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SM		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
131.87	108.36	0.99	0.03	#200 - 20.06 #230 - 18.63	2.30	32.90	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	1.06	0.80	1.06	0.80
3.5	-2.50	5.66	0.86	0.65	1.92	1.45
4	-2.25	4.76	0.53	0.40	2.45	1.85
5	-2.00	4.00	0.94	0.71	3.39	2.56
7	-1.50	2.83	2.74	2.08	6.13	4.64
10	-1.00	2.00	4.41	3.34	10.54	7.98
14	-0.50	1.41	6.55	4.97	17.09	12.95
18	0.00	1.00	7.26	5.51	24.35	18.46
25	0.50	0.71	7.56	5.73	31.91	24.19
35	1.00	0.50	8.06	6.11	39.97	30.30
45	1.50	0.35	7.61	5.77	47.58	36.07
60	2.00	0.25	9.72	7.37	57.30	43.44
80	2.50	0.18	13.89	10.53	71.19	53.97
120	3.00	0.13	22.26	16.88	93.45	70.85
170	3.50	0.09	9.83	7.45	103.28	78.30
200	3.75	0.07	2.16	1.64	105.44	79.94
230	4.00	0.06	1.89	1.43	107.33	81.37

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
		3.28	2.31	0.57	-0.22	-1.45

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.38	0.38	1.63	-0.68	2.61

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory
715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O25 #1
Analysis Date: 01-16-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
143.70	143.70	0.33	0.14	#200 - 0.45 #230 - 0.36	0.50	13.60	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.82	0.57	0.82	0.57
4	-2.25	4.76	0.48	0.33	1.30	0.90
5	-2.00	4.00	0.73	0.51	2.03	1.41
7	-1.50	2.83	1.62	1.13	3.65	2.54
10	-1.00	2.00	1.75	1.22	5.40	3.76
14	-0.50	1.41	2.61	1.82	8.01	5.58
18	0.00	1.00	4.16	2.89	12.17	8.47
25	0.50	0.71	6.32	4.40	18.49	12.87
35	1.00	0.50	12.54	8.73	31.03	21.60
45	1.50	0.35	20.62	14.35	51.65	35.95
60	2.00	0.25	29.74	20.70	81.39	56.65
80	2.50	0.18	37.56	26.14	118.95	82.79
120	3.00	0.13	20.44	14.22	139.39	97.01
170	3.50	0.09	3.29	2.29	142.68	99.30
200	3.75	0.07	0.36	0.25	143.04	99.55
230	4.00	0.06	0.13	0.09	143.17	99.64

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.93	2.54	2.35	1.84	1.12	0.68	-0.66

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.6	0.33	1.1	-1.38	5.35

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County

Sample Name: O25 #2

Analysis Date: 01-16-12

Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
134.48	134.48	0.57	0.42	#200 - 0.96 #230 - 0.83	0.50	18.00	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.97	0.72	0.97	0.72
3.5	-2.50	5.66	1.32	0.98	2.29	1.70
4	-2.25	4.76	0.47	0.35	2.76	2.05
5	-2.00	4.00	0.16	0.12	2.92	2.17
7	-1.50	2.83	0.92	0.68	3.84	2.85
10	-1.00	2.00	1.49	1.11	5.33	3.96
14	-0.50	1.41	3.40	2.53	8.73	6.49
18	0.00	1.00	4.67	3.47	13.40	9.96
25	0.50	0.71	6.22	4.63	19.62	14.59
35	1.00	0.50	10.46	7.78	30.08	22.37
45	1.50	0.35	15.63	11.62	45.71	33.99
60	2.00	0.25	23.37	17.38	69.08	51.37
80	2.50	0.18	37.07	27.57	106.15	78.94
120	3.00	0.13	22.88	17.01	129.03	95.95
170	3.50	0.09	3.71	2.76	132.74	98.71
200	3.75	0.07	0.44	0.33	133.18	99.04
230	4.00	0.06	0.17	0.13	133.35	99.17

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.97	2.65	2.43	1.96	1.11	0.59	-0.79

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.61	0.33	1.21	-1.54	5.84

Granularmetric Report
Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O25 #3
Analysis Date: 01-16-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
143.91	143.91	0.11	0.04	#200 - 0.15 #230 - 0.12	0.90	19.20	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.35	0.24	0.35	0.24
3.5	-2.50	5.66	2.14	1.49	2.49	1.73
4	-2.25	4.76	0.09	0.06	2.58	1.79
5	-2.00	4.00	1.27	0.88	3.85	2.67
7	-1.50	2.83	1.22	0.85	5.07	3.52
10	-1.00	2.00	1.62	1.13	6.69	4.65
14	-0.50	1.41	2.91	2.02	9.60	6.67
18	0.00	1.00	3.89	2.70	13.49	9.37
25	0.50	0.71	5.28	3.67	18.77	13.04
35	1.00	0.50	8.31	5.77	27.08	18.81
45	1.50	0.35	14.36	9.98	41.44	28.79
60	2.00	0.25	34.78	24.17	76.22	52.96
80	2.50	0.18	42.31	29.40	118.53	82.36
120	3.00	0.13	22.51	15.64	141.04	98.00
170	3.50	0.09	2.49	1.73	143.53	99.73
200	3.75	0.07	0.17	0.12	143.70	99.85
230	4.00	0.06	0.04	0.03	143.74	99.88

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.90	2.55	2.37	1.94	1.31	0.76	-0.91

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.64	0.32	1.17	-1.79	6.54

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O25 #4
Analysis Date: 01-16-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SP-SM		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
109.67	102.55	0.16	0.00	#200 - 6.97 #230 - 6.63	1.60	9.70	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.00	0.00	0.00	0.00
4	-2.25	4.76	0.00	0.00	0.00	0.00
5	-2.00	4.00	0.16	0.15	0.16	0.15
7	-1.50	2.83	0.41	0.37	0.57	0.52
10	-1.00	2.00	0.60	0.55	1.17	1.07
14	-0.50	1.41	0.96	0.88	2.13	1.95
18	0.00	1.00	0.99	0.90	3.12	2.85
25	0.50	0.71	0.97	0.88	4.09	3.73
35	1.00	0.50	1.38	1.26	5.47	4.99
45	1.50	0.35	1.76	1.60	7.23	6.59
60	2.00	0.25	4.27	3.89	11.50	10.48
80	2.50	0.18	26.80	24.44	38.30	34.92
120	3.00	0.13	49.05	44.73	87.35	79.65
170	3.50	0.09	12.95	11.81	100.30	91.46
200	3.75	0.07	1.72	1.57	102.02	93.03
230	4.00	0.06	0.37	0.34	102.39	93.37

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
	3.18	2.95	2.67	2.30	2.11	1.00

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	2.47	0.18	0.8	-2.67	12.34

Granularmetric Report

Depths and elevations based on measured values

Project Name: Carteret County

Sample Name: O26 #1

Analysis Date: 01-16-12

Analyzed By: LA

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
134.35	134.35	0.31	0.13	#200 - 0.47 #230 - 0.37	0.60	12.70	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	4.50	3.35	4.50	3.35
5/16"	-3.00	8.00	0.00	0.00	4.50	3.35
3.5	-2.50	5.66	1.35	1.00	5.85	4.35
4	-2.25	4.76	0.88	0.66	6.73	5.01
5	-2.00	4.00	1.02	0.76	7.75	5.77
7	-1.50	2.83	2.37	1.76	10.12	7.53
10	-1.00	2.00	2.54	1.89	12.66	9.42
14	-0.50	1.41	3.97	2.95	16.63	12.37
18	0.00	1.00	4.58	3.41	21.21	15.78
25	0.50	0.71	5.48	4.08	26.69	19.86
35	1.00	0.50	7.86	5.85	34.55	25.71
45	1.50	0.35	10.25	7.63	44.80	33.34
60	2.00	0.25	16.94	12.61	61.74	45.95
80	2.50	0.18	39.66	29.52	101.40	75.47
120	3.00	0.13	27.28	20.31	128.68	95.78
170	3.50	0.09	4.60	3.42	133.28	99.20
200	3.75	0.07	0.45	0.33	133.73	99.53
230	4.00	0.06	0.13	0.10	133.86	99.63

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.98	2.71	2.49	2.07	0.94	0.03	-2.25

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.46	0.36	1.62	-1.64	5.22

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O26 #2
Analysis Date: 01-16-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
150.78	150.78	0.00	0.22	#200 - 0.24 #230 - 0.21	0.40	11.90	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	1.03	0.68	1.03	0.68
4	-2.25	4.76	0.43	0.29	1.46	0.97
5	-2.00	4.00	0.35	0.23	1.81	1.20
7	-1.50	2.83	0.56	0.37	2.37	1.57
10	-1.00	2.00	1.16	0.77	3.53	2.34
14	-0.50	1.41	2.24	1.49	5.77	3.83
18	0.00	1.00	3.46	2.29	9.23	6.12
25	0.50	0.71	5.21	3.46	14.44	9.58
35	1.00	0.50	9.62	6.38	24.06	15.96
45	1.50	0.35	18.78	12.46	42.84	28.42
60	2.00	0.25	35.38	23.46	78.22	51.88
80	2.50	0.18	49.46	32.80	127.68	84.68
120	3.00	0.13	20.46	13.57	148.14	98.25
170	3.50	0.09	2.11	1.40	150.25	99.65
200	3.75	0.07	0.16	0.11	150.41	99.76
230	4.00	0.06	0.04	0.03	150.45	99.79

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.88	2.49	2.35	1.96	1.36	1.00	-0.24

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.72	0.30	0.97	-1.77	7.34

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O26 #3
Analysis Date: 01-16-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SM		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
143.91	115.38	0.63	0.10	#200 - 21.83 #230 - 20.37	1.50	10.70	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.33	0.23	0.33	0.23
4	-2.25	4.76	0.17	0.12	0.50	0.35
5	-2.00	4.00	0.35	0.24	0.85	0.59
7	-1.50	2.83	1.56	1.08	2.41	1.67
10	-1.00	2.00	3.50	2.43	5.91	4.10
14	-0.50	1.41	4.04	2.81	9.95	6.91
18	0.00	1.00	3.70	2.57	13.65	9.48
25	0.50	0.71	3.36	2.33	17.01	11.81
35	1.00	0.50	3.36	2.33	20.37	14.14
45	1.50	0.35	3.53	2.45	23.90	16.59
60	2.00	0.25	5.84	4.06	29.74	20.65
80	2.50	0.18	19.16	13.31	48.90	33.96
120	3.00	0.13	48.16	33.47	97.06	67.43
170	3.50	0.09	13.11	9.11	110.17	76.54
200	3.75	0.07	2.34	1.63	112.51	78.17
230	4.00	0.06	2.10	1.46	114.61	79.63

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
		3.42	2.74	2.16	1.38	-0.84

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	2.09	0.23	1.33	-1.52	4.48

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O27 #1
Analysis Date: 01-17-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
143.02	143.02	0.01	0.18	#200 - 0.20 #230 - 0.20	0.50	16.70	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.34	0.24	0.34	0.24
3.5	-2.50	5.66	0.19	0.13	0.53	0.37
4	-2.25	4.76	0.27	0.19	0.80	0.56
5	-2.00	4.00	0.30	0.21	1.10	0.77
7	-1.50	2.83	1.35	0.94	2.45	1.71
10	-1.00	2.00	2.60	1.82	5.05	3.53
14	-0.50	1.41	4.71	3.29	9.76	6.82
18	0.00	1.00	6.74	4.71	16.50	11.53
25	0.50	0.71	10.04	7.02	26.54	18.55
35	1.00	0.50	16.44	11.49	42.98	30.04
45	1.50	0.35	25.72	17.98	68.70	48.02
60	2.00	0.25	32.99	23.07	101.69	71.09
80	2.50	0.18	27.10	18.95	128.79	90.04
120	3.00	0.13	12.77	8.93	141.56	98.97
170	3.50	0.09	1.06	0.74	142.62	99.71
200	3.75	0.07	0.13	0.09	142.75	99.80
230	4.00	0.06	0.00	0.00	142.75	99.80

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.78	2.34	2.10	1.54	0.78	0.32	-0.78

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.34	0.40	1.06	-1.02	4.24

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County

Sample Name: O27 #2

Analysis Date: 01-17-12

Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
145.82	145.82	0.02	0.32	#200 - 0.38 #230 - 0.35	0.50	12.00	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.60	0.41	0.60	0.41
3.5	-2.50	5.66	0.05	0.03	0.65	0.44
4	-2.25	4.76	0.34	0.23	0.99	0.67
5	-2.00	4.00	0.25	0.17	1.24	0.84
7	-1.50	2.83	1.08	0.74	2.32	1.58
10	-1.00	2.00	1.62	1.11	3.94	2.69
14	-0.50	1.41	2.73	1.87	6.67	4.56
18	0.00	1.00	3.92	2.69	10.59	7.25
25	0.50	0.71	5.60	3.84	16.19	11.09
35	1.00	0.50	10.11	6.93	26.30	18.02
45	1.50	0.35	17.93	12.30	44.23	30.32
60	2.00	0.25	33.83	23.20	78.06	53.52
80	2.50	0.18	48.88	33.52	126.94	87.04
120	3.00	0.13	16.92	11.60	143.86	98.64
170	3.50	0.09	1.29	0.88	145.15	99.52
200	3.75	0.07	0.14	0.10	145.29	99.62
230	4.00	0.06	0.04	0.03	145.33	99.65

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.84	2.45	2.32	1.92	1.28	0.85	-0.42

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.66	0.32	1	-1.7	6.84

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O27 #3
Analysis Date: 01-17-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
143.58	143.58	0.35	0.17	#200 - 0.49 #230 - 0.41	0.50	11.80	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.14	0.10	0.14	0.10
3.5	-2.50	5.66	0.08	0.06	0.22	0.16
4	-2.25	4.76	0.00	0.00	0.22	0.16
5	-2.00	4.00	0.20	0.14	0.42	0.30
7	-1.50	2.83	0.83	0.58	1.25	0.88
10	-1.00	2.00	0.91	0.63	2.16	1.51
14	-0.50	1.41	1.76	1.23	3.92	2.74
18	0.00	1.00	2.57	1.79	6.49	4.53
25	0.50	0.71	4.58	3.19	11.07	7.72
35	1.00	0.50	8.66	6.03	19.73	13.75
45	1.50	0.35	16.85	11.74	36.58	25.49
60	2.00	0.25	35.20	24.52	71.78	50.01
80	2.50	0.18	46.73	32.55	118.51	82.56
120	3.00	0.13	21.70	15.11	140.21	97.67
170	3.50	0.09	2.33	1.62	142.54	99.29
200	3.75	0.07	0.32	0.22	142.86	99.51
230	4.00	0.06	0.12	0.08	142.98	99.59

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.91	2.55	2.38	2.00	1.48	1.10	0.07

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.81	0.29	0.88	-1.56	6.8

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County

Sample Name: O27 #4

Analysis Date: 01-17-12

Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SM		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
152.59	133.95	0.74	0.00	#200 - 13.47 #230 - 12.72	1.80	20.30	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.18	0.12	0.18	0.12
4	-2.25	4.76	0.43	0.28	0.61	0.40
5	-2.00	4.00	0.48	0.31	1.09	0.71
7	-1.50	2.83	2.00	1.31	3.09	2.02
10	-1.00	2.00	2.34	1.53	5.43	3.55
14	-0.50	1.41	2.85	1.87	8.28	5.42
18	0.00	1.00	2.26	1.48	10.54	6.90
25	0.50	0.71	2.05	1.34	12.59	8.24
35	1.00	0.50	2.36	1.55	14.95	9.79
45	1.50	0.35	2.90	1.90	17.85	11.69
60	2.00	0.25	6.53	4.28	24.38	15.97
80	2.50	0.18	39.09	25.62	63.47	41.59
120	3.00	0.13	52.80	34.60	116.27	76.19
170	3.50	0.09	13.57	8.89	129.84	85.08
200	3.75	0.07	2.22	1.45	132.06	86.53
230	4.00	0.06	1.15	0.75	133.21	87.28

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
	3.44	2.98	2.62	2.18	2.00	-0.61

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	2.22	0.21	1.15	-2.12	7.34

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O28 #1
Analysis Date: 01-17-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
155.07	155.07	0.15	0.00	#200 - 0.12 #230 - 0.09	0.50	12.80	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.48	0.31	0.48	0.31
4	-2.25	4.76	0.43	0.28	0.91	0.59
5	-2.00	4.00	0.32	0.21	1.23	0.80
7	-1.50	2.83	0.85	0.55	2.08	1.35
10	-1.00	2.00	1.34	0.86	3.42	2.21
14	-0.50	1.41	2.04	1.32	5.46	3.53
18	0.00	1.00	2.76	1.78	8.22	5.31
25	0.50	0.71	4.40	2.84	12.62	8.15
35	1.00	0.50	7.23	4.66	19.85	12.81
45	1.50	0.35	13.63	8.79	33.48	21.60
60	2.00	0.25	34.42	22.20	67.90	43.80
80	2.50	0.18	57.64	37.17	125.54	80.97
120	3.00	0.13	26.81	17.29	152.35	98.26
170	3.50	0.09	2.36	1.52	154.71	99.78
200	3.75	0.07	0.16	0.10	154.87	99.88
230	4.00	0.06	0.05	0.03	154.92	99.91

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.91	2.59	2.42	2.08	1.58	1.18	-0.09

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.85	0.28	0.93	-1.93	7.91

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O28 #2
Analysis Date: 01-17-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SW		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
155.35	155.35	0.22	0.01	#200 - 0.25 #230 - 0.16	0.50	13.40	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.31	0.20	0.31	0.20
3.5	-2.50	5.66	0.00	0.00	0.31	0.20
4	-2.25	4.76	0.32	0.21	0.63	0.41
5	-2.00	4.00	0.50	0.32	1.13	0.73
7	-1.50	2.83	0.95	0.61	2.08	1.34
10	-1.00	2.00	1.25	0.80	3.33	2.14
14	-0.50	1.41	2.72	1.75	6.05	3.89
18	0.00	1.00	3.72	2.39	9.77	6.28
25	0.50	0.71	5.65	3.64	15.42	9.92
35	1.00	0.50	9.21	5.93	24.63	15.85
45	1.50	0.35	14.65	9.43	39.28	25.28
60	2.00	0.25	37.10	23.88	76.38	49.16
80	2.50	0.18	55.69	35.85	132.07	85.01
120	3.00	0.13	20.79	13.38	152.86	98.39
170	3.50	0.09	1.89	1.22	154.75	99.61
200	3.75	0.07	0.22	0.14	154.97	99.75
230	4.00	0.06	0.14	0.09	155.11	99.84

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.87	2.49	2.36	2.01	1.49	1.01	-0.27

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.76	0.30	0.95	-1.73	6.93

Granularmetric Report

Depths and elevations based on measured values

COASTAL TECH
Coastal Geology & Sediments Laboratory

715 North Drive Suite E
Melbourne, FL 32934
Phone (321) 751-1135
Fax (321) 751-2343

Project Name: Carteret County
Sample Name: O28 #3
Analysis Date: 01-17-12
Analyzed By: LA

Easting (ft):	Northing (ft):	Coordinate System:	Elevation (ft):

USCS:	Munsell:	Comments:
SM		

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
142.70	111.00	0.67	0.09	#200 - 23.35 #230 - 22.80	1.70	13.90	

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cum. Grams Retained	C. % Weight Retained
3/4"	-4.25	19.03	0.00	0.00	0.00	0.00
5/8"	-4.00	16.00	0.00	0.00	0.00	0.00
11/16"	-3.50	11.31	0.00	0.00	0.00	0.00
5/16"	-3.00	8.00	0.00	0.00	0.00	0.00
3.5	-2.50	5.66	0.17	0.12	0.17	0.12
4	-2.25	4.76	0.33	0.23	0.50	0.35
5	-2.00	4.00	0.30	0.21	0.80	0.56
7	-1.50	2.83	1.09	0.76	1.89	1.32
10	-1.00	2.00	1.29	0.90	3.18	2.22
14	-0.50	1.41	2.36	1.65	5.54	3.87
18	0.00	1.00	3.54	2.48	9.08	6.35
25	0.50	0.71	4.85	3.40	13.93	9.75
35	1.00	0.50	6.31	4.42	20.24	14.17
45	1.50	0.35	7.67	5.37	27.91	19.54
60	2.00	0.25	13.42	9.40	41.33	28.94
80	2.50	0.18	34.72	24.33	76.05	53.27
120	3.00	0.13	26.49	18.56	102.54	71.83
170	3.50	0.09	5.74	4.02	108.28	75.85
200	3.75	0.07	1.14	0.80	109.42	76.65
230	4.00	0.06	0.78	0.55	110.20	77.20

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
		3.39	2.43	1.79	1.17	-0.27

Moment Statistics	Mean Phi	Mean mm	Sorting	Skewness	Kurtosis
	1.89	0.27	1.13	-1.38	4.89

Core Penetration Graphs
ODMDS Core 18 – ODMDS Core 28

Prepared for:

Moffatt & Nichol
1616 East Millbrook Road, Suite 160
Raleigh, NC 27609

Submitted by:

Alpine Ocean Seismic Survey, Inc.
155 Hudson Avenue
Norwood, NJ 07648

February 9, 2012

Penetration Graph for Core No. O18, Run 1

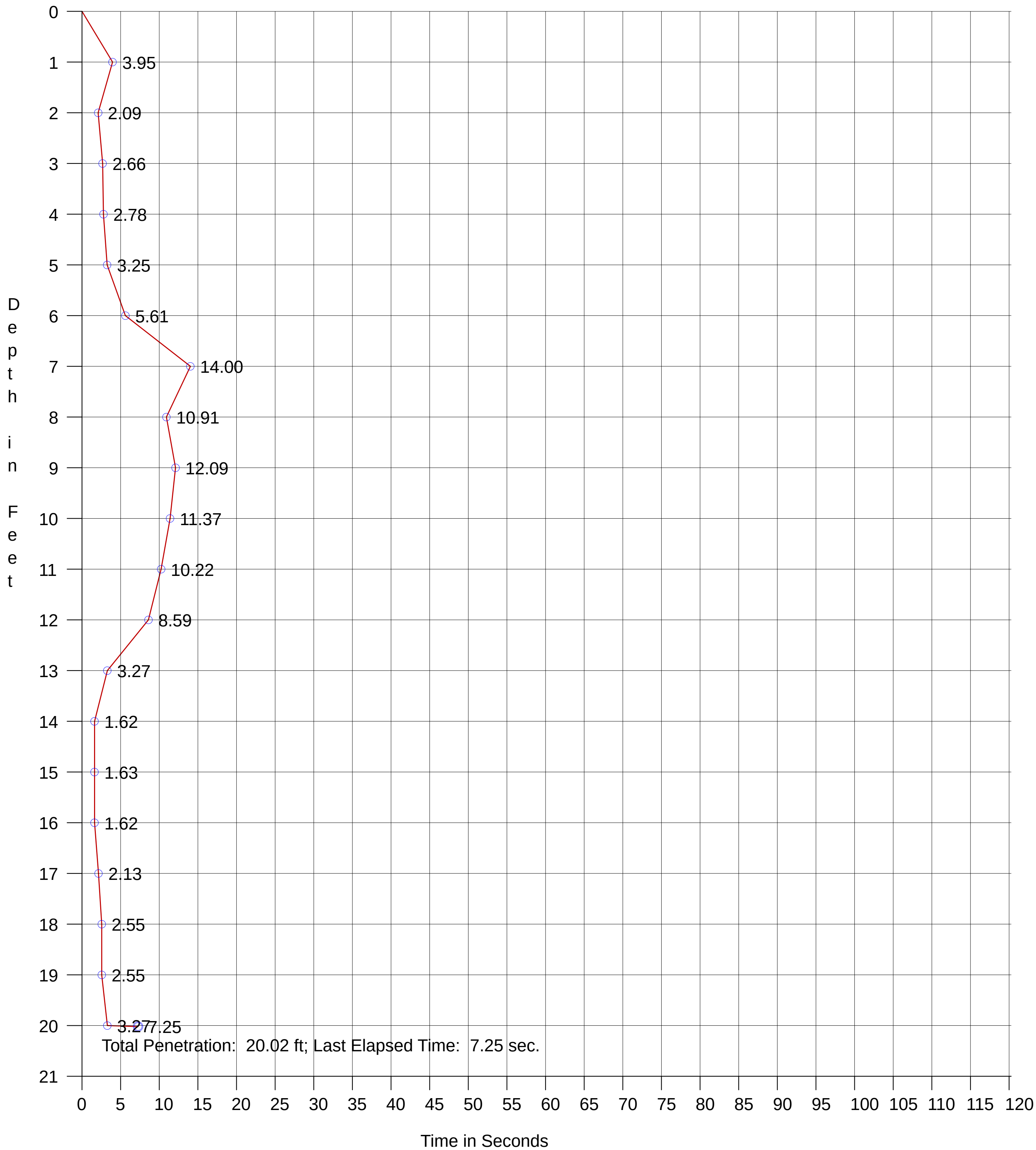
Date: 12/12/2011
Start Time: 11:49:17 AM
End Time: 11:51:10 AM

Penetration: 20.02 ft
Recovery: 17.90 ft
W. D. Corrected: 44.07 ft
W. D. Raw: 43.69 ft

Easting: 2690367.29
Northing: 332252.65
Coord. System: NCSPCS 83

Lat: 76°42'16.3980" dW N
Long: 034°38'27.5280" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O19, Run 1

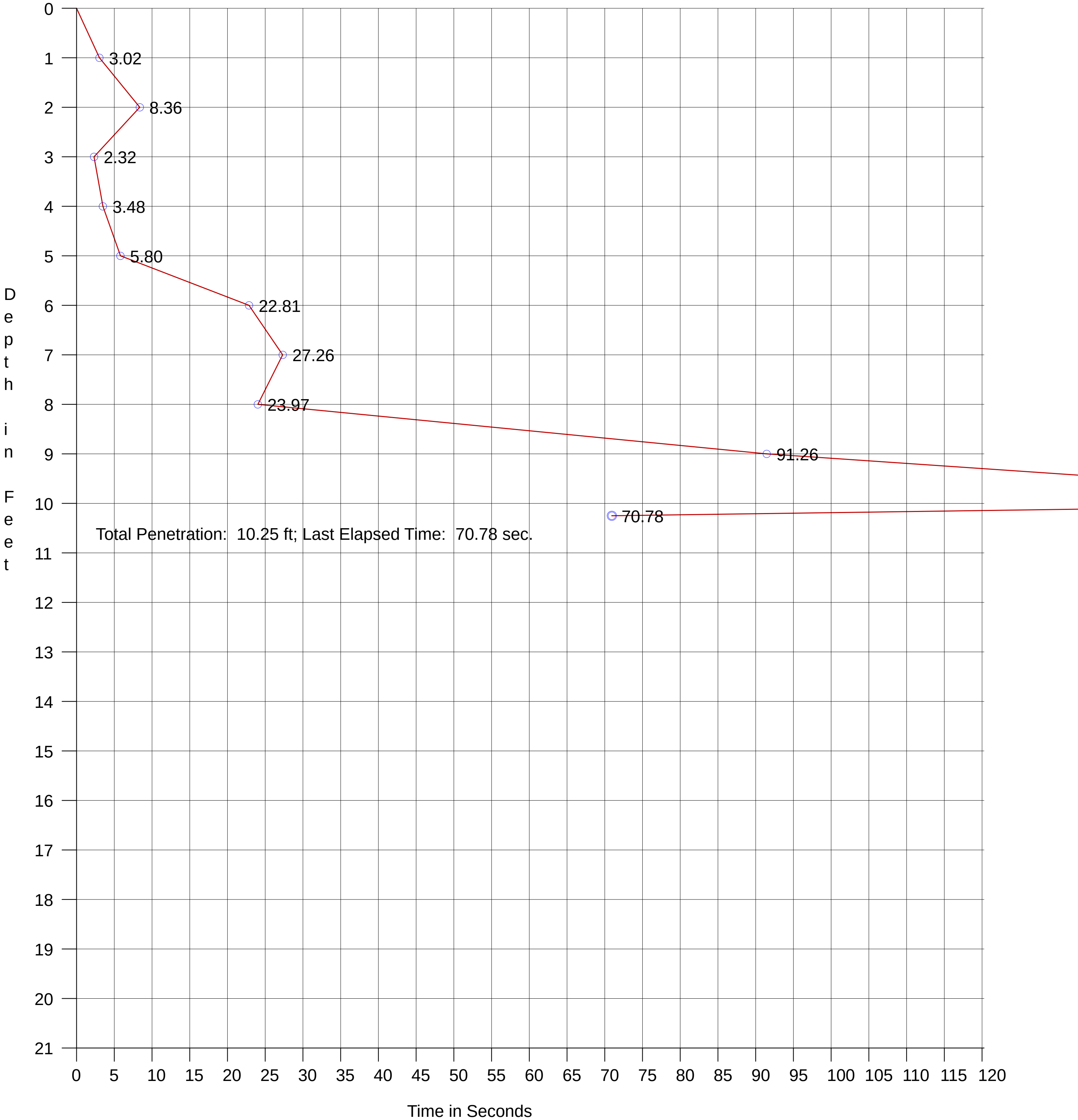
Date: 12/11/2011
Start Time: 9:31:30 AM
End Time: 9:38:56 AM

Penetration: 10.25 ft
Recovery: 8.50 ft
W. D. Corrected: 36.08 ft
W. D. Raw: 37.09 ft

Easting: 2691366.45
Northing: 332250.27
Coord. System: NCSPCS 83

Lat: 76°42'04.4460" dW N
Long: 034°38'27.2760" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O19, Run 2

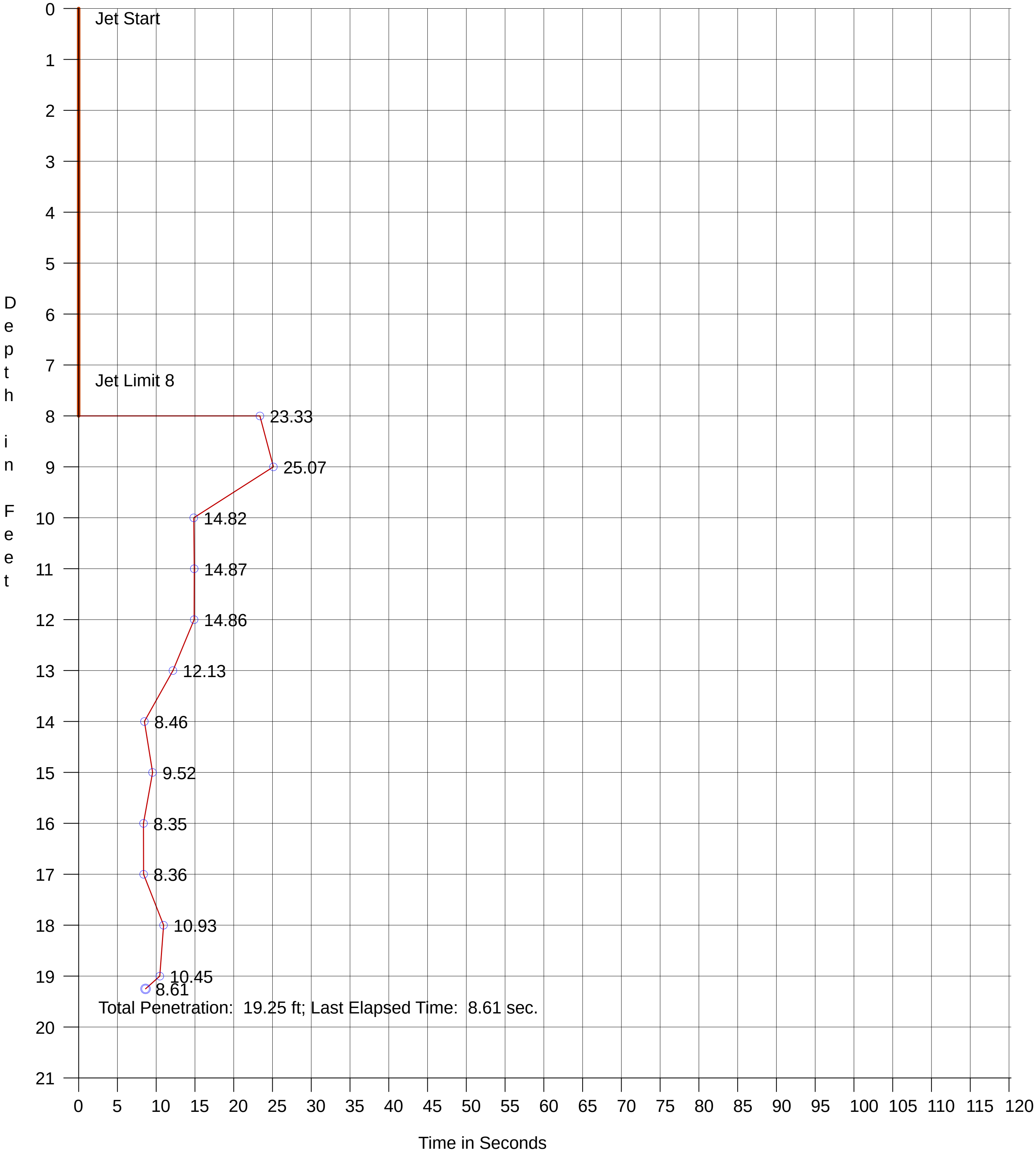
Date: 12/11/2011
Start Time: 10:01:35 AM
End Time: 10:05:52 AM

Penetration: 19.25 ft
Recovery: 15.00 ft
W. D. Corrected: 36.09 ft
W. D. Raw: 36.68 ft

Easting: 2691363.16
Northing: 332243.67
Coord. System: NCSPCS 83

Lat: 76°42'04.4880" dW N
Long: 034°38'27.2100" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O20, Run 1

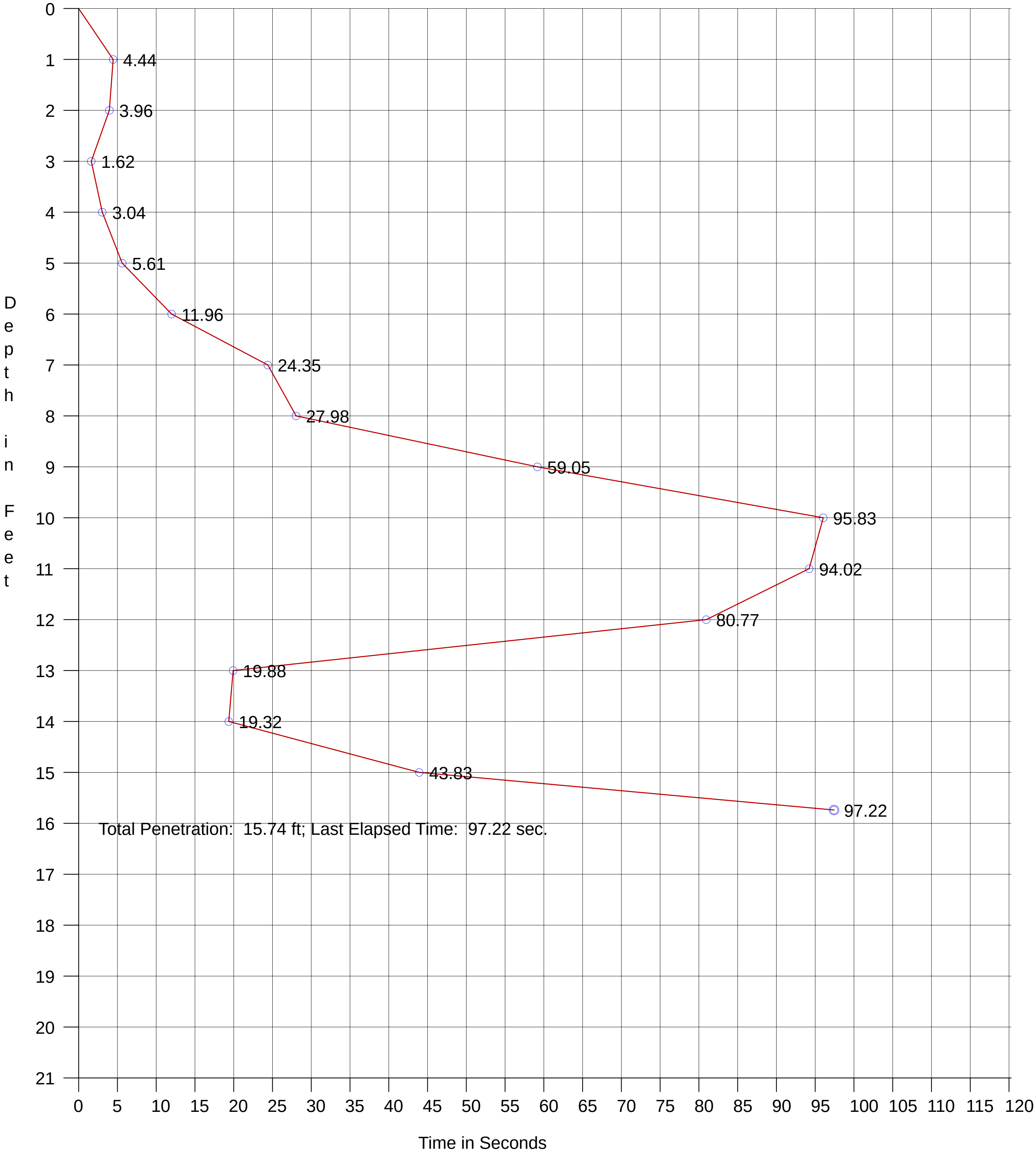
Date: 12/11/2011
Start Time: 8:58:15 AM
End Time: 9:08:11 AM

Penetration: 15.74 ft
Recovery: 13.83 ft
W. D. Corrected: 36.43 ft
W. D. Raw: 37.7 ft

Easting: 2692364.69
Northing: 332250.35
Coord. System: NCSPCS 83

Lat: 76°41'52.5000" dW N
Long: 034°38'27.0480" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O21, Run 1

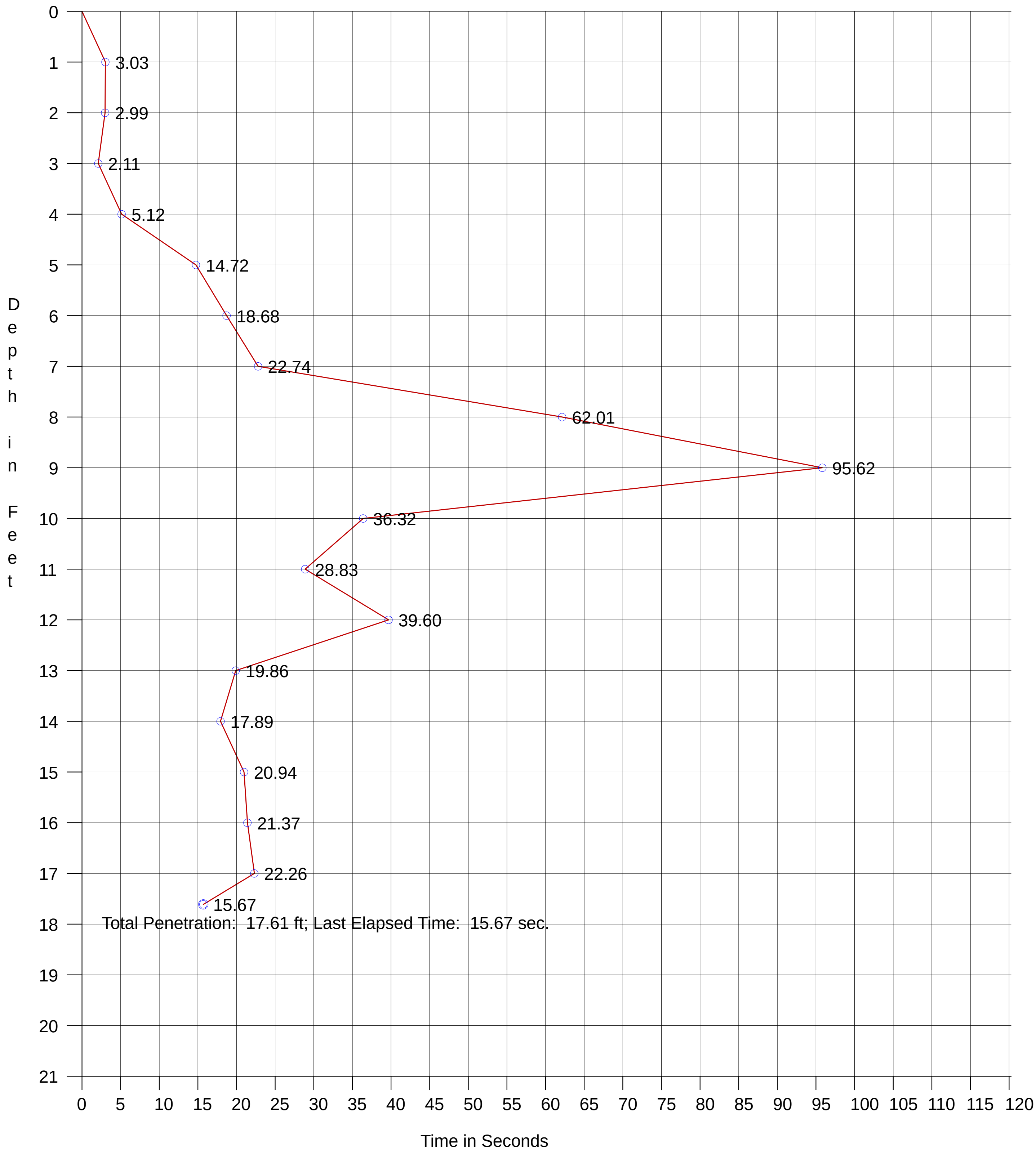
Date: 12/11/2011
Start Time: 7:19:11 AM
End Time: 7:26:47 AM

Penetration: 17.61 ft
Recovery: 15.92 ft
W. D. Corrected: 37.05 ft
W. D. Raw: 38.19 ft

Easting: 2693363.50
Northing: 332249.29
Coord. System: NCSPCS 83

Lat: 76°41'40.5480" dW N
Long: 034°38'26.8080" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O22, Run 1

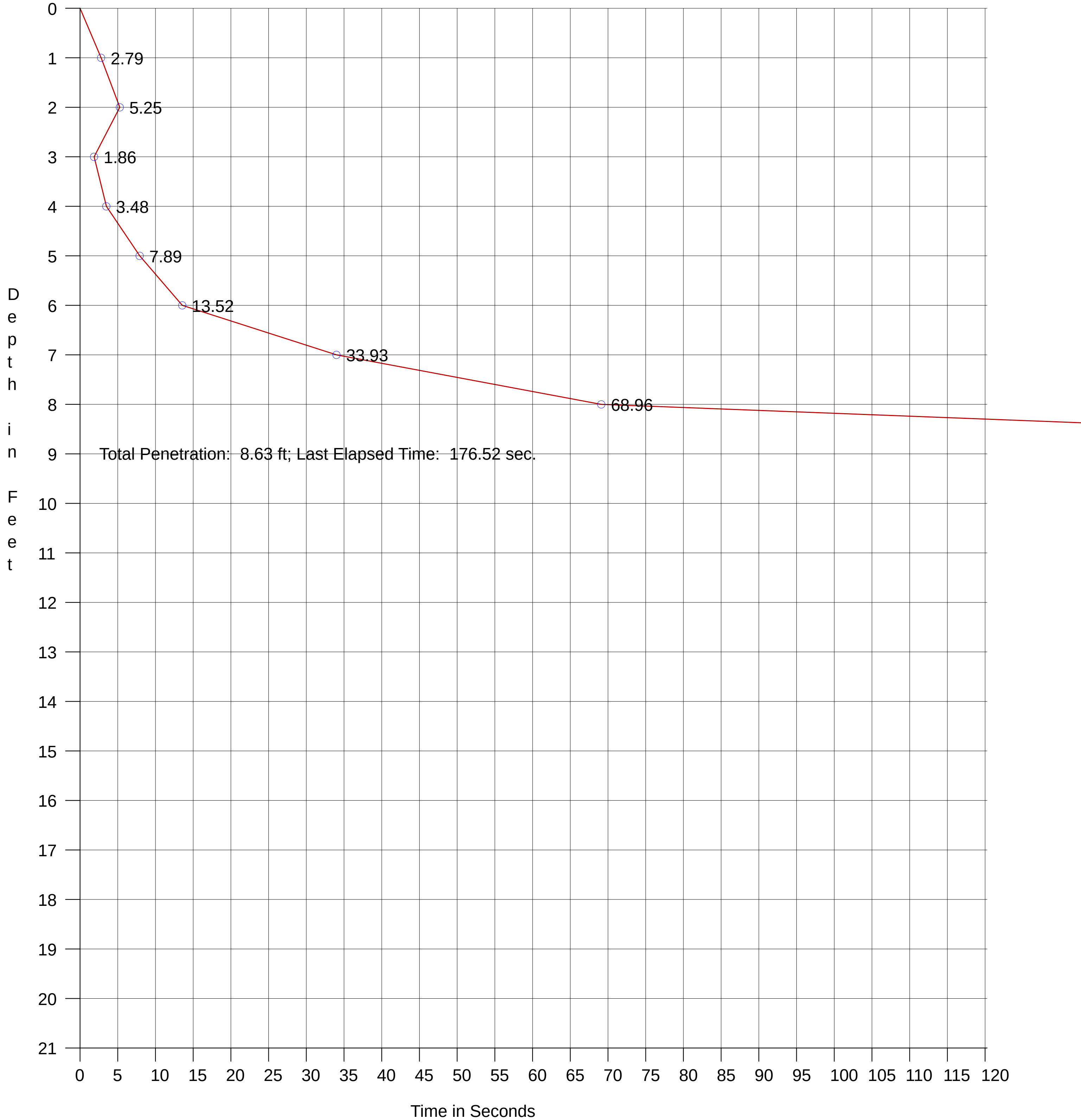
Date: 12/10/2011
Start Time: 4:29:30 PM
End Time: 4:34:47 PM

Penetration: 8.63 ft
Recovery: 6.83 ft
W. D. Corrected: 36.80 ft
W. D. Raw: 36.03 ft

Easting: 2694363.93
Northing: 332252.81
Coord. System: NCSPCS 83

Lat: 76°41'28.5780" dW N
Long: 034°38'26.6160" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O22, Run 2

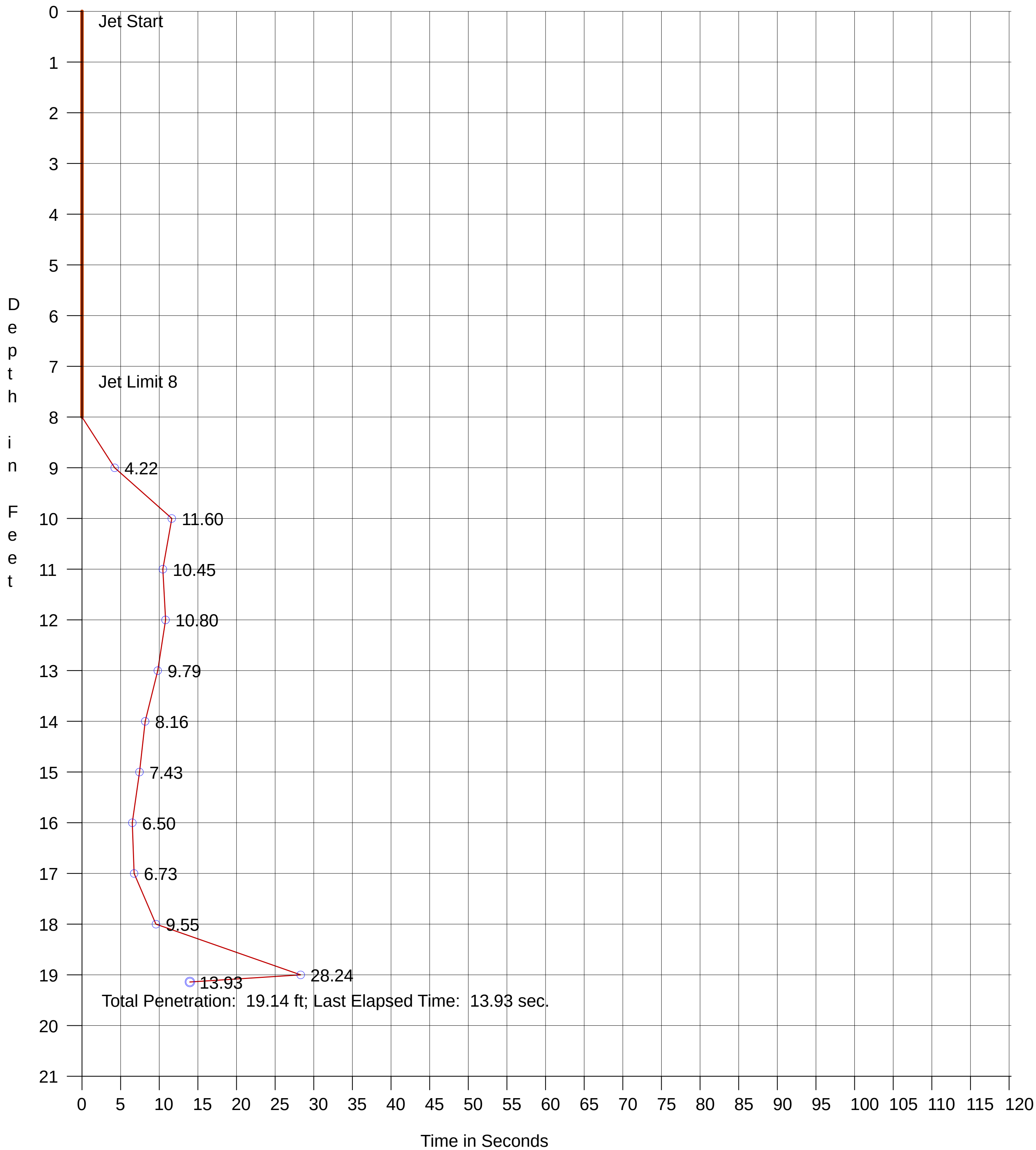
Date: 12/10/2011
Start Time: 4:51:54 PM
End Time: 4:56:06 PM

Penetration: 19.14 ft
Recovery: 14.00 ft
W. D. Corrected: 32.74 ft
W. D. Raw: 32.14 ft

Easting: 2694363.56
Northing: 332253.70
Coord. System: NCSPCS 83

Lat: 76°41'28.5840" dW N
Long: 034°38'26.6220" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O24, Run 1

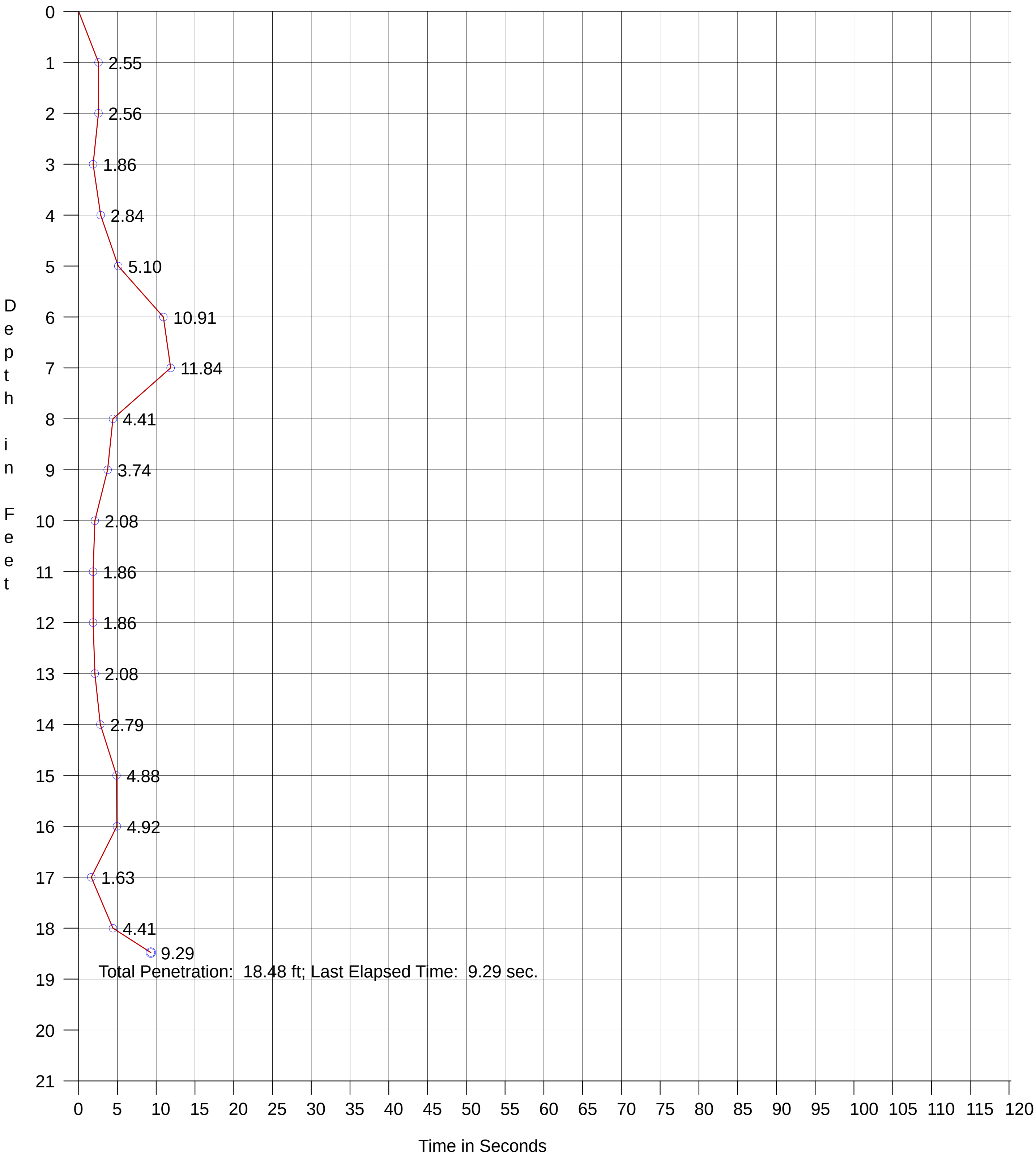
Date: 12/12/2011
Start Time: 12:11:23 PM
End Time: 12:12:45 PM

Penetration: 18.48 ft
Recovery: 13.75 ft
W. D. Corrected: 49.27 ft
W. D. Raw: 48.71 ft

Easting: 2690361.98
Northing: 331252.24
Coord. System: NCSPCS 83

Lat: 76°42'16.7400" dW N
Long: 034°38'17.6400" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O25, Run 1

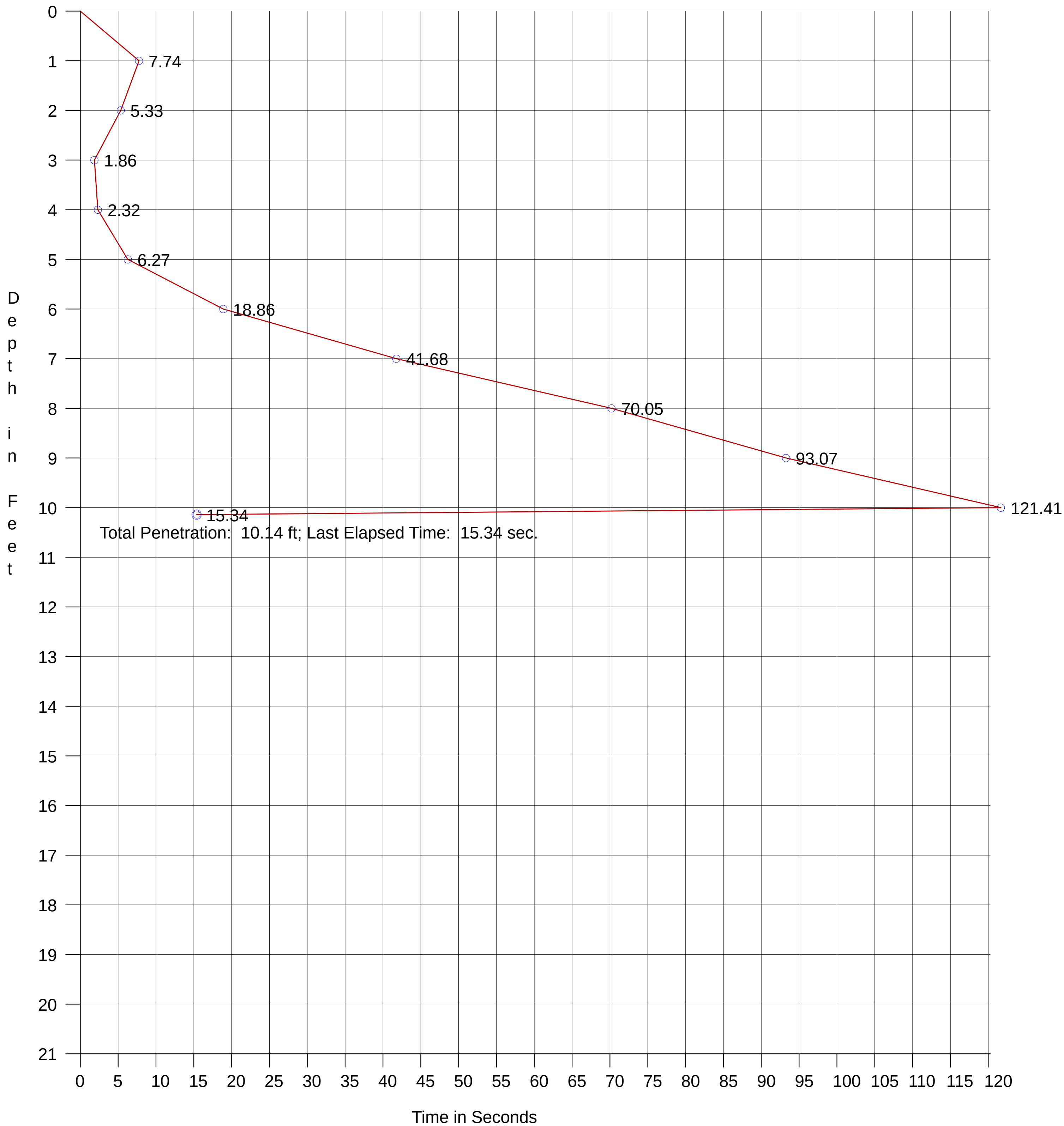
Date: 12/11/2011
Start Time: 10:31:03 AM
End Time: 10:37:27 AM

Penetration: 10.14 ft
Recovery: 8.00 ft
W. D. Corrected: 41.97 ft
W. D. Raw: 42.10 ft

Easting: 2691364.49
Northing: 331253.07
Coord. System: NCSPCS 83

Lat: 76°42'04.7460" dW N
Long: 034°38'17.4180" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O25, Run 2

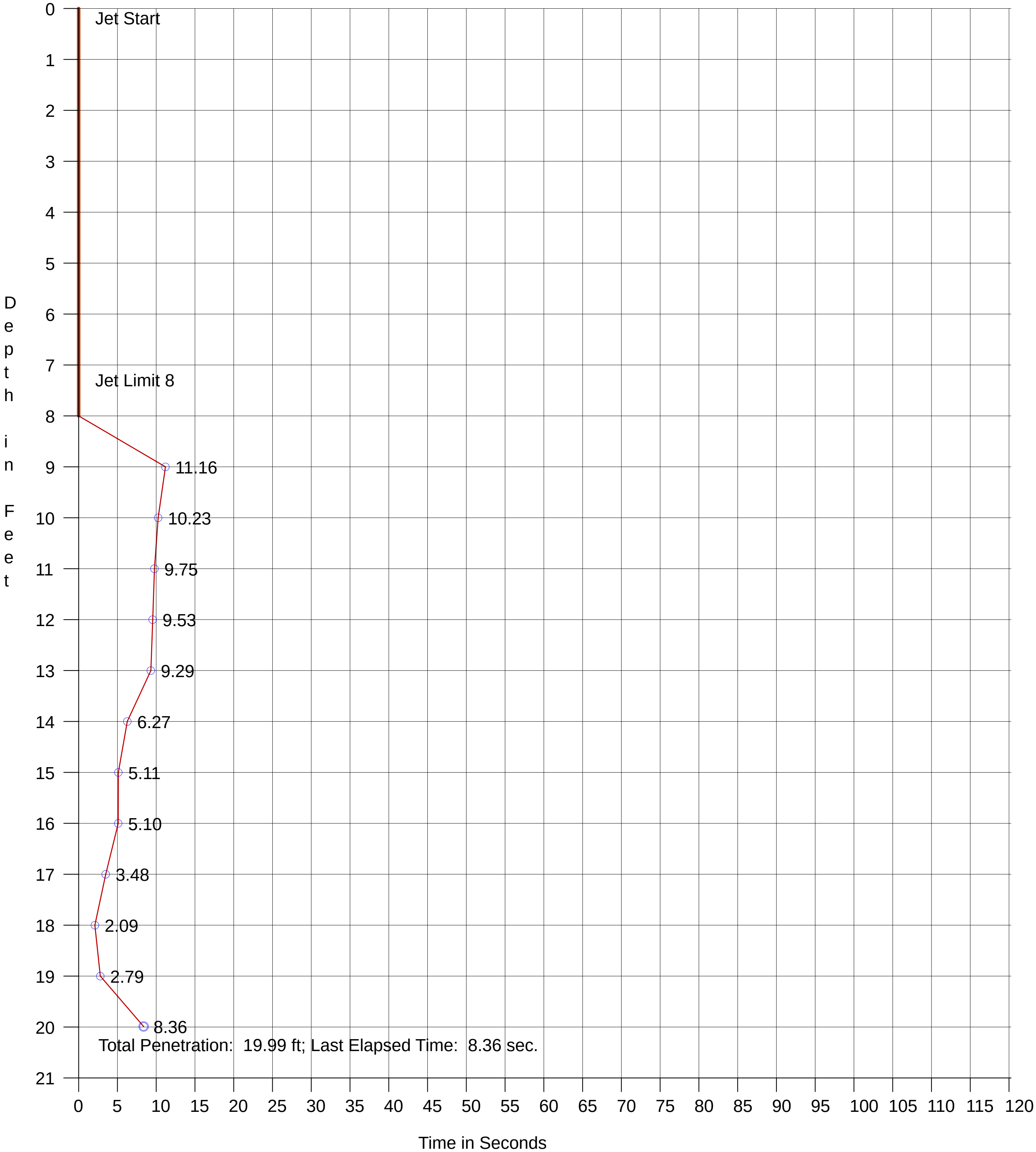
Date: 12/11/2011
Start Time: 10:55:21 AM
End Time: 10:59:00 AM

Penetration: 19.99 ft
Recovery: 11.50 ft
W. D. Corrected: 41.97 ft
W. D. Raw: 39.39 ft

Easting: 2691367.19
Northing: 331253.49
Coord. System: NCSPCS 83

Lat: 76°42'04.7100" dW N
Long: 034°38'17.4180" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O26, Run 1

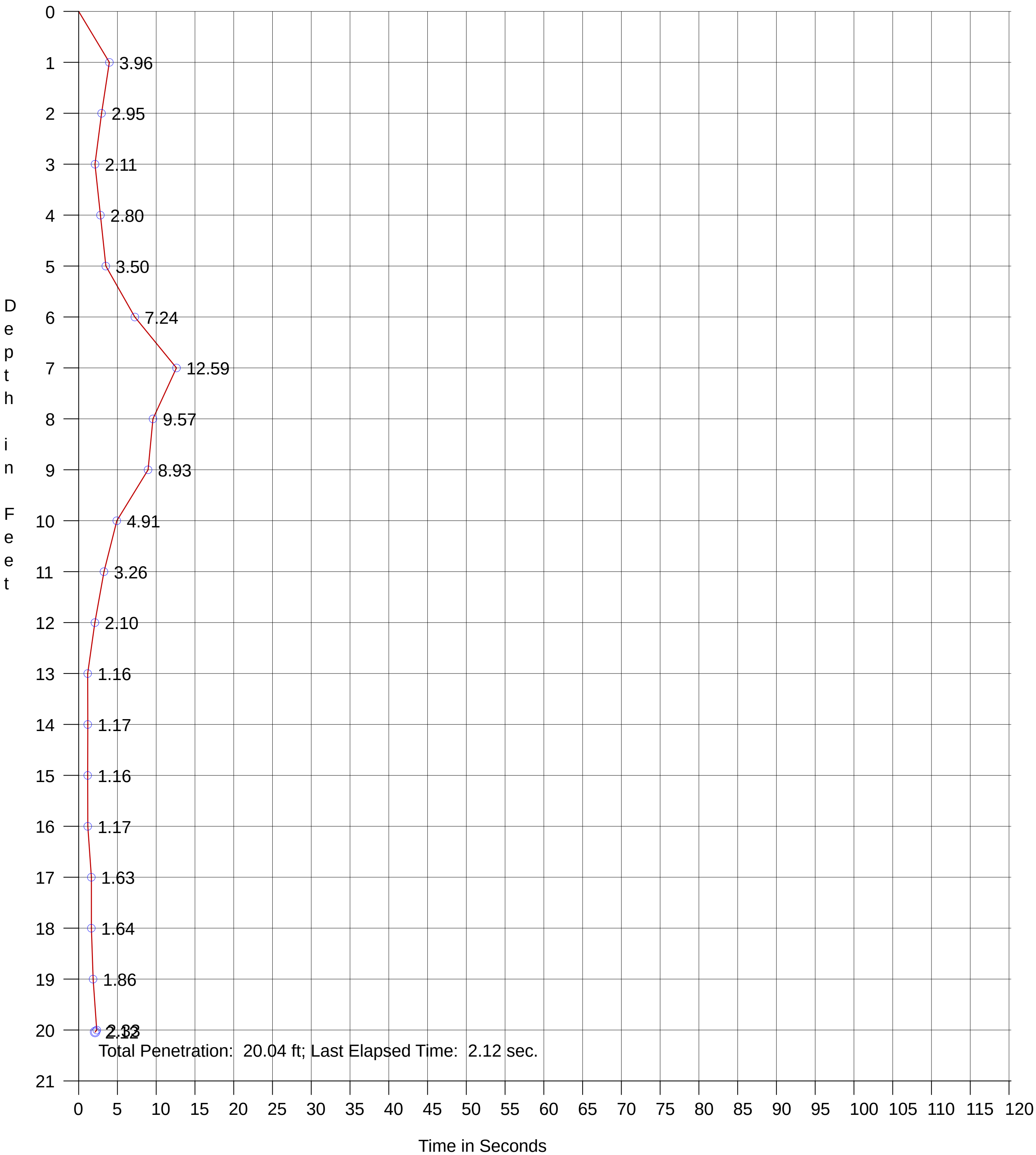
Date: 12/11/2011
Start Time: 8:31:53 AM
End Time: 8:33:17 AM

Penetration: 20.04 ft
Recovery: 13.80 ft
W. D. Corrected: 45.70 ft
W. D. Raw: 47.10 ft

Easting: 2692365.13
Northing: 331247.31
Coord. System: NCSPCS 83

Lat: 76°41'52.7760" dW N
Long: 034°38'17.1300" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O27, Run 1

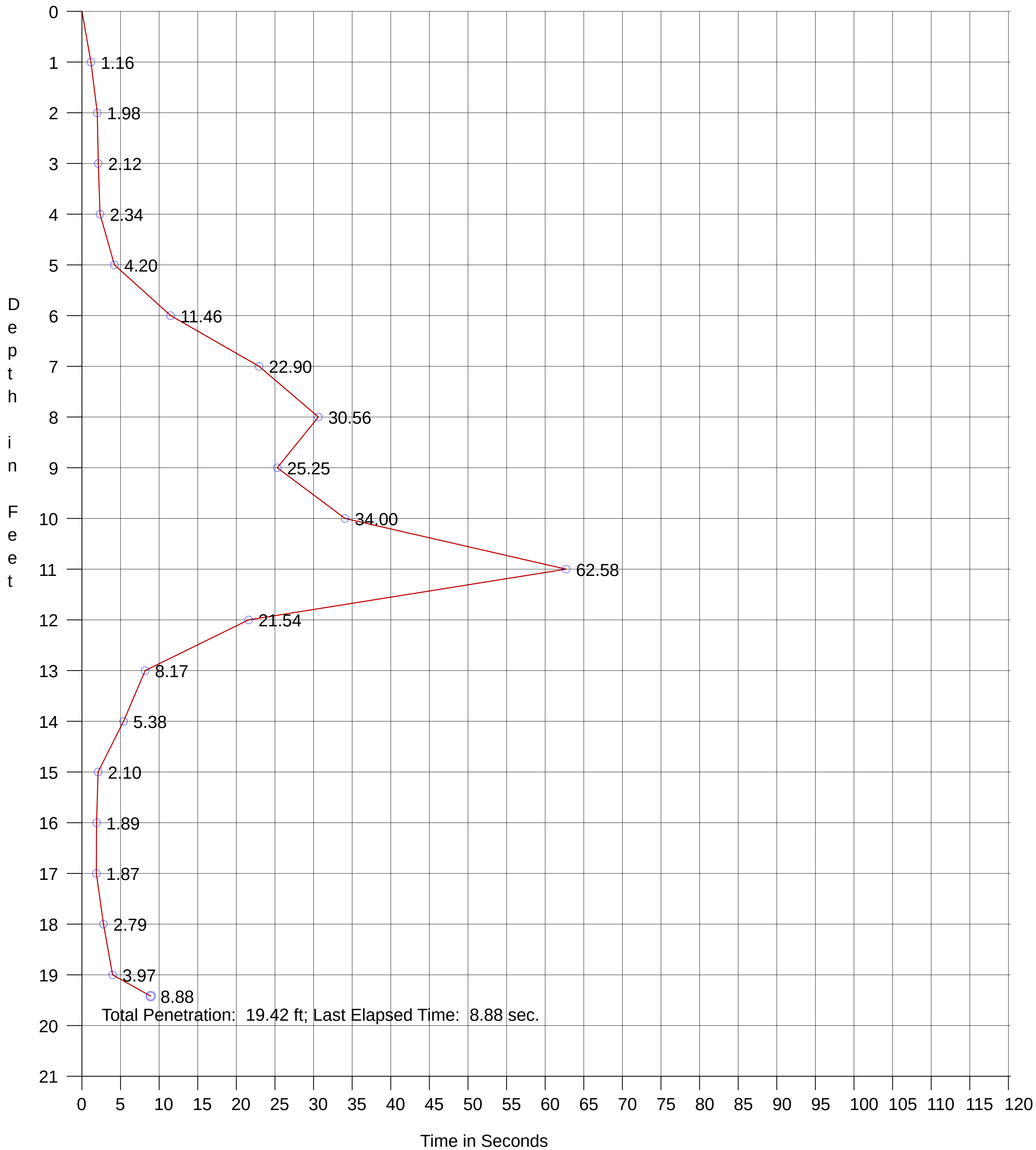
Date: 12/11/2011
Start Time: 8:04:51 AM
End Time: 8:09:14 AM

Penetration: 19.42 ft
Recovery: 16.75 ft
W. D. Corrected: 43.63 ft
W. D. Raw: 45.06 ft

Easting: 2693366.30
Northing: 331253.48
Coord. System: NCSPCS 83

Lat: 76°41'40.7940" dW N
Long: 034°38'16.9620" dN W
Datum: NAVD 88

Comment:



Penetration Graph for Core No. O28, Run 1

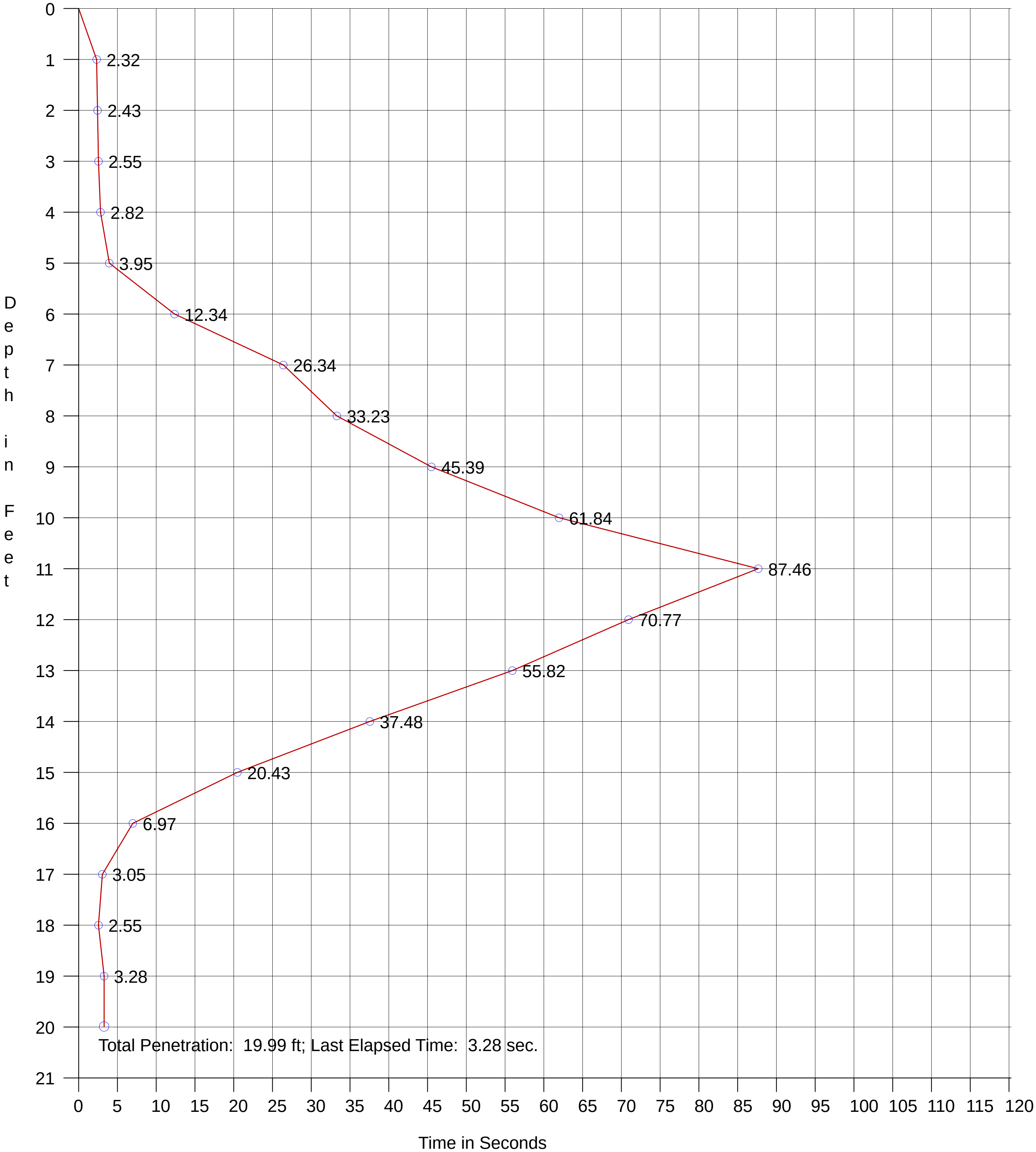
Date: 12/10/2011
Start Time: 3:58:57 PM
End Time: 4:08:00 PM

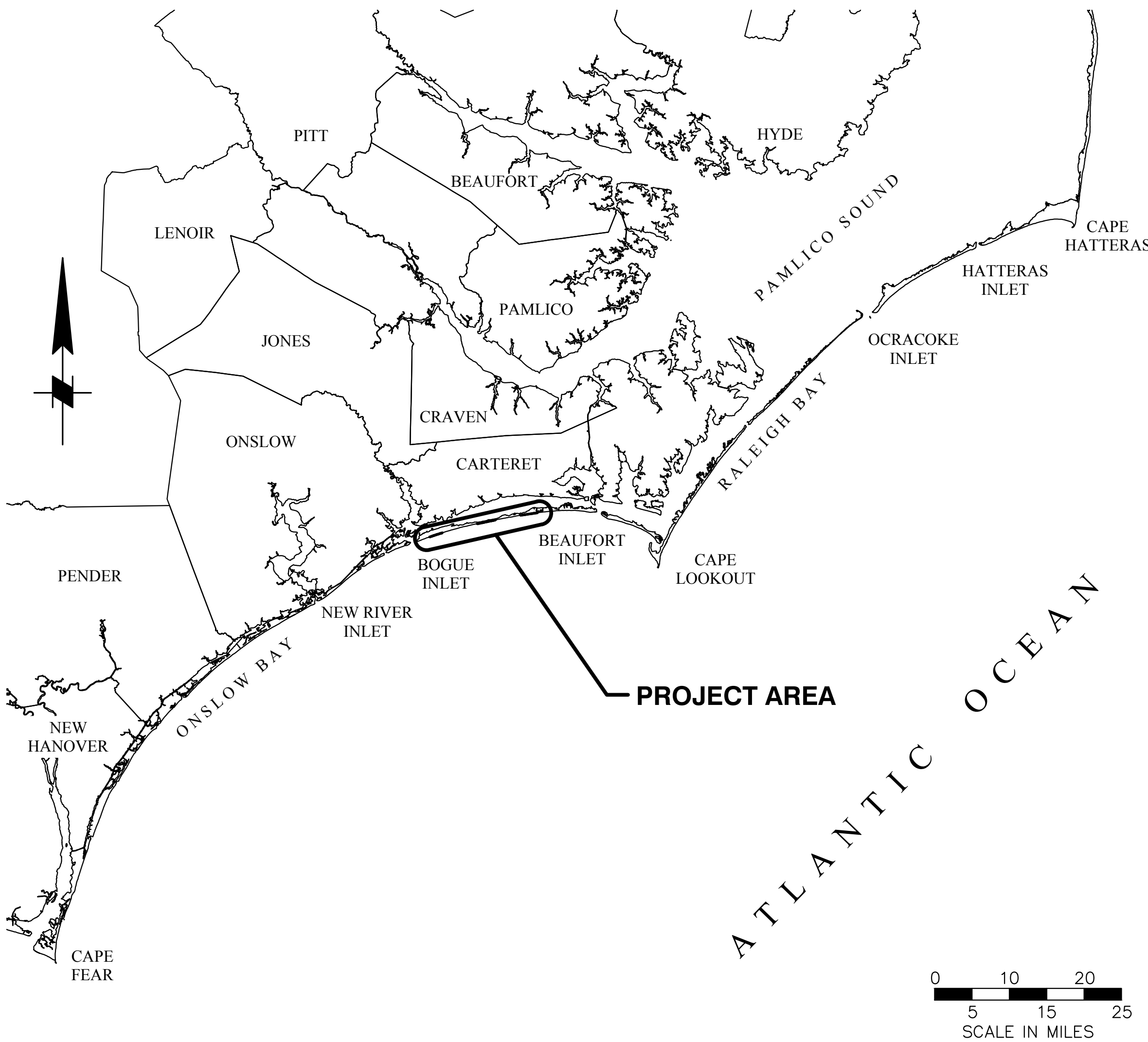
Penetration: 19.99 ft
Recovery: 12.90 ft
W. D. Corrected: 42.72 ft
W. D. Raw: 41.51 ft

Easting: 2694358.58
Northing: 331246.13
Coord. System: NCSPCS 83

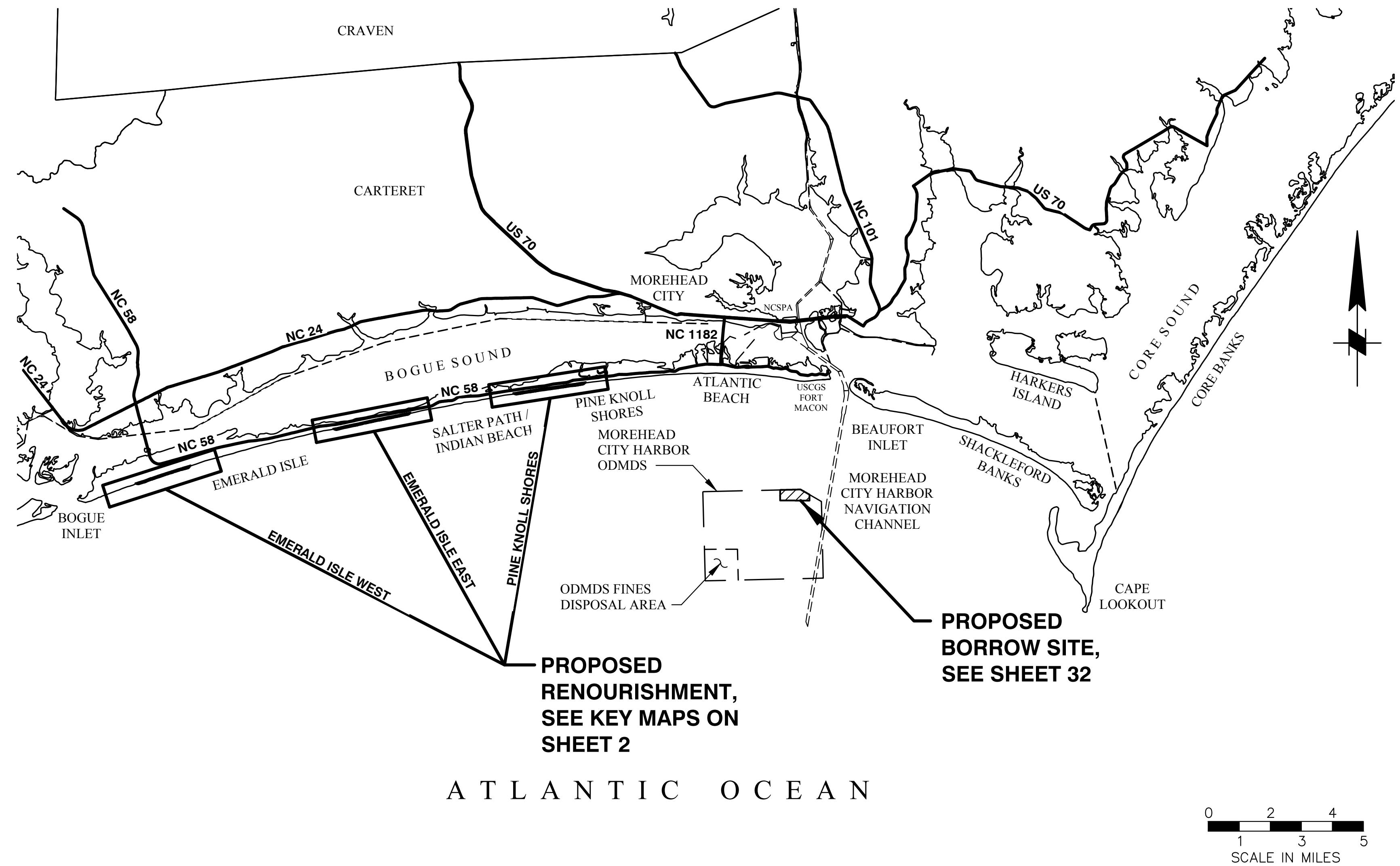
Lat: 76°41'28.9200" dW N
Long: 034°38'16.6620" dN W
Datum: NAVD 88

Comment:



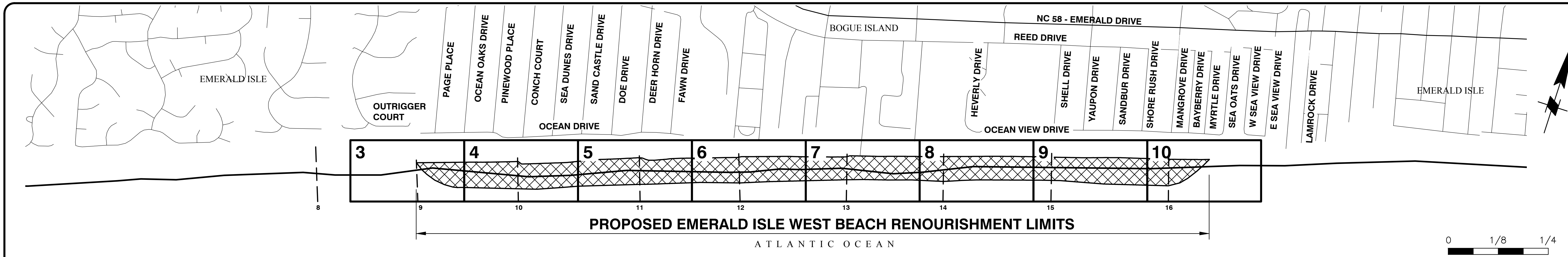


VICINITY MAP

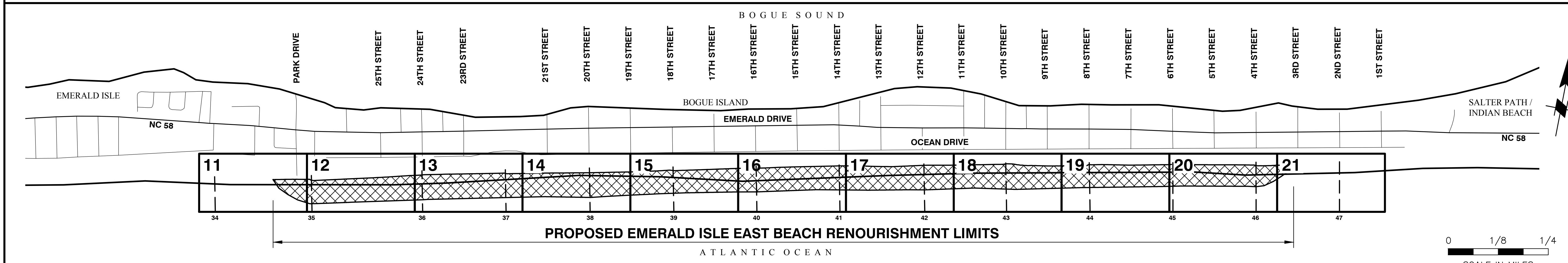


LOCATION MAP

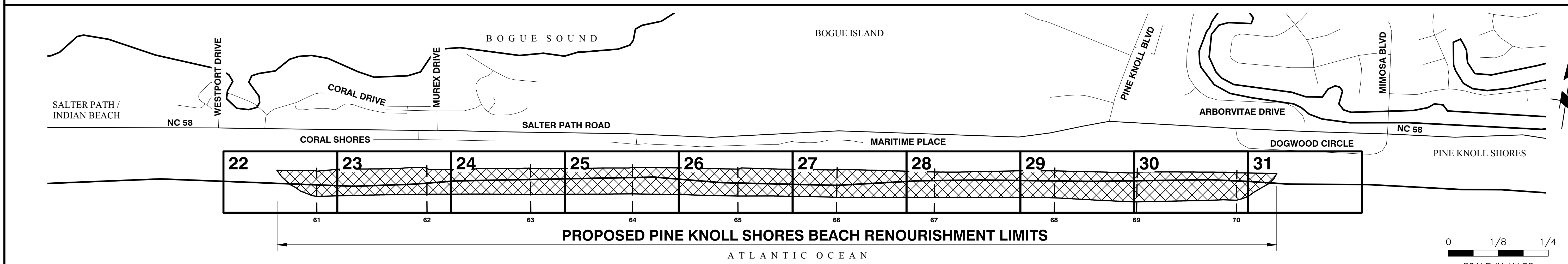
PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT** *DATUM:* **NAVD 88 (FT)** *PREPARED BY:* **MOFFATT & NICHOL**	*PREPARED FOR:* **CARTERET COUNTY, NORTH CAROLINA** *DATE:* **FEBRUARY 2012**	*SHEET TITLE:* **VICINITY AND LOCATION MAP**	*SHEET* **1** *OF* **48**



EMERALD ISLE WEST KEY MAP

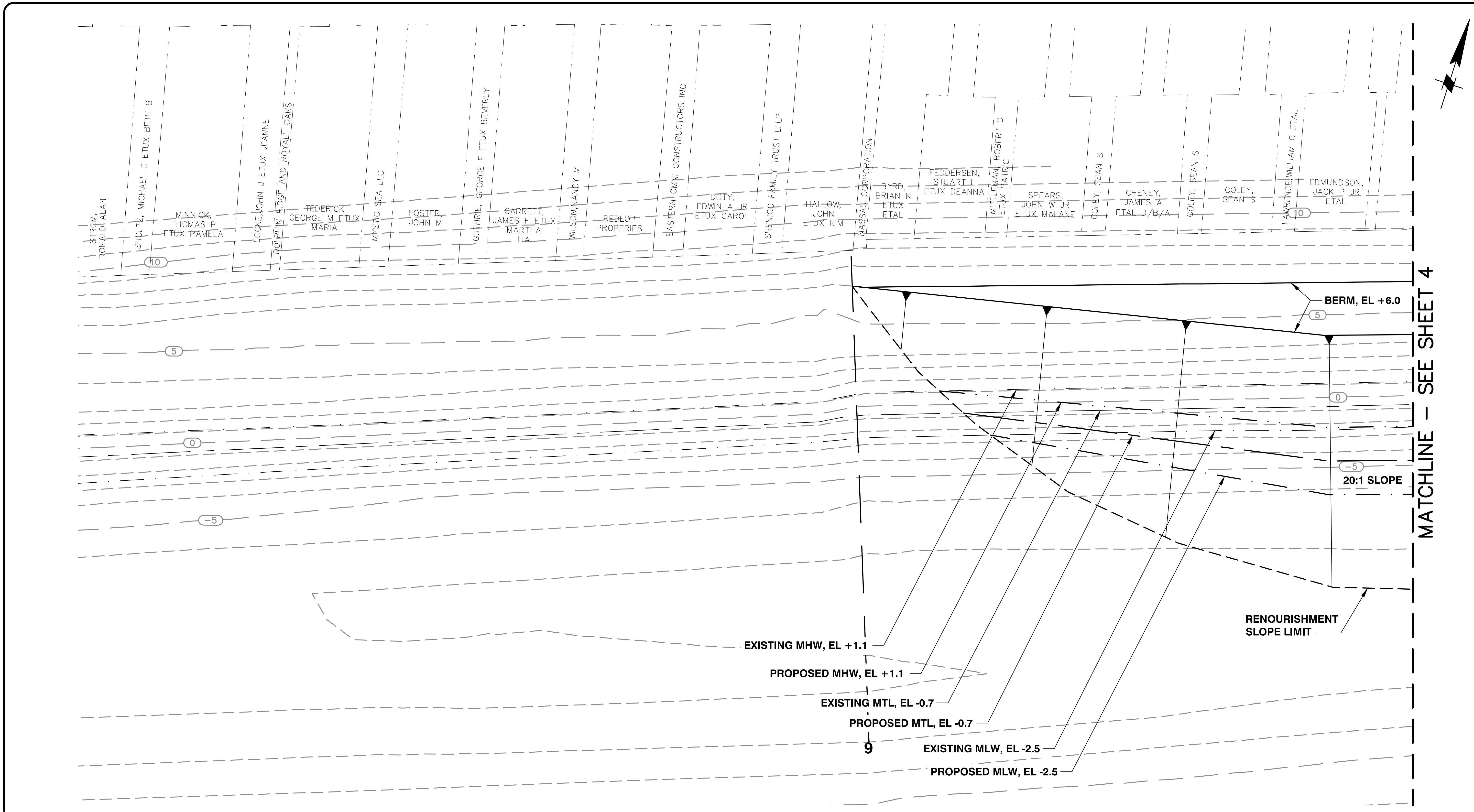


EMERALD ISLE EAST KEY MAP



PINE KNOLL SHORES KEY MAP

PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT** *DATUM:* **NAVD 88 (FT)** *PREPARED BY:* **MOFFATT & NICHOL**	*PREPARED FOR:* **CARTERET COUNTY, NORTH CAROLINA** *DATE:* **FEBRUARY 2012**	*SHEET TITLE:* **KEY MAPS**	*SHEET* **2** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY,**
EMERALD ISLE & PINE KNOLL SHORES
POST-IRENE RENOURISHMENT PROJECT

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

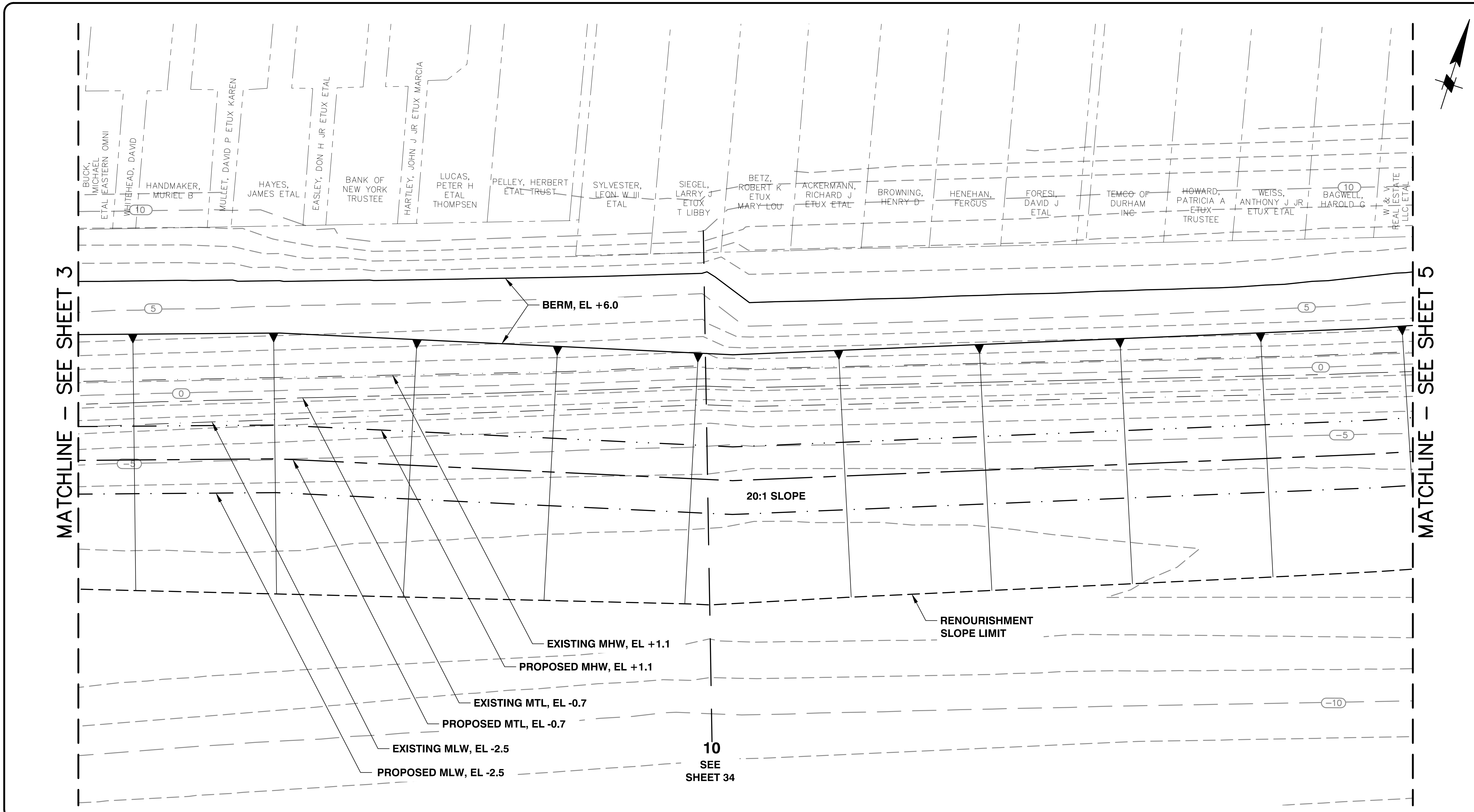
DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE WEST RENOURISHMENT PLAN
1 OF 8

0 100' 200'
1"=100'

SHEET
3
OF
48



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

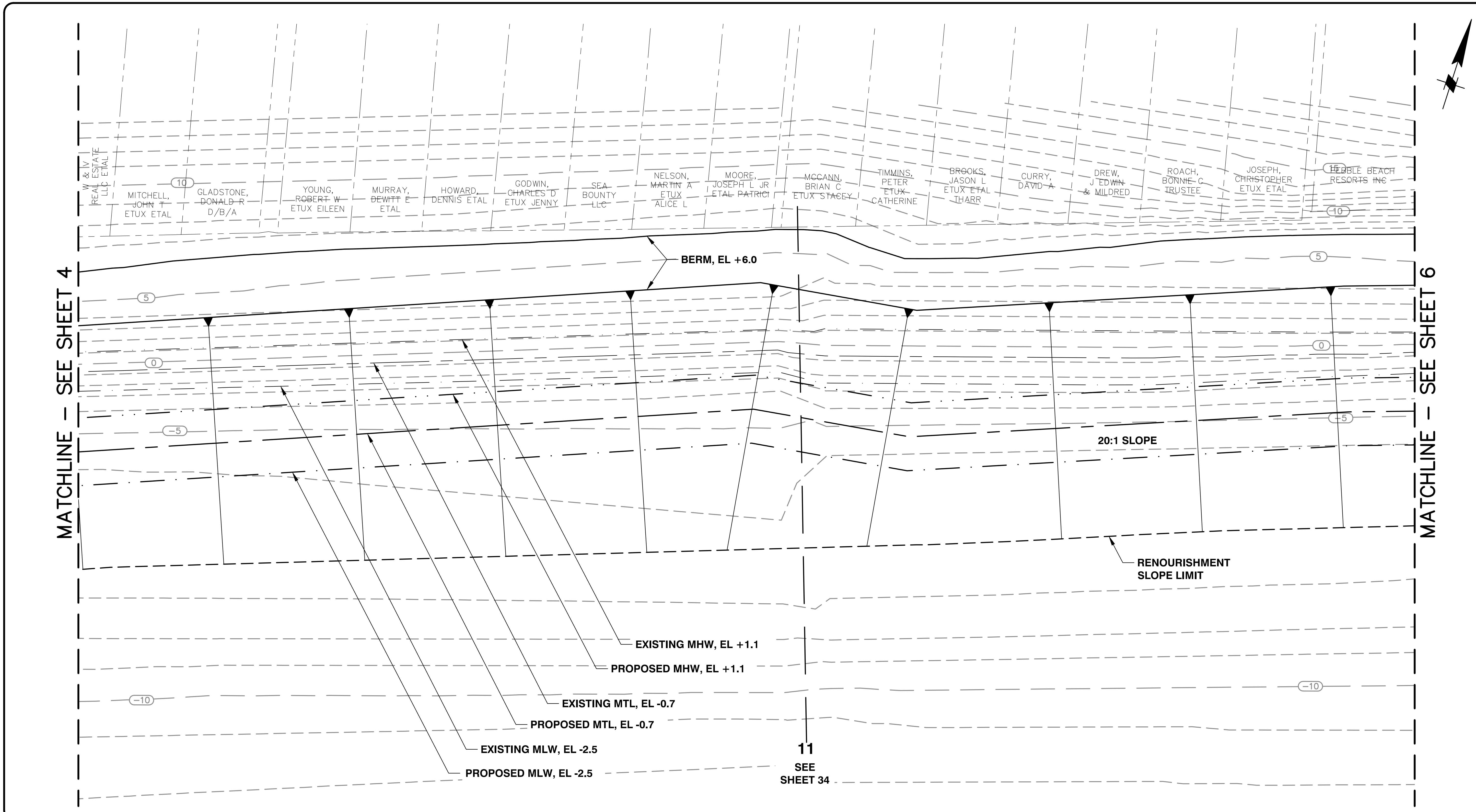
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE: **EMERALD ISLE WEST RENOURISHMENT PLAN 2 OF 8**

0 100' 200'
1"=100'

SHEET **4** OF **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

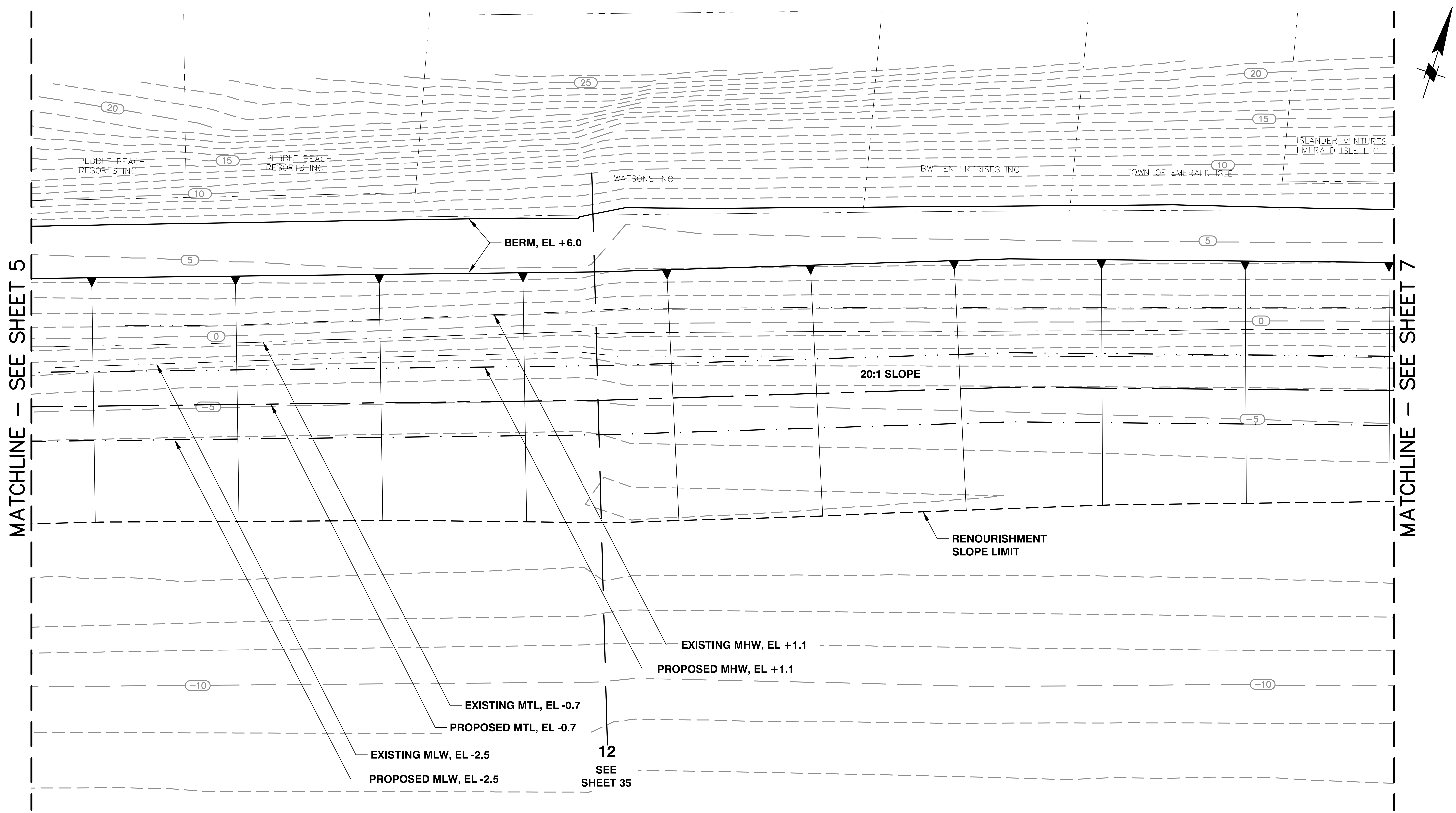
PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE: **EMERALD ISLE WEST RENOURISHMENT PLAN 3 OF 8**

0 100' 200'
1"=100'



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

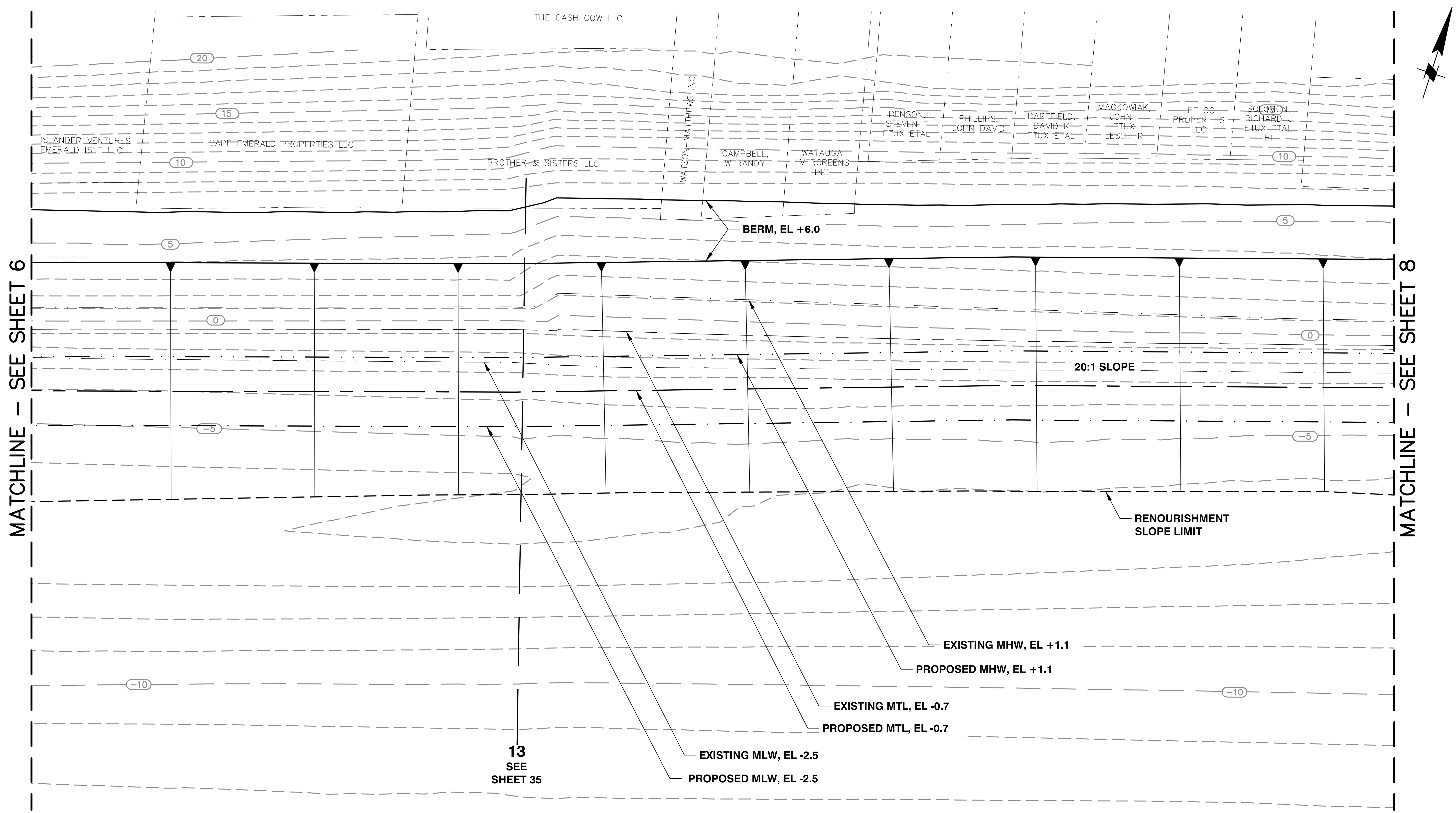
DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE WEST RENOURISHMENT PLAN 4 OF 8

0 100' 200'
1"=100'

SHEET **6** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

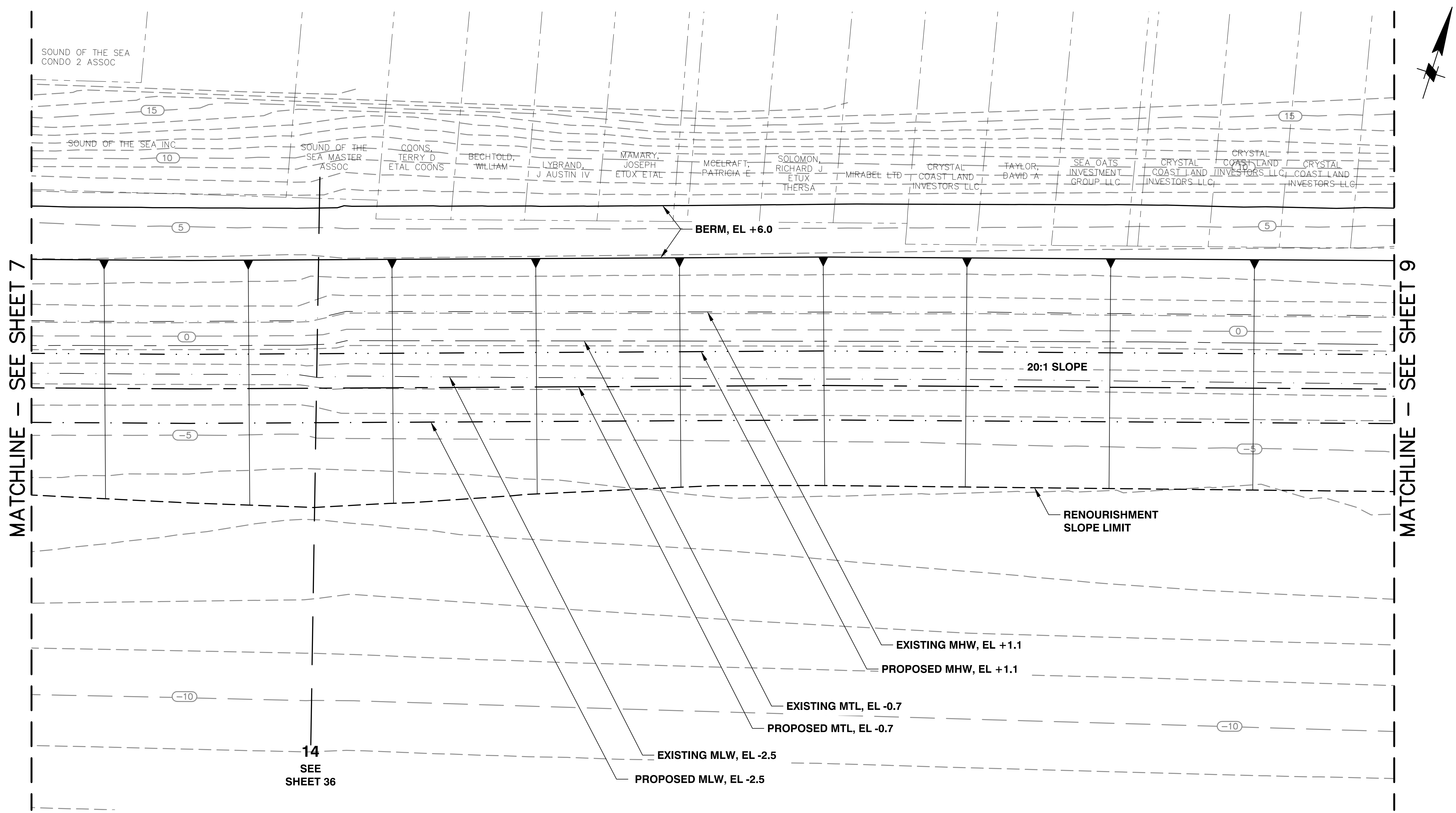
EMERALD ISLE WEST RENOURISHMENT PLAN

5 OF 8

0 100' 200'

1"=100'

SHEET **7** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

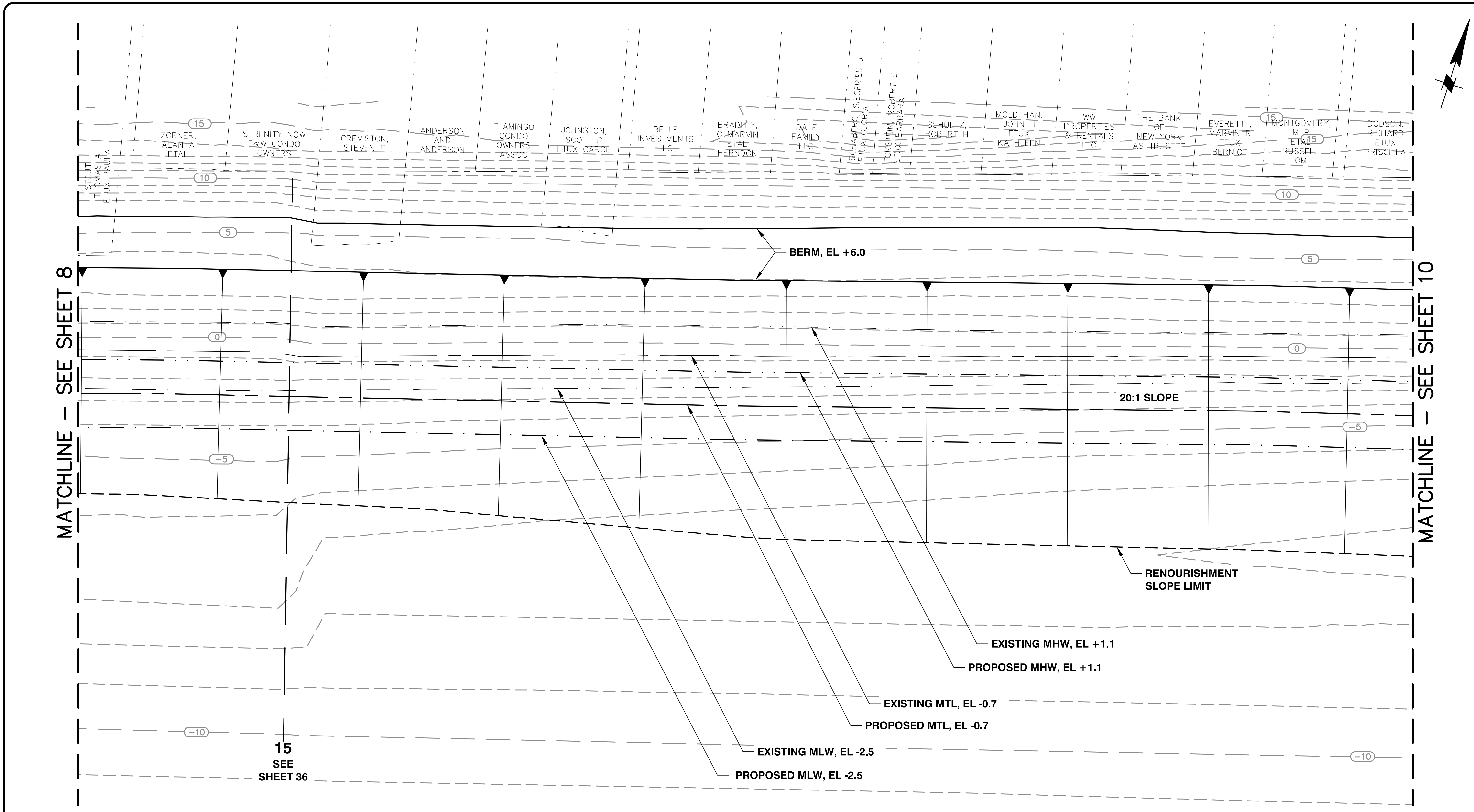
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

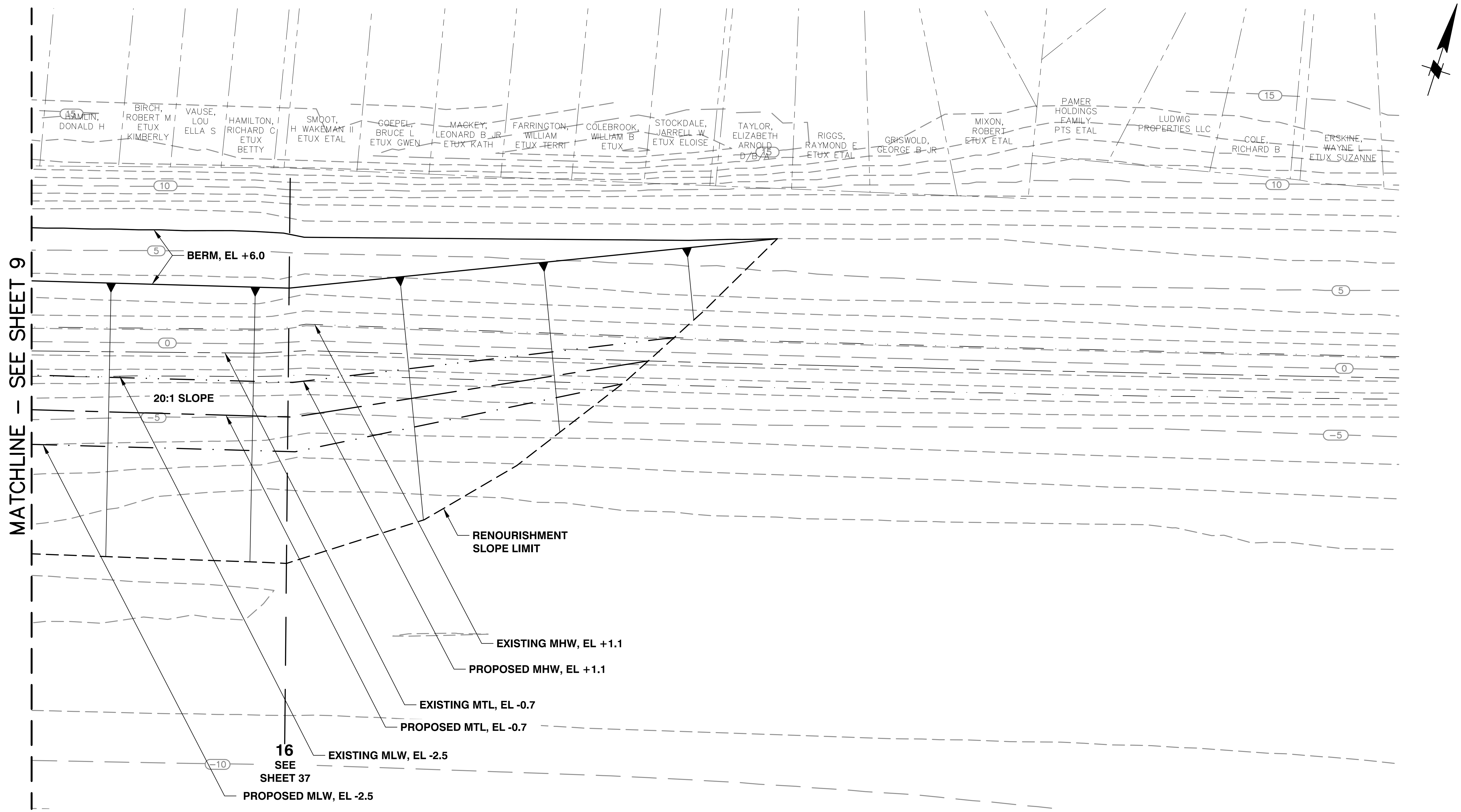
SHEET TITLE:

EMERALD ISLE WEST RENOURISHMENT PLAN
6 OF 8

0 100' 200'
1"=100'



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT** *DATUM:* **NAVD 88 (FT)** *PREPARED BY:* **MOFFATT & NICHOL**	*PREPARED FOR:* **CARTERET COUNTY, NORTH CAROLINA** *DATE:* **FEBRUARY 2012**	*SHEET TITLE:* **EMERALD ISLE WEST RENOURISHMENT PLAN 7 OF 8** 0 100' 200' 1"=100'	*SHEET* **9** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

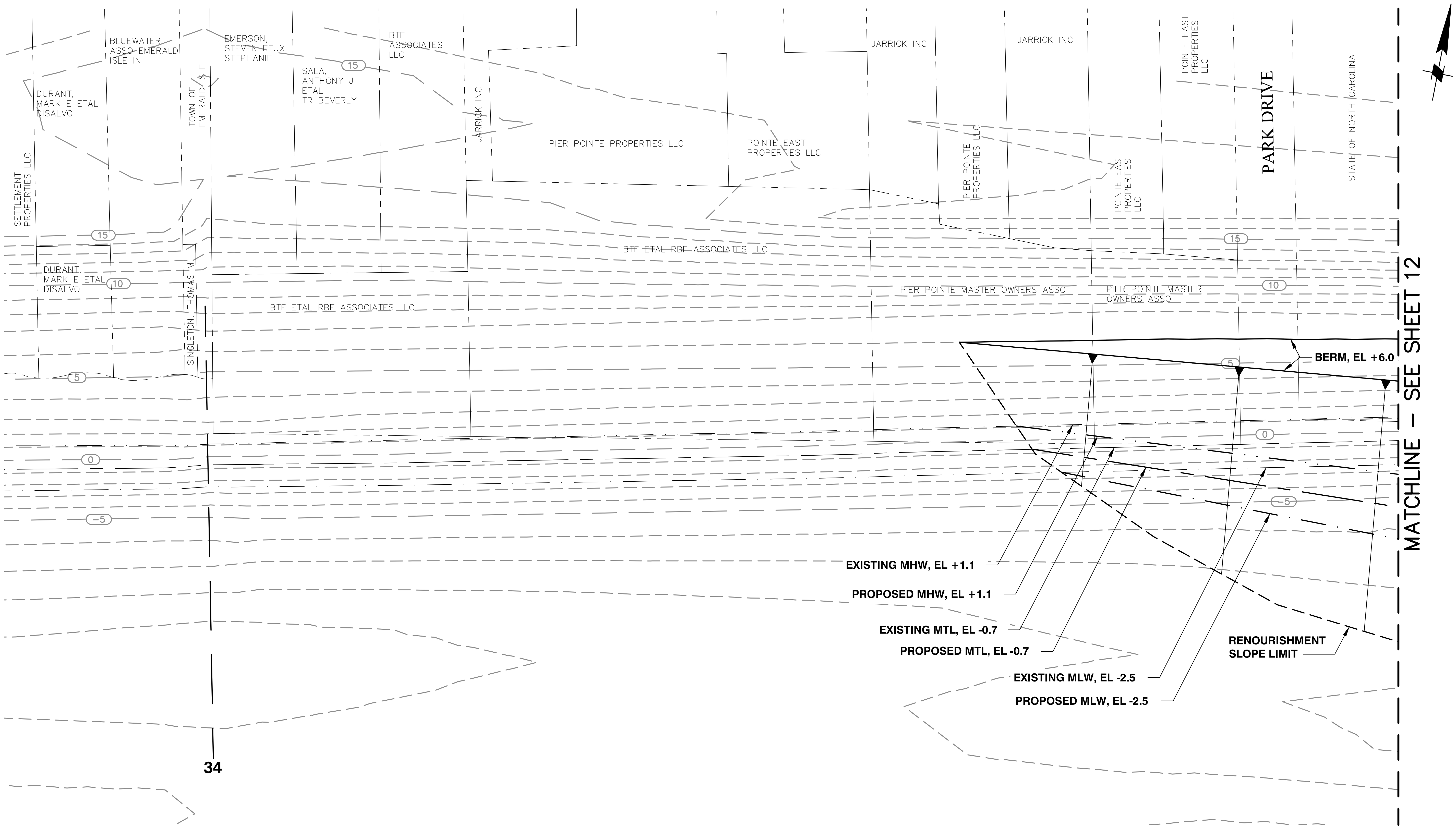
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:
EMERALD ISLE WEST RENOURISHMENT PLAN
8 OF 8

0 100' 200'
1"=100'

SHEET **10** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

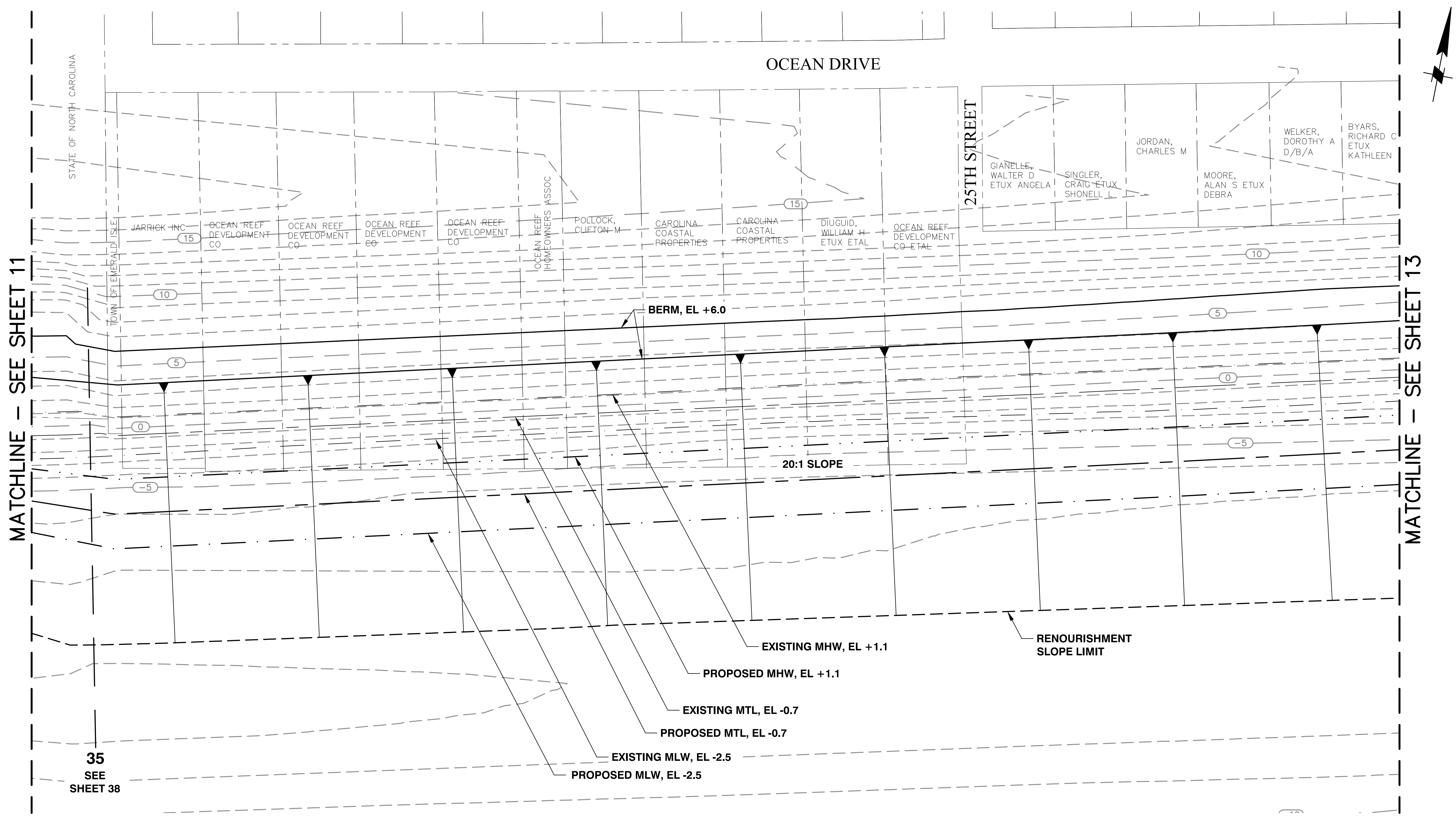
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT PLAN 1 OF 11

0 100' 200'
1"=100'



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

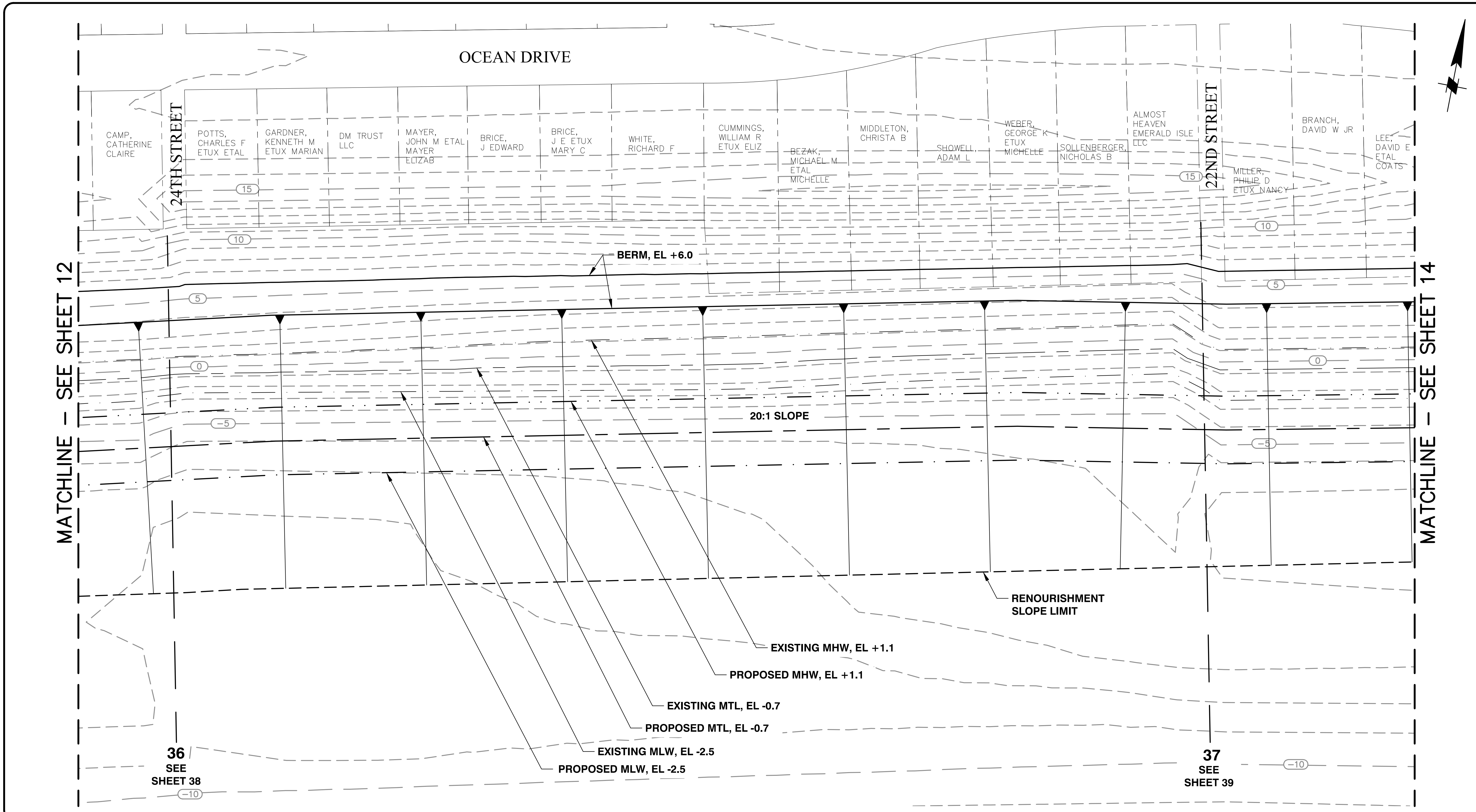
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE: **EMERALD ISLE EAST RENOURISHMENT PLAN 2 OF 11**

0 100' 200'
1"=100'

SHEET 12 OF 48



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

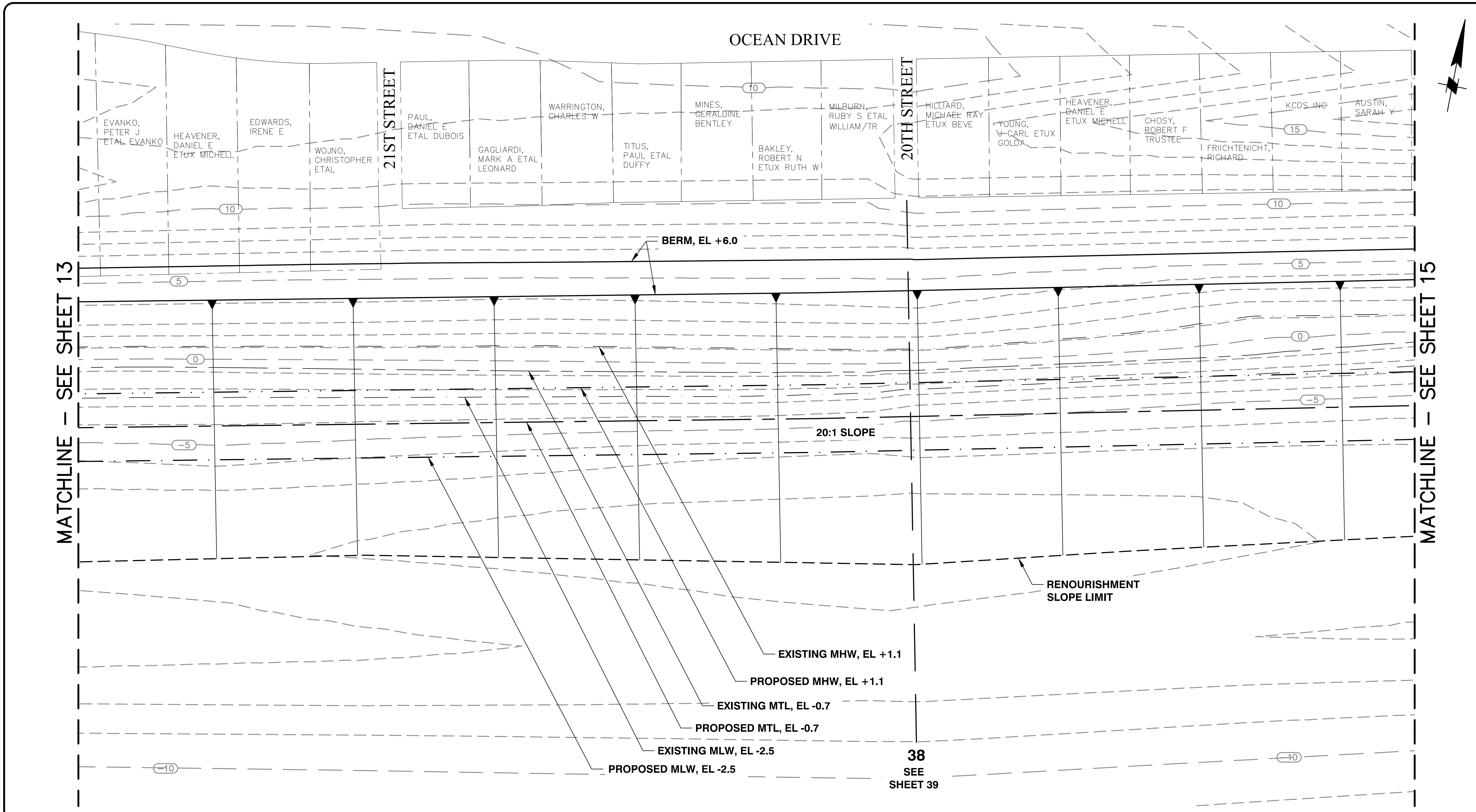
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT PLAN 3 OF 11

0 100' 200'
1"=100'



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

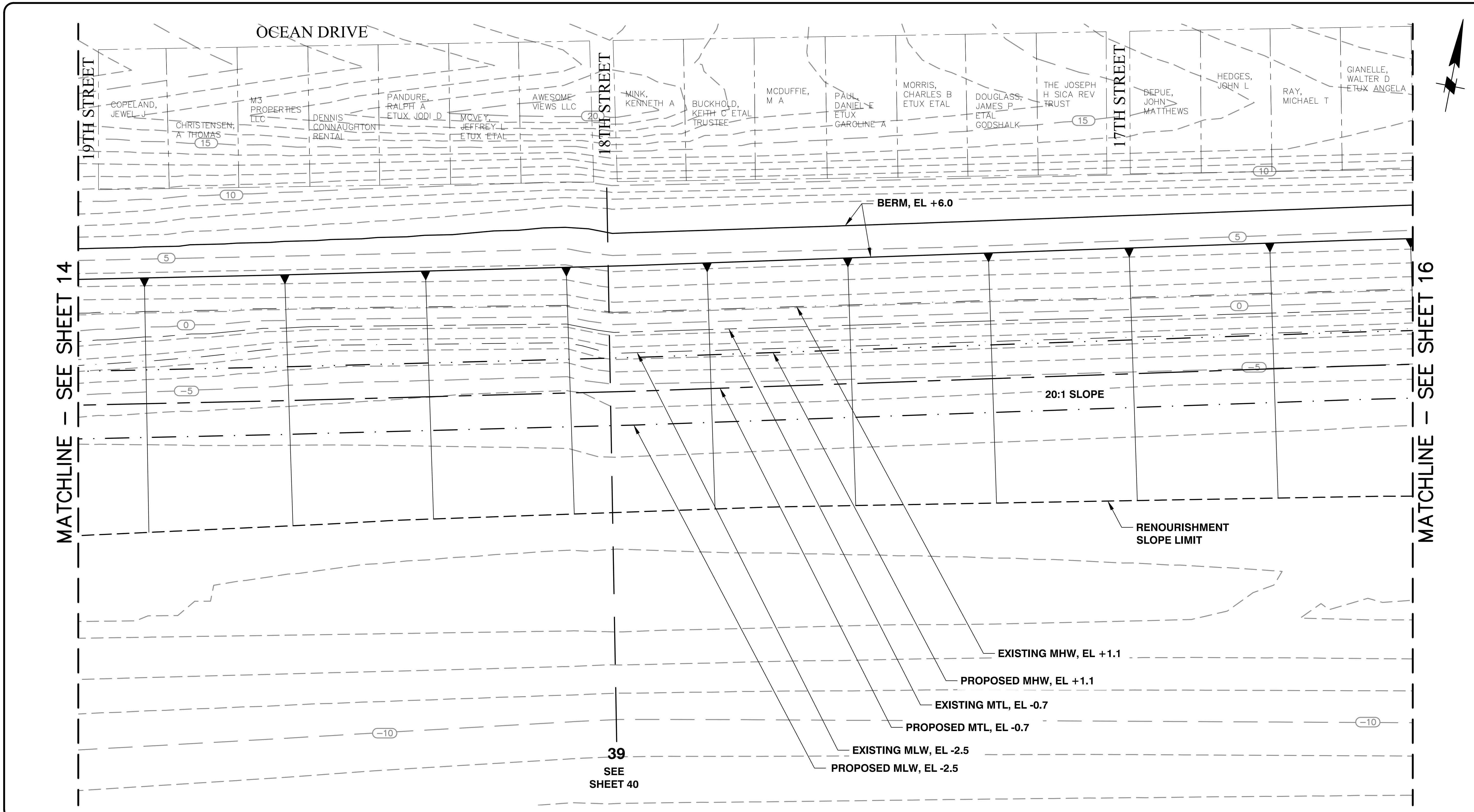
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE: **EMERALD ISLE EAST RENOURISHMENT PLAN 4 OF 11**

0 100' 200'
1"=100'

SHEET **14** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

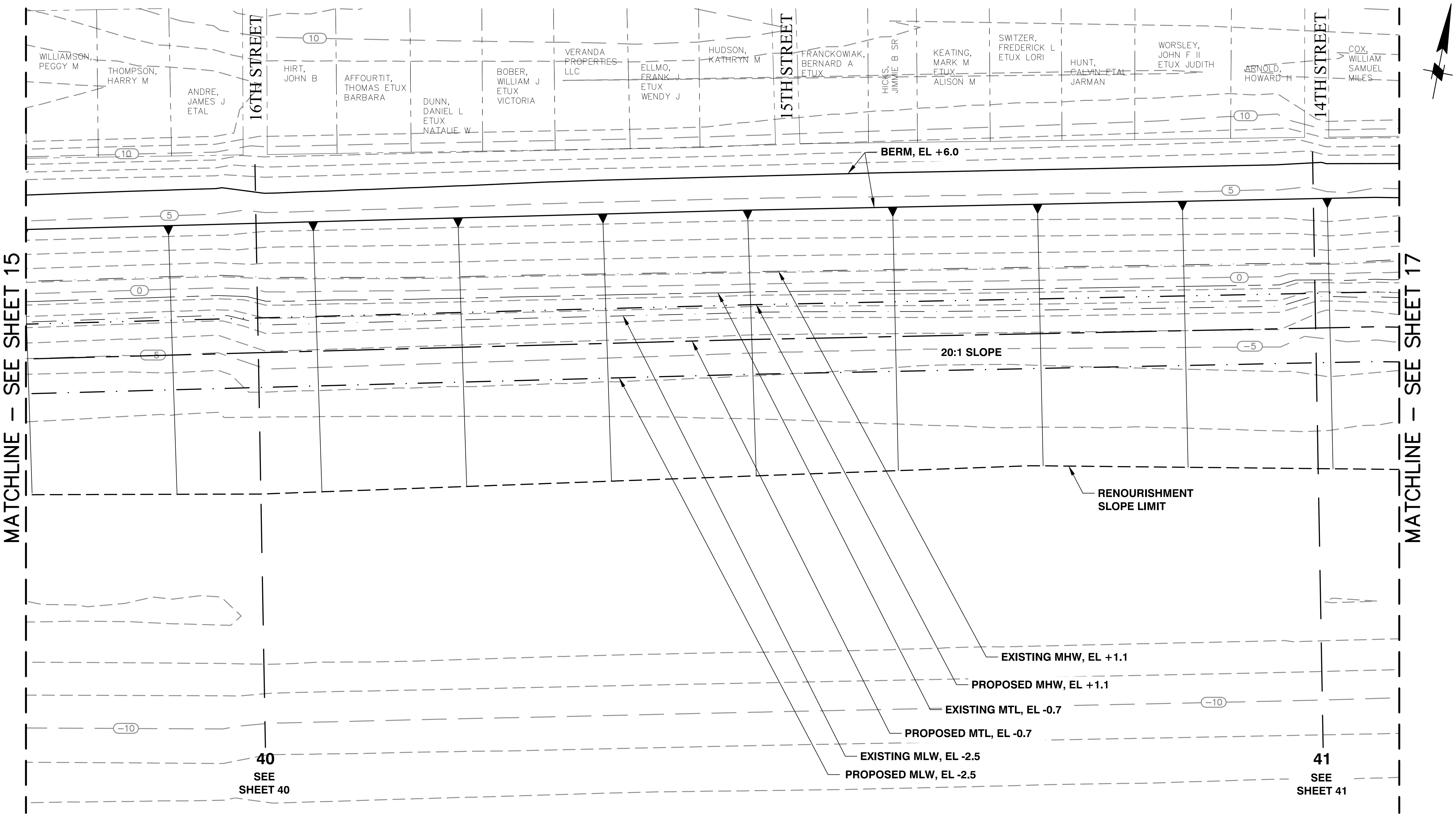
DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT PLAN 5 OF 11

0 100' 200'
1"=100'

SHEET **15** OF **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

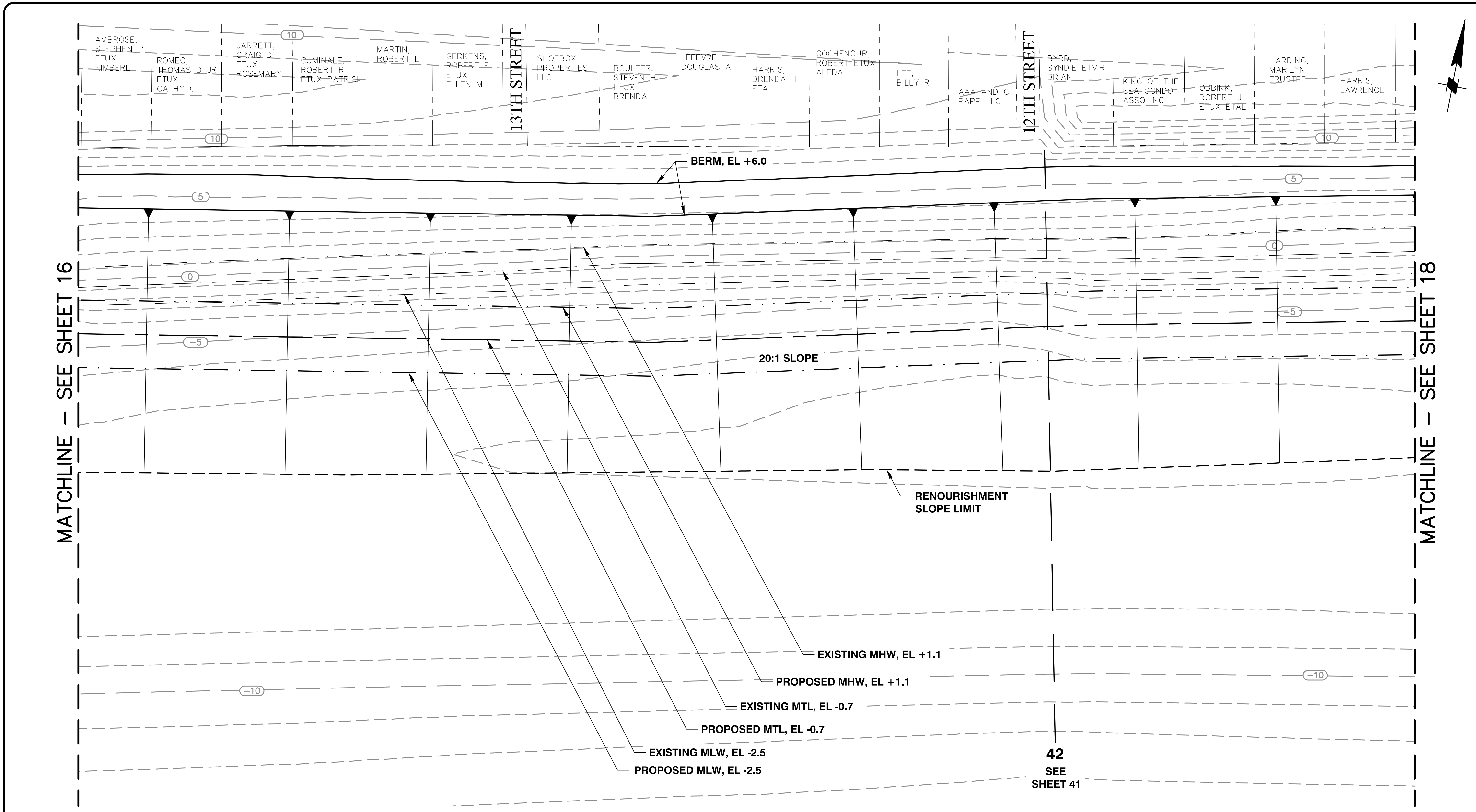
DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT PLAN
6 OF 11

0 100' 200'
1"=100'

SHEET **16** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

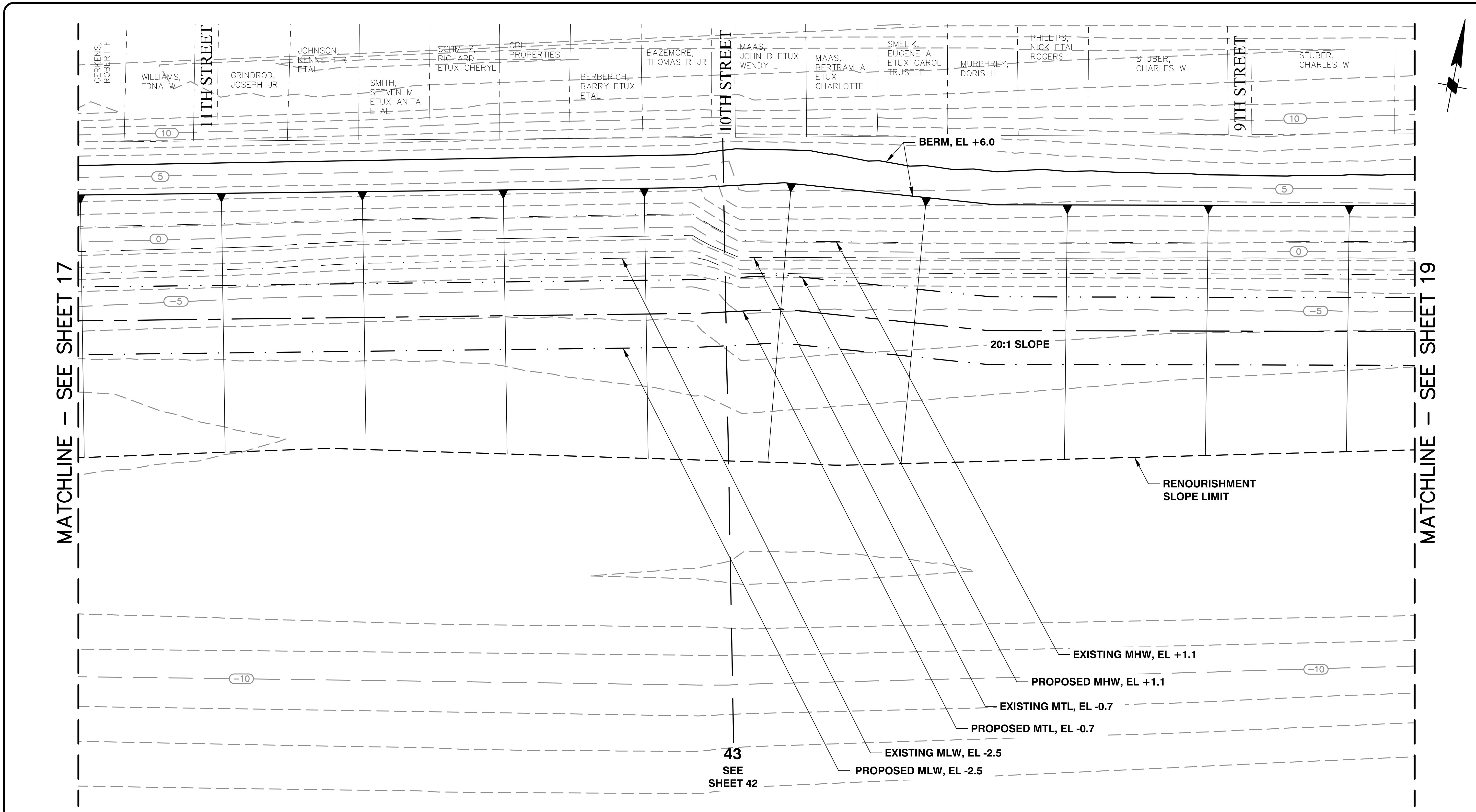
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE: **EMERALD ISLE EAST RENOURISHMENT PLAN 7 OF 11**

0 100' 200'
1"=100'

SHEET **17** OF **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

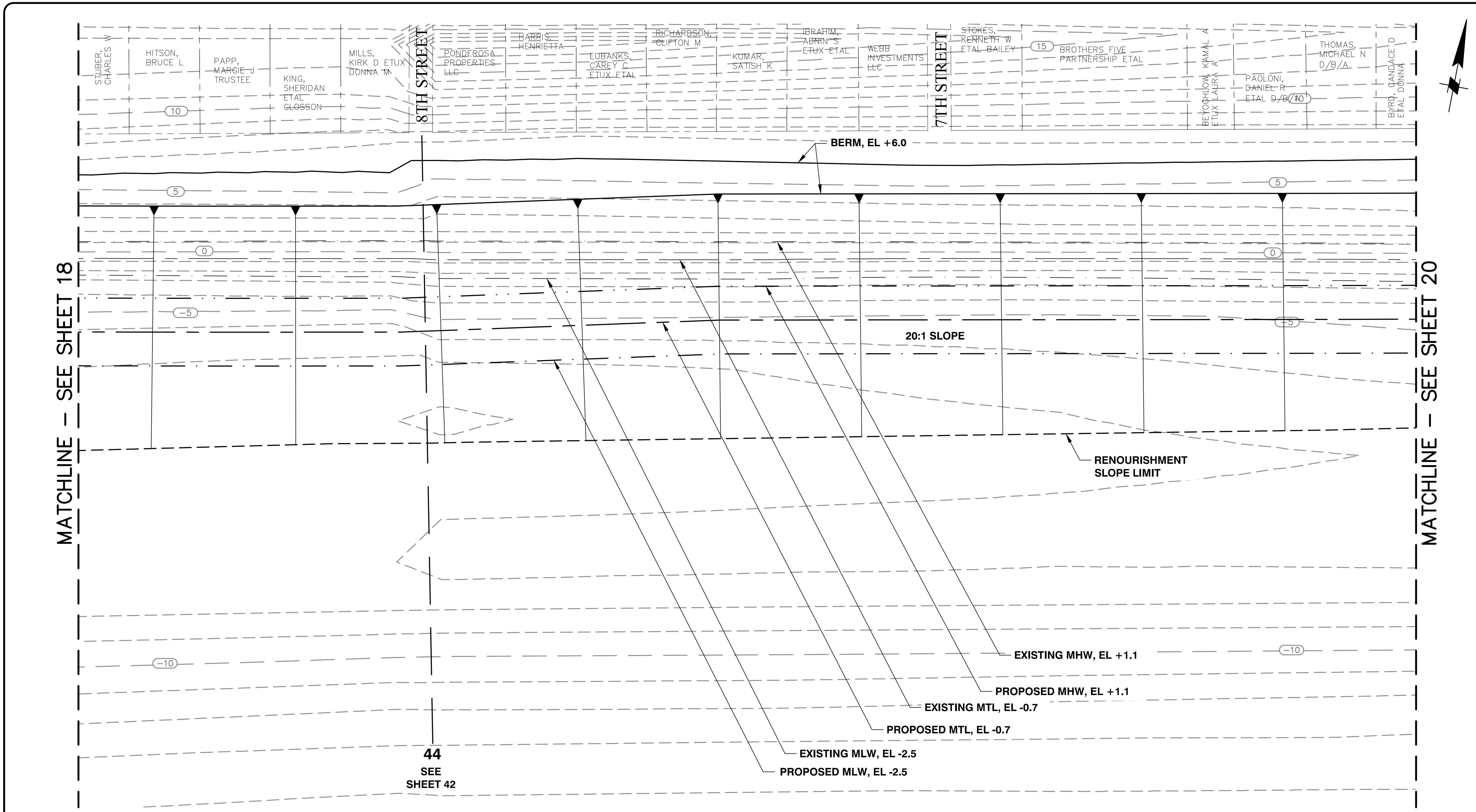
SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT PLAN

8 OF 11

0 100' 200'
1"=100'

SHEET **18** OF **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

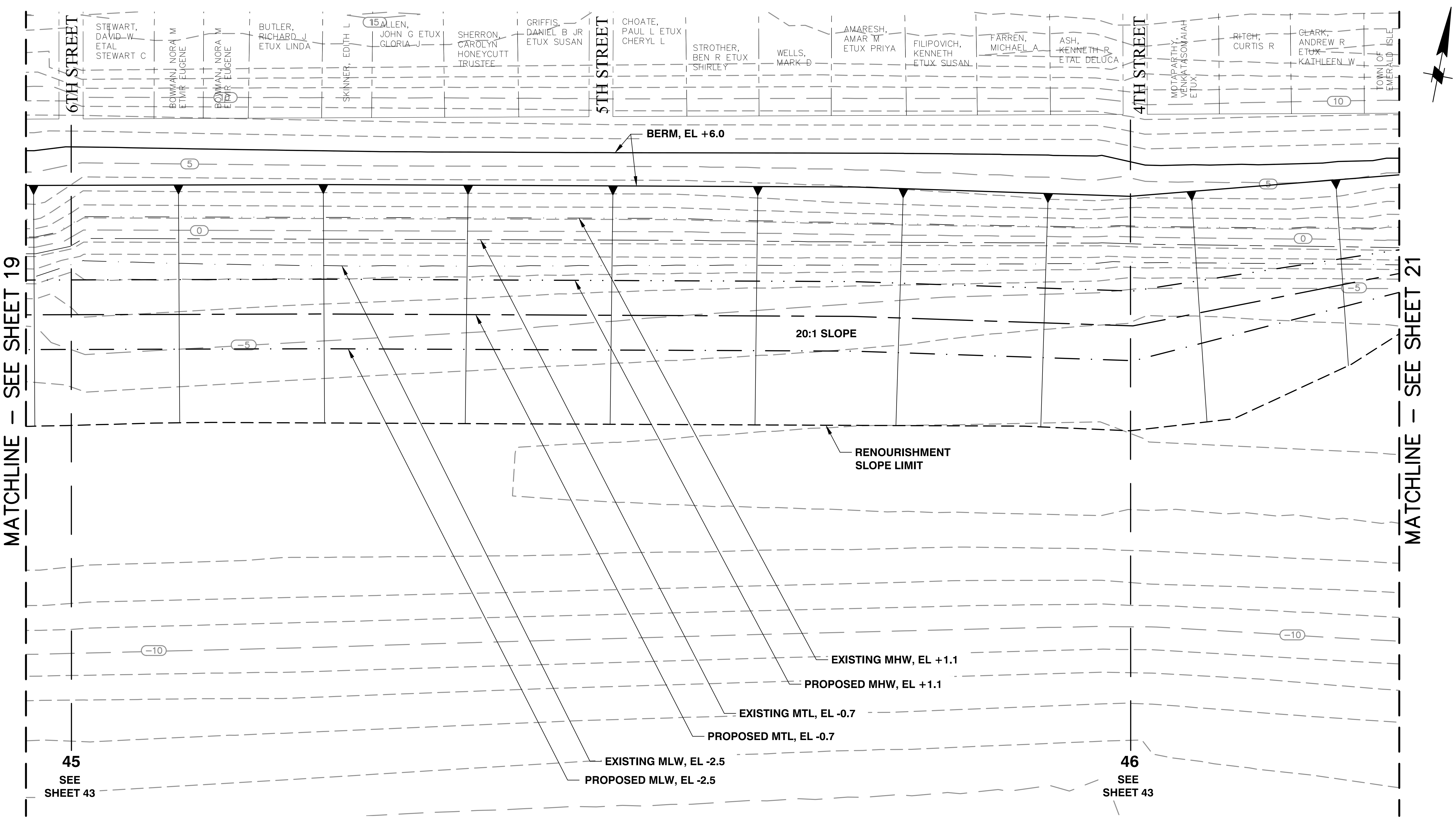
EMERALD ISLE EAST RENOURISHMENT PLAN

9 OF 11

0 100' 200'

1"=100'

SHEET **19** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

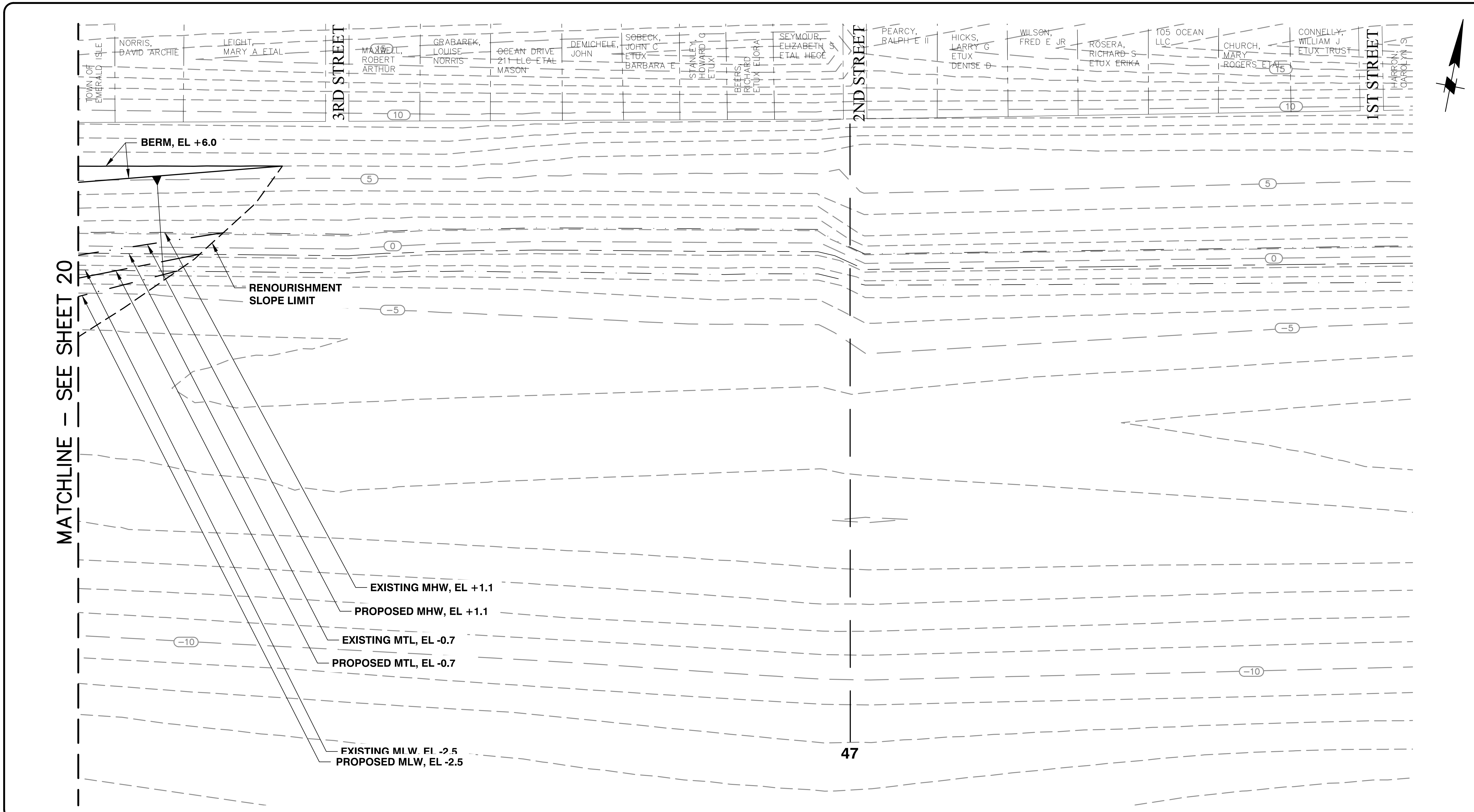
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT PLAN 10 OF 11

0 100' 200'
1"=100'



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

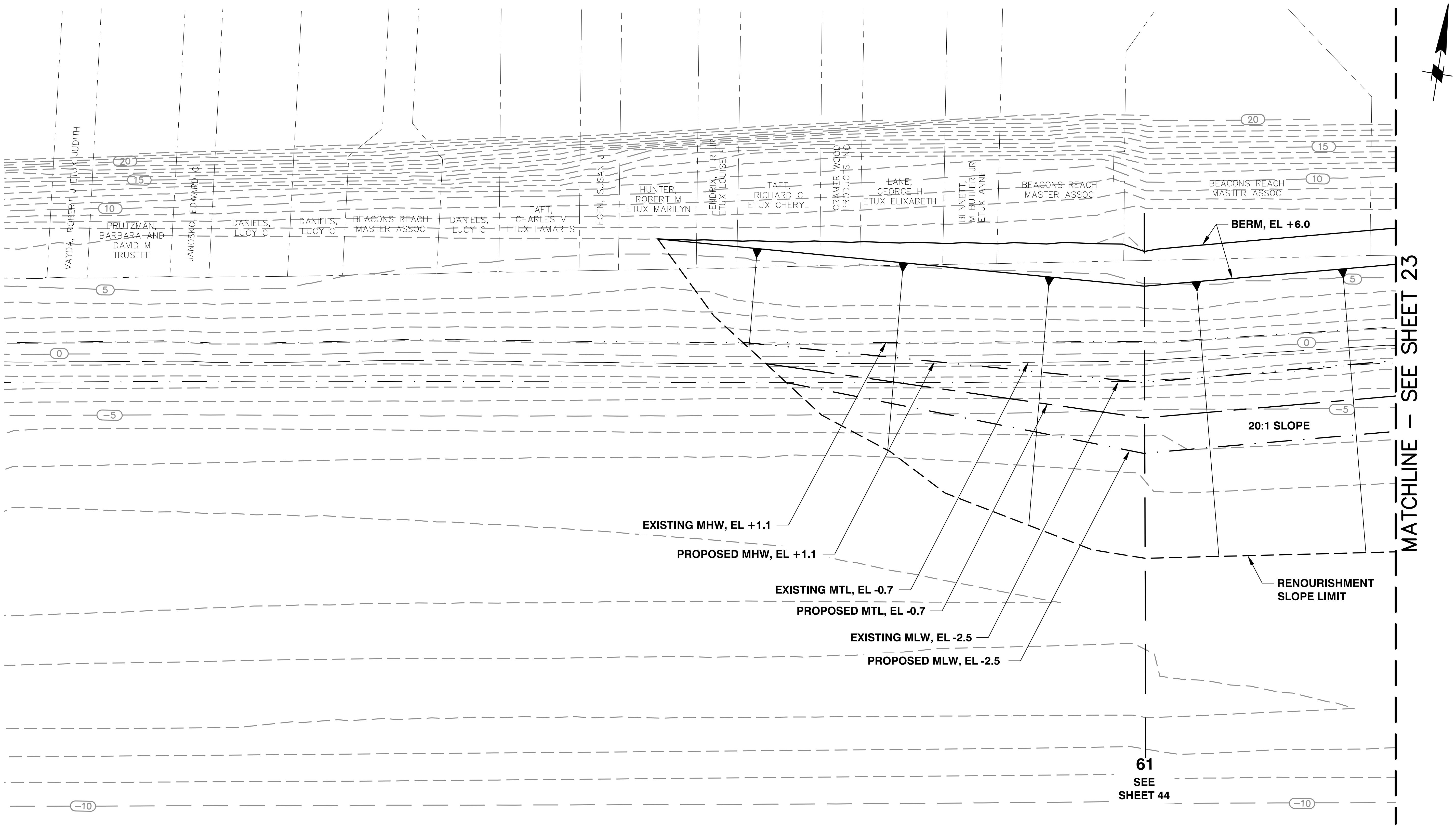
DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT PLAN
11 OF 11

0 100' 200'
1"=100'

SHEET
21
OF
48



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

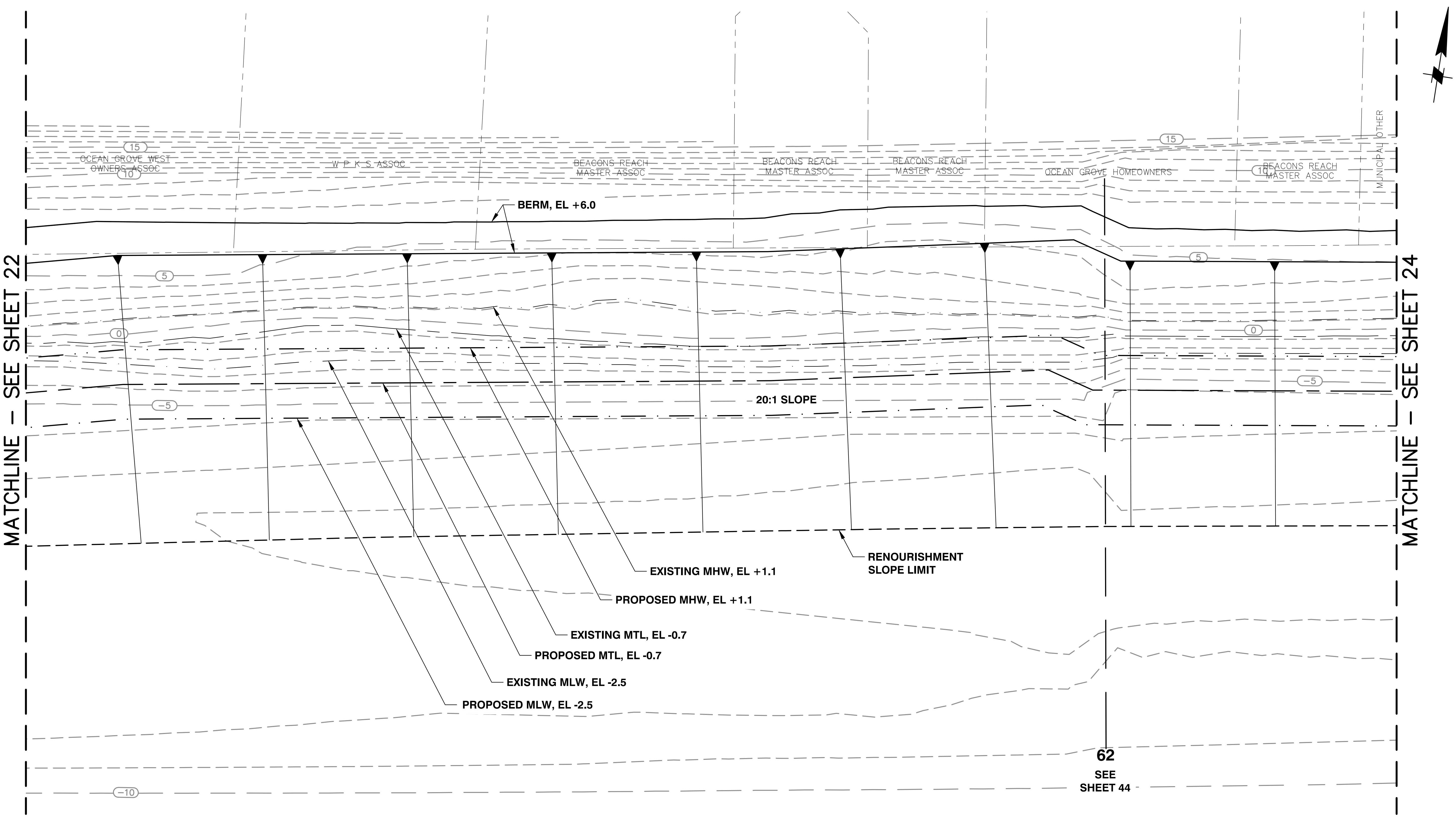
DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT PLAN
1 OF 10

0 100' 200'
1"=100'

SHEET 22 OF 48



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

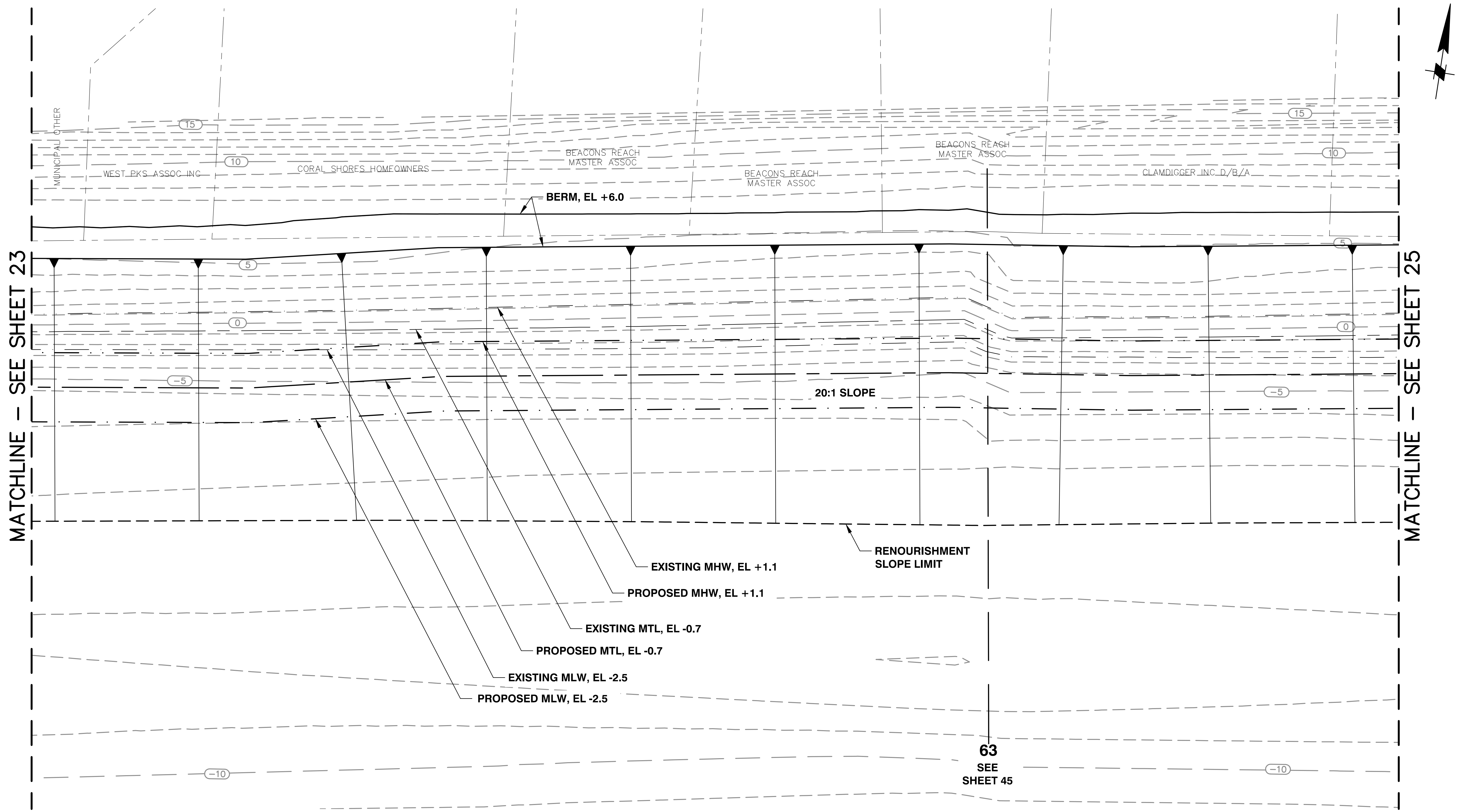
DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT PLAN
2 OF 10

0 100' 200'
1"=100'

SHEET **23** OF **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

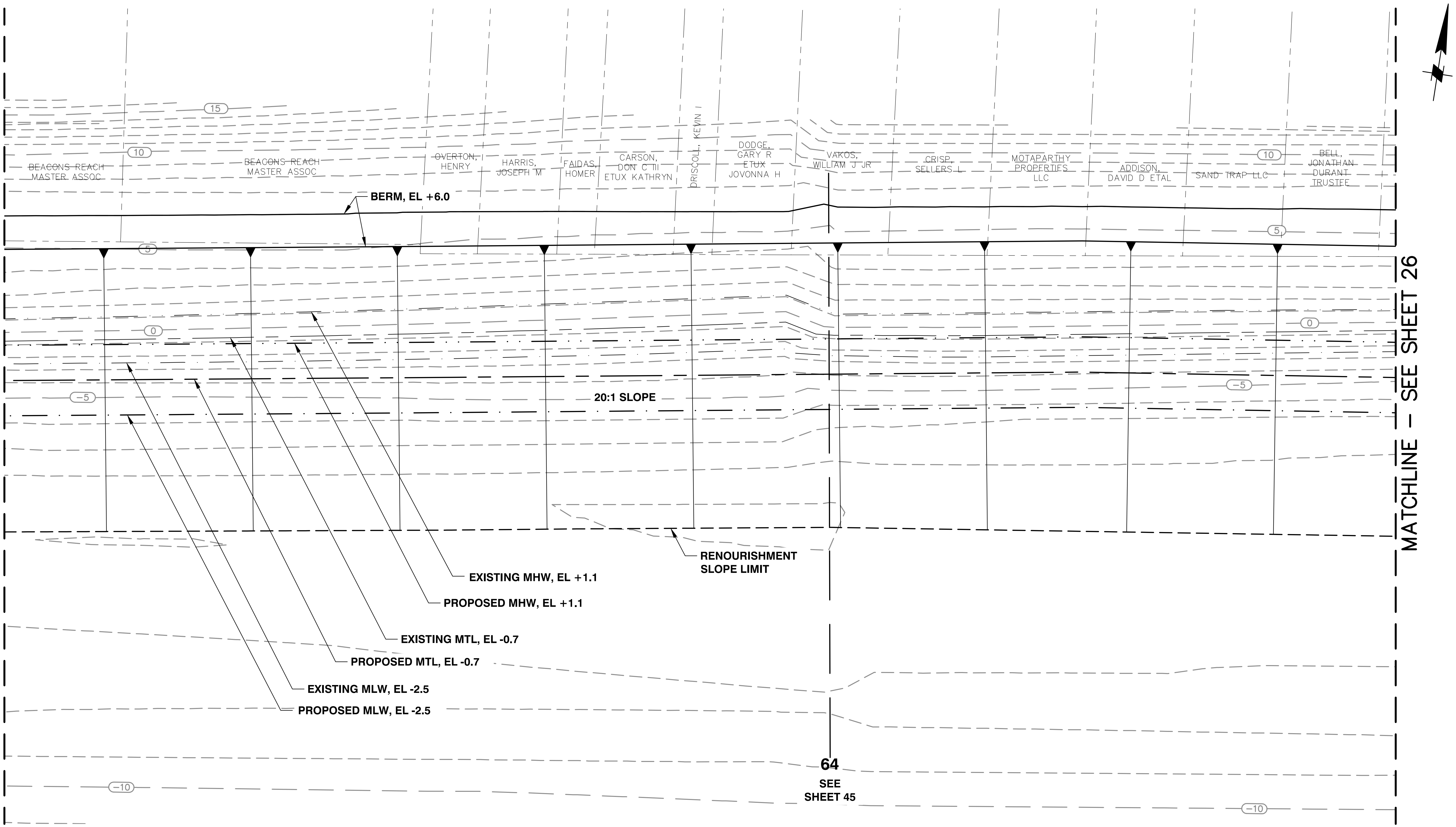
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE: **PINE KNOLL SHORES RENOURISHMENT PLAN 3 OF 10**

0 100' 200'
1"=100'

SHEET **24** OF **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

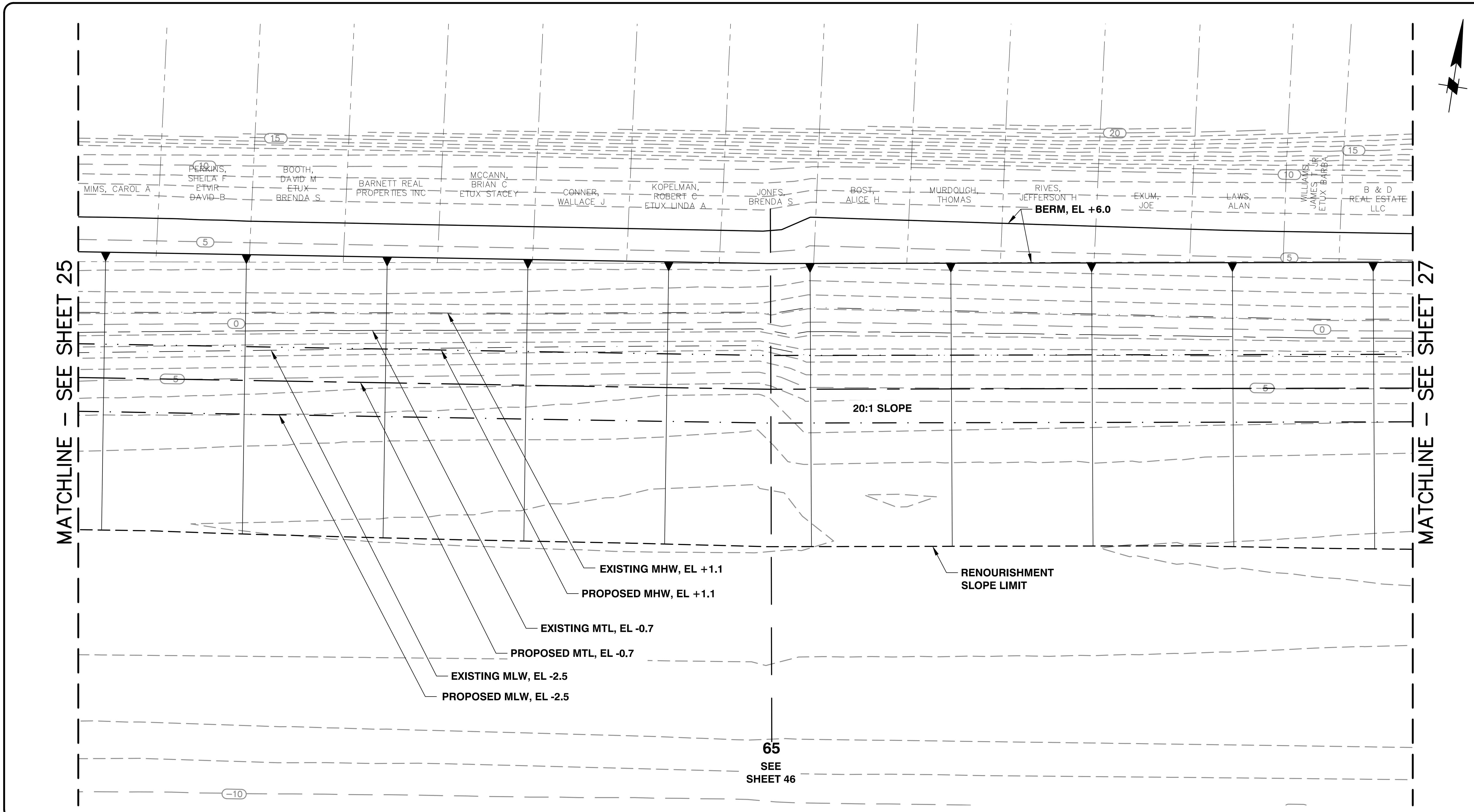
DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT PLAN
4 OF 10

0 100' 200'
1"=100'

SHEET **25** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

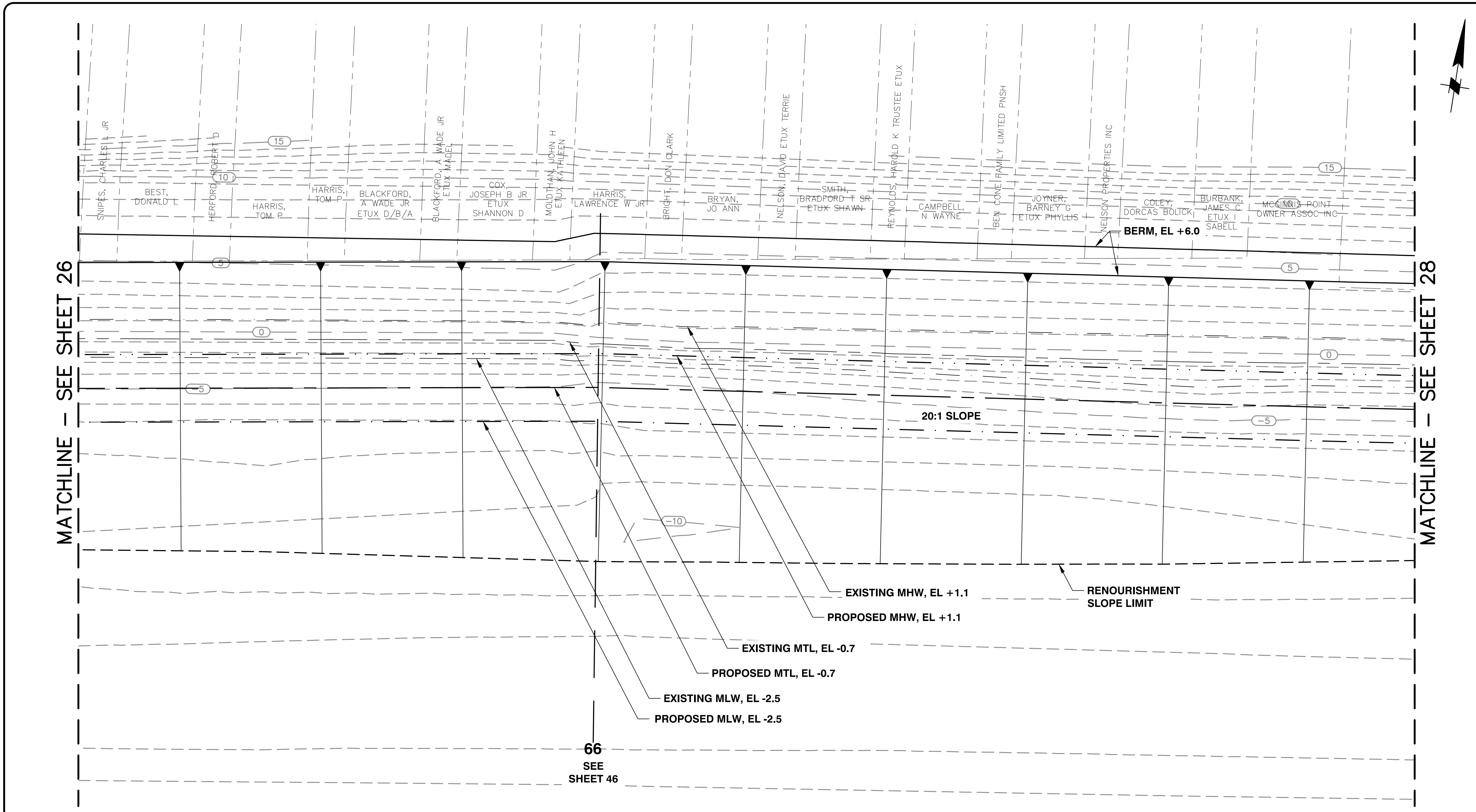
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE: **PINE KNOLL SHORES RENOURISHMENT PLAN 5 OF 10**

0 100' 200'
1"=100'

SHEET **26** OF **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

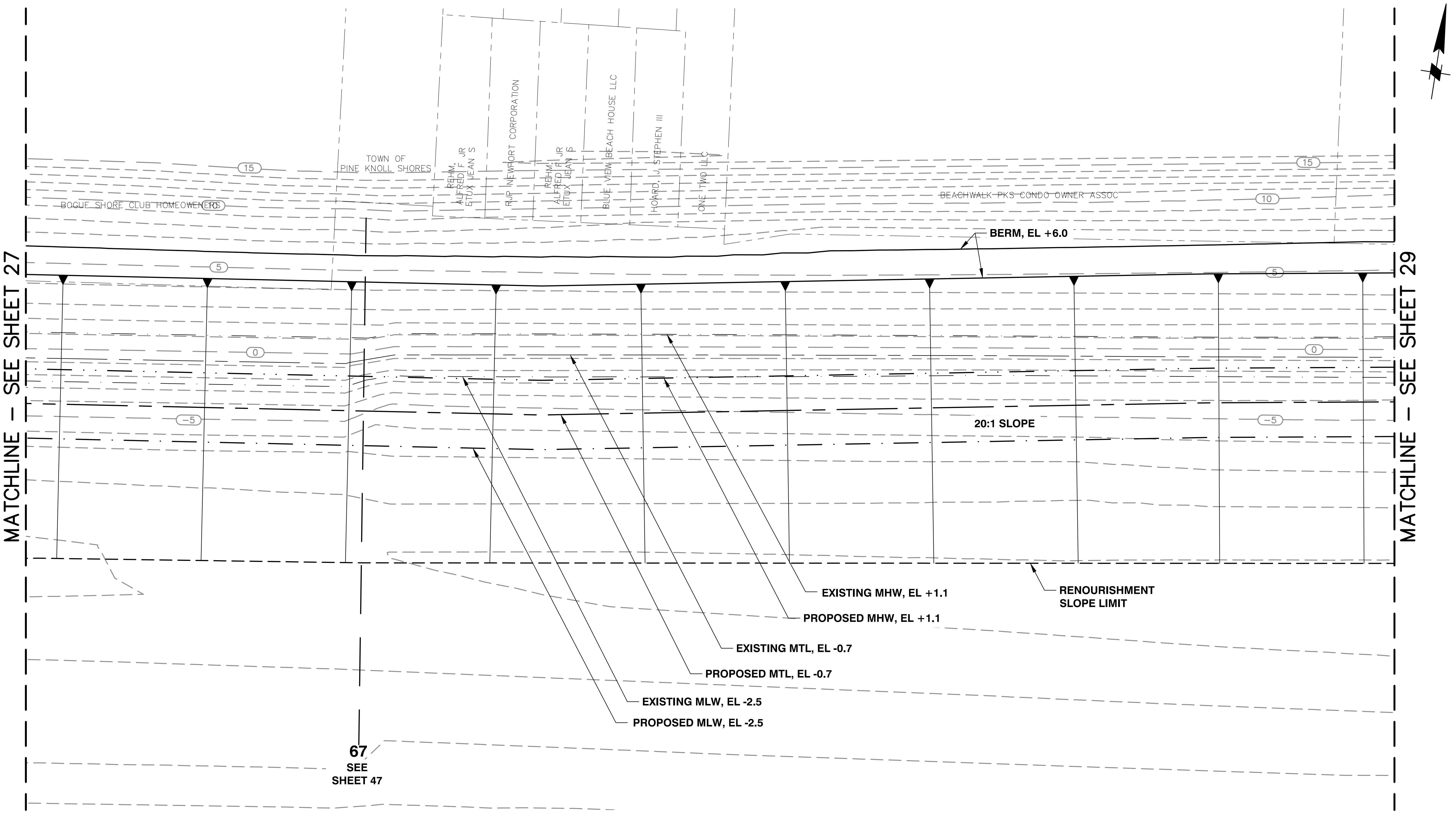
DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT PLAN
6 OF 10

0 100' 200'
1"=100'

SHEET **27** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

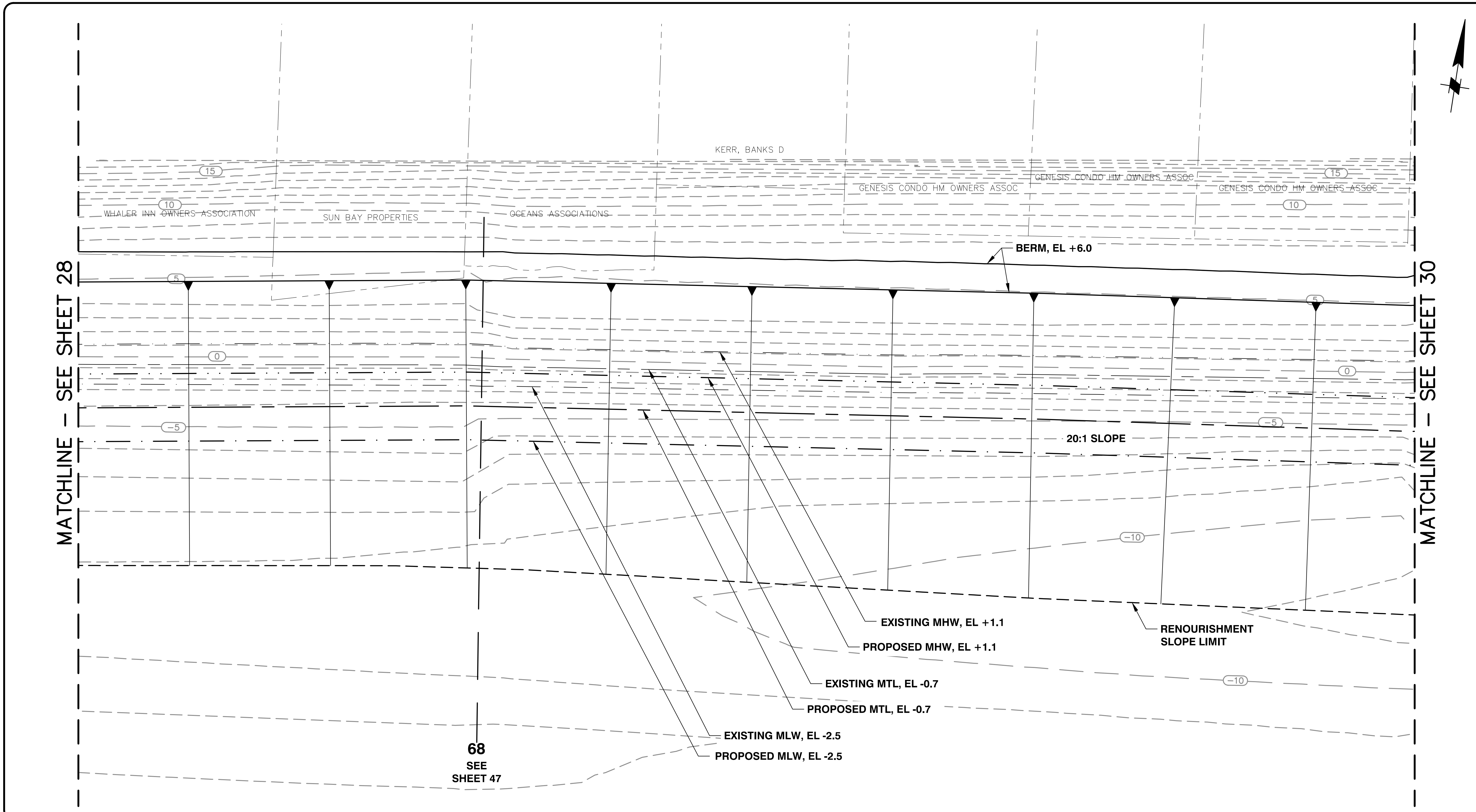
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE: **PINE KNOLL SHORES RENOURISHMENT PLAN 7 OF 10**

0 100' 200'
1"=100'

SHEET **28** OF **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

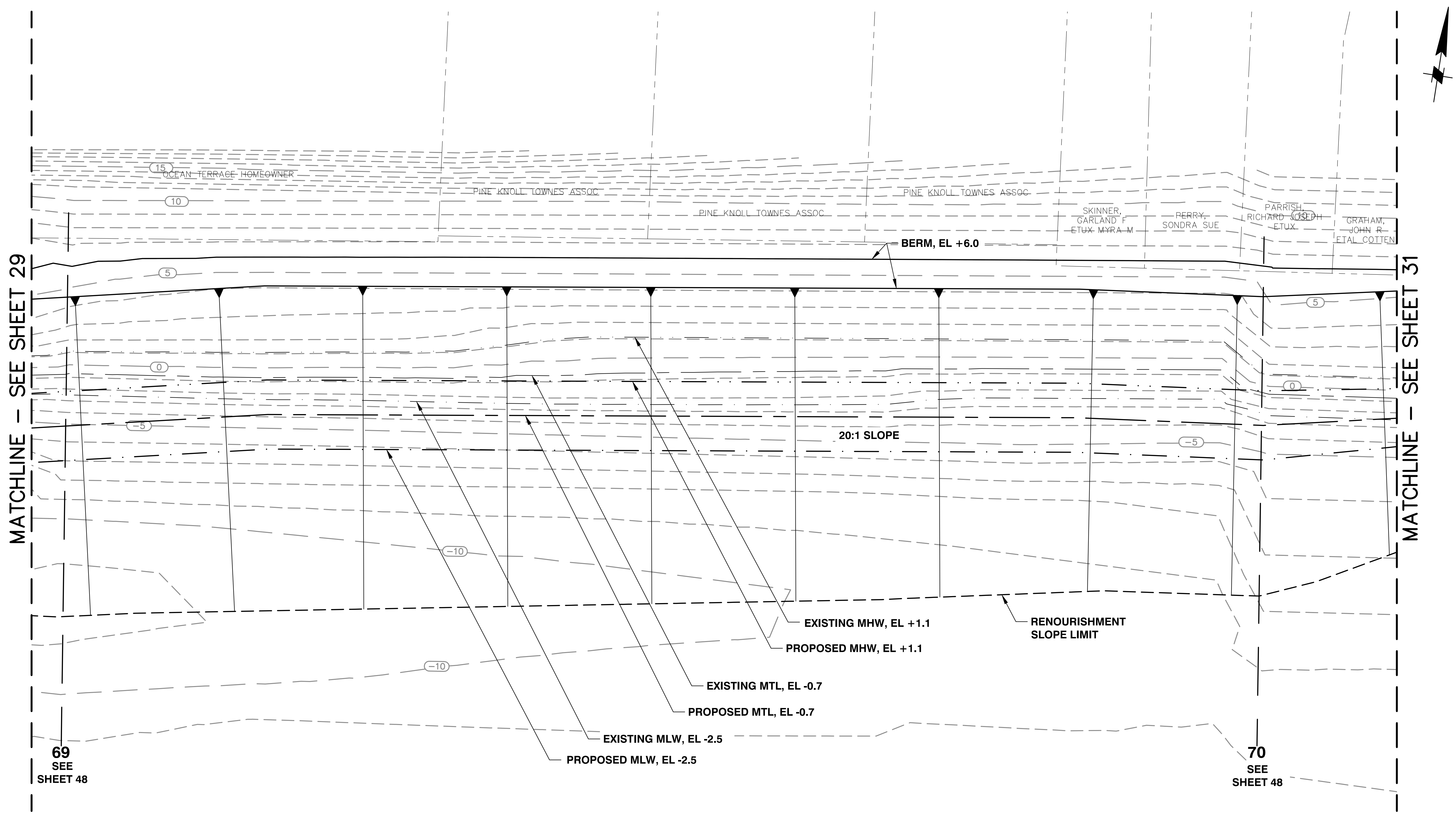
DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT PLAN
8 OF 10

0 100' 200'
1"=100'

SHEET **29** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

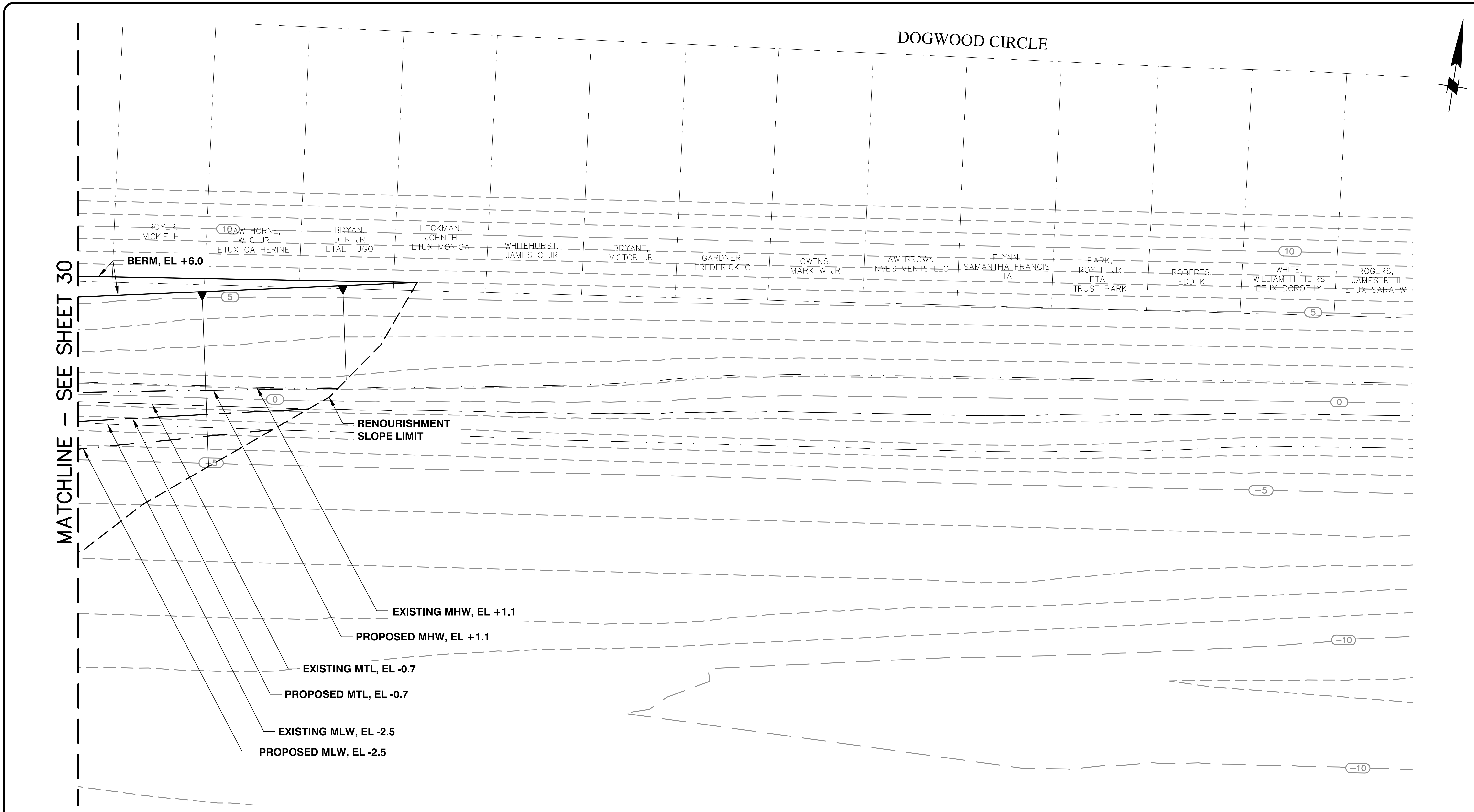
DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT PLAN
9 OF 10

0 100' 200'
1"=100'

SHEET **30** *OF* **48**



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

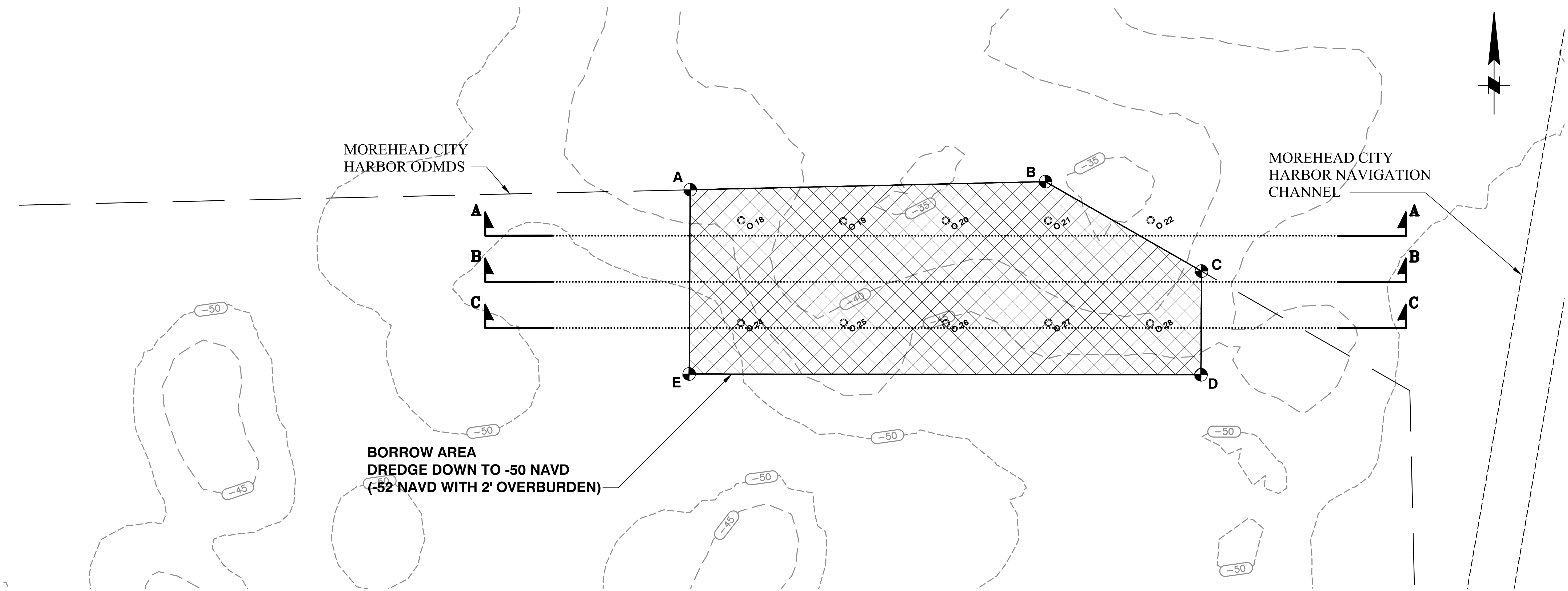
DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT PLAN 10 OF 10

0 100' 200'

1"=100'



PROPOSED BORROW AREA
COORDINATE TABLE

POINT	NORTHING	EASTING
A	332550.96	2689868.87
B	332630.61	2693337.87
C	331756.97	2694861.09
D	330745.34	2694856.17
E	330752.97	2689859.35

LEGEND

A — PROPOSED BORROW AREA CONTROL POINT

— 2011 VIBRACORE LOCATION
(SEE ATTACHMENT 1 FOR DATA SUMMARY)

NOTES

1. BATHYMETRICAL CONTOURS SHOWN BASED ON MULTIBEAM SURVEYS PERFORMED BY GEODYNAMICS IN 2011 FOR ODMDS AND 2009 FOR BEAUFORT INLET.
2. BORROW AREA COORDINATES ARE NC STATE PLANE, NAD 1983 (FEET).

PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

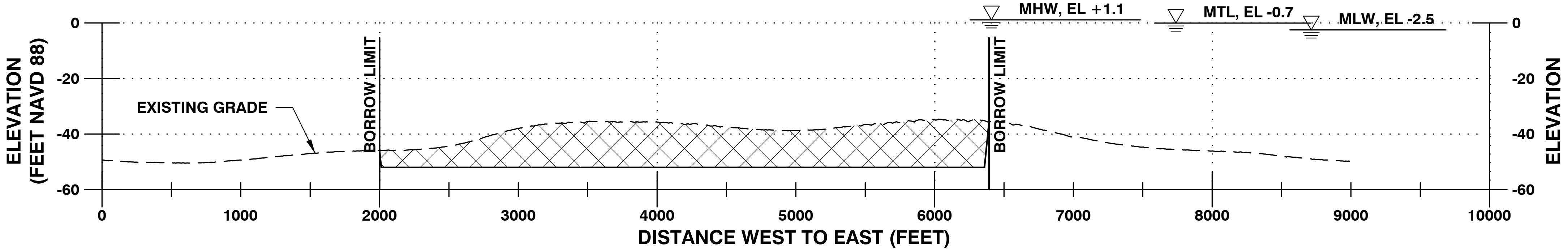
SHEET TITLE:

BORROW AREA SITE PLAN

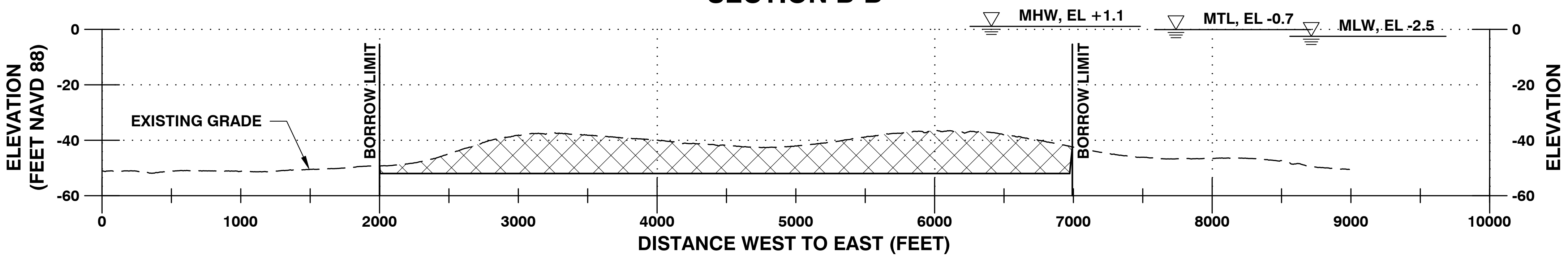
0 1000' 2000'
1"=1000'

SHEET 32 *OF* 48

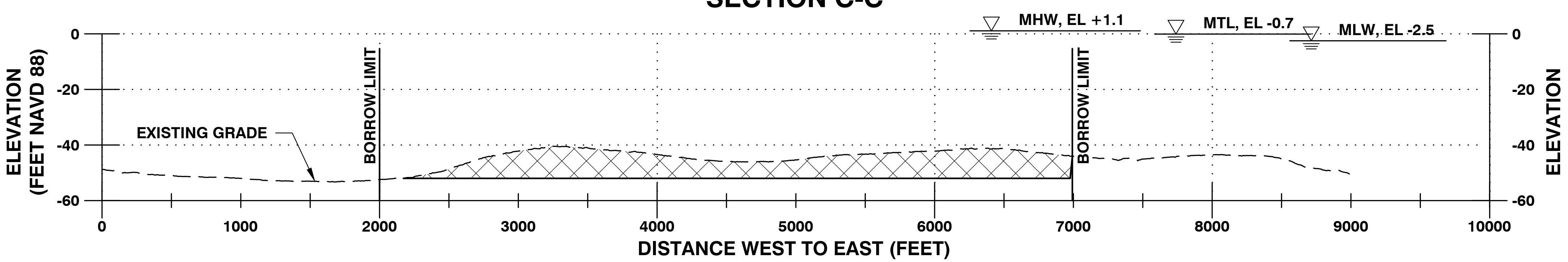
SECTION A-A



SECTION B-B



SECTION C-C



NOTE

TYPICAL EXCAVATION DEPTH VIA HOPPER DREDGE WILL BE 3 FEET PER PASS (INCOMPLETE CUTS).

PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

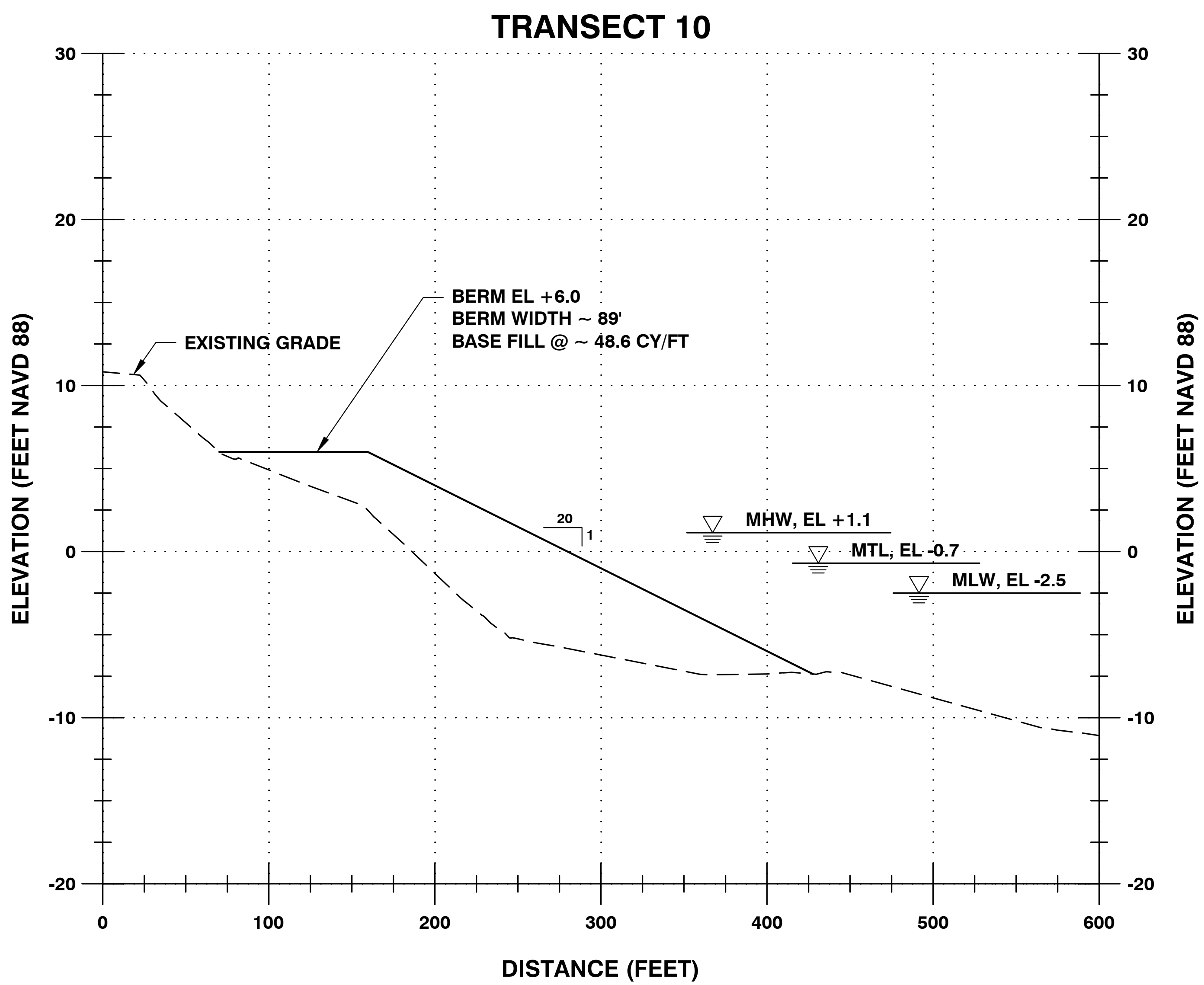
DATUM: **NAVD 88 (FT)**

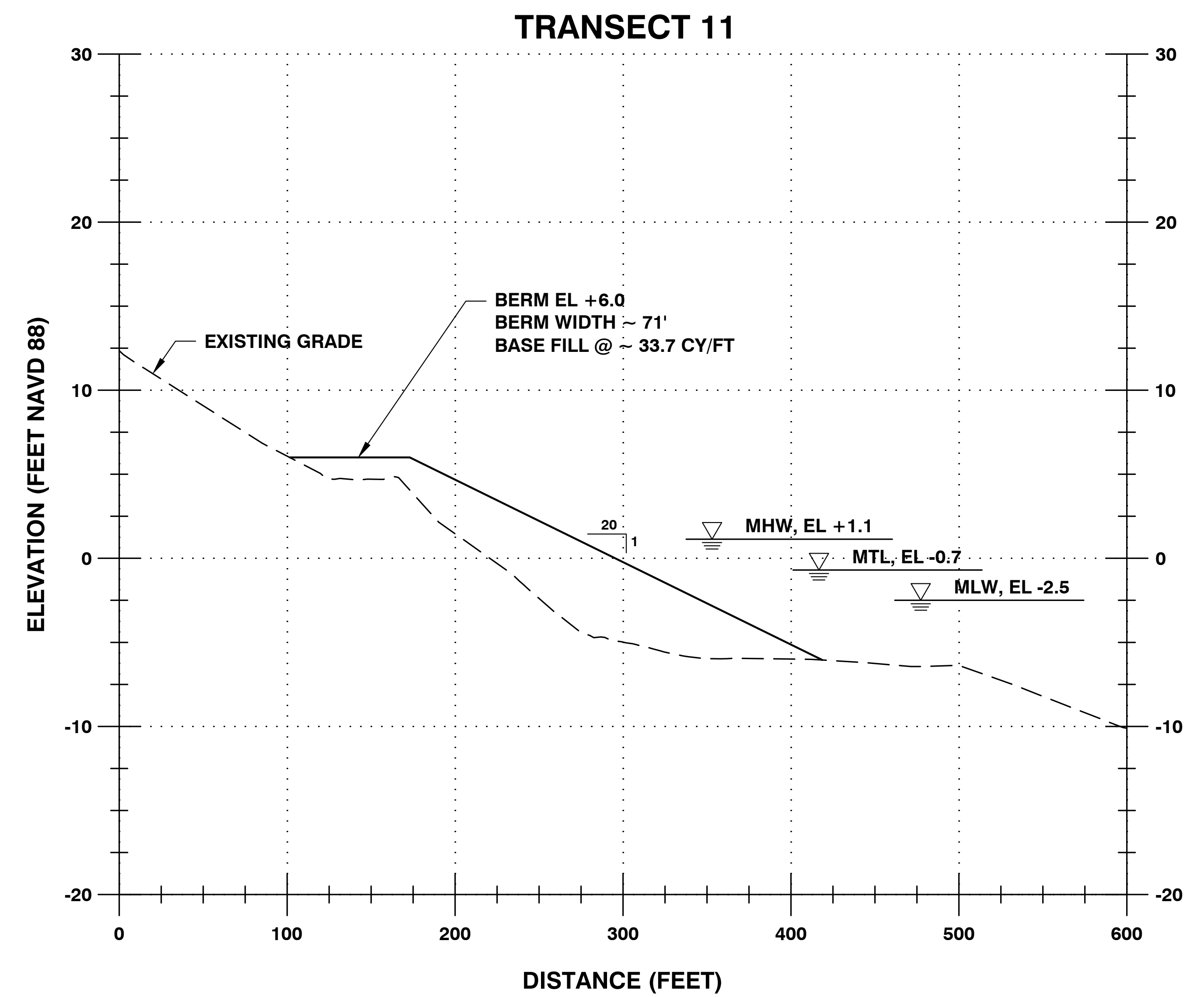
PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE: **BORROW AREA TYPICAL SECTIONS**





PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

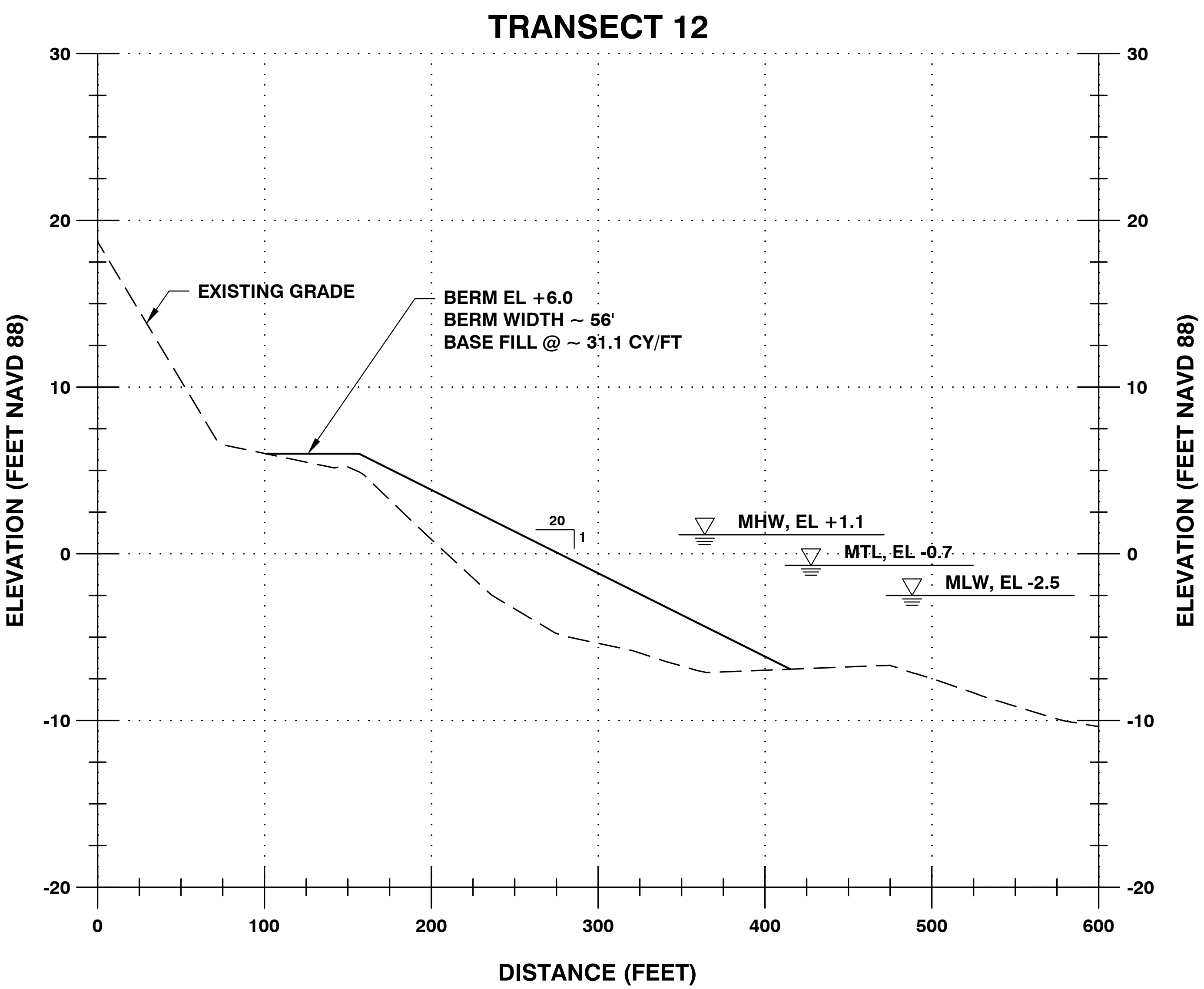
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

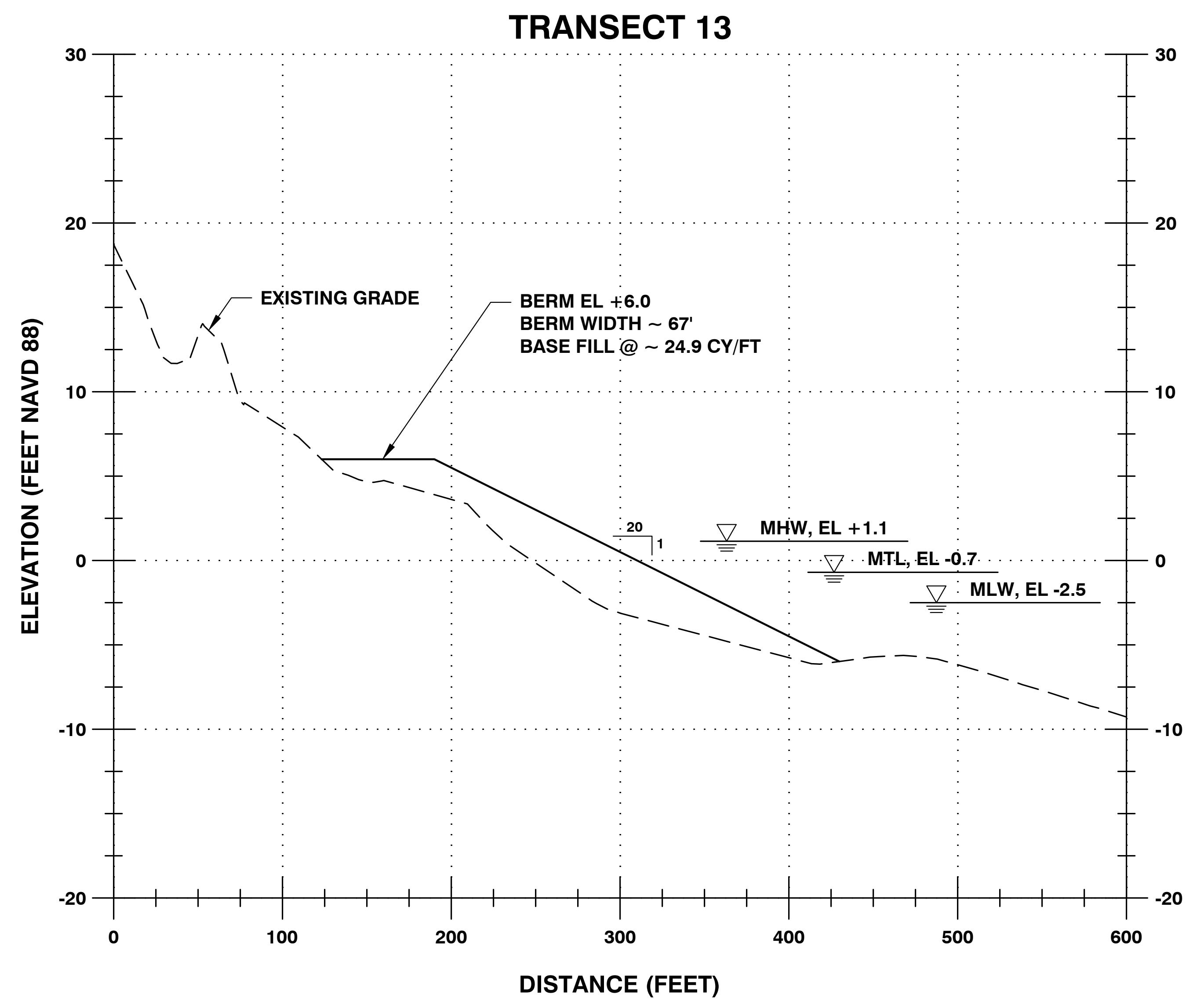
DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE WEST RENOURISHMENT CROSS SECTIONS TRANSECTS 10 AND 11

SHEET **34** *OF* **48**





PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

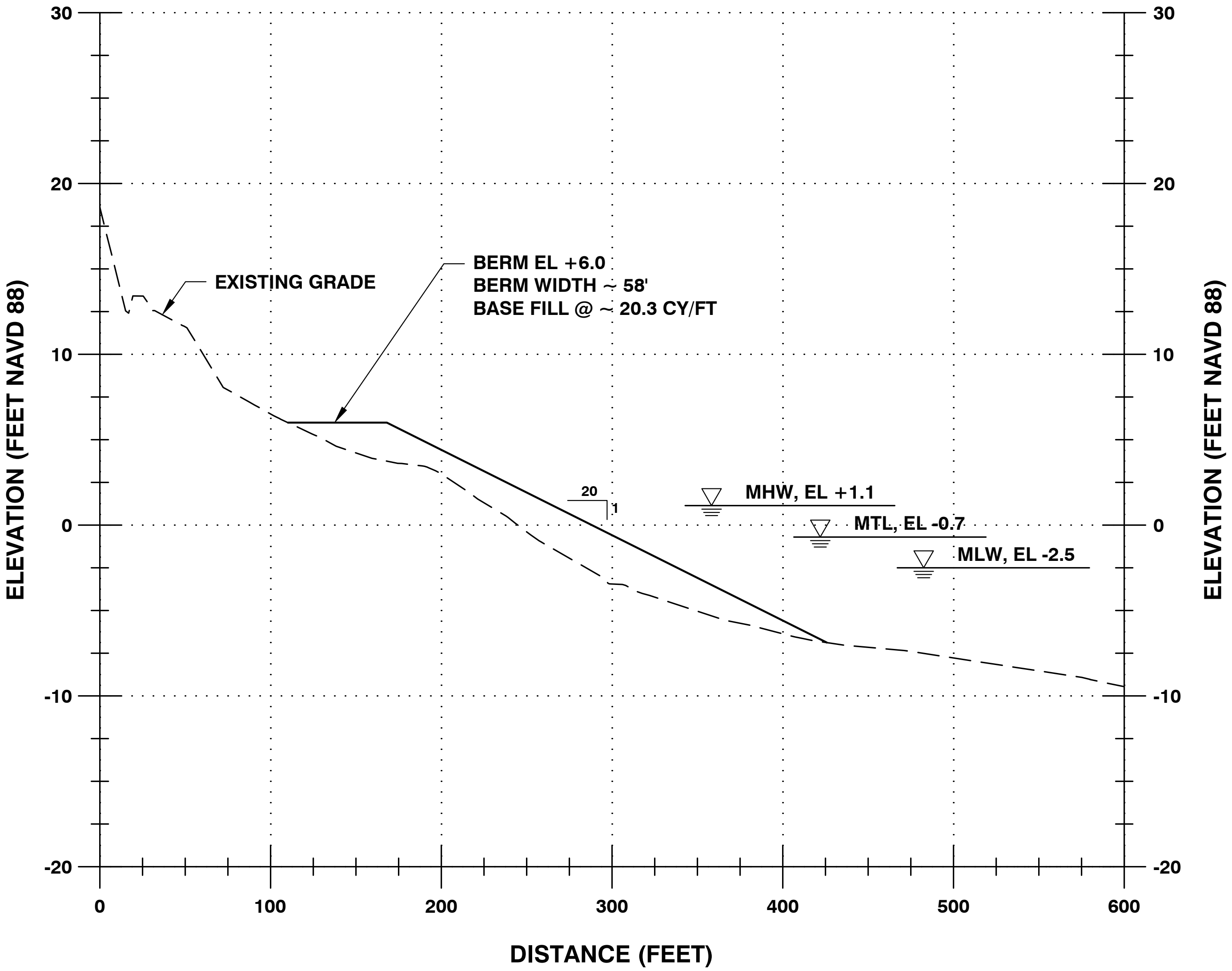
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

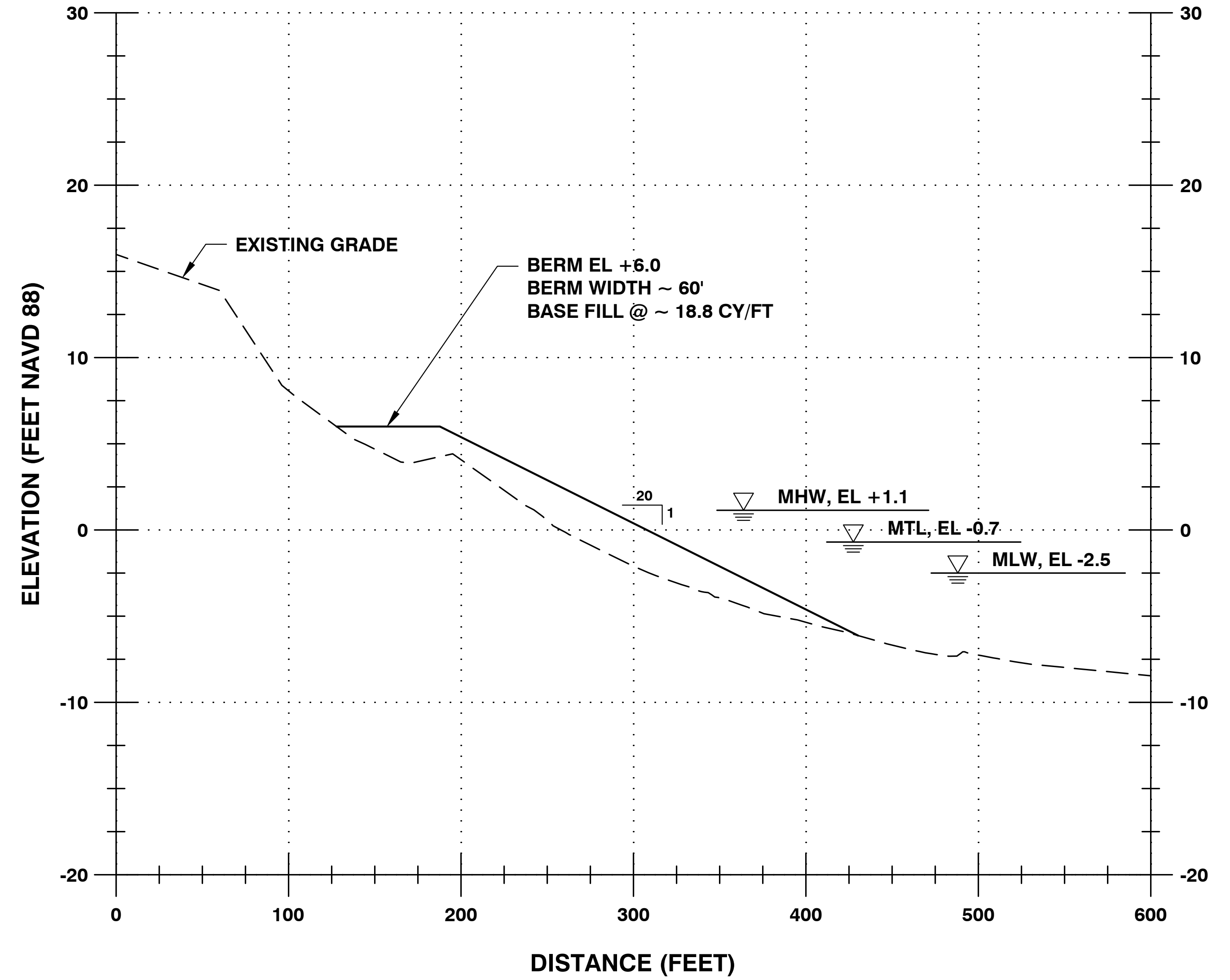
SHEET TITLE:

EMERALD ISLE WEST RENOURISHMENT CROSS SECTIONS TRANSECTS 12 AND 13

TRANSECT 14



TRANSECT 15



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

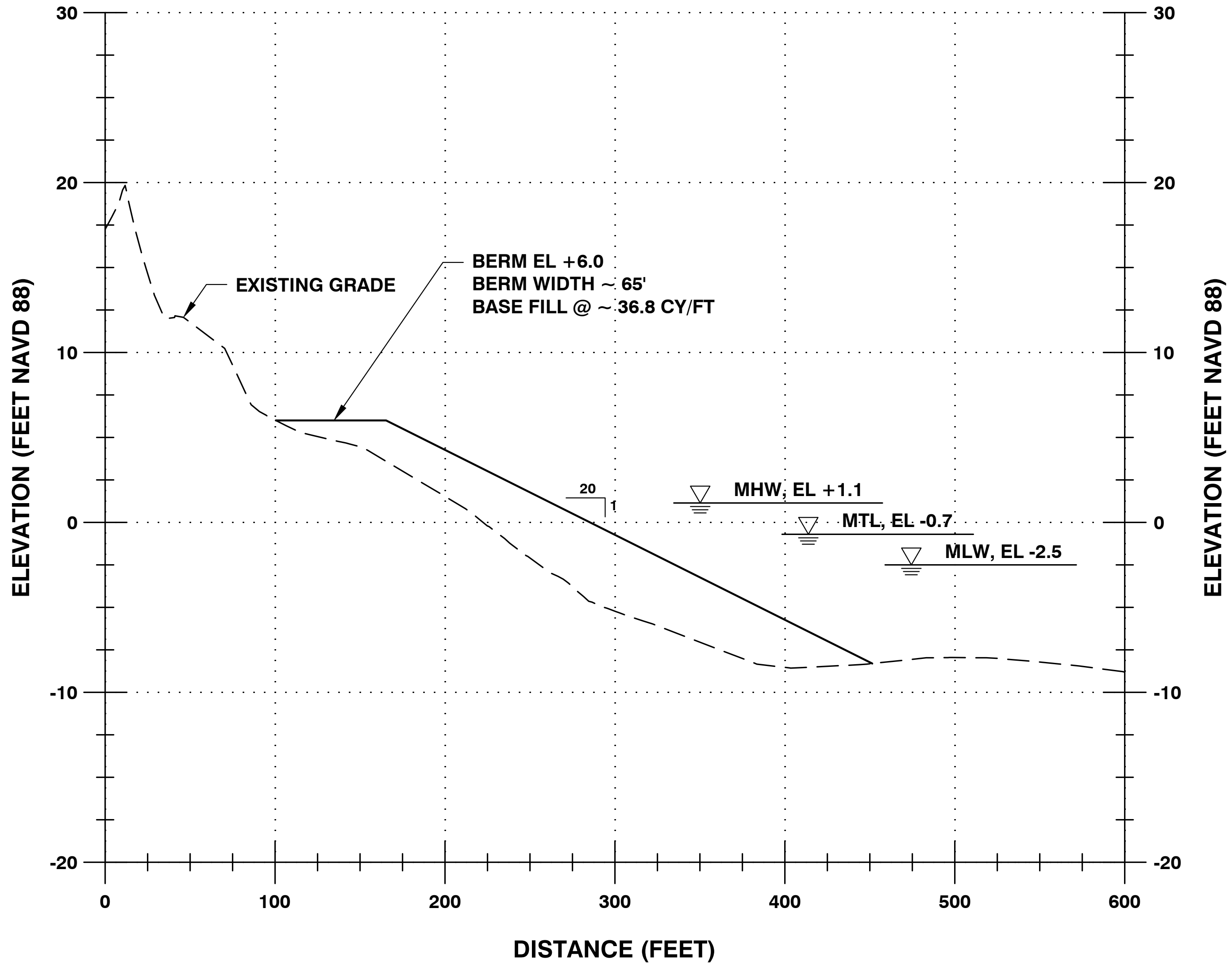
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE WEST RENOURISHMENT CROSS SECTIONS TRANSECTS 14 AND 15

TRANSECT 16



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

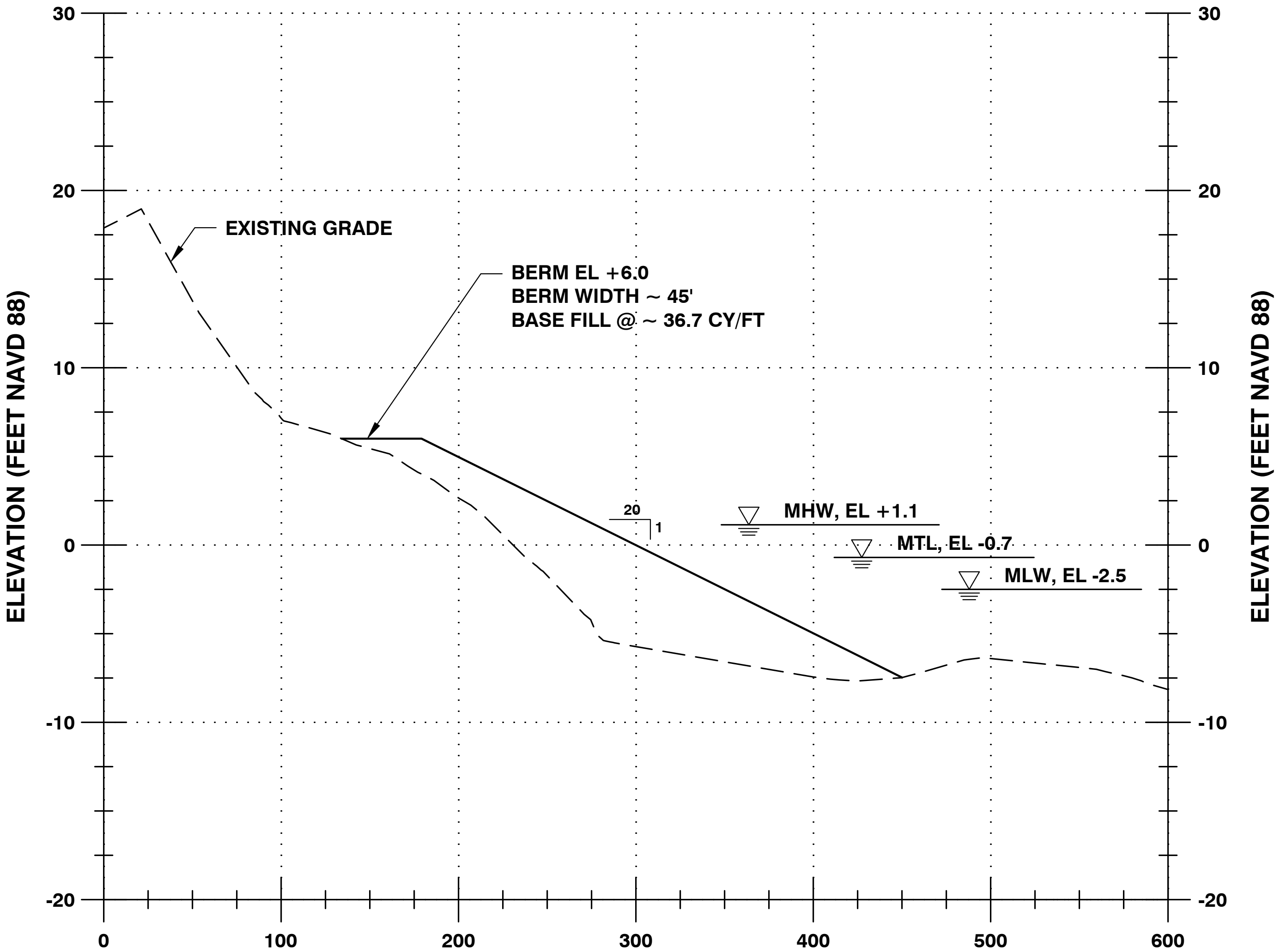
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

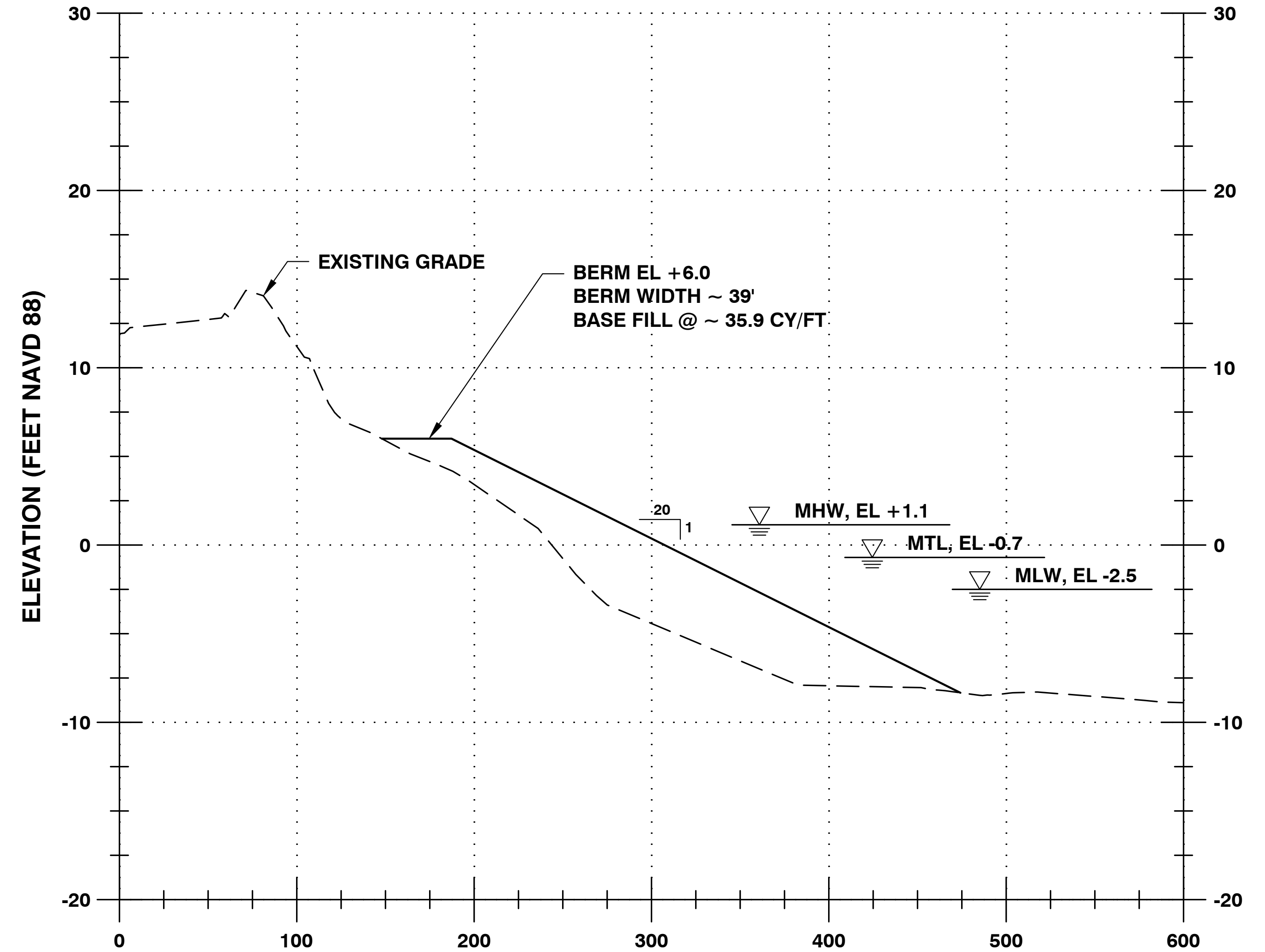
SHEET TITLE: **EMERALD ISLE WEST RENOURISHMENT CROSS SECTIONS TRANSECT 16**

SHEET **37** OF **48**

TRANSECT 35



TRANSECT 36



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

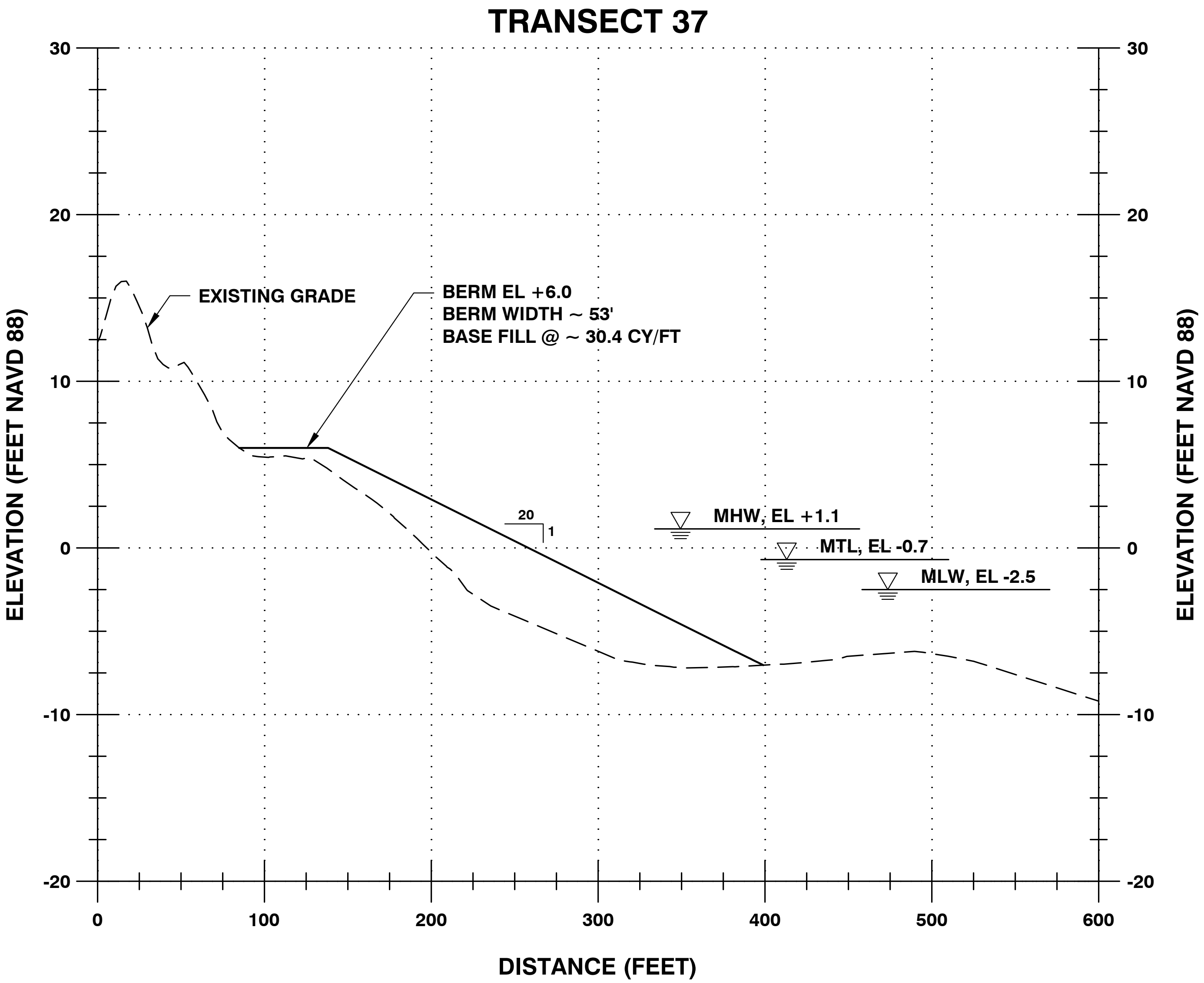
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

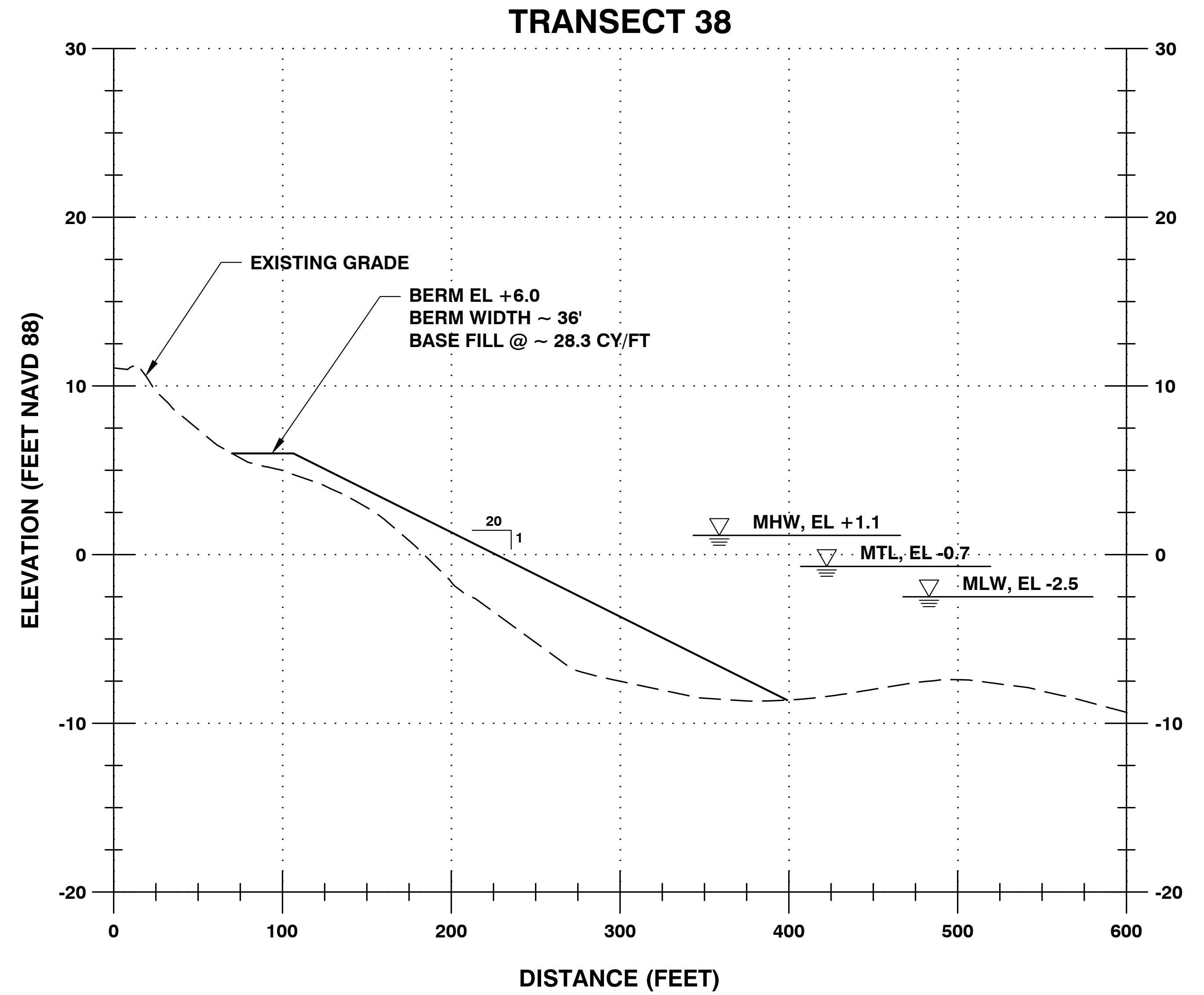
DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT CROSS SECTIONS TRANSECTS 35 AND 36

SHEET **38** *OF* **48**





PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

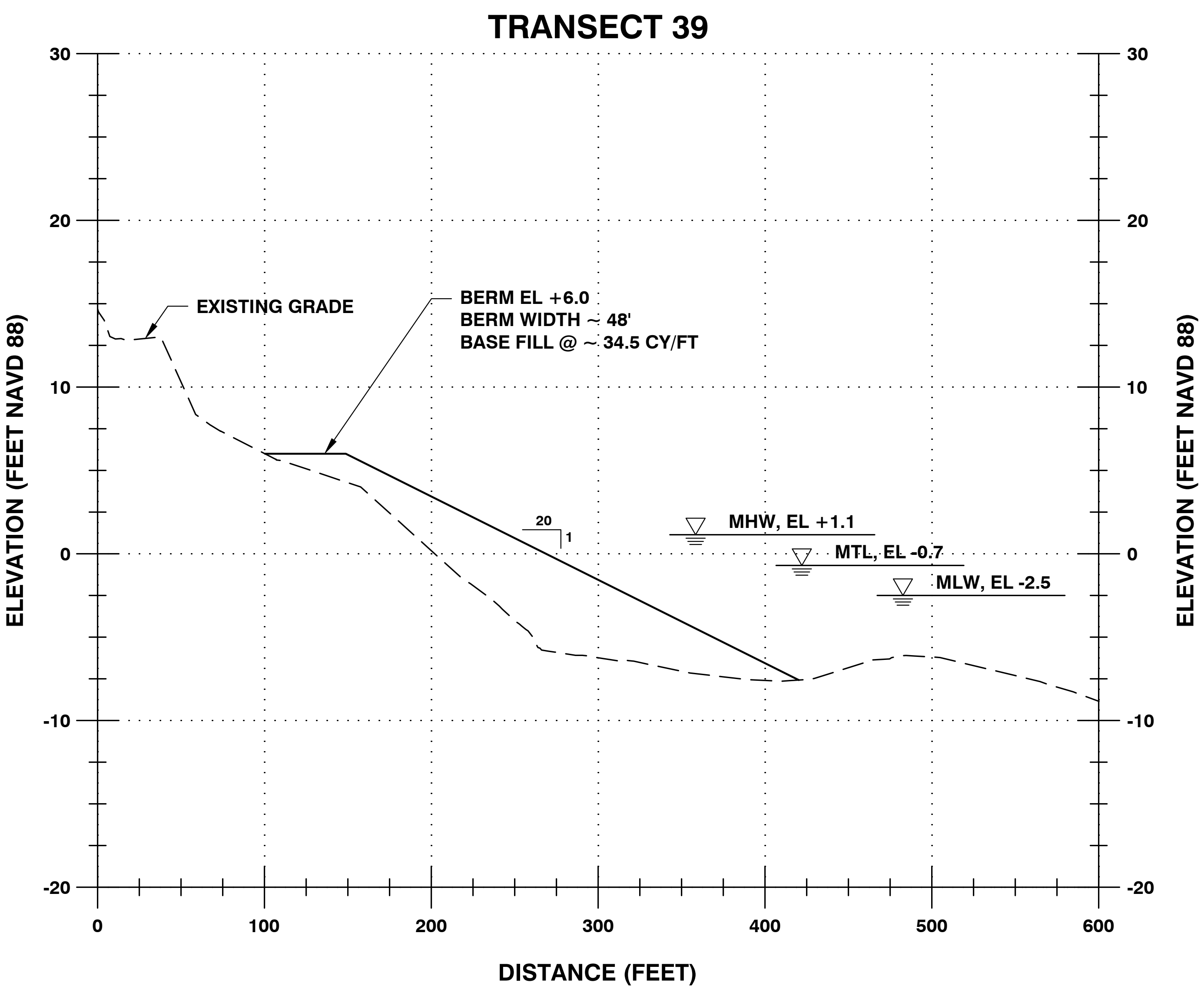
PREPARED BY: **MOFFATT & NICHOL**

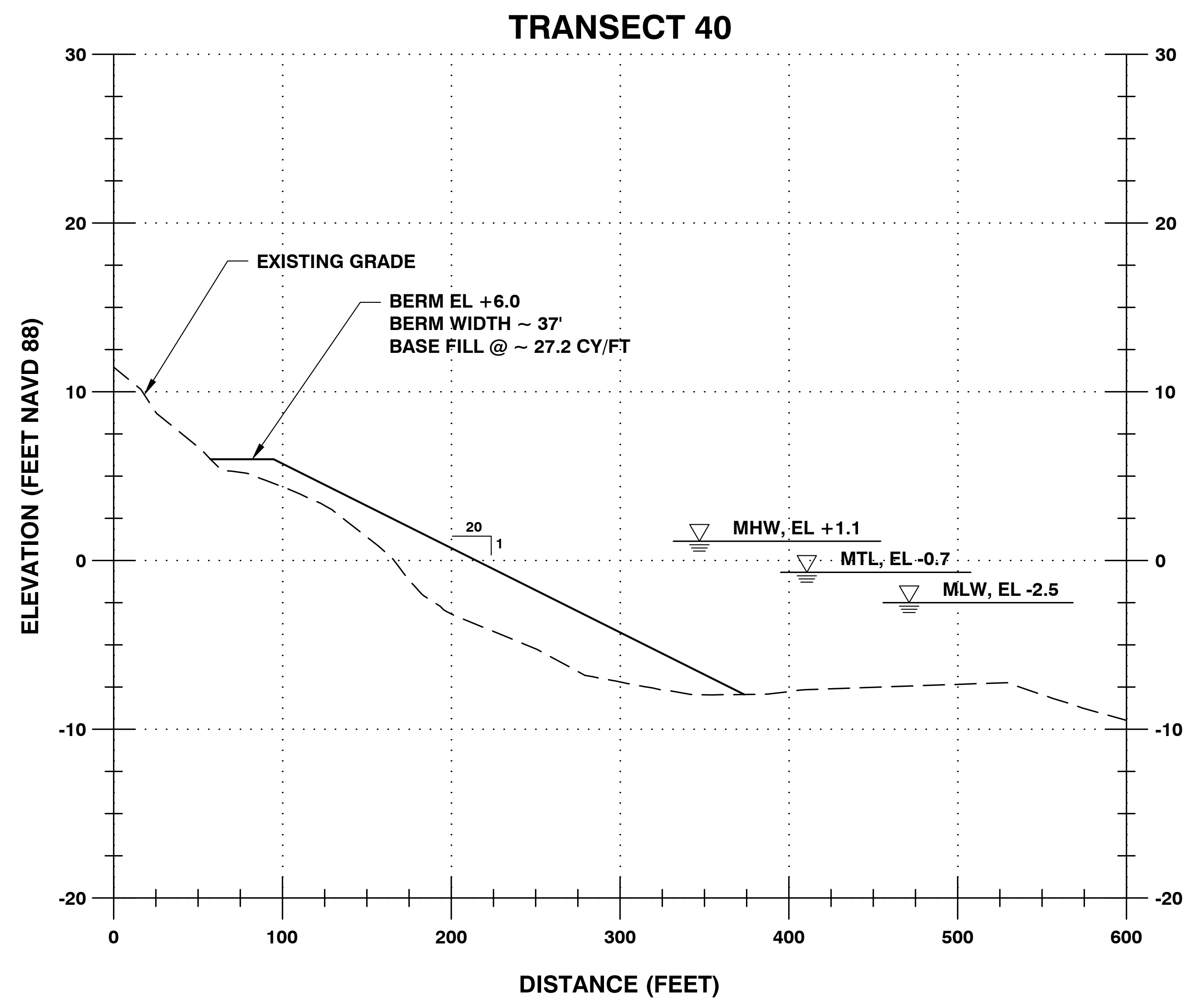
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT CROSS SECTIONS TRANSECTS 37 AND 38





PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

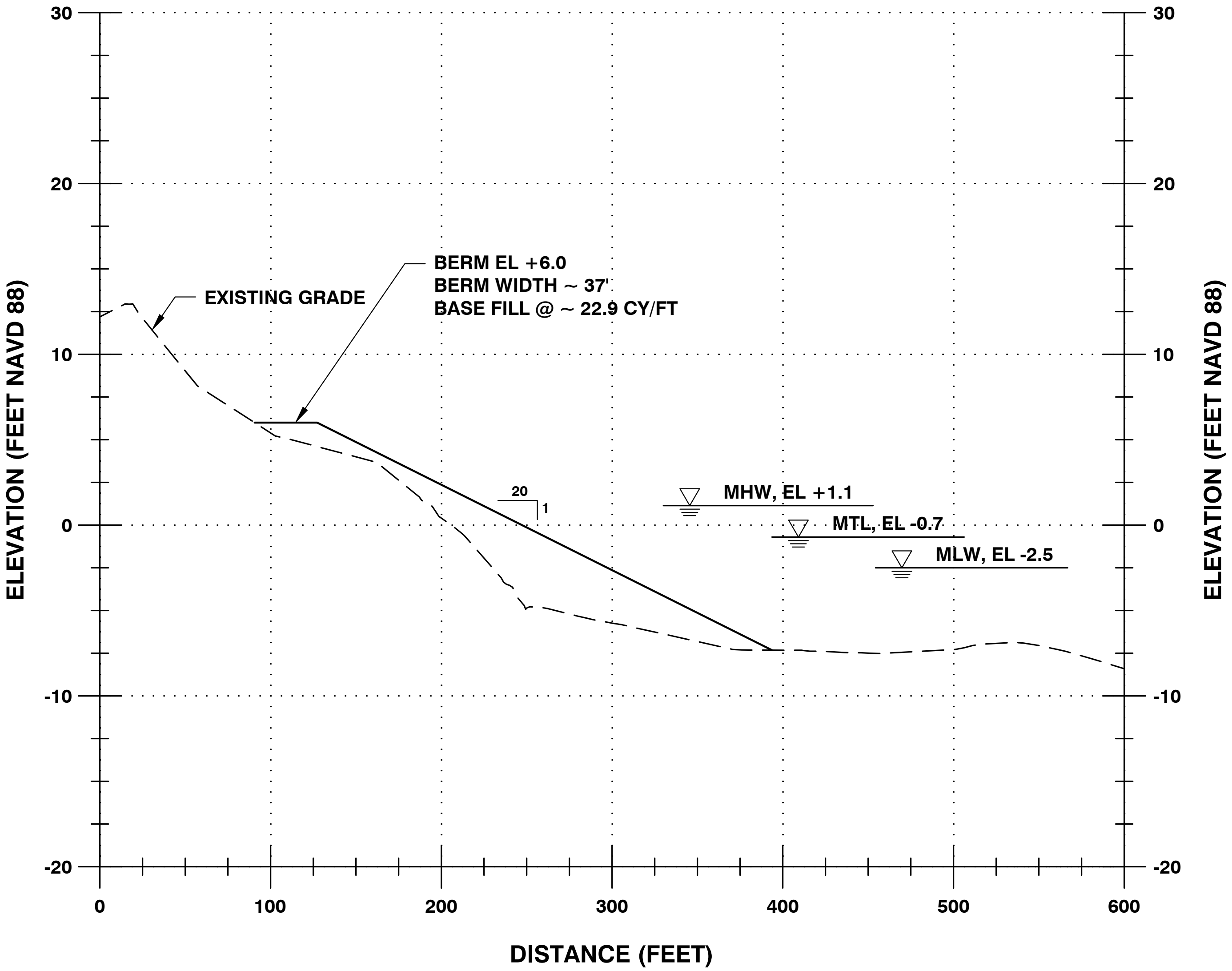
DATE: **FEBRUARY 2012**

SHEET TITLE:

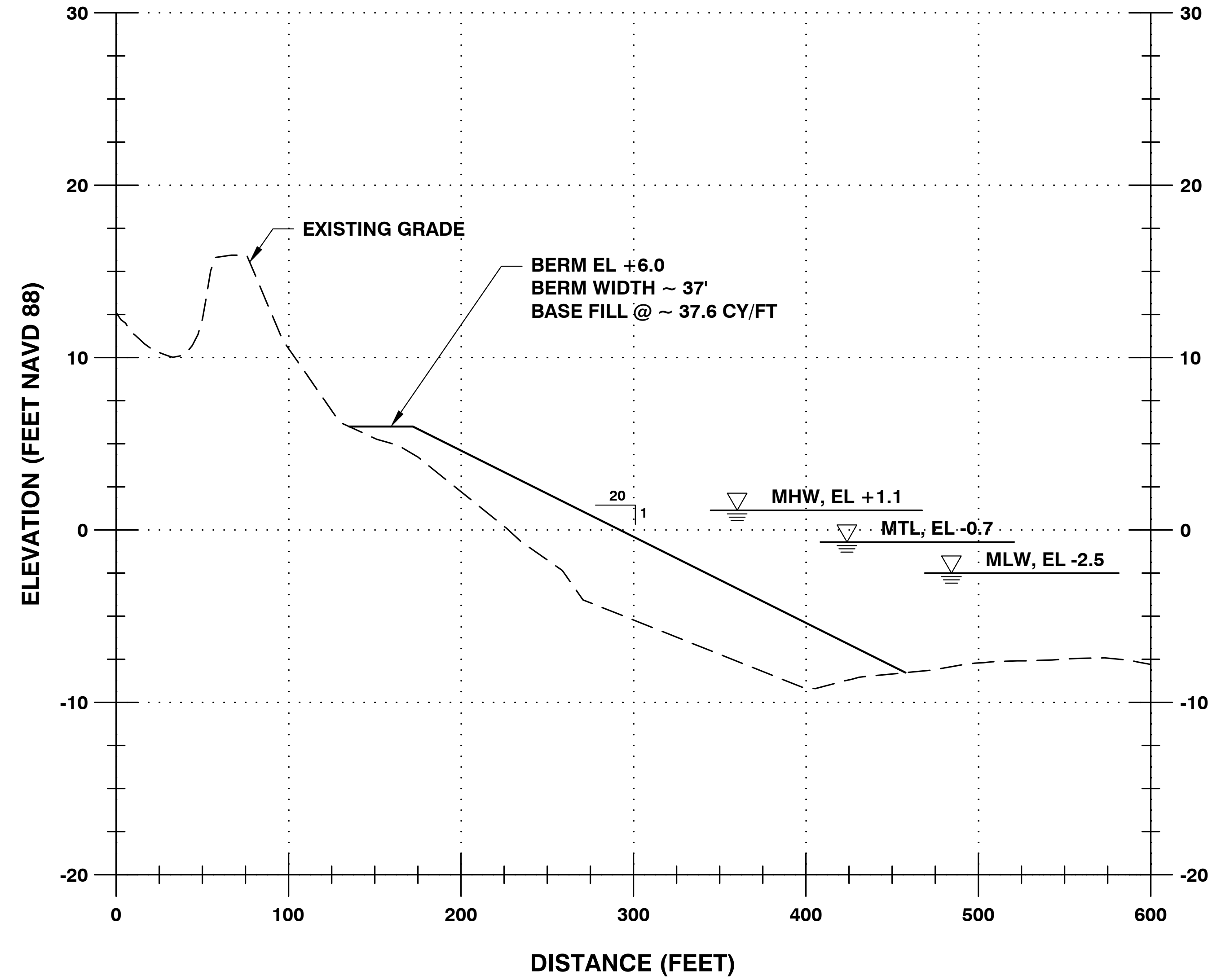
EMERALD ISLE EAST RENOURISHMENT CROSS SECTIONS TRANSECTS 39 AND 40

SHEET **40** *OF* **48**

TRANSECT 41



TRANSECT 42



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

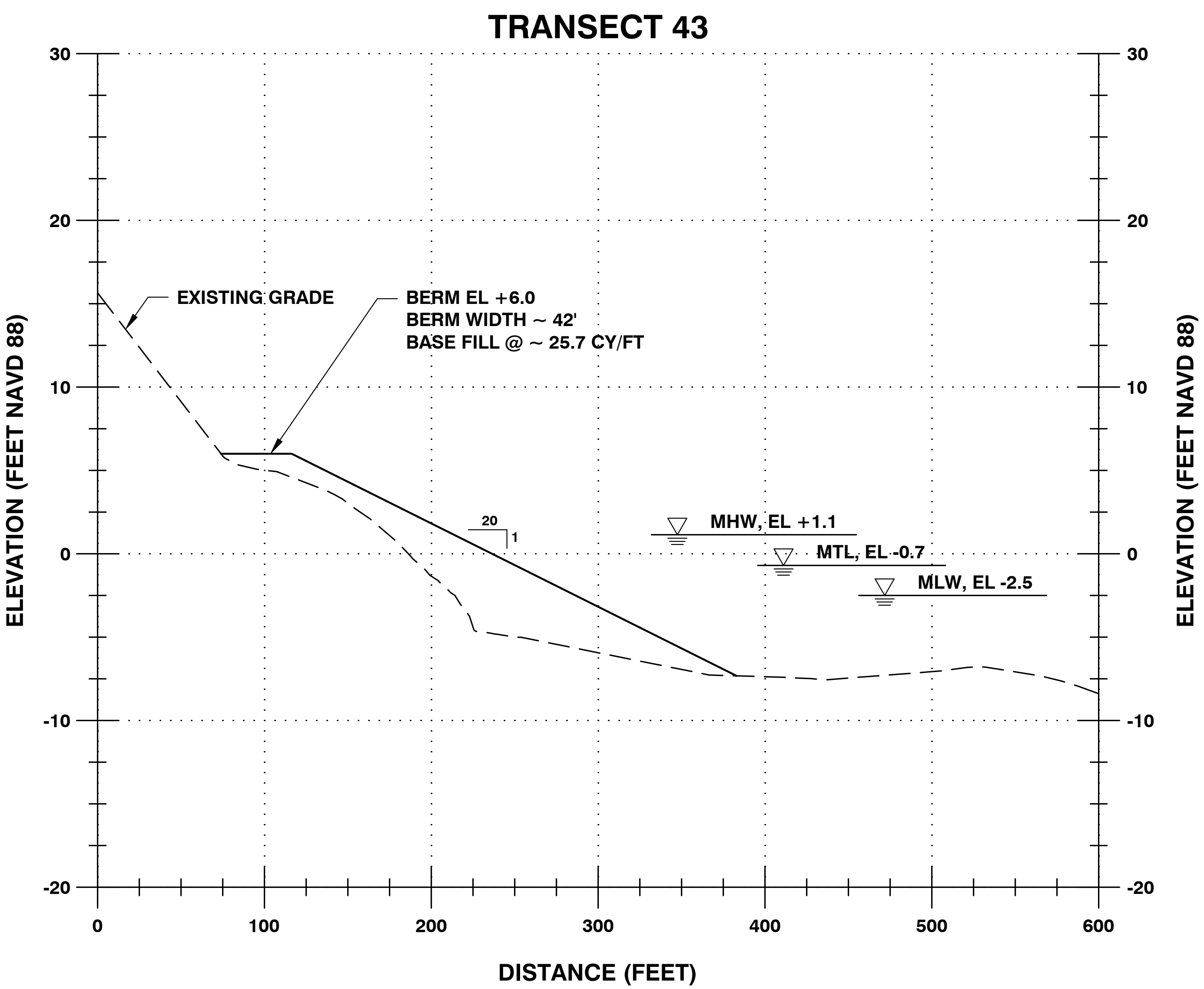
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

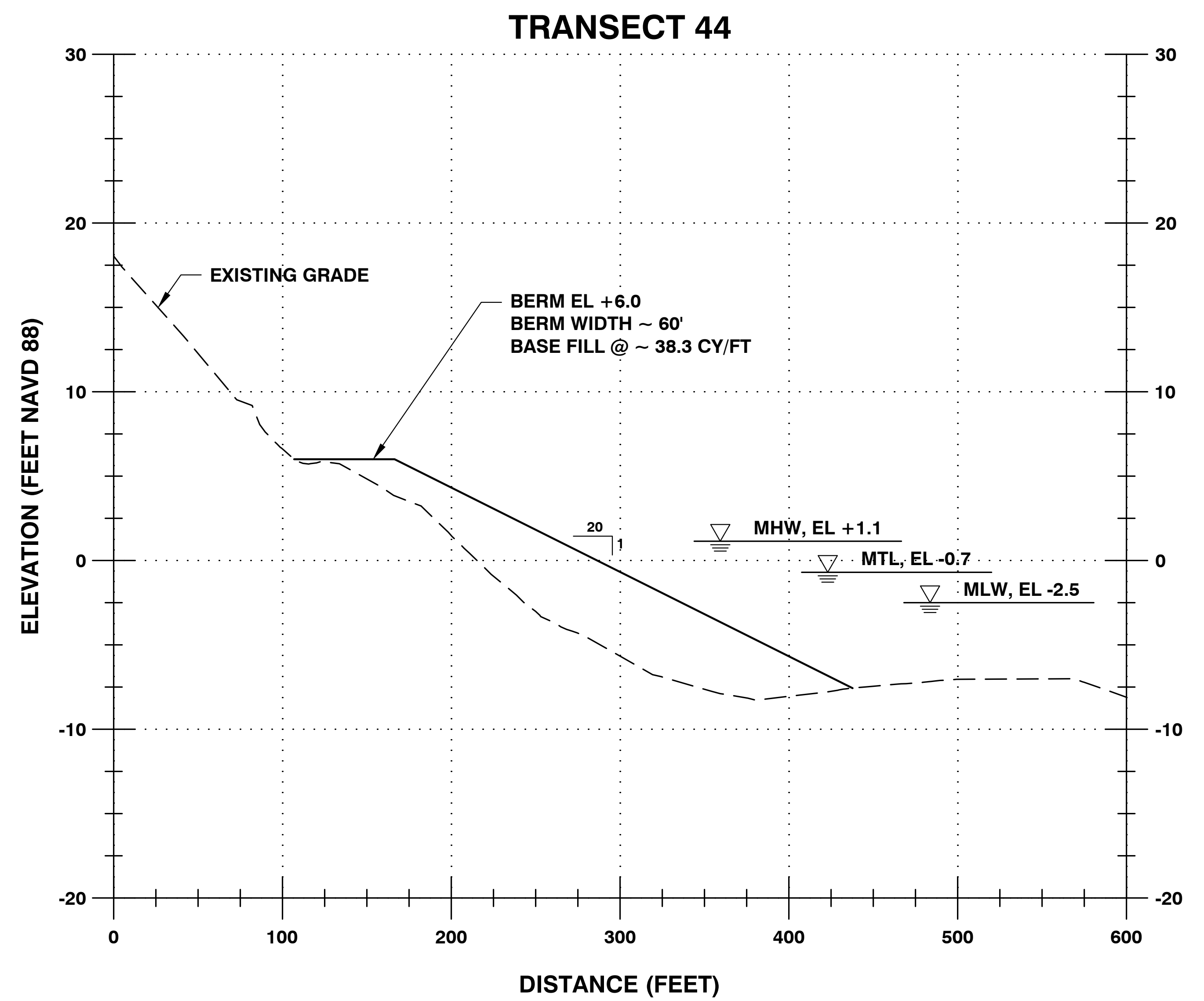
DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT CROSS SECTIONS TRANSECTS 41 AND 42

SHEET **41** *OF* **48**





PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

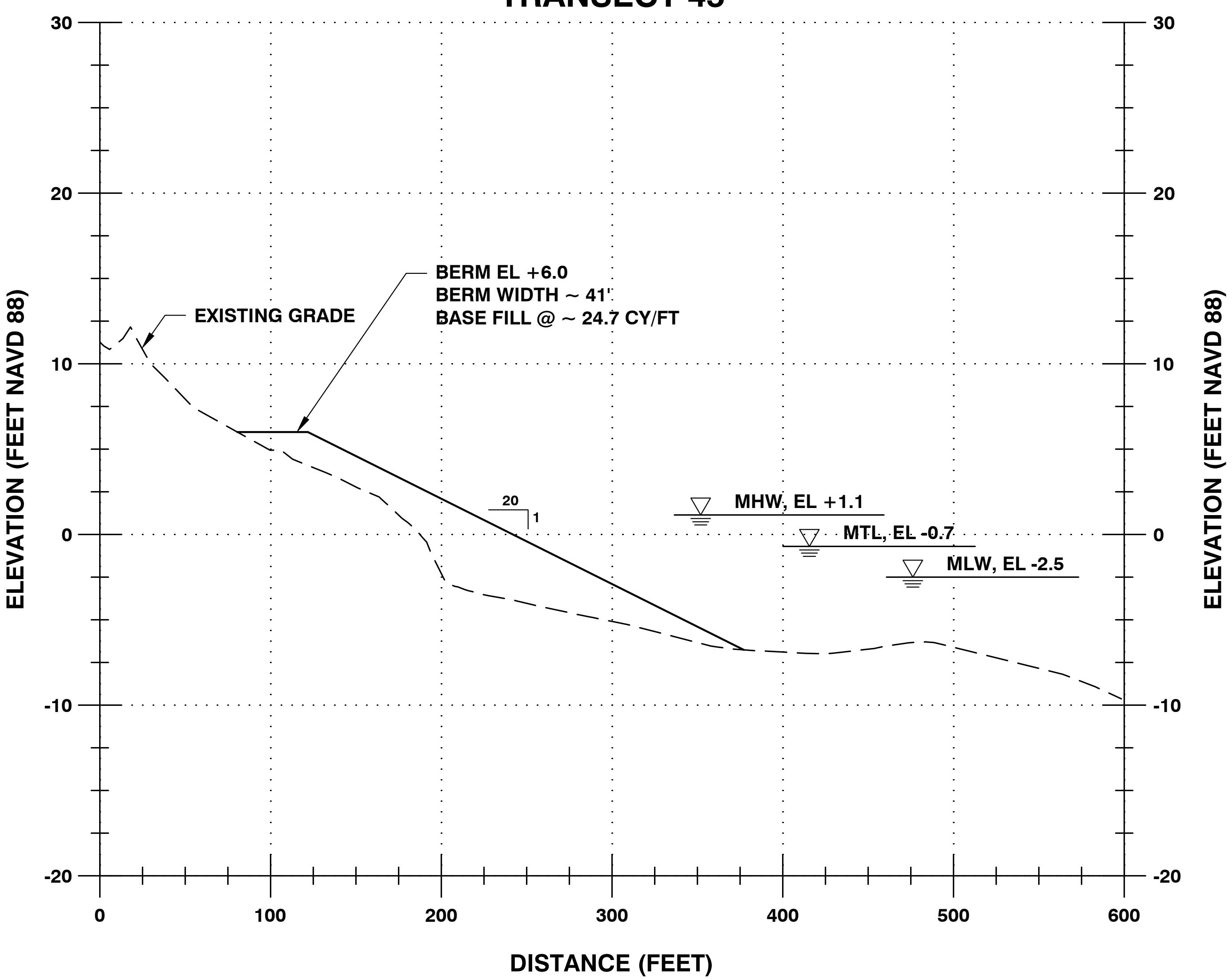
DATE: **FEBRUARY 2012**

SHEET TITLE:

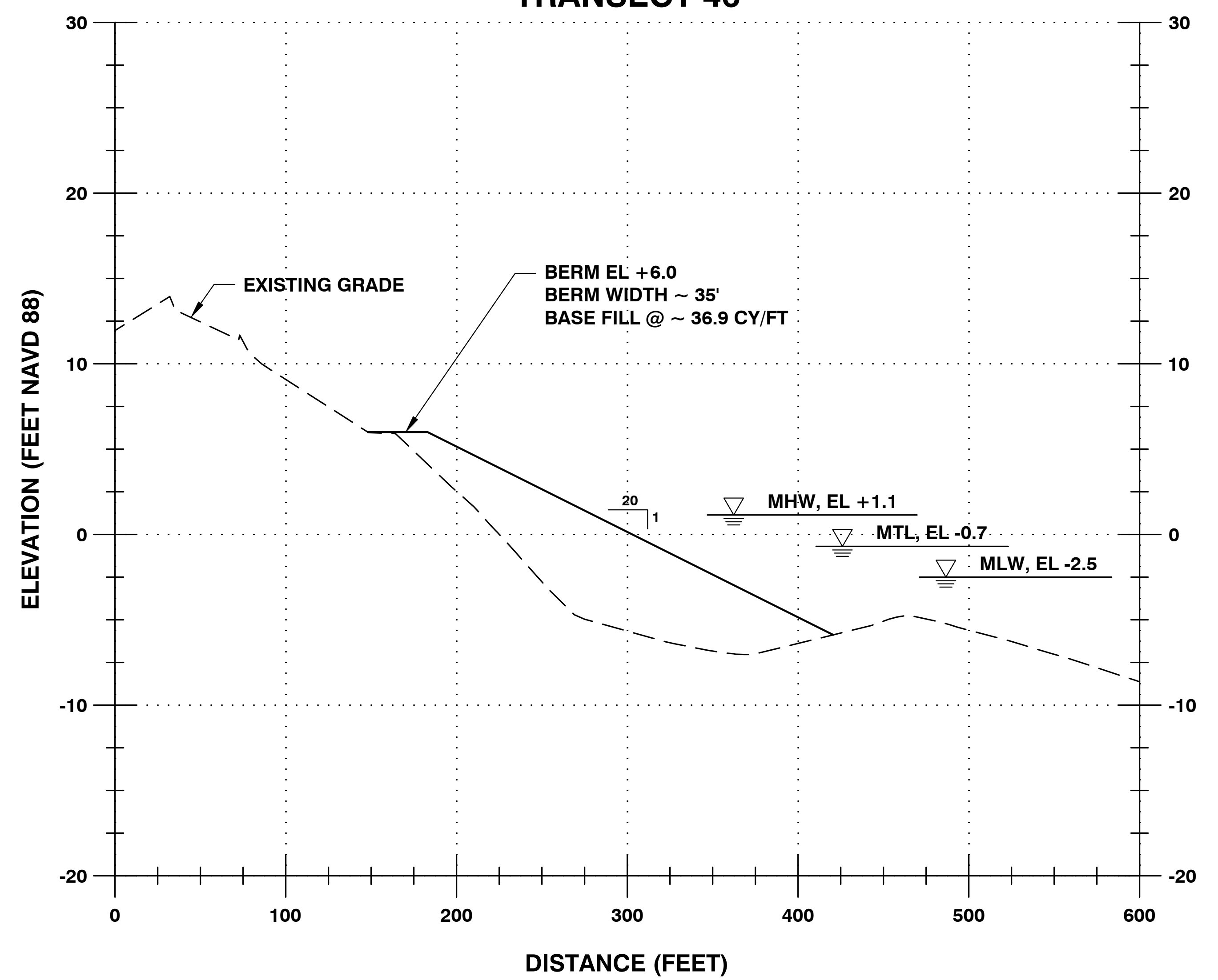
EMERALD ISLE EAST RENOURISHMENT CROSS SECTIONS TRANSECTS 43 AND 44

SHEET **42** *OF* **48**

TRANSECT 45



TRANSECT 46



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

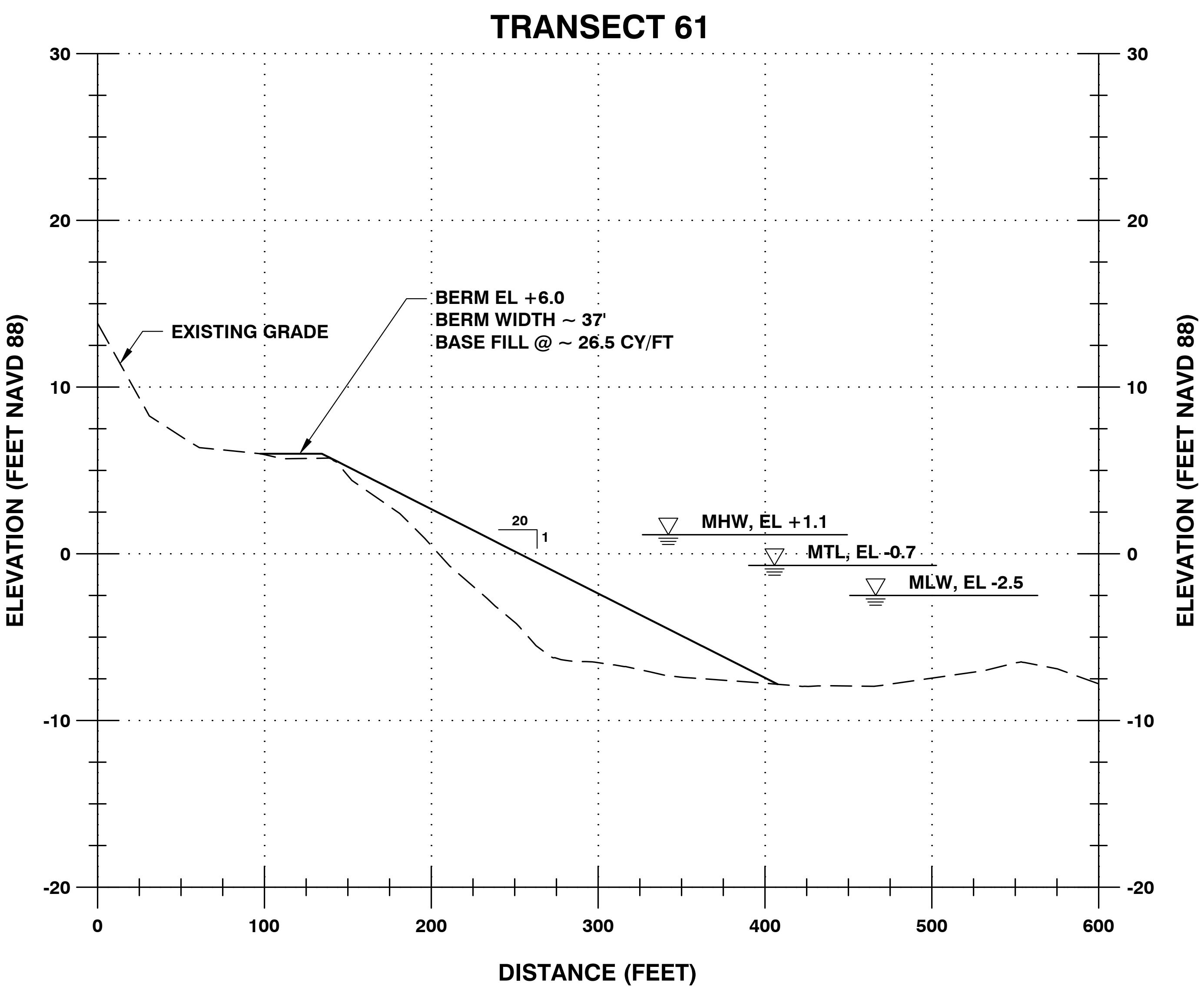
PREPARED BY: **MOFFATT & NICHOL**

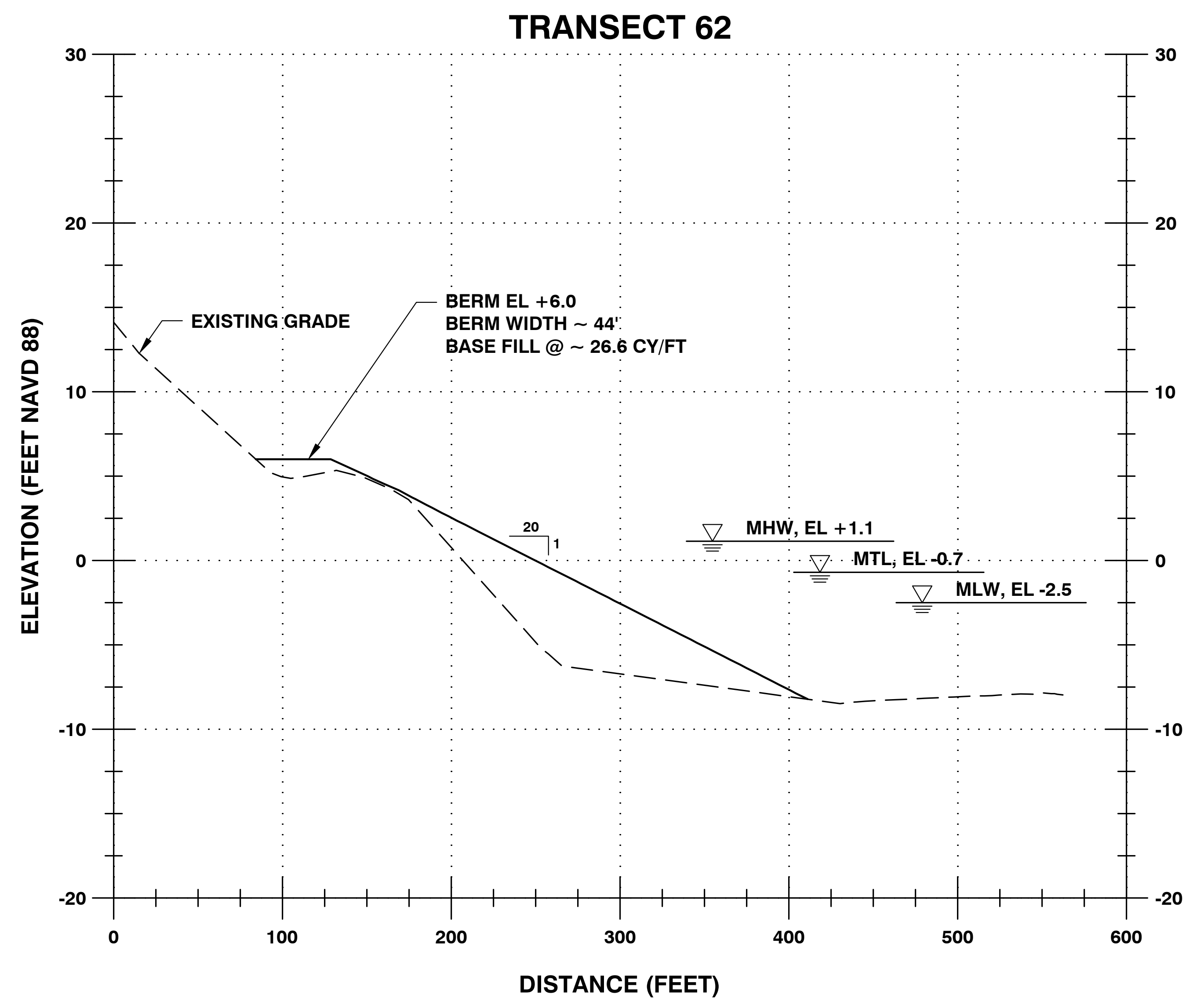
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

EMERALD ISLE EAST RENOURISHMENT CROSS SECTIONS TRANSECTS 45 AND 46





PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

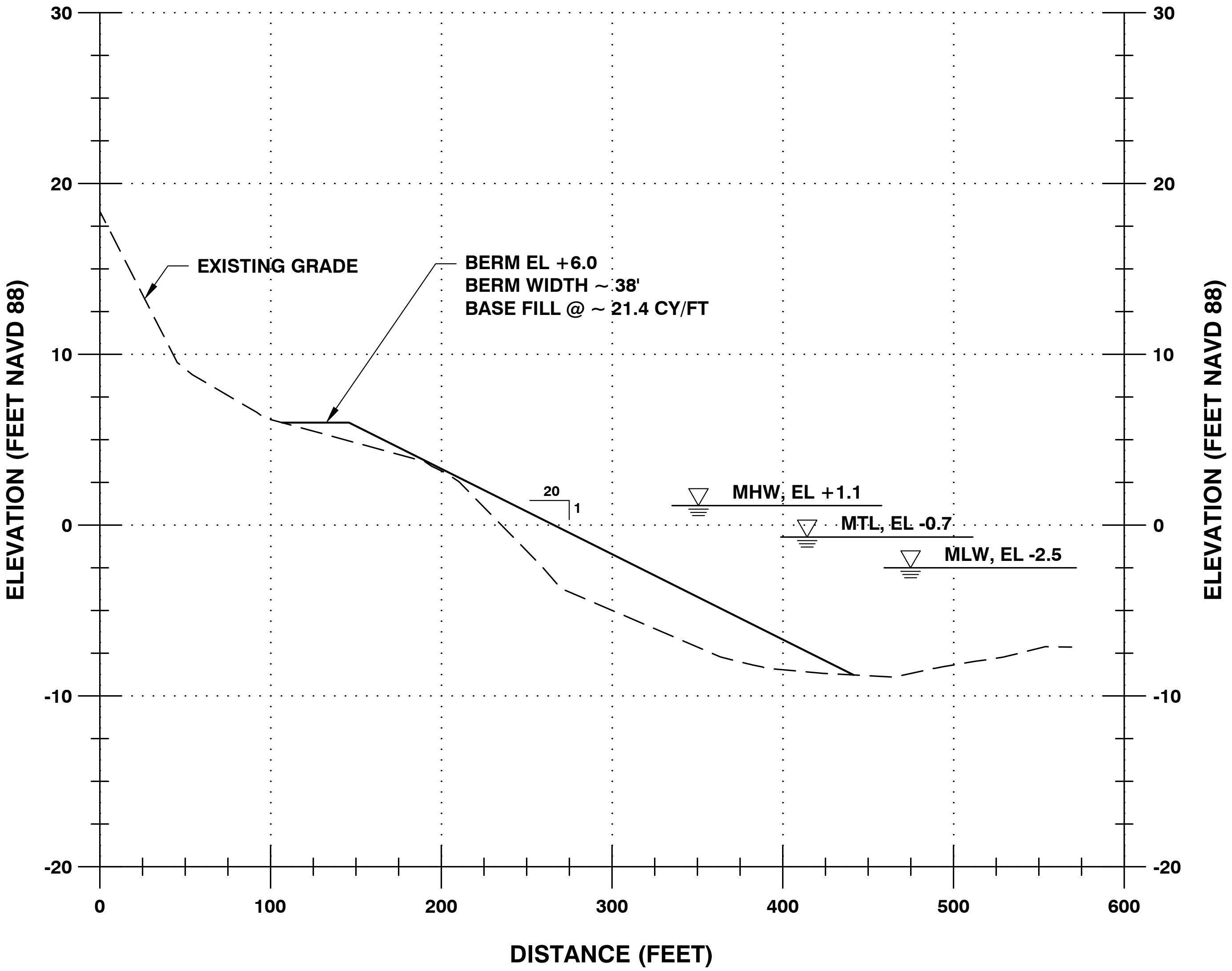
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

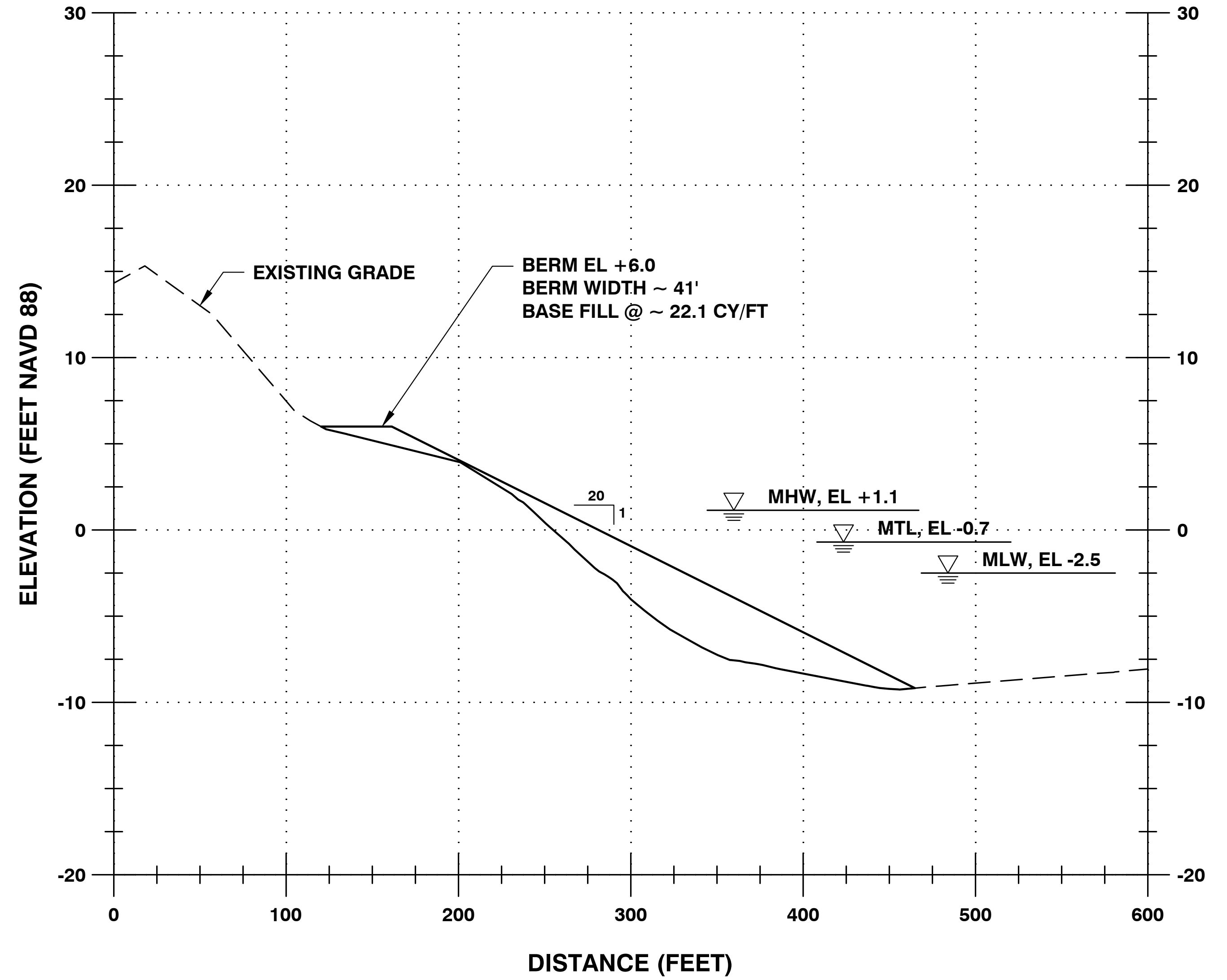
SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT CROSS SECTIONS TRANSECTS 61 AND 62

TRANSECT 63



TRANSECT 64



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

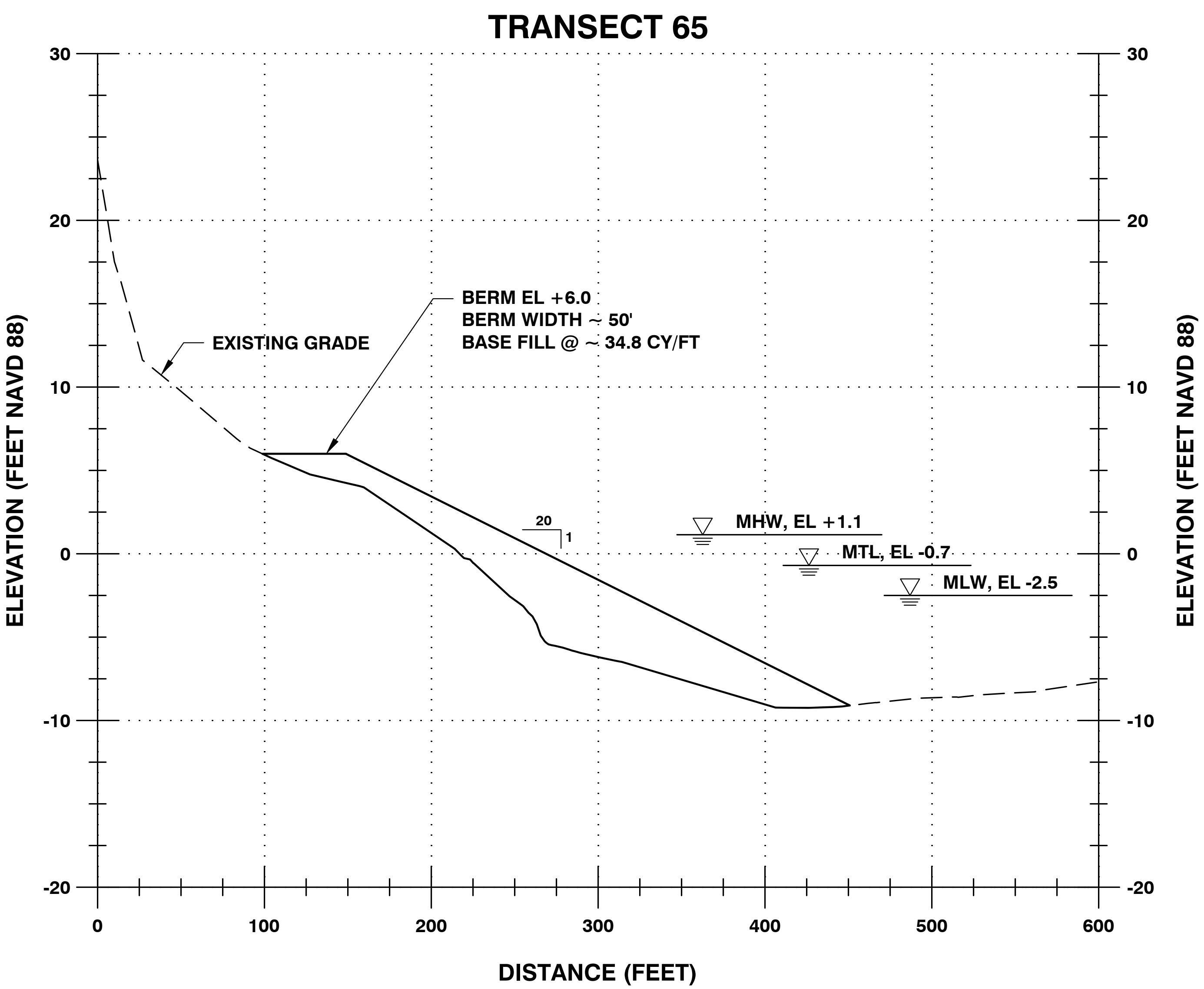
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

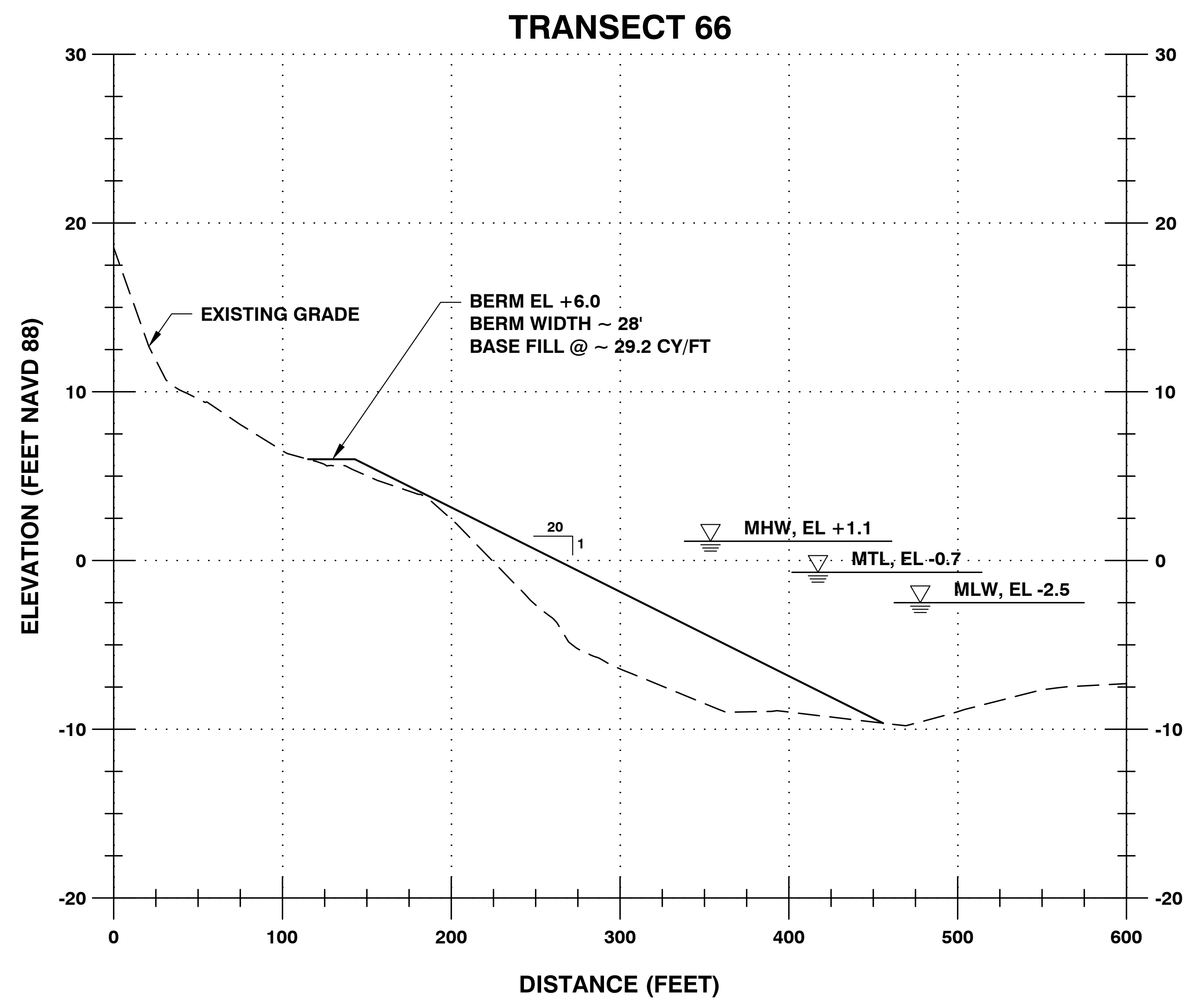
DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT CROSS SECTIONS TRANSECTS 63 AND 64

SHEET **45** *OF* **48**





PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

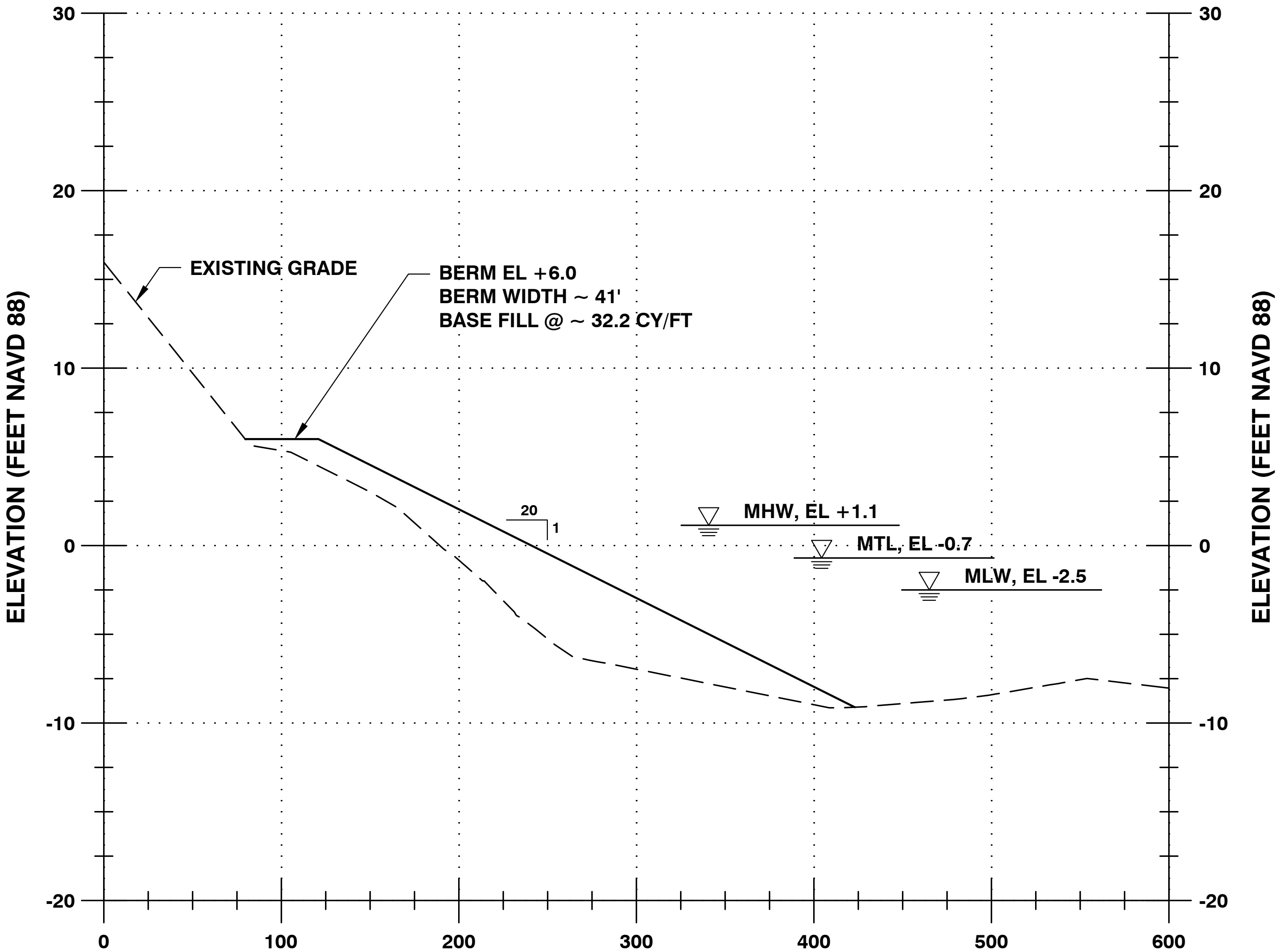
DATE: **FEBRUARY 2012**

SHEET TITLE:

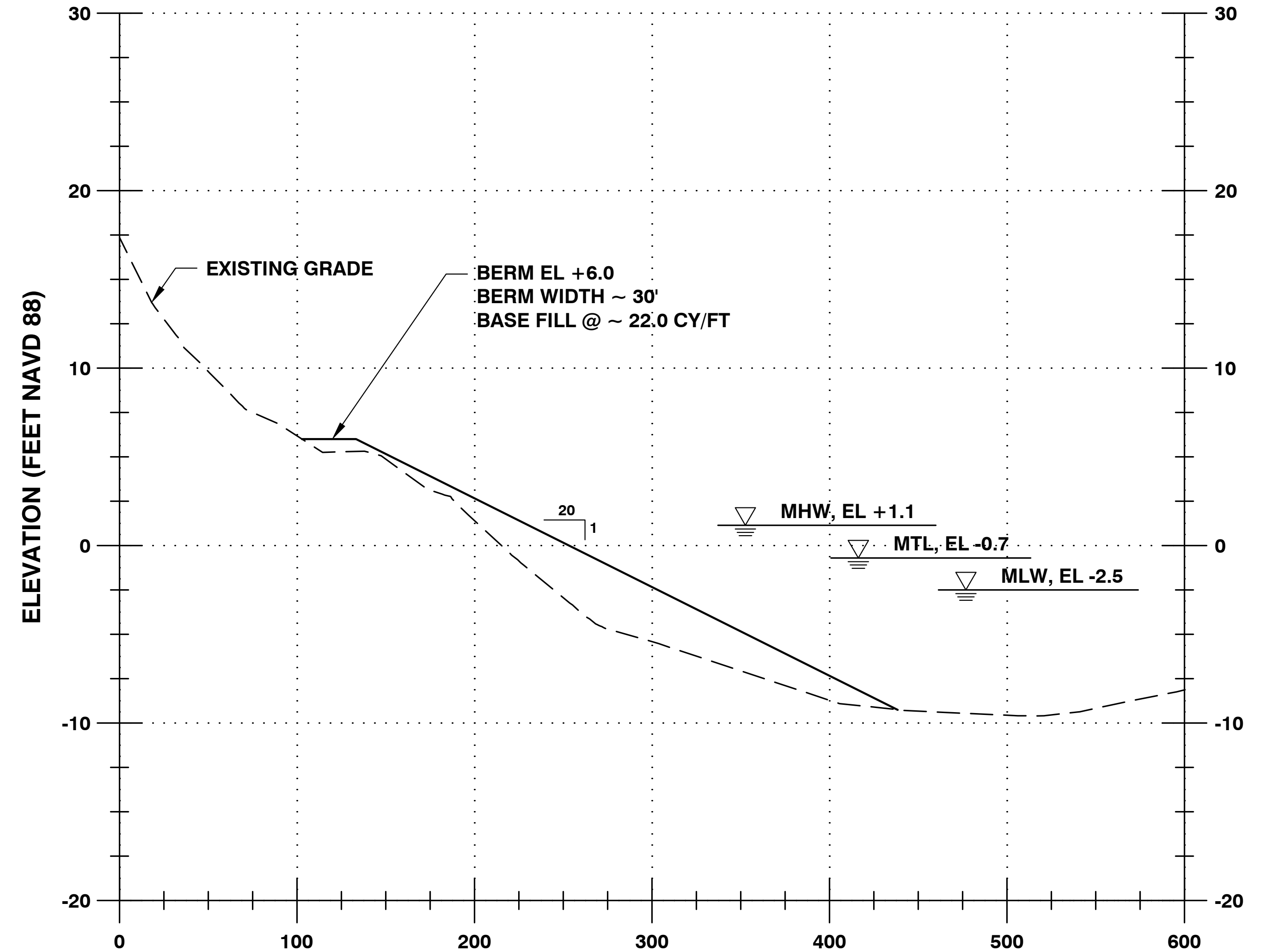
PINE KNOLL SHORES RENOURISHMENT CROSS SECTIONS TRANSECTS 65 AND 66

SHEET **46** *OF* **48**

TRANSECT 67



TRANSECT 68



PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

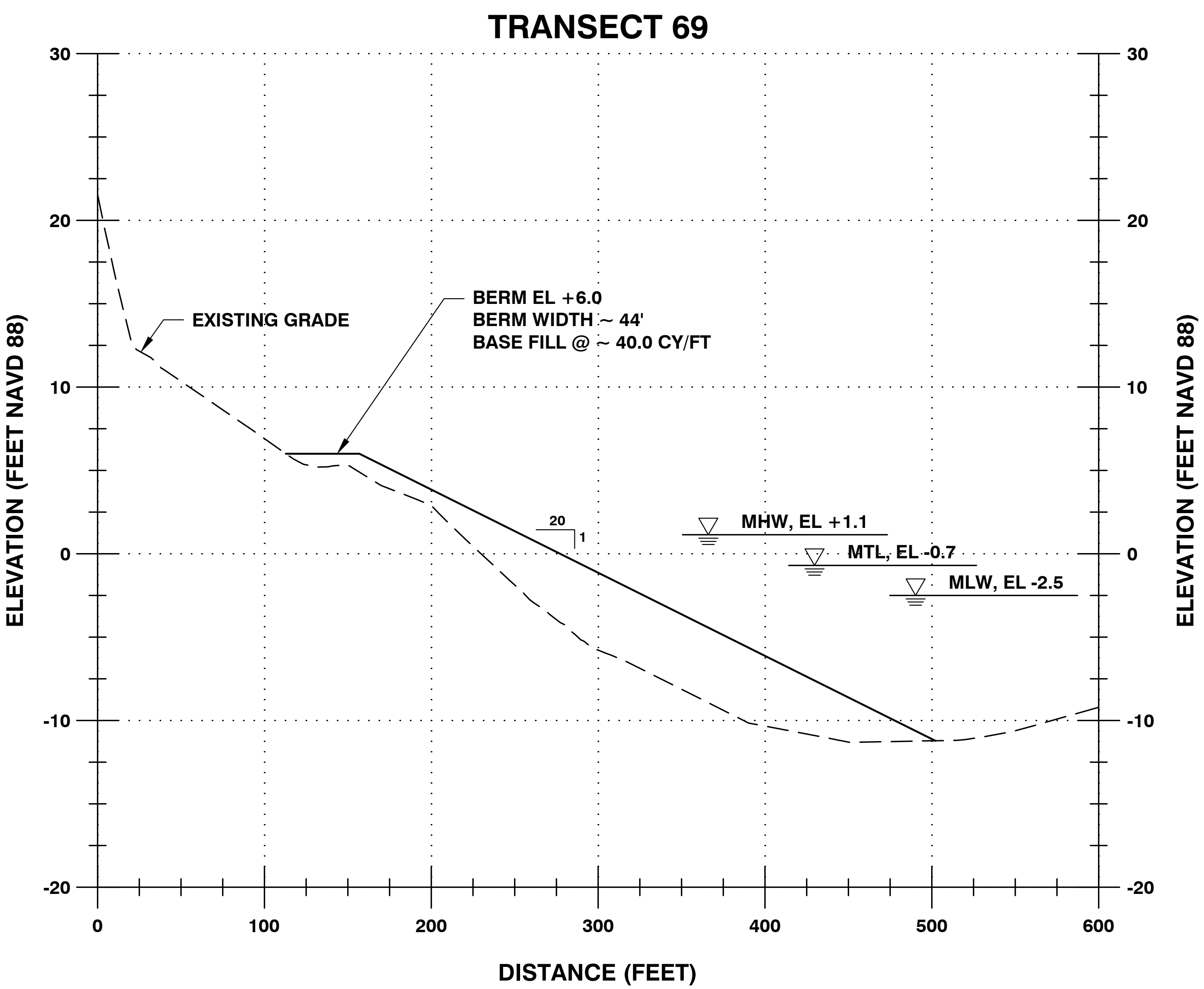
PREPARED BY: **MOFFATT & NICHOL**

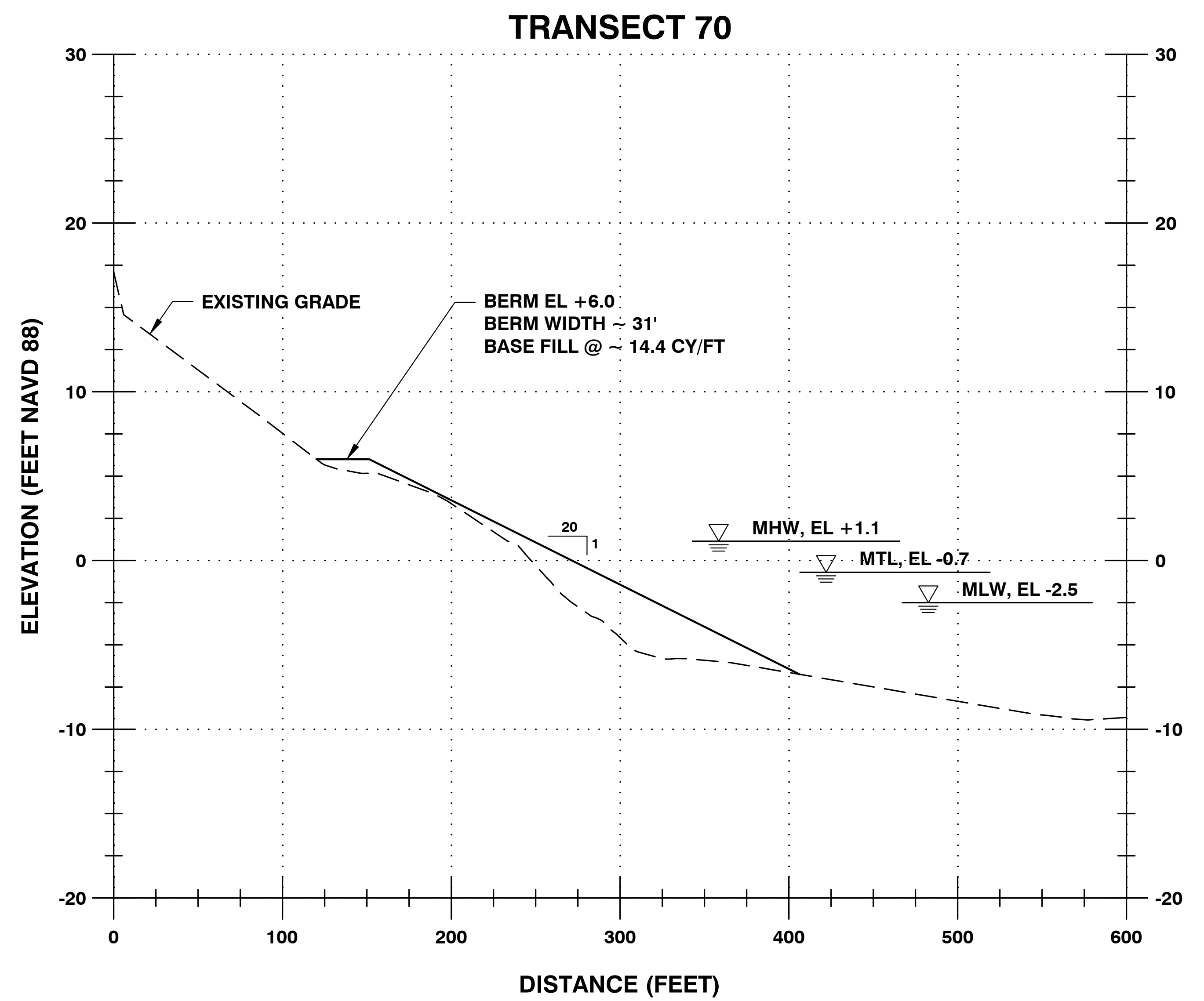
PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT CROSS SECTIONS TRANSECTS 67 AND 68





PROJECT TITLE: **CARTERET COUNTY, EMERALD ISLE & PINE KNOLL SHORES POST-IRENE RENOURISHMENT PROJECT**

DATUM: **NAVD 88 (FT)**

PREPARED BY: **MOFFATT & NICHOL**

PREPARED FOR: **CARTERET COUNTY, NORTH CAROLINA**

DATE: **FEBRUARY 2012**

SHEET TITLE:

PINE KNOLL SHORES RENOURISHMENT CROSS SECTIONS TRANSECTS 69 AND 70

North Carolina Department of Cultural Resources

State Historic Preservation Office

Peter B. Sandbeck, Administrator

Michael F. Easley, Governor
Lisbeth C. Evans, Secretary
Jeffrey J. Crow, Deputy Secretary

Office of Archives and History
Division of Historical Resources
David Brook, Director

June 3, 2008

W. Coleman Long, Chief
Planning and Environmental Branch
Wilmington District, Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402-1890

Re: Place dredge material from Morehead City ODMDS on beaches of Bogue Banks, Carteret County, ER 08-1235

Dear Mr. Long:

Thank you for your letter of April 23, 2008, regarding the above project. We concur that no pre-construction cultural resources surveys of the Offshore Dredged Material Disposal Site (ODMDS) are necessary as long as the post-project depth of the ODMDS does not exceed the original bottom contour.

The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Secrion 106 codified at 36 CFR Part 800.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, contact Renee Gledhill-Earley, environmental review coordinator, at 919-807-6579. In all future communication concerning this project, please cite the above referenced tracking number.

Sincerely,

Renee Gledhill-Earley

for Peter Sandbeck

North Carolina Department of Cultural Resources
State Historic Preservation Office
Peter B. Sandbeck, Administrator

Michael F. Easley, Governor
Lisbeth C. Evans, Secretary
Jeffrey J. Crow, Deputy Secretary

Office of Archives and History
Division of Historical Resources
David Brook, Director

June 3, 2008

W. Coleman Long, Chief
Planning and Environmental Branch
Wilmington District, Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402-1890

Re: Place dredge material from Morehead City ODMDS on beaches of Bogue Banks, Carteret County, ER 08-1235

Dear Mr. Long:

Thank you for your letter of April 23, 2008, regarding the above project. We concur that no pre-construction cultural resources surveys of the Offshore Dredged Material Disposal Site (ODMDS) are necessary as long as the post-project depth of the ODMDS does not exceed the original bottom contour.

The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Secrion 106 codified at 36 CFR Part 800.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, contact Renee Gledhill-Earley, environmental review coordinator, at 919-807-6579. In all future communication concerning this project, please cite the above referenced tracking number.

Sincerely,

Renee Gledhill-Earley

for Peter Sandbeck

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
69 DARLINGTON AVENUE
WILMINGTON, NORTH CAROLINA 28403-1343

REPLY TO
ATTENTION OF:

July 12, 2011

Regulatory Division

Action ID No. SAW-2011-01091

Mr. James F. Bennett, Chief
Branch of Environmental Assessment
Bureau of Ocean Energy Management
Regulation and Enforcement
381 Elden Street, Mail Stop 4042
Herndon, Virginia 20170

Dear Mr. Bennett:

The U.S. Army Corps of Engineers (Corps), Wilmington District, Regulatory Division has been contacted by the Town of Emerald Isle and Carteret County inquiring about Corps permitting authority for their proposal to extract material within an Offshore Dredge Material Disposal Site (ODMDS) and to place the sediment along a certain "hotspot", or eroded area, on the beach of Emerald Isle in Carteret County, North Carolina. This proposal would be a single and complete project independent of the County's multi-decadal Bogue Banks Master Beach Nourishment Plan (Master Plan), as coordinated with Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) in our October 28, 2010 letter. Also, please reference the June 8, 2011 telephone conversation between Ms. Jennifer Culbertson and Mr. Geoff Wikel of your office and Mr. Mickey Sugg of my regulatory staff concerning both agencies' regulatory permitting roles in the dredge and fill placement activity for this "hotspot" area of Emerald Isle.

As you most likely are aware, Corps' regulatory jurisdiction is measured from the baseline (generally the intersection of the shore and the open sea or mean high water) in a seaward direction a distance of three nautical miles. The only exception is with "special regulatory powers" for the construction of artificial islands, installations and other devices of the seabed, pursuant to section 4(f) of the Outer Continental Shelf Lands Act of 1953 as amended.

For this project (description enclosed), the dredging operation in the ODMDS is proposed outside of our regulatory authority, but falls within BOEMRE's jurisdiction. However, the fill placement of the material on the beach is subject to our permitting authority under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, but does not occur within BOEMRE's area of jurisdiction. With overlapping regulatory authority and project scope, it is imperative that our agencies closely coordinate our review efforts in order to streamline both regulatory permitting processes and to comply with the National Environment Policy Act (NEPA). To accomplish this effort, our office has previously held several pre-application conversations with BOEMRE to discuss the proper roles for each agency. The following is a recommended outline of agency responsibilities (lead, cooperating, or joint effort) to coordinate permit review for this project as it relates to consultation for Section 7 of the Endangered Species Act (ESA), Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), National Historic Preservation Act (NHPA), and the Coastal Zone Management Act (CZMA):

*Note: The project, as currently described to us, is not expected to require an Environmental Impact Statement for the Corps.

1) ESA- The lead agency in Section 7 consultation for potential impacts on threatened and endangered species will be separated by the following activities, dredging and fill placement. In our discussion with your office, it was agreed that BOEMRE will be the lead agency for dredging activities in the ODMDS and will consult with the National Marine Fisheries Service (NMFS) for species under their purview, i.e. turtles in the water column and whales. The Corps will be the lead agency for the fill placement activity on the shoreline and will consult with the U.S. Fish and Wildlife Service for species under their purview, i.e. nesting turtles and bird species. At this time, our office foresees a single Biological Assessment (BA) that will be used to evaluate effects on all threatened and endangered species within the project area. The BA, developed by the applicant, will be reviewed by our offices prior to submitting to the respective consulting service agency for a final effect determination.

2) Magnuson-Stevens Act- BOEMRE and the Corps will consult jointly with NMFS, requesting them to separate the responsibility by jurisdictions. In other words, the request would detail that BOEMRE has consultation responsibility for Essential Fish Habitat (EFH) issues associated with the project outside the 3-mile limit or during the dredging activity; and the Corps would accept the EFH responsibility for activities within the 3-mile limit associated with the beach fill placement. Again, it is anticipated that the applicant will develop one EFH Assessment document for both of our agencies.

3) NHPA- Similar to the Magnuson-Stevens Act effort, consultation with the North Carolina State Historic Preservation Office (SHPO) will be conducted jointly with a request to separate responsibilities by jurisdiction. BOEMRE will

comply with NHPA outside the 3-mile limit while the Corps will consult with SHPO concerning cultural resources inside the 3-mile limit.

4) CZMA- With the State of North Carolina jurisdictional waters limited to inside the 3-mile zone, the Corps will accept the responsibility as the lead federal agency in all coordination efforts with the State as it relates to the CZMA.

As we move forward with anticipation that Emerald Isle and Carteret County will request BOEMRE and Corps authorizations, it is our intention to fully engage your agency in the development and/or approval of all required documents as they relate to the above laws, including the Corps' development of our Environmental Assessment. At this time, we do anticipate that the Corps and BOEMRE will be joint lead agencies for NEPA purposes, but will likely prepare separate NEPA documents.

Please advise us, at your earliest convenience, as to your agency's concurrence to coordinate in the manner above for the Emerald Isle and Carteret County "hot spot" dredging and beach nourishment project. If you have any questions concerning this request, please do not hesitate to contact Mr. Sugg in the Wilmington Regulatory Field Office at (910) 251-4811.

Sincerely,

Dale Beter, Chief
Wilmington Regulatory Field Office

Copies Furnished (without Enclosures):

Mr. Doug Huggett
Division of Coastal Management
North Carolina Department of
Environment and Natural Resources
400 Commerce Avenue
Morehead City, North Carolina 28557-3421

Mr. Roy Brownlow
Division of Coastal Management
North Carolina Department of
Environment and Natural Resources
400 Commerce Avenue
Morehead City, North Carolina 28557-3421

Mr. Greg Rudolph
Carteret County Shore Protection Office
Post Office Box 4297
Emerald Isle, North Carolina 28594

Mr. Johnny Martin
Moffatt & Nichol
1616 East Millbrook Road, Suite 160
Raleigh, North Carolina 27609

Mr. Layton Bedsole
Dial Cordy & Associates
First Union Building, Suite 601
201 North Front Street
Wilmington North Carolina 28401

Ms. Jennifer Culbertson
Bureau of Ocean Energy Management
Regulation and Enforcement
381 Elden Street, Mail Stop 4042
Herndon, Virginia 20170

Mr. Frank Rush, Town Manager
Town of Emerald Isle
7500 Emerald Drive
Emerald Isle, North Carolina 28594

United States Department of the Interior

BUREAU OF OCEAN ENERGY
MANAGEMENT, REGULATION AND ENFORCEMENT

Washington, DC 20240

JUL 19 2011

Mr. Gregory L. Rudolph
Carteret County Shore Protection Officer
Shore Protection Office
P.O. Box 4297
Emerald Isle, North Carolina 28594

Dear Mr. Rudolph:

The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) received your request dated July 08, 2011, for a negotiated agreement for approximately 299,900 cubic yards of beach compatible sand from the Morehead City Offshore Dredged Material Disposal Site (ODMDS) located in the Federal Outer Continental Shelf (OCS). The sand will be used to restore portions of Emerald Isle beach that are prone to higher than normal erosion rates. We understand that the Carteret County Shore Protection Office will be the sponsor for this project, and Dial Cordy and Associates, will be the administrators.

After review of the information provided by you and Dial Cordy and Associates, we have determined that Emerald Isle qualifies for a negotiated lease agreement for the identified OCS sand resources for the proposed project. This determination is based on three criteria: public accessibility of the project, the beach restoration is undertaken by a local government, and the project will be funded by local monies.

There are certain requirements that will need to be completed prior to the issuance of a negotiated agreement in order to fulfill applicable statutes including the National Environmental Policy Act, Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, Coastal Zone Management Act and National Historic Preservation Act. We ask that you continue to work with the BOEMRE Branch of Environmental Assessment and their representative, Ms. Jennifer Culbertson, on meeting these requirements.

The Leasing Division, Marine Minerals Branch coordinator for this project will be Mr. Charles Broadwater who can be reached at (703) 787-1192, or by email at Charles.Broadwater@boemre.gov. We look forward to working with you on this project. If you have any questions, please do not hesitate to call me at (703) 787-1215.

We look forward to working with you on this endeavor.

Sincerely,

Steven D. Textoris
Acting Chief, Leasing Division

United States Department of the Interior

BUREAU OF OCEAN ENERGY
MANAGEMENT, REGULATION AND ENFORCEMENT

Washington, DC 20240

AUG 0 8 2011

Mr. Dale Beter
U.S. Army Corps of Engineers - Wilmington District
Regulatory Division
69 Darlington Avenue
Wilmington, North Carolina 28403

Dear Mr. Beter:

Thank you for your July 12, 2011, letter requesting that the Bureau of Ocean Energy, Management, Regulation and Enforcement (BOEMRE) cooperate with the U.S. Army Corps of Engineers (USACE) during the environmental review for the Emerald Isle Beach Renourishment Project located in Carteret County, North Carolina. The proposed action would involve beach re-nourishment using sand from the Offshore Dredge Material Disposal Site located more than 3 nautical miles offshore of Bogue Banks, North Carolina.

The BOEMRE will coordinate and cooperate closely with the USACE during the National Environmental Policy Act (NEPA) process. The BOEMRE also recognizes the importance of initiating and agrees to participate in the required Endangered Species Act (ESA) Section 7 consultation; the Magnuson-Stevens Fishery and Conservation Management Act Essential Fish Habitat (EFH) consultation (Section 305); the National Historic Preservation Act Section (NHPA) 106 process; and the Coastal Zone Management Act (CZMA) Section 307 consistency process.

The BOEMRE concurs with your letter outlining that BOEMRE and USACE will consult separately with the National Marine Fisheries Service (NMFS) for the ESA Section 7 responsibilities within their jurisdictions. The BOEMRE will notify the NMFS of the Corps' involvement in the proposed project. The USACE will serve as lead agency for the ESA Section 7 consultation with U.S. Fish and Wildlife Service (FWS) and will notify the FWS of BOEMRE's involvement with the proposed project. The Corps and BOEMRE will act jointly to consult with NMFS for the EFH consultation, addressing their combined jurisdiction. Similar to the EFH consultation, the Corps and BOEMRE will also act jointly for NHPA Section 106 consultation with the request that the North Carolina State Historic Preservation Office recognize the separate responsibilities by jurisdiction. The BOEMRE expects the Corps to be the lead federal agency for CZMA Section 307 compliance with the BOEMRE acting in a consulting role.

It is BOEMRE policy to negotiate a new agreement for each use of Outer Continental Shelf material; therefore, this agreement only applies to the NEPA and environmental requirements for this project. The final NEPA document, as well as the outcome of other environmental requirements, may be used to establish stipulations of conditions in future negotiated agreements.

The BOEMRE looks forward to working with the Corps during this process. If you would like to discuss any of these items further, please contact Jennifer Culbertson at (703) 787-1742 or by e-mail at Jennifer.Culbertson@boemre.gov.

Sincerely,

Geoffrey L. Wikel
Acting Chief, Branch of Environmental Assessment

cc: Mr. Mickey Sugg
U.S. Army Corps of Engineers, Regulatory Division

Ms. Renee Orr
Bureau of Ocean Energy Management, Regulation and Enforcement, Leasing Division

Mr. Greg Rudolph
Carteret County Shore Protection Office

Mr. Johnny Martin
Moffatt & Nichol

Mr. Layton Bedsole
Dial Cordy & Associates

Mr. Frank Rush
Town of Emerald Isle

Appendix A

Biological Opinion for the use of Hopper Dredges (NMFS 1997)

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, Maryland 20910

SEP 25 1997

R. L. VanAntwerp
Brigadier General, U.S. Army
Division Engineer
South Atlantic Division, Corps of Engineers
Room 313, 77 Forshyth St., S.W.
Atlanta, Georgia 30355-6801

Dear Brigadier General VanAntwerp;

Enclosed is the regional biological opinion concerning the use of hopper dredges in channels and borrow areas along the Southeast U.S. Atlantic coast. This biological opinion amends the regional opinion conducted in 1995, and supersedes the interim biological opinion issued on April 9, 1997. The opinion recognizes the efforts of the Corps of Engineer's (COE) South Atlantic Division (SAD) to minimize sea turtle takes through application of new technology such as draghead deflectors, seasonal dredging windows, termination of projects in which high rates of turtle takes are observed, and elevated staff effort to identify and resolve site-specific problems. Despite these major efforts and continuing plans by the COE to improve the effectiveness of the rigid draghead deflector and to resolve dredging schedules to reduce the likelihood of sea turtle interactions, NMFS believes that further sea turtle takes are likely in future years. However, we believe that these takes are not likely to jeopardize the continued existence of any species. An annual incidental take, by injury or mortality of 35 loggerheads 7 Kemp's ridleys, 7 green turtles, 2 hawksbills, and 5 shortnose sturgeon is listed in the incidental take statement appended to the enclosed opinion. This annual take level can be monitored over fiscal years to be consistent with project contracts.

I appreciate your continued commitment to reduce sea turtle takes associated with dredging in your Division. COE Division and District staff have facilitated the excellent working relationship that exists between our offices within the SAD. We look forward to continuing these cooperative efforts in sea turtle conservation.

Sincerely,

for Hilda Diaz-Soltero
Office Director
Office of Protected Resources

Endangered Species Act - Section 7 Consultation

Biological Opinion

Agency: U.S. Army Corps of Engineers, South Atlantic Division

Activity: The continued hopper dredging of channels and borrow areas in the southeastern United States

Consultation Conducted By: National Marine Fisheries Service, Southeast Regional Office

Date Issued: September 25, 1997

Background

Hopper dredging in channels and borrow areas along the southeastern coast of the United States during the spring of 1997 resulted in an unanticipated high rate of loggerhead turtle take. The number of takes quickly approached the incidental take level established in the regional biological opinion (BO) issued to the Army Corps of Engineers (COE) on August 25, 1995. A formal consultation considering the take rates as well as the dredging locations and conditions was conducted and an interim biological opinion (IBO) was issued on April 9, 1997 and is incorporated herein by reference. The IBO concluded that continued hopper dredging during the 1997 fiscal year was likely to take additional sea turtles but was not likely to jeopardize the continued existence of any species. The incidental take, by injury or mortality, of seven (7) documented Kemp's ridleys, seven (7) green turtles, two (2) hawksbills, sixteen (16) loggerhead turtles, and five (5) shortnose sturgeon was set pursuant in the IBO. This modification added 15 loggerheads to the annual incidental take level, bringing the 1997 fiscal year total incidental take level to 35 loggerheads.

The history of Endangered Species Act (ESA) Section 7 consultations on the deployment of hopper dredges to maintain the depths of southeastern channels is discussed in the August 25, 1995 BO and is incorporated herein by reference. Although no endangered sea turtles have been taken in any channel dredging projects during the 1997 fiscal year, 28 loggerheads have been taken, including 9 loggerheads taken subsequent to the issuance of the IBO (Table 1).

During 1997, the COE responded to high rates of sea turtle takes by assessing each dredging project, modifying draghead deflectors when apparently necessary, conducting relative abundance surveys and relocation trawling, and ultimately ending a number of projects prior to completion (Kings Bay, Brunswick Harbor, Savannah Harbor, Morehead City).

1991 Biological Opinion

Two hundred twenty-five sea turtle takes, including 22 live turtles, were documented between 1980 and 1990 in the Southeast channels despite limited observer coverage in most channels throughout most of that decade (Table 2a.). Seventy-one of these turtles were taken in four months of dredging in the Canaveral ship channel in 1980, the first year in which observers were required. Twenty-one were observed in over two years of dredging in the Kings Bay Channel in 1987-1989, after observers were first deployed on dredges in that channel. Observers were required on most hopper dredges after 1989. Documented takes of turtles on dredges in Brunswick and other Southeast U.S. channels indicated that sea turtles were vulnerable to hopper dredges in all southeastern channels during warmer months. These observations resulted in the Section 7 consultation that concluded with a BO issued on November 25, 1991.

The November 1991 BO was the first cumulative area consultation between NMFS and COE's South Atlantic Division (SAD) regarding hopper dredging. The BO considered hopper dredging in channels from the Canaveral in Florida through Oregon Inlet, North Carolina. The 1991 BO concluded that continued unrestricted hopper dredging in Southeast U.S. channels could jeopardize the continued existence of listed sea turtles. The Opinion established a reasonable and prudent alternative to unrestricted hopper dredging which prohibited the use of a hopper dredge in the Canaveral ship channel, and from April 1 through November 30 in other southeastern channels north of Canaveral. An incidental take level was established based on assumptions that takes would be significantly reduced due to limited dredging windows, but that water temperatures in some years would result in turtle presence in channels during December and March. Observers were required on dredges equipped with outflow and/or inflow screening in March and December. The presence or absence of turtles in December would determine the further need for observer coverage into January. The documented incidental take of a total of five (5) Kemp's ridley, green, hawksbill or leatherback turtle mortalities in any combination of which no more than two (2) are Kemp's ridley, or fifty (50) loggerhead turtle mortalities was set. The Opinion anticipated that seasonal restrictions on hopper dredging would be adjusted on a channel-by-channel basis as better information on turtle occurrence was collected.

Additionally, the development and testing of a draghead deflector was promoted.

1995 Biological Opinion

Between 1992 and 1995, only 16 sea turtle takes were documented (Table 2b.), including three that were alive when collected during dredging operations in the SAD under the dredging windows established in the November 1991 BO (see above). During that period COE developed a rigid draghead deflector that appeared to be effective during videotaped dredging trials using mock turtles, as well as during experimental dredging associated with trawling in the Canaveral Channel. COE also completed a study of six Southeast channels to determine seasonal abundance and spatial distribution of these turtles. A discussion of the findings can be found in the COE report entitled "Assessment of Sea Turtle Abundance in Six South Atlantic U.S. Channels" (Dickerson et al. 1994), summarized in the 1995 BO. Based on the new information, COE requested expanded dredging windows and observer requirements. NMFS considered their request and developed alternative dredging windows and observer requirements and added requirements for the use of hopper dredges in borrow areas along the east coast.

After 1995, COE districts within the SAD generally required observers in some channels, such as Kings Bay, throughout the winter, beyond the new monitoring windows. SAD hopper dredge projects were initially conducted in the middle of the dredging windows, when nearshore waters were cool. During 1996, only nine sea turtle takes, including one green turtle and eight loggerheads, were documented (Table 2c.). No more than three takes occurred in any project. The new dredging windows and draghead deflector requirements appeared to provide good protection to sea turtles.

Hopper dredging operations contracted for the 1997 fiscal year were planned for early in the calendar year, however a number of operations were not begun until late winter. Beginning on March 2, 1997, loggerhead takes occurred in Kings Bay at rates higher than previously observed. Six turtles were taken in four days of dredging. While consulting with NMFS regarding this unprecedented rate of loggerhead takes, a COE specialist from the Waterways Experiment Station proposed some modifications to the draghead with the potential to reduce sea turtle takes. Relocation trawling was also initiated, beginning March 9,1997; however, as can be seen on Table 2, these efforts did not preclude further sea turtle takes in Kings Bay. Dredging was terminated on March 12, 1997, with only 53 percent of the project completed.

Table 1 lists the sea turtle takes observed in hopper dredges throughout the SAD during 1997, as well as the steps taken by COE to reduce the likelihood of takes. Deflector dragheads were re-engineered to fit specific dredges wherever possible and relocation trawling was initiated. Dredging was terminated prior to completion of projects in Kings Bay, Brunswick Harbor, Savannah Harbor and Charleston Harbor. Consultation was reinitiated to consider the effects of the remaining hopper dredging projects anticipated for the 1997 fiscal year. In addition to those specific projects listed in the resulting April 1997 IBO, dredging at Reach II of the Myrtle Beach dredge disposal area is likely to begin before the fiscal year ends. Despite ongoing dredging at the Oregon Inlet, no sea turtle takes have been documented since May 15.

Proposed Activity

This consultation addresses the use of hopper dredges in channels and borrow areas along the Atlantic portion of COE's SAD within the existing dredging windows (Table 3). Channels dredged by hopper dredges include: Oregon Inlet, Morehead and Wilmington Harbors, Charleston, Port Royal and Savannah harbors, Brunswick, Kings Bay, Jacksonville, St. Augustine and Ponce de Leon inlets, West Palm Beach, Miami and Key west channels. Borrow areas that may be dredged by hopper dredges include areas off of Dade County Florida and Myrtle Beach South Carolina.

Draghead deflectors will be used on all projects and observers will be required at least during those periods identified in Table 3. Year-round observer coverage will likely be required by the COE for most channels, particularly those with histories of high sea turtle catch rates such as Kings Bay. Within the South Atlantic Division, the COE will try to schedule dredging of the highest risk areas (Canaveral, Brunswick, Savannah, and Kings Bay) during periods when nearshore waters are coolest -- after December 15 but well before March. Priority for winter dredging will also be given to areas that have substrates that reduce the efficiency of the deflector (Wilmington Harbor channel, Reach 1 of Myrtle Beach). Completion of all projects during the cold-water months will be attempted when possible.

Listed Species and Critical Habitat

Listed species under the jurisdiction of the NMFS that may occur in channels along the southeastern United States and which may be affected by dredging include:

THREATENED:
(1) the threatened loggerhead turtle - Caretta caretta

ENDANGERED:

(1) the endangered right whale - *Eubalaena glacialis*
(2) the humpback whale - *Megaptera novaeangliae*
(3) the endangered/threatened green turtle - *Chelonia mydas*
(4) the endangered Kemp's ridley turtle - *Lepidochelys kempii*
(5) the endangered hawksbill turtle - *Eretmochelys imbricata*
(6) the endangered shortnose sturgeon - *Acipenser brevirostrum*

Green turtles in U.S. waters are listed as threatened, except for the Florida breeding population which is listed as endangered.

Additional endangered species which are known to occur along the Atlantic coast include the finback (*Balaenoptera physalus*), the sei (*Balaenoptera borealis*), and sperm (*Physeter macrocephalus*) whales and the leatherback sea turtle (*Dermochelys coriacea*). NMFS has determined that these species are unlikely to be adversely affected by hopper dredging activities.

Information on the biology and distribution of sea turtles can be found in the 1991 and 1995 BOs, which are incorporated by reference. Channel specific information has been collected by COE for channels at Morehead City, Charleston, Savannah, Brunswick, Fernandina and Canaveral, and is presented in detail in COE summary report entitled "Assessment of Sea Turtle Abundance in Six South Atlantic US Channels" (Dickerson *et al*., 1994) and in the COE Biological Assessment.

There is no significant new information regarding the status of these species that has not been discussed in the BOs that have been incorporated by reference (March 12, 1997 and August 25, 1995).

Assessment of Impacts

The Biological Opinion issued in 1991 contained strict dredging windows that appeared to be very effective at limiting the number of sea turtles taken by hopper dredges during channel maintenance dredging in the Southeast U.S. along the Atlantic coast. Between 1991 and 1995, no more than 8 turtles were taken in any year, and many of those taken were released alive. Studies conducted by the COE (Dickerson *et al*., 1994) documented turtle distribution and abundance in six channels that suggesting the existing windows were accurate. However, the COE requested expansion of existing windows to lessen the burden of maintenance dredging while testing and further developing a rigid draghead deflector design. The deflector was effective at pushing aside mock turtles when tested during 1994, and preliminary field trials in the Canaveral shipping channel had encouraging results. NMFS considered this new information, presented by the COE in a biological assessment forwarded to NMFS in November 1994. The resulting BO, issued August 25 1995 expanded dredging windows and modified observer requirements.

Only 9 sea turtle takes were documented in 1996, suggesting that the expanded dredging windows and the deflector requirements provided protection to sea turtles that was similar to the previously more-restrictive windows. However, the COE's internal policy resulted in conduct of most of the hopper dredging projects during months when coastal waters were still cold, consistent with the previous dredging. The increased rate of take observed during 1997 and discussed below suggests that the restriction of hopper dredging to months when nearshore waters are cold remains the best method for minimizing sea turtle takes.

Unfortunately, a number of dredging projects contracted for early 1997 in the SAD but not restricted to mid-winter months, were delayed into the Spring. This delay coincided with a unseasonably warm winter, when the waters of Kings Bay reached 60°F in early March. The incidental take of nine loggerheads in Kings Bay over only 11 days of dredging indicated that the nearshore abundance of loggerheads was high, apparently higher than during the late 1980's when observers were first deployed on hopper dredges in Kings Bay.

There were other indicators of high nearshore sea turtle abundance along the Southeast U.S. Atlantic coast during 1997. Commercial shrimp trawling conducted without the use of turtle excluder devices (TEDs) offshore of South Carolina and Georgia between May 15 and July 15 resulted in sea turtle catch rates higher than previously documented. Sixty nine sea turtles were taken in 29 days of shrimping off of South Carolina, including 65 loggerheads, 3 ridleys and 1 leatherback. Forty-six sea turtles were taken in 17 days of towing off of Georgia. The sea turtle catch per unit effort (CPUE) for this operation is about 0.35 turtles per hour of trawling, standardized to 100 feet (30.5 m) of total headrope length fished. The CPUE (same units) for commercial shrimp trawling in the 1970s and 1980s reported by Henwood and Stuntz (1987a) was only 0.0487. Loggerhead turtles were the predominant species reported by Henwood and Stuntz and have also been predominantly observed in this study. They account for most of the increase in overall CPUE. The CPUE for loggerheads alone has been greater than 0.30 turtles per hour, while the value reported in Henwood and Stuntz was 0.0456 turtles per hour. The rates of taking for leatherback and Kemp's ridley turtles in the Atlantic study area have also been higher than anticipated.

The high relative density of sea turtles during 1997 may be due to an unseasonably warm winter or other factors contributing to annual variations in abundance, due to an actual increase in the abundance of benthic immature sea turtles in the loggerhead population, or due to a combination of these factors. Trends in the status of loggerheads are generally identified at the nesting beach, when the most accessible life stage, adult nesting females, can be counted. Because they mature at 20 to 30 years of age, increases or decreases in the abundance of benthic immature loggerheads as determined by incidental captures in nearshore waters would not be observed for decades. While nesting beach surveys suggest that the South Florida population of loggerheads increased and now appears to be stable, increases have not been apparent on nesting beaches of Georgia and South Carolina. Further work on the development of multi-year in-water sampling sites is needed to identify trends in multiple age-classes of the loggerhead population.

The COE noted that 14 of the 28 takes that occurred during 1997 were on the same dredge, the Eagle. The high rate of takes, particularly on this dredge, suggested that the deflecting draghead was not installed properly or was not being operated properly. Takes occurred in a number of the 1997 dredge projects during clean-up. Ridges left behind after the initial dredging are leveled during clean-up, but the draghead passes over troughs. Takes occurring during clean-up may be difficult to avoid since the draghead deflector must remain hard on the bottom to be effective.

The COE has been conducting meetings between districts within the SAD to discuss the results of assessments of channel conditions and dredge inspections. They have determined that the draghead deflector has not been working properly due to poor education of the dredge operators on its proper use, and due to poor tailoring of the deflector to specific dragheads. Increased efforts to educate dredge operators are planned. Additionally, since fewer than 10 private hopper dredges operate within SAD, engineers that have designed the conceptual deflector will be sent to the dredges to insure that the deflectors are adapted to each draghead and that the operators understand how to use the deflector effectively.

CUMULATIVE EFFECTS

"Cumulative effects" are those effects of future state or private activities, not involving Federal actions, that are reasonably certain to occur within the action area of the Federal action subject to consultation. These are discussed in detail in the biological opinions incorporated by reference.

Conclusion:

NMFS believes that the elevated rate of observed sea turtle takes by dredges in the southeastern United States during March of 1997 was likely due to increased abundance of loggerheads in nearshore waters due to an unseasonably warm winter. There is no way to predict whether similar conditions will be encountered in upcoming seasons. Over the past six years, the COE's SAD has continuously expressed a commitment to minimize sea turtle takes, and has conducted research and taken repeated steps to further this goal. Repeated termination of dredging operations due to high sea turtle takes during 1997 confirms their commitment to avoid sea turtle takes. Further efforts to educate the dredging industry and recruit their interest and involvement in avoiding sea turtle takes are necessary and are planned by the COE. Additionally, the COE has committed to additional efforts to improve the effectiveness of the deflecting draghead. The sea turtle deflector should be tailored to each hopper dredge draghead and the dredge operators should be fully trained in the operation of the draghead to ensure proper use and improve effectiveness. Improvements in operator and deflector performance are necessary prior to reliance on the draghead as a mechanism for reducing sea turtle takes.

NMFS anticipates that the COE's interest in improving the performance of the deflector, their commitment to limit the use of hopper dredges in channels of high sea turtle abundance during periods when nearshore waters are likely to be cold, and their overall goal of further reducing sea turtle takes during hopper dredge activities will minimize the interactions of hopper dredges with sea turtles. However, annual variation in the abundance of sea turtles in some channels and borrow areas make it likely that sea turtle takes will still occur. Additionally, overall increases in loggerhead and Kemp's ridley populations are anticipated due to TED requirements that have reduced the mortality rates of benthic lifestages of these species. Lastly, in some years high levels of hopper dredging activity may be necessary. For example, termination of projects prior to completion during FY 1997 may result in an increase in the number and length of hopper dredging projects necessary for channel maintenance during FY 1998. Therefore, NMFS believes that up to 35 loggerheads may be taken by injury or mortality, as well as 7 Kemp's ridleys, 7 green turtles, 2 hawksbills, and 5 shortnose sturgeon. These takes are not likely to jeopardize the continued existence of these species and the ongoing commitment by the COE to further minimize takes may reduce the likelihood of sea turtle takes in the future even if nearshore sea turtle abundances increase.

Conservation Recommendations

Pursuant to section 7(a)(1) of the ESA, conservation recommendations are made to assist COE in reducing or eliminating adverse impacts to loggerhead, green, and Kemp's ridley turtles that result from hopper dredging in the southeastern United States. The recommendations made in the 1995 BO are pertinent to this consultation as well, and therefore remain valid. Further recommendations are given below.

- Because of the possibility of annual variation in water temperatures, sea turtle abundance, and hopper dredging demand, NMFS has retained the dredging windows established in the 1995 BO. However, the COE has expressed a commitment to deploy hopper dredges during cold-water periods in channels with high sea turtle abundance or with substrates that render the deflector ineffective. NMFS appreciates the COE's commitment to do this, and recommends that the SAD priority list be finalized and distributed to the Districts and NMFS prior to the initiation of dredging during FY 1998.

- The COE should work with the dredging industry to insure their understanding of the importance of sea turtle conservation and to increase the industry's interest in minimizing sea turtle takes.

- Greater than 50% of the loggerheads taken in North Carolina may be from the northern nesting assemblage of loggerheads. While recent loggerhead nesting beach surveys did not identify a decline in the number of nesting females on beaches north of Cape Canaveral, increases observed in the south Florida nesting assemblage have not been noted. High sea turtle catch rates during only the early weeks of the wood debris clean-up conducted by COE off Cape Fear during 1997, as well as preliminary work conducted in North Carolina, suggest that turtles may be abundant in North Carolina channels primarily during migration into and emigration out of North Carolina inshore waters. The COE should work with the NMFS Beaufort Laboratory and the North Carolina Division of Marine Fisheries to document the movements of sea turtles off North Carolina during spring and fall months. Results from these studies may provide insights into further safe dredging windows to minimize the likelihood of takes of loggerheads from the more vulnerable northern nesting assemblage. Summer windows would reduce the pressure to complete all SAD hopper dredging during cold-water periods.

- The COE should investigate further modifications of the draghead to minimize the need for clean-up. Some method to level the peaks and valleys created by dredging would reduce the amount of time dragheads are removed from the bottom sediments.

Incidental Take Statement

Section 7(b)(4) of the Endangered Species Act (ESA) requires that when a proposed agency action is found to be consistent with section 7(a)(2) of the ESA, and the proposed action may incidentally take individuals of listed species, NMFS will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. It also states that reasonable and prudent measures, and terms and conditions to implement the measures, be provided that are necessary to minimize such impacts. Only incidental taking resulting from the agency action, including incidental takings caused by activities approved by the agency, that are identified in this statement and that comply with the specified reasonable and prudent alternatives, and terms and conditions, are exempt from the takings prohibition of section 9(a), pursuant to section 7 of the ESA.

Based on the high rate of sea turtle takes observed during of 1997, increases in the Kemp's ridley population, possible increases in the benthic lifestages of loggerhead populations, annual variation in nearshore abundance of sea turtles and hopper dredge demands, the NMFS anticipates that hopper dredging in the Southeast U.S. Atlantic area of the SAD may result in the injury or mortality of sea turtles and shortnose sturgeon. Therefore, a low level of incidental take, and terms and conditions necessary to minimize and monitor takes, are established. The annual (by fiscal year) documented incidental take, by injury or mortality, of seven (7) Kemp's ridleys, seven (7) green turtles, two (2) hawksbills, thirty-five (35) loggerhead turtles, and five (5) shortnose sturgeon is set pursuant to section 7(b)(4) of the ESA.

To ensure that the specified levels of take are not exceeded early in any project, COE should reinitiate consultation for any project in which more than one turtle is taken within 24 hours, or once five or more turtles are taken. The Southeast Region, NMFS, will cooperate with COE in the review of such incidents to determine the need for developing further mitigation measures or to terminate the remaining dredging activity. *

Section 7(b)(4)(c) of the ESA specifies that in order to provide an incidental take statement for an endangered or threatened species of marine mammal, the taking must be authorized under section 101(a)(5) of the Marine Mammal Protection Act of 1972 (MMPA). Since no incidental take in the Atlantic Region has been authorized under section 101(a)(5) of the MMPA, no statement on incidental take of endangered right whales is provided.

The reasonable and prudent measures that the NMFS believes are necessary to minimize the impact of hopper dredging in channels and borrow areas in the southeastern United States have been discussed with COE. The following terms and conditions are established, in addition to those identified in the 1995 BO, to implement these measures and to document the incidental take should such take occur.

1. The COE's draghead deflector engineer that assistant in this design design should inspect the rigid draghead deflector annually to ensure that the deflector has been tailored appropriately to each draghead. Additionally, the inspector should assess whether the dredge operator appears to be familiar with the operation of the draghead deflector and provide necessary training where appropriate.

2. If the rigid draghead deflector appears to be ineffective in Wilmington Harbor and slows the dredging project such that the amount of time the hopper dredge will be deployed is increased, the deflector should be removed from the draghead for that channel.

3. The COE should develop an educational/training program for dredge operators to increase their understanding of how the draghead deflector works and why it is necessary.

SOUTH ATLANTIC COAST HOPPER
DREDGING (Calendar Year 97)

Project	Dredge Period	Approximate Amount of Work Completed	Turtle Takes	Mitigative Measures Taken	Remarks
Kings Bay	3/1/97 to 3/12/97	Removed 437,000 out of 821,000 CY Approximately 53% completed.	L 3/2/97 L 3/4/97 L 3/5/97 L 3/6/97 L 3/6/97 L 3/6/97 L 3/8/97 L 3/8/97 L 3/12/97	Sea turtle deflecting draghead used. Jacksonville Dist. specialist inspected deflector on 3/6/97. Relocation trawling started 3/9/97. Extensive, ongoing consultation with NMFS as takes occurred. All work terminated 3/12/97 due to high take levels even though relocation trawling had become operational.	Water temp. 57 to 58 F. Dredge Eagle 1. Two takes in one batch on 3/6/97 and 3/8/97. Contract required removal of relatively small veneer of material. Most takes occurred through starboard dragarm. Rapidity of takes was a surprise to all concerned.
Brunswick Harbor	2/6/97 to 3/19/97	Removed 975,400 CY. Work stopped at 50% completion.	L 3/9/97	Sea turtle deflecting draghead used. Sea turtle abundance, based on visual observations, prompted termination of work because of potential for unacceptable levels of entrainment.	Water temp 63 F. Dredge RN Weeks. Historic abundance of sea turtles and high levels of entrainment in 1991 was part of the reason for termination of work.
Savannah Harbor	3/4/97 to 3/22/97	Removed about 545,500 CY, or about 52% of what could have been dredged.	L 3/14/97 L 3/22/97 L 3/22/97	Sea turtle deflecting draghead used. Dredging terminated so as not to take any more sea turtles.	Water temp. 63 F. Numerous sea turtles sighted. Dredge Ouachita was 'skimming' high areas to bring depth to acceptable levels quickly before leaving for urgent work in Mississippi River.
Charleston Harbor	3/14/97 to 3/26/97	Bid qty 900,000 CY Req. qty 408,000 CY Removed qty 350,000 CY. About 39% completed.	L 3/19/97 L 3/20/97 L 3/21/97 L 3/25/97 L 3/26/97	WES expert / developer of sea turtle deflecting draghead system, conducted onboard inspection and made recommendations. Some changes to draghead and dredging operation made. Relocation trawling performed.	Water temp. 61 F. Dredge Eagle 1.
Myrtle Beach borrow area (Phase 1)	9/15/96 to 5/13/97	Bid qty 2.5 million CY. Work completed.	L 4/15/97 L 5/04/97 L 5/09/97	Sea turtle deflecting draghead used. Relative abundance trawling on 3/28-29/97, with 12 hours of "nets in water", yielded one loggerhead. Trawling on 5/8 thru 5/13/97 yielded no sea turtles.	This is one of 3 phases / reaches of total project. Part of work in all phases is by pipeline dredge. Total quantity of material to be dredged is about 6 million CY
Morehead City Harbor	4/25/97 to 5/16/97)	About 120,000 CY removed out of about 1,720,000 CY. About 7% of work completed.	L 4/27/97 L 4/30/97 L 5/01/97 L 5/02/97 L 5/15/97 L 5/15/97	Sea turtle deflecting draghead. Relocation trawling began 5/8/97 and continued until termination of dredging. One loggerhead captured on 5/9/97. Nighttime trawling performed 5/10 & 5/11 with no turtles captured. Because of concern over extensive takes, dredging terminated with only 7 % of work done.	Dredge Manhatten Island
Wilmington Harbor (Interior Channels)	2/14/97 to 3/13/97	About 217,300 CY removed. Work completed.	No takes		Dredge McFarland
MOTSU	3/14/97 to 4/3/97	About 60,000 CY. removed. Work completed.	No takes		Dredge McFarland
Wilmington Harbor (Ocean Bar)	4/3/97 to 4/30/97	About 300,000 CY Work completed.	L 4/07/97	Sea turtle deflecting draghead.	Dredge RN Weeks
Dade County Beach (Miami Reach)	3/30/97 7/20/97 (estimate)	About 380,00 of 475,000 CY completed as of 6/6/97.	No takes	Based on past dredging and anecdotal information about sea turtlesin area, takes are not anticipated.	

L = Loggerhead CY = Cubic Yards

ıle 2a. Sea turtle takes (includes live, injured and killed) observed on hopper dredges prior to the regional consultation. Observers were not required on all projects until 1989, after which extensive monitoring was required.

Year	Project	Turtle Takes
1980 Total = 71	Canaveral	50 Cc, 3 Cm, 18 Unidentified
1981 Total = 6	Canaveral	3 Cc, 1 Cm, 2 Unidentified
1984/1985 Total = 12	Canaveral	1 Cc, 11 Unidentified
1986 Total = 9	Canaveral	5 Cc
	Kings Bay	1 Cc, 3 Cm
1987 Total = 5	Kings Bay	3 Cc, 1 Cm, 1 Unidentified
1988 Total = 46	Brunswick	1 Cc
	Canaveral	13 Cc, 3 Cm, 18 Unidentified
	Kings Bay	6 Cc, 3 Lk, 2 Cm
1989 Total = 21	Canaveral	9 Cm, 2 Unidentified
	Kings Bay	8 Cc, 1 Cm
	Savannah	1 Cc
1990 Total = 12	Canaveral	3 Cc, 5 Cm
	Kings Bay	4 Cc
1991 Total = 43	Brunswick	20 Cc, 1 Lk, 1 Unidentified
	Charleston	3 Cc
	Kings Bay	1 Cc
	Savannah	17 Cc

:c = *Caretta caretta*, Loggerhead ; Cm = *Chelonia mydas*, Green turtle; Lk = *Lepidochelys kempi*, Kemp's ridley turtle ble 2b. Sea turtle takes (includes live, injured and killed) observed on hopper dredges between the November 1991 and the August 1995 Regional Biological Opinion

Year	Project	Turtle Takes
1992 Total = 2	Port Royal, SC	2 Cc
1994 Total = 8	Canaveral	1 Cm
	Morehead City	1 Cc
	Kings Bay	2 Cc
	Savannah	3 Cc, 1 Lk
1995 Total = 6	Canaveral	1 Cc
	Palm Beach	3 Cc, 2 Cm

: = *Caretta caretta*, Loggerhead ; Cm = *Chelonia mydas*, Green turtle; Lk = *Lepidochelys* *ɪmpi*, Kemp's ridley turtle

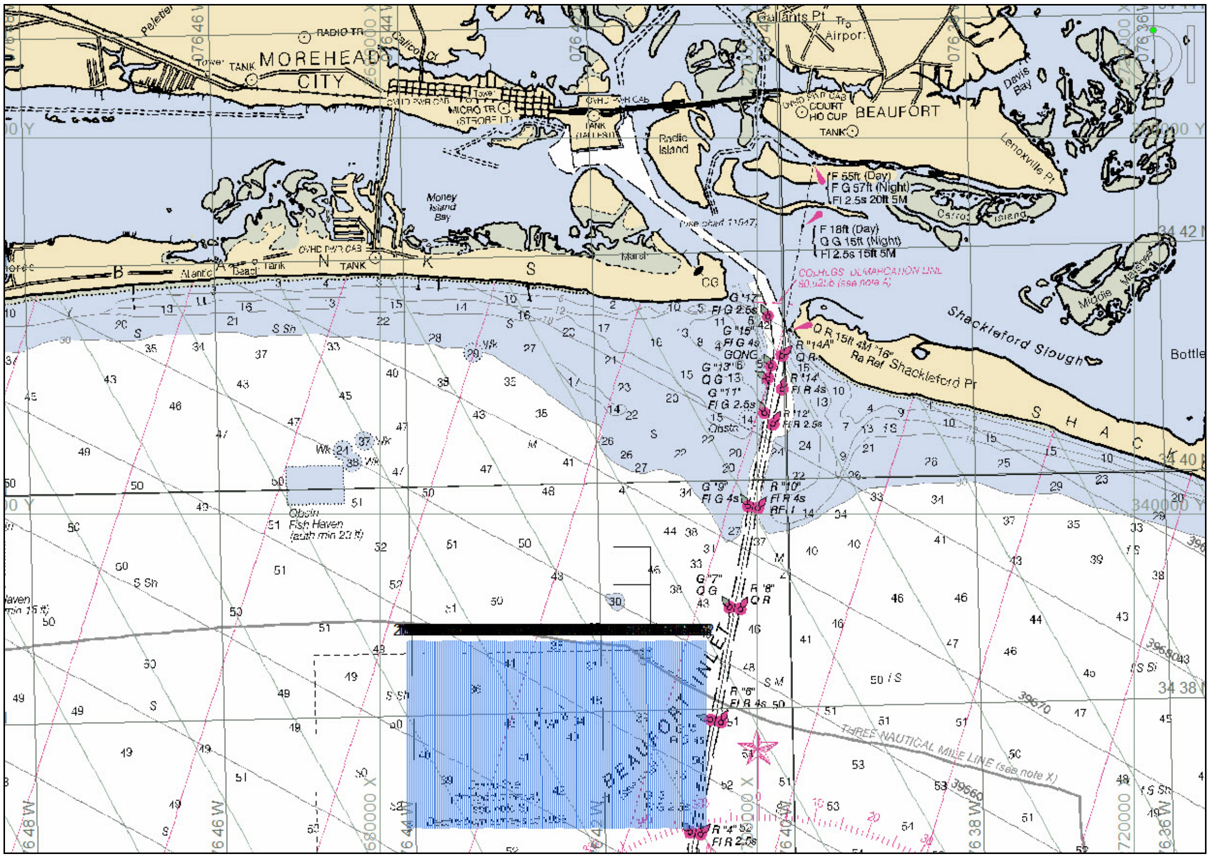
ıble 2c. Sea turtle takes (includes live, injured and killed) observed on hopper dredges after the August 25, 1995 Biological Opinion

Year	Project	Turtle Takes
1996 Total = 9	Morehead City Harbor	1 Cc
	Myrtle Beach (Borrow Area Reach I)	2 Cc
	Kings Bay	1 Cc
	Palm Beach	1 Cc, 1 Cm
	Wilmington Harbor	3 Cc
1997 Total = 28	Brunswick Harbor	1 Cc
	Charleston Harbor	5 Cc
	Kings Bay	9 Cc
	Morehead City Harbor	6 Cc
	Myrtle Beach (Borrow Area Reach 1)	3 Cc
	Savannah Harbor	3 Cc
	Wilmington Harbor (Ocean Bar)	1 Cc

TABLE 3: Current requirements for dredging windows, observer requirements and use of hopper dredges in borrow areas along the east coast established in the August 1995 BO.

AREA		SEA TURTLE MONITORING: NAVIGATION CHANNELS		SEA TURTLE MONITORING: BORROW AREAS	
	WHALE MONITORING	WINDOWS	MONITORING	WINDOWS	MONITORING
North Carolina to Pawleys Island, SC (includes channels at Oregon Inlet, Morehead City and Wilmington)	One observer (daytime coverage) between 1 Dec and 31 Mar. Monitoring by dredge operator and sea turtle observer between 1 Apr and 30 Nov.	Year Round	Two observers (100% monitoring) 1 Apr - 30 Nov	Year Round	One observer (50% monitoring) 1 Apr - 30 Nov
Pawleys Island, SC to Tybee Island, GA (includes channels at Charleston, Port Royal and Savannah)	One observer (daytime coverage) between 1 Dec and 31 Mar. Monitoring by dredge operator and sea turtle observer between 1 Apr and 30 Nov.	1 Nov - 31 May	Two observers (100% monitoring) 1 Nov - 30 Nov and 1 Apr - 31 May	Year Round	One observer (50% monitoring) 1 Apr - 30 Nov
Tybee Island, GA to Titusville, FL (includes channels at Brunswick, Kings Bay, Jacksonville, St. Augustine, and Ponce de Leon Inlet)	Aerial surveys in right whale critical habitat, 1 Dec thru 31 Mar. One observer (daytime coverage) between 1 Dec and 31 Mar.	1 Dec - 15 Apr	Two observers (100% monitoring) 1 Apr - 15 Apr	Year Round	One observer (50% monitoring) 1 Apr - 15 Dec
Titusville, FL to Key West, FL (includes channels at West Palm Beach, Miami and Key West)	Whale observations are not necessary beyond those conducted between monitoring of dredge spoil.	Year Round	Two observers (100% monitoring) year round	Year Round	One observer (50% monitoring) year round

An Archaeological Remote Sensing and Target Identification Survey of Bogue Banks Offshore Borrow Areas Q2, Y1 and ODMDS, Carteret County, North Carolina



ODMDS Remote Sensing Survey Area

Submitted to:

Moffat & Nichol Engineers

Submitted by:

Mid-Atlantic Technology and Environmental Research, Inc.

An Archaeological Remote Sensing and Target Identification Survey of Bogue Banks Offshore Borrow Areas Q2, Y1 and ODMDS, Carteret County, North Carolina

Submitted To:

Moffat & Nichol Engineers
1616 East MillBrook Road, Suite 160
Raleigh, North Carolina

Submitted By:

Mid-Atlantic Technology and Environmental Research, Inc.
441 Blossom Ferry Road
Castle Hayne, North Carolina 28429

Principal Investigator:

Wes Hall

8 September 2011

ABSTRACT

Carteret County and their consultants are currently engaged in the development of a comprehensive Bogue Banks Master Beach Nourishment Plan and Programmatic Environmental Impact Statement that will permit beach nourishment activities to be carried out over a multi-decadal (up to 50 year) time frame.

As a part of the investigations related to development of the engineering plan and Environmental Impact Statement, Mid-Atlantic Technology and Environmental Research, Inc. of Castle Hayne, North Carolina under a subcontract agreement with Moffat Nichol Engineers, of Raleigh, North Carolina, has conducted Phase I and II underwater archaeological investigations of proposed sand borrow areas.

The underwater archaeological project was divided into two components. The first part of the investigation was a marine remote sensing survey of a 10,000 by 16,000 feet in size potential borrow area located in a designated Ocean Dredge Material Disposal Site (Borrow Area ODMDS) positioned offshore Atlantic Beach, North Carolina. The second part of the investigation was a Phase II underwater archaeological identification and assessment of a total of 16 remote sensing targets. The remote sensing targets included: nine located in potential sand Borrow Area Q2, one located in Borrow Area Y and six targets that were selected after the completion of the remote sensing survey of Borrow Area ODMDS.

Borrow Areas Q2 and Y were created during a previous beach study conducted in 2007 by the USCOE, Wilmington District. These studies provided the basis for the remote sensing targets selected for identification from Borrow Areas Q2 and Y.

At the completion the archaeological remote sensing survey of the ODMDS Borrow Area a total of 25 magnetic and or acoustic target/anomalies were located. Of the twenty five remote sensing targets recorded within the ODMDS Borrow Area six were selected for addition underwater investigation.

During the underwater archaeological identification and assessment of portion of the project 14 of the 16 targets were relocated and at least partially identified. All of the targets identified were found to be associated with modern debris that appears to be related to either the present day Ocean Dredge Material Disposal Site or past artificial reef systems such as the tire reefs created in the 1970s. Target Y-1 near Bogue Inlet proved to be associated with a small natural rock outcrop with extensive coral growth. No submerged cultural resources or historic artifacts were identified during the investigations of Borrow Areas Q2, Y-1 or ODMDS.

TABLE OF CONTENTS

Page

LIST OF FIGURES

INTRODUCTION

Bogue Banks is a 25-mile long barrier island, in Carteret County, North Carolina. The island includes the communities of Emerald Isle, Indian Beach/Salter Path, Pine Knoll Shores, and Atlantic Beach. The beach along Bogue Banks is a popular tourist destination and is very important to the economy of Carteret County. Since the 1990s when several hurricane events exacerbated beach erosion concerns in Bogue Banks beach communities, the County has been working with the U.S. Army Corps of Engineers (USACE) to develop a long-range shore protection plan.

The foundation of the long range shore protection plan was a federally cost-shared 50-year Shore Protection Project in combination with locally funded interim measures that were designed to keep beaches viable until the long-range Shore Protection Plan could be constructed. However, in the past few years federal support for the 50-year Shore Protection Plan has eroded along with the beaches. Current as well as past Presidential administrations have placed restrictions on federally funded Shore Protection Projects and have forced Carteret County to investigate pro-active management of Bogue Bank erosion concerns.

Carteret County and their consultants are currently engaged in the development of a comprehensive Bogue Banks Master Beach Nourishment Plan and Programmatic Environmental Impact Statement (EIS) that will permit beach nourishment activities to be carried out over a multi-decadal (up to 50 year) time frame.

As a part of these investigations related to development of the engineering plan and EIS, Mid-Atlantic Technology and Environmental Research, Inc. (M-AT) of Castle Hayne, North Carolina under a subcontract agreement with Moffat Nichol Engineers, of Raleigh, North Carolina, has conducted Phase I and II underwater archaeological investigations of proposed sand borrow areas. This work was conducted pursuant to provisions of Section 106 of the National Preservation Act of 1966 (36 CFR 800, Protection of Historic Properties) and the Abandon Shipwreck Act of 1987 (Abandon Shipwreck Guidelines, National Park Service, Federal Register, Vol. 55, No. 3, 4 December 1990, pages 50116-50145) [1]

---

[1]A national policy for historic preservation has been established in accordance with authorization contained in Sections 106 and 110 (formerly E.O. 11593) of the National Historic Preservation Act of 1966, as amended following the Advisory Council on Historic Preservation Regulations (36 CFR 800). Executive Order 11593 and the Historic Preservation Act Amendments of 1980 specified that the Federal Government shall provide leadership in preserving, restoring, and maintaining the historic and cultural environment of the nation. In 1988, the Abandoned Shipwreck Act (Public Law 100-298) declared that the states (or territories of the U.S.) are to manage shipwrecks in state waters. As a result of these acts and other legislation, state and federal agencies are required to administer cultural properties under their control in a spirit of stewardship and trusteeship. Each agency is required to initiate such measures as are necessary to insure that policies, plans, and programs will preserve sites, structures, and objects of historical or archaeological significance that exist on properties owned by the Federal Government or that are subject to federal regulation.

The underwater archaeological project was divided into two components. The first part of the investigation was a marine remote sensing survey of a potential borrow area located in a designated Ocean Dredge Material Disposal Site (O.D.M.D.S.) positioned offshore Atlantic Beach, North Carolina. The proposed borrow area was approximately 10,000 by 16,000 feet in size and is herein referred to as Borrow Area ODMDS. The second part of the investigation was a Phase II underwater archaeological identification and assessment of a total of 16 remote sensing targets.

The remote sensing targets that included in the underwater investigations were as follows: Nine (9) located in potential sand Borrow Area Q2 - **Targets Q2-20, 21, 23, 24, 28, 29, 30, 31, 32**; one (1) located in Borrow Area Y - **Target Y-1**; and six (6) targets that were selected after the completion of the remote sensing survey of Borrow Area ODMDS -**Targets ODMDS-2, 8, 11, 12, 21, 24**.

Borrow Areas Q2 and Y were created and are part of a previous beach study conducted a few years ago by the USCOE, Wilmington District. As part of that study M-AT was contracted by the USCOE to complete a Phase I underwater archaeological survey for potential borrow areas that included Q2 and Y. The underwater archaeological investigations were conduct in 2007 and the report entitled: *An Archaeological Remote Sensing Survey of Bogue Banks Offshore Borrow Areas, Carteret County, North Carolina (Hall 2008)* was finalized in 2008. The 2007 underwater archaeological investigations provided the basis for the remote sensing targets selected for identification during this project (i.e. Borrow Areas Q2 and Y).

Historical research and field investigations for this project were carried out between 15 July and 23 August 2011.

PROJECT LOCATION

The ODMDS is located over three nautical miles offshore of Atlantic Beach, North Carolina at the eastern end of Bogue Banks and is immediately west of the navigation channel entrance to Beaufort Inlet. The remote sensing survey area or proposed borrow site was rectangular in shape approximately 16,000-feet long east to west by 10,000-feet wide north to south. Borrow Area ODMDS is positioned in the northeastern quadrant of the general O.D.M.D.S. (Figures 1 and 2). Figures 2 and 3 show the project location and the relative position of each proposed borrow area.

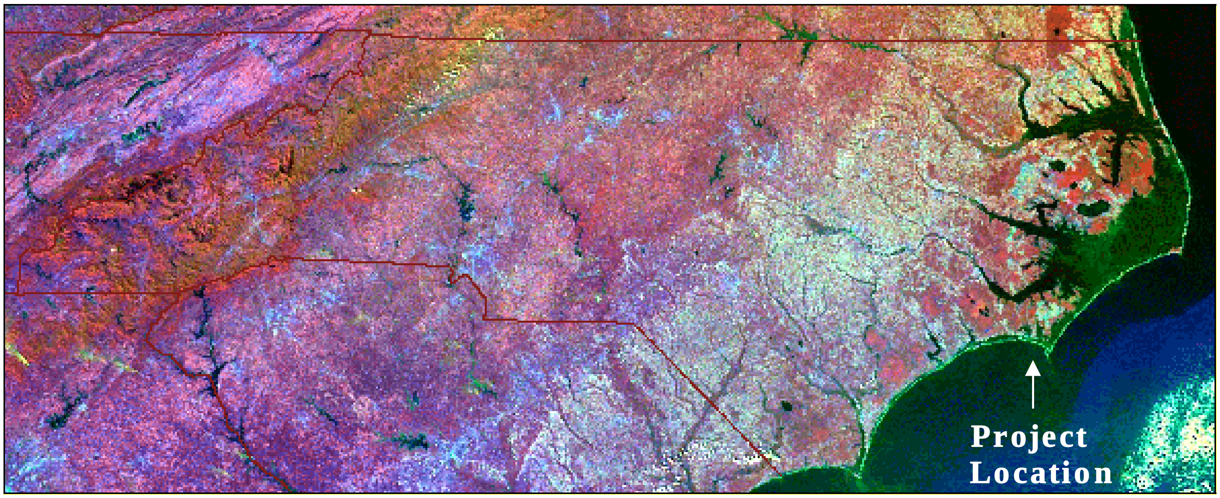


Figure 1. Project Location Map.

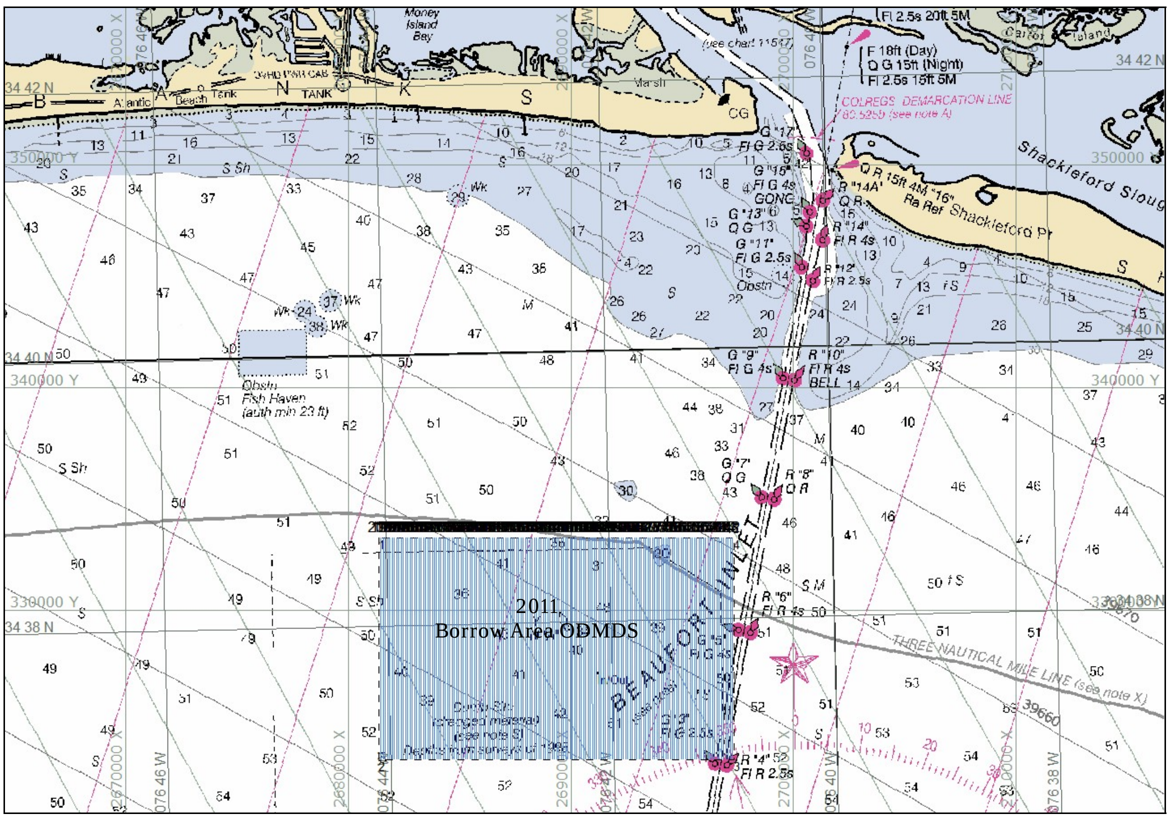


Figure 2. 2011 proposed Borrow Area ODMDS.

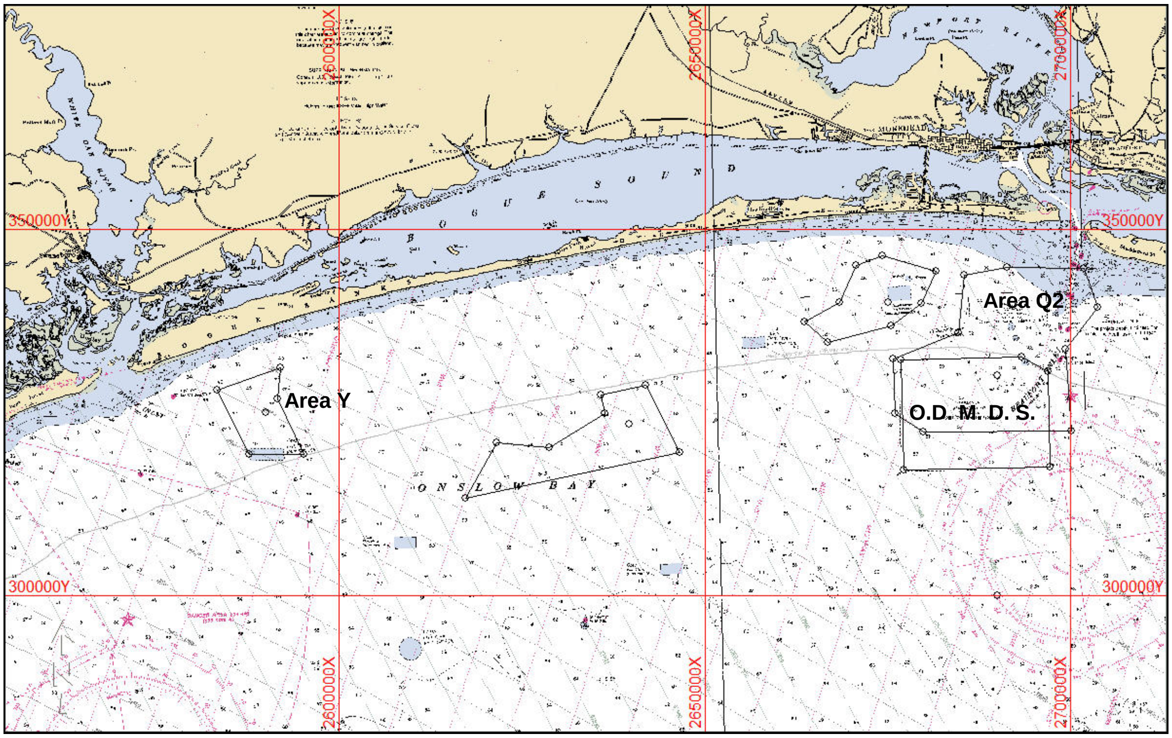


Figure 3. Relative Position of the O.D.M.D.S., and Borrow Areas Q2 and Y.
(other designated areas are not part of these investigations)

HISTORICAL BACKGROUND

North Carolina's barrier islands formed nearly 18,000 years ago when coastal areas submerged during the Holocene epoch. High sand ridges built up along the mainland beaches by wind and water action, during the last period of glaciations. As the sea level rose, the ridge system failed, causing low-lying areas behind to flood. As a result, lagoons and shallow sounds were formed, leaving the existing dune ridges as barrier islands.

Inlets have been formed by the wave action and shifting sands. Most of the inlets are temporary, either migrating along the coast or closing altogether as near shore currents transport sand parallel to the coastline. Permanent inlets occur along the southern coast where the mouths of significant rivers provide enough force to maintain stable inlets (Tubby 2000:59).

In the late seventeenth century, the region particularly around Cape Lookout was commonly visited by New England whalers where they set temporary camps among the dunes (Angley 1982:5). Permanent settlement of the Bogue Banks began in the early eighteenth century. In 1720 Cristopher Gale received a patent for 9,461 acres, "being on the banks and Marshes adjacent betwixt Topsail and Bogue Inlet and is commonly called Bogue Banks and Bogue Island" (Angley 1984:1).

In 1722, Beaufort was appointed as "a port for the unloading and discharging [of] vessels," it was clear that development and growth would depend on trade entering and clearing through Beaufort Inlet (Paul 1970:370373; Angley 1982:8). Unlike many of the inlets along the North Carolina coast, Beaufort Inlet was relatively stable and open and offered a safe and deep channel for ship traffic (Stick 1958:312).

Throughout the eighteenth century Beaufort and Bogue Inlets were of only local importance to trade and travel. As in most of eastern North Carolina, early trade centered around lumber products. Beaufort Inlet served the rich Newport River area plantations and Bogue Inlet served the White Oak River and its tributaries. Naval stores, lumber, and agricultural goods from both these areas were exported to the West Indies in exchange for glassware, cloth, furniture, coffee and rum (Angley 1984:1).

Beaufort supported a strong, though small, shipbuilding industry (Tatham 1806). In 1810, Jacob Henry, a former representative from Carteret County to the North Carolina House of Commons, commented upon the local shipbuilding industry at Beaufort:

> The principal trade carried on here is ship building in which they have acquired a very considerable reputation. Live oak and Cedar are the timbers principally used but the stock is by no means so abundant as it has been. Some of the swiftest sailors and best built Vessels in the United States have been launch'd here, particularly the Ship Minerva, a well known Packet between Charleston and New York. There are at present five Vessels at the Stocks, two of which are ready to be launch'd (Newsome 1929:399 Watts 1997:5).

In 1815, a hurricane struck the Bogue Banks area and devastated Beaufort. The storm was described as "being one of the most violent and disastrous ever known upon the coast." Because of the storm Beaufort Inlet changed significantly; the bar was "injured so that but 12 feet could be brought over it at low water." Fortunately the channel eventually recovered from the storm's damage and by 1830 depth on the bar had increased to eighteen feet at mean low water. By 1854, the bar channel had decreased slightly to a depth of 15 1/2 feet and had migrated slightly to the south (Watts 1997:5).

The development of the railroad in the mid-nineteenth century brought significant changes to Beaufort and the development of a new port facility at Sheppard’s Point creating a decline in commerce through Beaufort. In 1841, John Motley Morehead, then governor of North Carolina, began to promote the idea of the establishment of a port facility at the eastern terminus of the Atlantic and North Carolina Railroad. By 1858 the port and rail facility had become a reality. The editor of the Greensboro *Patriot* described the conditions and natural advantages which he believed would benefit maritime traffic through Beaufort Inlet to the new port facility at Morehead City in September 1858:

> Beaufort, is about three miles, this being about the widest part of the harbor. The channel is in the form of a half-moon, one horn running

> eastwardly along the Shackleford banks, called Core Sound, and the other westwardly by Morehead and Carolina cities, which are situated on Bogue Sound. The deepest water is along Newport River, which runs in nearly a north direction between Morehead City and Beaufort, touching the railroad wharf in the former place. The main channel is about one mile wide, so that the inside of the channel would be some two miles from Beaufort, though vessels drawing from nine to ten feet water can approach the Beaufort wharves at full tide. Running up the channel about three miles from the bar, we come to the railroad wharf at Morehead City, where vessels drawing eighteen feet can approach with ease, and unload and take in lading with the greatest safety (Konkle 1922:341-342).

Within six months the rail and port facility at Morehead City was prospering. Ships were continually calling at the wharfs and being loaded with cargoes directly from train cars (Konkle 1922:360-361).

The Civil War closed Beaufort Inlet to trade and disrupted the lives of the inhabitants of Morehead City and Beaufort. Union forces took Morehead City on March 22, 1862. Just days later Union troops crossed the Newport River and took control of Beaufort. Confederate forces still controlled Fort Macon, however. On April 22, several Union vessels anchored near Harker's Island to the east of Beaufort, including the steamer *Alice Price* which served as General Burnside's temporary headquarters. A Union gunboat and one or two smaller vessels were positioned inside Beaufort Inlet, controlling the approaches and exits to Bogue and Core Sounds. By April 25 a fierce battle ensued and the fall of Fort Macon was imminent, Confederate forces burned the bark *Glen* on April 25 to keep it out of Union hands.

On April 26, Colonel Moses J. White, commander of Fort Macon, surrendered to Generals Parks and Burnside on Shackleford Banks (Angley 1982:34; Stick 1958:148-153).

The occupation of Fort Macon and the surrounding vicinity provided Union naval forces with access to a deep-water port and place of rendezvous that was used to support the blockading squadron throughout the remainder of the war. During December 1864 and January 1865, a fleet under the command of Admiral David Porter massed at Beaufort Harbor in preparation for their assault on Fort Fisher in Wilmington, the last major stronghold of the Confederacy in North Carolina. During the Civil War at least five Confederate vessels were captured at sea in the Cape Lookout area: the schooners *Edwin, Julia, Revere,* and *Louisa Agnes,* captured in 1861; and the steamer *Banshee,* taken on November 21, 1863 (Angley 1982:35; Price 1948:n.p.). One Confederate vessel was totally lost in the vicinity as a result of enemy action. On July 9, 1864, the side-wheel steamer *Pevensey* was chased ashore and blown up on Bogue Banks, approximately nine miles west of Beaufort Inlet (Hill 1975:11-13). Not all known shipwrecks near Beaufort were a result of enemy action. On June 12, 1863, while en route from the Delaware Capes to Charleston, the U.S.S. *Lavender* ran aground in heavy seas near Cape Lookout Shoals. The *Lavender* was a screw tug of 173 tons. On July 20, 1865, the 186-ton Union screw steamer *Quinnebaugh* went ashore on Beaufort bar in rough weather after her machinery failed. The *Quinnebaugh* was transporting Union troops, refugees, and civilians north at the time of her loss (Shomette 1973:88-89; Berman 1972:141; Lytle and Holdcamper 1975:291).

Although of lesser importance, Bogue Inlet was also blockaded by Union forces. Because of ongoing concerns that the Confederates were using Bogue Inlet to supply the Confederate war effort, the U.S.S. *Ellis* under the command of William B. Cushing was sent to maintain the blockade in mid-October 1862. Use of Bogue Inlet to run the blockade appears to have been somewhat limited. Only a single schooner was reported lost at the inlet during the war years. The schooner was reported "ashore on the west breaker" at Bogue Inlet in mid-November 1863 (Angley 1984:6).

Just six years after the Civil War, the federal government began measures to reduce the severity of maritime disasters along the coast by establishing the United States Life Saving Service. In 1874, seven stations were established along the North Carolina coast. In 1875 a similar station was authorized by Congress for Cape Lookout. However, was not until ten years later that the station was finally built. Over the following years three other live saving stations were established on Core Banks, and a station was also established near Fort Macon (Angley 1982:35-36; Stick 1958:169-170, 310-313). It was not until the early twentieth century that Congress also recognized the need for a life saving station at Bogue Inlet (Angley 1984:11).

In the latter years of the nineteenth century the U.S. Army Corps of Engineers conducted several investigations on the feasibility of improvements to navigation of the White Oak River and Bogue Inlet. During that time produce including naval stores, cotton, peanuts, lumber, and fish from the White Oak River and Swansboro were transported to Beaufort Harbor by small boats that navigated the sound. After several studies, the various proposed projects including a jetty to help stabilize the inlet were disapproved as being at a cost that exceeded demand (Angley 1984:8-10).

Commerce on the White Oak River in 1906 was determined to be 21,532 tons most of which was timber and sawn lumber. The remaining tonnage consisted of seafood, agricultural commodities and some general merchandise. Almost all of the cargo passed from Swansboro through the inland channel to Morehead City or Beaufort (Angley 1984;13). Until the 1920s Beaufort was the southern terminus of of the Intracoastal Waterway along the Atlantic Seaboard. In 1932, the Intracoastal Waterway was extended from Beaufort to the Cape Fear River south of Wilmington. By 1938, traffic on the waterway consisted of 8,500 motor vessels, 200 barges, and 300 tugs conducting 9,000 trips. Intracoastal Waterway became a primary artery for cargo including seafood, fertilizer, agricultural products, lumber, petroleum product and other merchandise (Angley 1984;14).

Following the Civil War at Morehead City and Beaufort the fishing industry became an important source of income. Menhaden fishing was of particular importance. From 1865 to 1873, the State of North Carolina's first menhaden processing plant was in operation on Harker's Island. By 1900 several menhaden plants were in operation at various locations on Bogue and Core Sounds including Beaufort (Hill 1975:16-18 Watts 1997:7).

Although the fishing industry was growing, the port at Morehead City developed slowly. Limited traffic through the port was mostly attributed to the depth of water over the bar of the entrance channel to Beaufort Inlet. The size of the shoals related to the bar was also increasing in size. By the 1880s the Federal government began to make improvements to the inlet in an attempt to increase maritime trade to port. Over the next eight years five jetties were constructed on Shackleford Point and another six jetties were constructed on Fort Macon Point. By 1889 the deterioration of the inlet had been halted (Angley 1982:40). To further improve the inlet the entrance channel across the Beaufort Inlet bar was dredged to a depth of 20 feet at mean low water in 1905 and 1907. A 20-foot channel, 200 feet wide, was also established between the inlet and the wharves at Morehead City. A smaller channel, seven feet deep and 100 feet wide, was created to serve the wharves along the Beaufort waterfront (Angley 1982:40).

In 1912 federal records indicate 12 sailing vessels and 35 gasoline powered vessels were registered at Morehead City. At Beaufort 175 sailing vessels, 240 gasoline powered vessels, and six barges were registered. Between 1 July 1898 and 3 June 1908, 82 vessels were reported lost off the North Carolina coast (Angely 1982:42).

In 1923 the tugboat *Juno* sank in the Beaufort Inlet channel creating a hazard to navigation and caused great difficulty to vessels attempting to use the inlet. The wreck of the *Juno* was eventually leveled with explosives but the need for channel improvements was clear. Beginning in 1926 the federal government made considerable improvements to the use of the Port of Morehead City by increasing the depth of the channel from Beaufort Inlet from 20-feet to 30-feet (Stick 1952:237-238 Watt 1997:9-10).

During World War Two German submarines brought war within sight of coastal communities. On one night, March 18, 1942, German submarines sank three tankers in the Cape Lookout area: the *Papoose,* the *W. E. Hutton,* and the *E. M. Clark.* Just five days later another tanker, the *Naeco* was sunk in the same vicinity (Stick 1952:234). Following the attacks, coastal communities of North Carolina were developed “black out” system along with coastal watches. In addition, a more efficient convoy system for tankers and other commercial vessels was devised. Additional planes and patrol vessels were also put into service particularly for the Cape Lookout area (Stick 1952:237-239 Watts 1997:10).

The value of deepwater ports was recognized by the North Carolina State Legislature in 1945 with the creation of the NC State Ports Authority. In 1949 the General Assembly approved the issue of $7.5 million in bonds for construction and improvement of seaports to promote trade throughout the state. Terminals equipped to handle oceangoing vessels were completed at Wilmington and

Morehead City in 1952. Their positions nearly midway between major competing ports in Virginia and South Carolina made them more accessible to North Carolina traders. Morehead City has become a major port for products including phosphate, scrap metal, sulfur, rubber asphalt and other bulk products. At Morehead City, planning continues for expansion onto Ports Authority property on Radio Island and preparing for the larger ships of the future (ncstateport.com).

PRE-SURVEY CONSULTATION AND DOCUMENTATION

As part of the investigative effort, M-AT first conducted a literature search to help document man's activities in the vicinity and to provide a historical context for the assessment of potential cultural resources discovered offshore. The search helped to determine the extent and type of commercial and naval activity offshore, which further assisted in the assessment of targets identified during field investigations. This research focused on primary and secondary materials, as compiled by environmental and archeological agencies responsible for managing the State's cultural resources and depositories, such as libraries and museums. In addition, research included consultation with local historians and the State Underwater Archaeologist at Fort Fisher.

The following offices and/or institutions were contacted:

- Underwater Archaeology Unit, Division of Archives and History, Fort Fisher, NC
- North Carolina Maritime Museum, Beaufort, NC
- NC State Archives
- Office of the Historian, U.S. Coast Guard, Washington, D.C.
- Marine Casualty Branch, U.S. Coast Guard
- Maritime Historian, Sanctuaries and Reserves Division, National Oceanic and Atmospheric Administration

Preliminary secondary sources examined:

- The Encyclopedia of American Shipwrecks
- Merchant Steam Vessels of the United States 1807 - 1868
- Shipwrecks of the Western Hemisphere
- Shipwrecks of the Civil War
- Official Records of the Union and Confederate Navies in the War of the Rebellion
- Automated Wreck and Obstruction Information System of the National Oceanic and Atmospheric Administration
- Web Site Review of http://anchor.ncd.noaa.gov/awois/search.cfm
- Historical Maps and Charts

Researchers reviewed source materials at each institution and conducted interviews with librarians/technical staff to determine the best potential sources for background information. A list of known or potential shipwrecks has been developed for the vicinity.

DESCRIPTION OF INVESTIGATIONS

Remote Sensing Survey of Borrow Area ODMDS

M-AT's underwater archaeology team conducted the survey using a 25-foot long survey vessel Two primary remote sensing devices were used: a Geometrics 882 cesium marine magnetometer and a Marine Sonic 600 kHz digital, side-scan sonar. Each instrument was interfaced with a Trimble 232 Differential Global Positioning System.

Data was collected along parallel lines spaced at 100-foot intervals. Magnetic data, along with corresponding positioning data, was recorded at .5-second sample intervals (or approximately every 5 feet along a track line at 6 knots) using HYPACK™ data acquisition software. Water depths within the ODMDS Borrow Area range between 50-feet in the offshore portion of the borrow area to 35-feet on the inshore portion. A 40 pound tri-wing depressor was utilized to maintain the magnetometer tow sensor at a depth of 10 to 20 feet above the bottom within ODMDS survey area. The 882 sensor was trailed behind the depressor. At 6 knots the depressor's tow-line traveled at approximately a 40 degree angle to the transom of the survey vessel. Beginning at the offshore or deeper portion of each borrow area the magnetometer height was set. Using the angle of the depressor's tow line and its length, the height of the magnetometer sensor was adjusted to achieve a maximum of a 20-foot sensor height above the bottom.

Side scan sonar data was recorded with Marine Sonic Sea Scan® acoustic data acquisition software using an onboard PC computer system. Side Scan Sonar data was recorded at a scale of 164 feet (50 meters) per channel. The height of sonar fish was adjusted to achieve the best records for the conditions.

Magnetic Background Variation

Artificial induced variation in magnetic data or background noise was maintained at less than .3 nanoteslas (nT) at a sample rate of ½ second. Noise spikes, such as those produced by sharp turns or rapid changes in speed, were easily identified and removed during the data editing process. Once the data had been reduced to pole, the magnetic background was represented by the "zero value data" depicted in the magnetic contour maps.

Data Analysis / Cultural Resources

During field investigations, data being produced by the magnetometer, side-scan sonar were closely monitored. Targets (magnetic or acoustic) were identified and recorded as they were generated. Also noted on field records was information about the local environment, which included man-made features such as pipelines, channel markers, crab traps, and conditions that could influence magnetic or acoustic data.

After the survey area was completed, archaeologists edited the magnetic data for detailed analysis and comparison to acoustic data. Editing was performed in three phases. The initial phase consisted of using HYPACK's single-beam editing program to review raw data in individual survey lines and to delete any artificially induced noise or data spikes. While editing survey lines, a preliminary target table was developed that included individual target coordinates, signature characteristics, intensity, and duration. Once all survey lines for an area were edited, the edited data was converted to an xyz file (Easting and Northing State Plane Coordinates, and magnetometer data – measured in nanoteslas), also using HYPACK. Next, the xyz files were imported into a Triangular Irregular Network (TIN) modeling program that was used to contour the data in 1-nanotesla intervals. Once the data was contoured, the contour graphic was converted to a dxf file and imported into AutoCAD in order to clearly view individual magnetic anomalies and their association with acoustic target signatures. Once in AutoCAD, additional editing of the total magnetic intensity was performed without affecting individual magnetic anomalies. For example, dramatic or pronounced diurnal changes that frequently will create a "striped," "zigzag," or "herring bone" pattern in the contour lines can was edited out and averaged across a survey area to create a more realistic and accurate contour map.

A second major analytical technique employed included the subtraction of general background from each successive data sample to develop the actual field gradient. The gradient is the vertical difference (z) between samples. By subtracting successive data samples one from the other the effects of diurnal change are completely eliminated. The resulting data represents only the localized changes in the magnetic background created by ferrous object(s) (i.e. anomalies). When graphically represented by contouring (using the same method described above), only the intensity of variation and localize influence is represented.

During the analysis process, magnetic anomalies were categorized using the anomaly intensity, duration and/or extent, and signature characteristics. In addition, the anomaly's geographic location was taken into consideration, as well as its association with acoustic target signatures.

After magnetic data was developed into a target list, acoustic data was examined using SeaScan™ acoustic data review software to identify any unnatural or man-made features in the records. Once identified, acoustic features were described using visible length, width, and height from the bottom surface. The coordinates of the acoustic features also were recorded.

Data Assessment (General)

Target signatures were evaluated using the National Register of Historic Places criteria[2] as a basis for the assessment. For example, although an historic object might produce a remote sensing target signature, it is unlikely that a single object (such as a historic anchor or cannon ball) has the potential to meet the criteria for nomination to the National Register of Historic Places.

Target assessment was based primarily on the nature and characteristics of the acoustic and magnetic signatures. Shipwrecks – large or small – often have distinctive acoustic signatures, which are characterized by geometrical features typically found only in a floating craft. Most geometrical features identified on the bottom (in open water) are manmade objects. Often an acoustic signature will have an associated magnetic signature. Generally, if the acoustic signature demonstrates geometric forms or intersecting lines with some relief above the bottom surface and have a magnetic signature of any sort; it can be categorized as a potentially significant target. Often, modern debris near docks, bridges, or an anchorage is easily identified solely based on the characteristics of its acoustic signature. However, it is more common to find material partially exposed. Frequently, these objects produce a record that obviously indicates a man-made object, but the object is impossible to identify or date. Also in making an archaeological assessment of any sonogram record, the history and modern use of the waterway must be taken into consideration. Naturally, historically active areas tend to have greater potential for submerged cultural resources. The assessment process prioritizes targets for further underwater archaeological investigations.

Magnetic target signatures alone are more difficult to assess. Without any supporting sonogram record, the type of the bottom sediments and the water currents become more important to the assessment process. A small, single-source magnetic signature has the least potential to be a significant cultural resource. Although it might represent a single history object, this type of signature has little potential to meet National Register criteria.

A more complex magnetic anomaly, represented by a broad monopolar or dipolar type signature, has a greater potential to be a significant cultural resource, depending on bottom type. Shipwrecks that occur in regions with hard bottoms, with little migrating sand, tend to remain exposed and are often visible on sonogram records. A magnetic anomaly that is identified in a hard bottom area and has no associated acoustic signature frequently can be discounted as being a historic

2 To qualify for the National Register, a historic shipwreck must "meet one or more of the National Register criteria A, B, C, and D. Determining the significance of a historic vessel depends on establishing whether the vessel is 1) the sole, best, or a good representative of a specific vessel type; 2) is associated with a significant designer or builder; or 3) was involved in important maritime trade, naval, recreational, government, or commercial activities" The criteria is described thusly:

A. [B]e associated with events that have made a significant contribution to the broad patterns of our history; or

B. be associated with the lives of persons significant in our past;

C. embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or

D. have yielded, or may be likely to yield, information important in prehistory or history.

(National Register Bulletin, U.S. Department of the Interior, National Park Service, Interagency Resources Division).

shipwreck. Most likely, such an anomaly is modern debris, such as wire rope, chain, or other ferrous material.

Soft migrating sand or mud can bury large wrecks, leaving little or no indication of their presence on the bottom. The types of magnetic signatures that a boat or ship might produce are infinite, because of the large number of variables including location, position, chemical environment, other metals, vessel type, cargo, sea state, etc. These variables are what determine the characteristics of every magnetic target signature. Since shipwrecks occur in a dynamic environment, many of the variables are subject to constant change. Thus, in making an assessment of a magnetic anomalies potential to represent a significant cultural resource, investigators must be circumspect in their predictions.

Broad, multi-component signatures (again, depending on bottom characteristics and other factors) often have the greatest potential to represent a shipwreck. On the other hand, high-intensity, multi-component, magnetic signatures (without an accompanying acoustic signature) in areas of relatively high velocity currents can be discounted as a historic resource. Eddies created by the high-velocity currents almost always keep some portion of a wreck exposed. Generally, wire rope or some other low-profile ferrous debris produces this type of signature in these circumstances. Many types of magnetic anomalies display characteristics that are not easily interpreted. The only definitive method of determining the nature of the object creating these anomalies is by physical examination.

DESCRIPTION OF FINDINGS

Potential for Submerged Cultural Resources

Prehistoric

Currently there is no evidence to suggest that there is a potential for significant prehistoric cultural resources in the offshore area of coastal North Carolina. Certainly, there is potential for isolated prehistoric artifacts and perhaps even concentrations of artifacts however, those types of sites have yet to be found and there are currently no criteria or method available to enhance their potential discovery. Late Pleistocene or Holocene landforms that may have supported direct evidence of prehistoric occupation in the offshore waters of North Carolina have been transgressed and homogenized by natural high-energy ocean processes. Therefore the potential for significant prehistoric site to be present or possibly impacted by offshore construction activity in the waters off the North Carolina coast are unlikely.

Historic

Investigations to identify documented shipwrecks near the project area revealed that numerous ships have wrecked in the vicinity of Bogue Banks, Beaufort Inlet and Bogue Inlet (see Historic Shipwrecks in the Vicinity of Bogue Banks - Appendix A). The historic shipwreck tentatively identified as the *Queen Anne's Revenge* and currently undergoing investigation immediately north of Borrow Area Q2 helps to demonstrate the potential for other historic shipwrecks in the vicinity of Beaufort Inlet. By way of example several targets identified during the 2007 survey of Borrow Area Q2 had similar magnetic signatures characteristic with that of the Queen Anne's Revenge shipwreck site.

Remote Sensing Survey ODMDS Borrow Area

At the completion of the marine magnetometer and side scan sonar survey of the ODMDS Borrow Area over 40 magnetic anomalies had been recorded. Of these, several were in relatively close geographic proximity suggesting that they may be related to the same event or activity. Base on solely on proximity, those anomalies were grouped into targets clusters. This created a total of 25 targets within the ODMDS Borrow Area either represented by individual anomalies or those grouped together. Of these targets, only 5 (five) had an associated sonar signatures (Figure 4). All other acoustic signatures were either ready identified as fish or objects such as buoy weights.

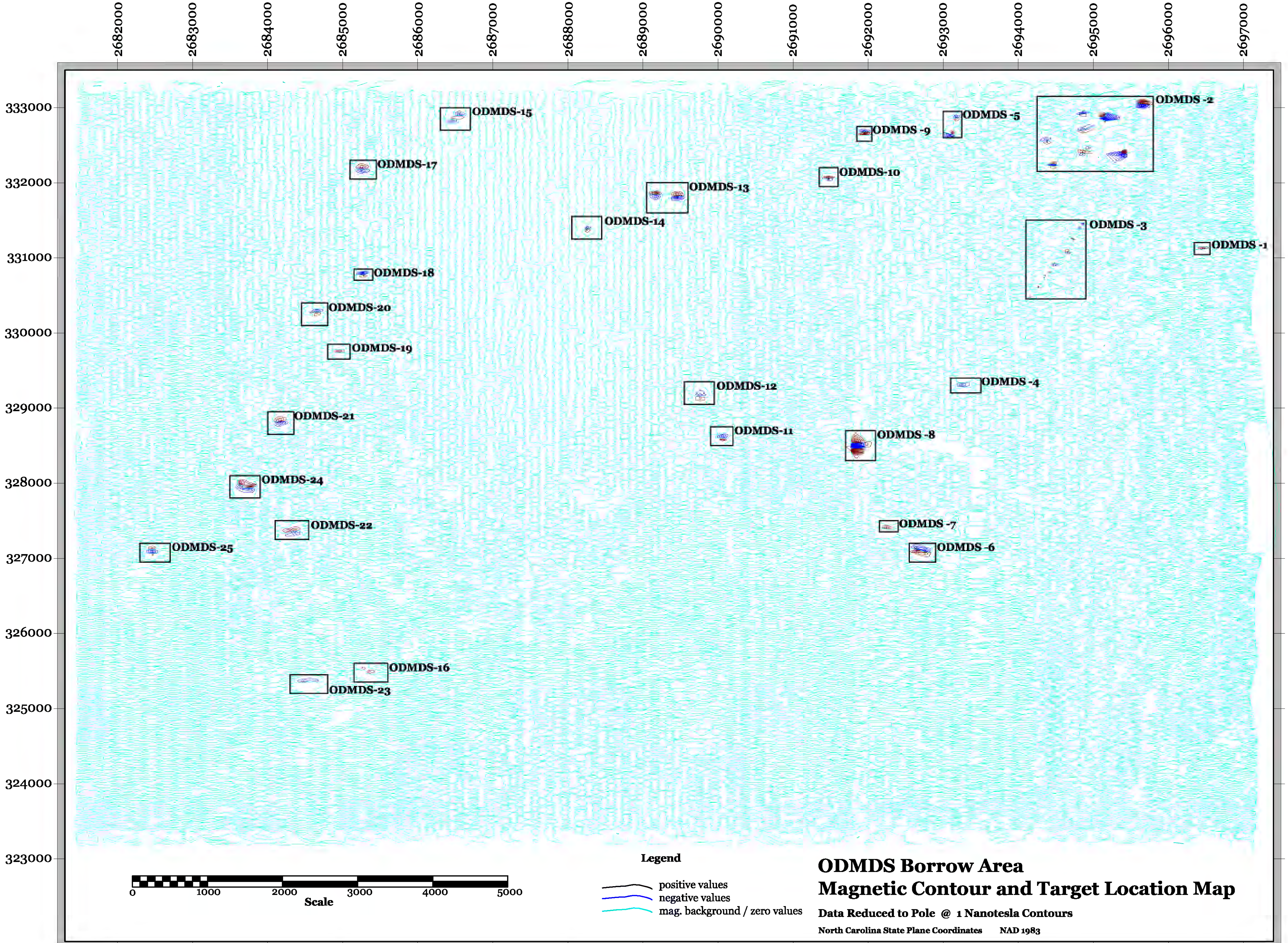


Figure 4. Magnetic Contour and Target Location Map.

Target Descriptions:

ODMDS 1
NC State Plane x=2696456 y=331126

Target ODMDS-1 consisted of a monopolar magnetic anomaly recorded along a single survey line with a maximum magnetic intensity of more than 4 nT. No acoustic target signature was identified in association with the magnetic anomaly.

The simple monopolar characteristic of the targets signature suggests that it was created by a single ferrous object with limited potential to be associated with a significant submerged cultural resource. No additional investigation or mitigation is recommended (Figure 5).

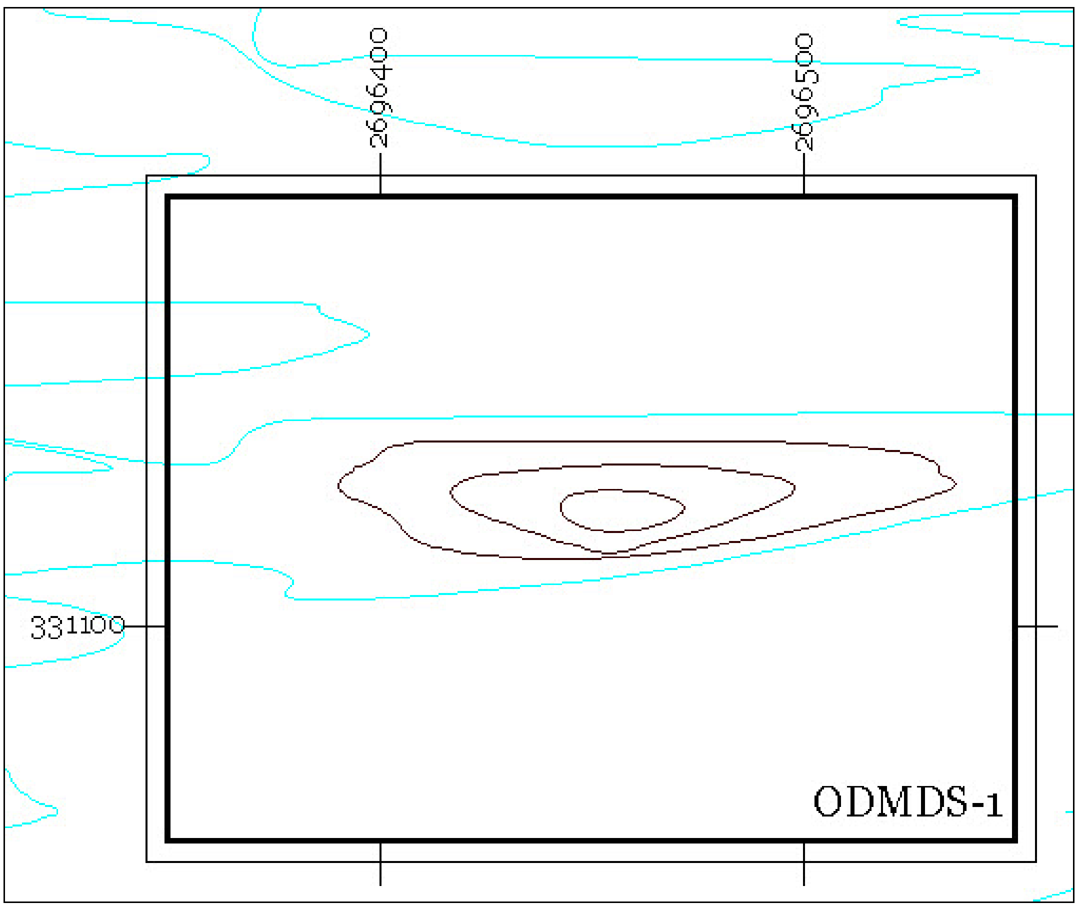


Figure 5. Target ODMDS-1 Magnetic Contour Signature.

ODMDS-2 – Cluster
NC State Plane x=2695144 y=332126

Target Cluster ODMDS-2 consisted of at least eight dipolar and multi-component magnetic anomalies. The individual anomalies although separated by as much as two hundred feet, were grouped together because of their general proximity within the ODMDS survey area. The targets ranged in intensity between 5 and 20 nT (Figure 6). No acoustic target signature was found in association with the various magnetic anomalies within the cluster.

Because of the potential for the cluster of magnetic anomalies to be related to a historic event or activity, this target was selected for diver identification and assessment during the target identification portion of this project.

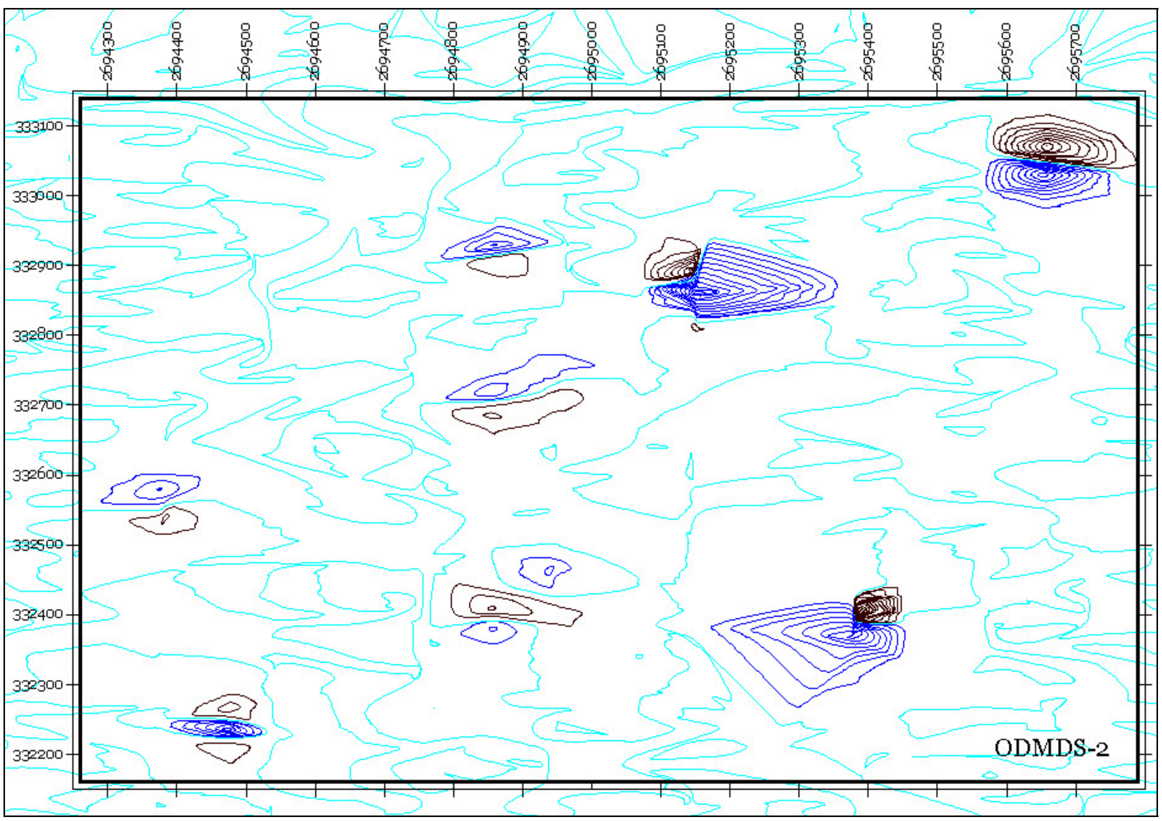


Figure 6. Target Cluster ODMDS -2 Magnetic Contour Signature.

ODMDS-3
NC State Plane x=2694491 y=330904

Target cluster ODMDS-3 was group together as a linear series of magnetic anomalies with a magnetic intensity between 1 and 4 nT. The line of anomalies extended for more than 800 feet (Figure 7). A faint linear acoustic signature that extended across sonar records over at least four survey lines suggesting that magnetic anomalies associated with target cluster ODMDS-3 was created by a wire rope or shielded cable (Figure 8).

The linear relationship of the magnetic target and supporting sonar records indicates it has little potential to be associated with a significant cultural resource. No additional underwater archaeological investigation or mitigation is recommended.

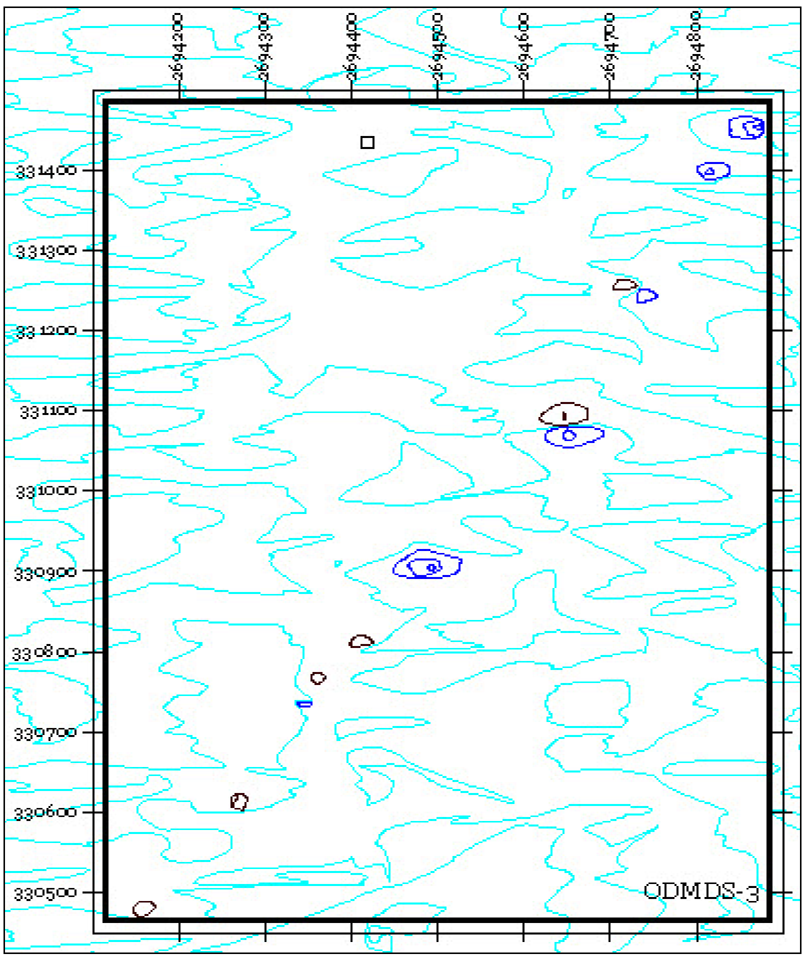


Figure 7. Target ODMDS-3 Magnetic Contour Signature.

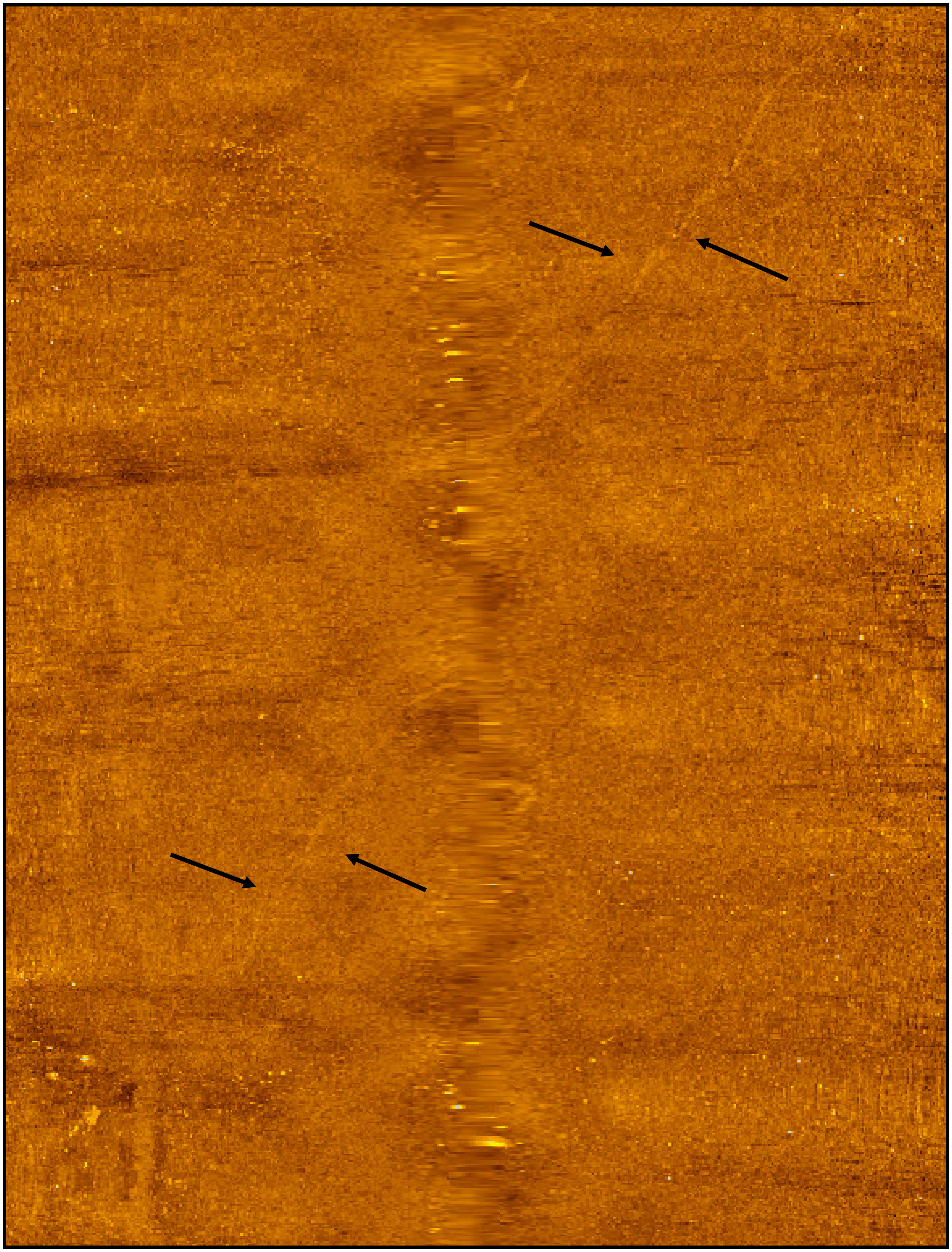


Figure 8. Target ODMDS-3 Sonar Target Signature. (nadir removed from sonar record)

ODMDS-4
NC State Plane x=2693245 y=329310

Target ODMDS-4 had a monopolar magnetic signature with an intensity of more than 4 nT (Figure 9). No acoustic target signature was found in association with the magnetic signature.

The simple monopolar characteristic of the targets signature suggests that it was created by a single ferrous object with limited potential to be associated with a significant submerged cultural resource. No additional investigation or mitigation is recommended.

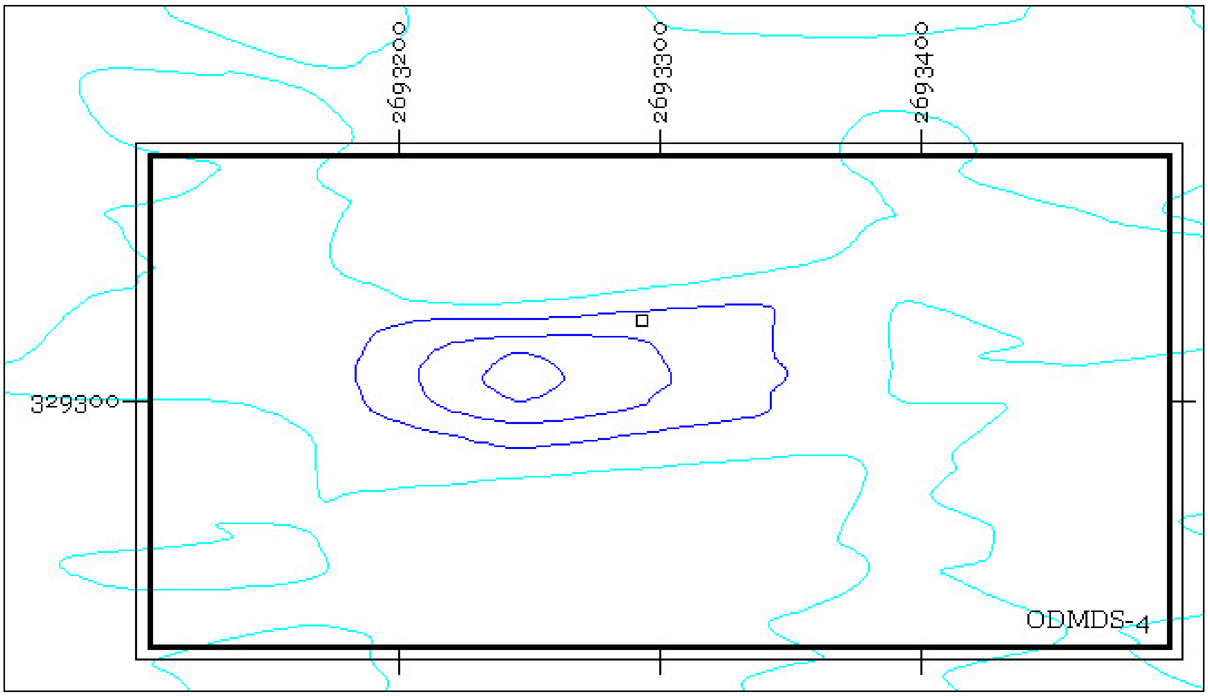


Figure 9. Target ODMDS-4 Magnetic Contour Signature.

ODMDS-5
NC State Plane x=2693107 y=332650

Target cluster ODMDS-5 consisted of at least two dipolar magnetic anomalies on two survey lines with a maximum magnetic intensity of 10 nT (Figure 10). No acoustic target signature was identified in association with the magnetic anomalies. The intensity, proximity, and characteristics of the targets signatures suggest they may be related or similar objects.

Although they may be related, the individual anomalies appear emanate from a single source each with limited potential to be associated with a significant submerged cultural resource. No additional underwater archaeological investigation or mitigation is recommended.

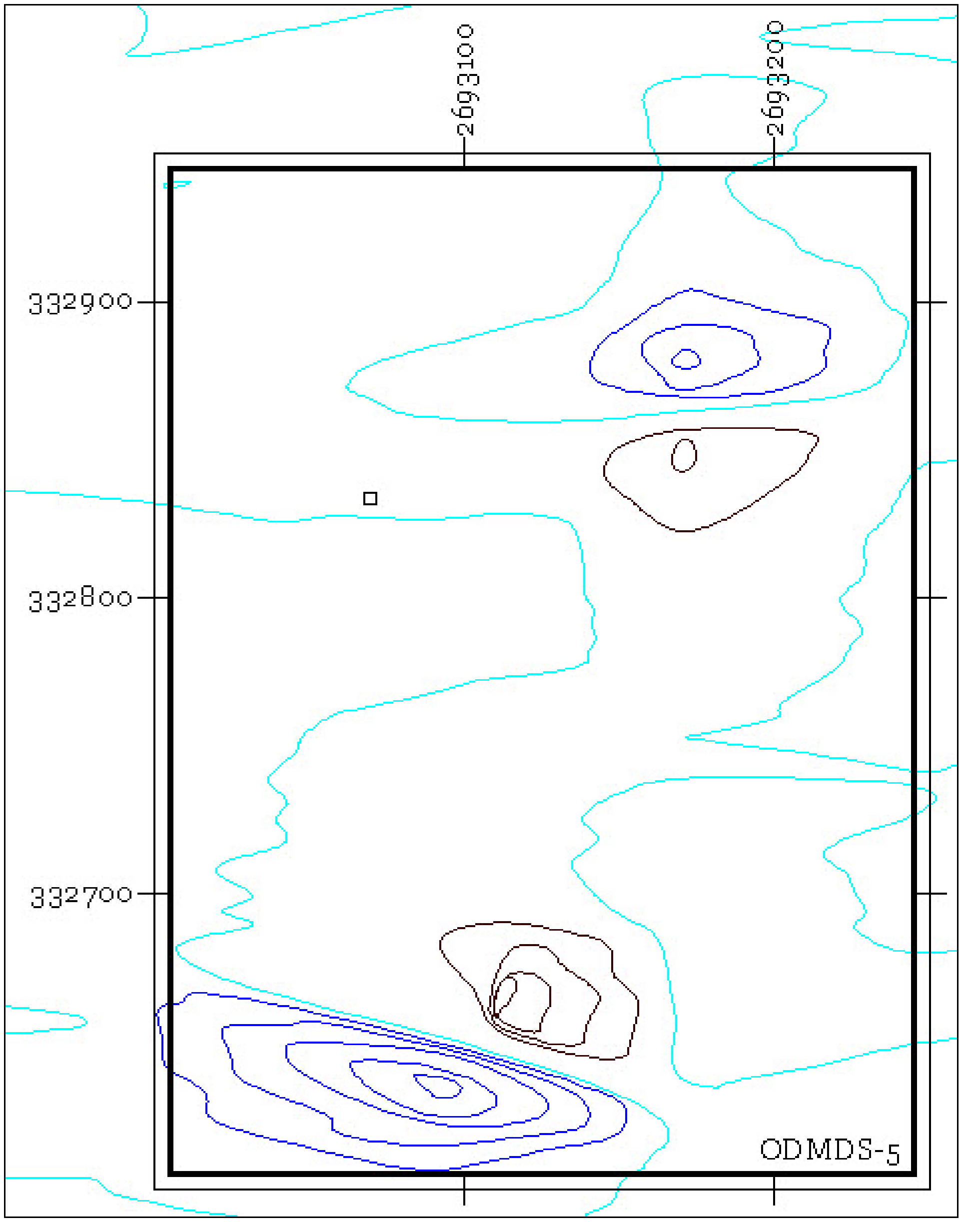


Figure 10. Target Cluster ODMDS-5 Magnetic Contour Signature.

ODMDS-6
NC State Plane x=2692702 y=327105

Target ODMDS-6 consisted of broad multi-component magnetic anomaly on two survey lines with a maximum magnetic intensity of 10 nT (Figure 11). No acoustic target signature is associated with the magnetic signature.

Broad multi-component characteristics can be related to more than one ferrous object or objects lying in close proximity. In some circumstances this type of magnetic signature has the potential to be associated with a submerged cultural resource; however this targets location within an offshore shore dredge disposal area makes it more likely to be associated with ferrous debris. No additional underwater archaeological investigation or mitigation is recommended.

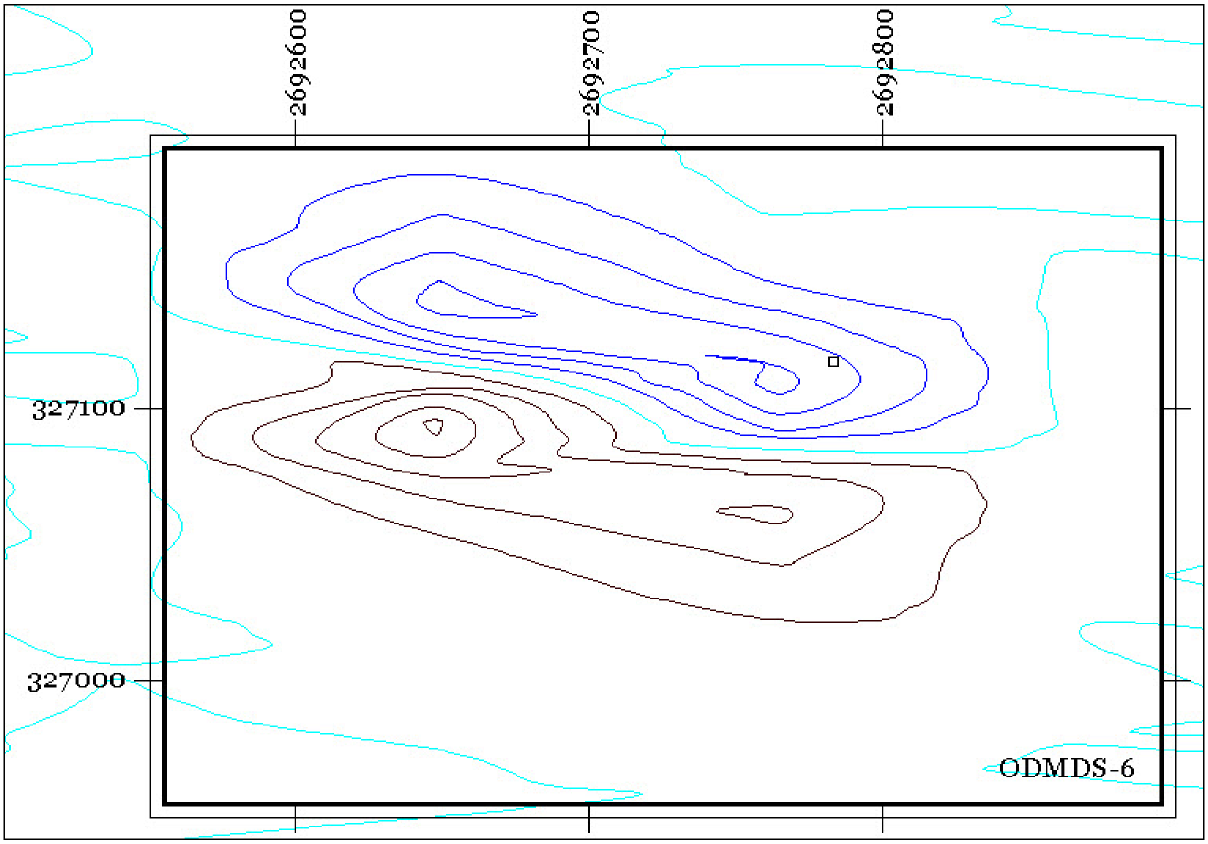


Figure 11. Target ODMDS-6 Magnetic Contour Signature.

ODMDS-7
NC State Plane x=2692246 y=327412

Target ODMDS-7 has a monopolar magnetic signature with an intensity of more than 3 nT (Figure 12). No acoustic target signature was found in association with the magnetic signature.

The simple monopolar characteristic of the targets signature suggests that it was created by a single ferrous object with limited potential to be associated with a significant submerged cultural resource. No additional investigation or mitigation is recommended.

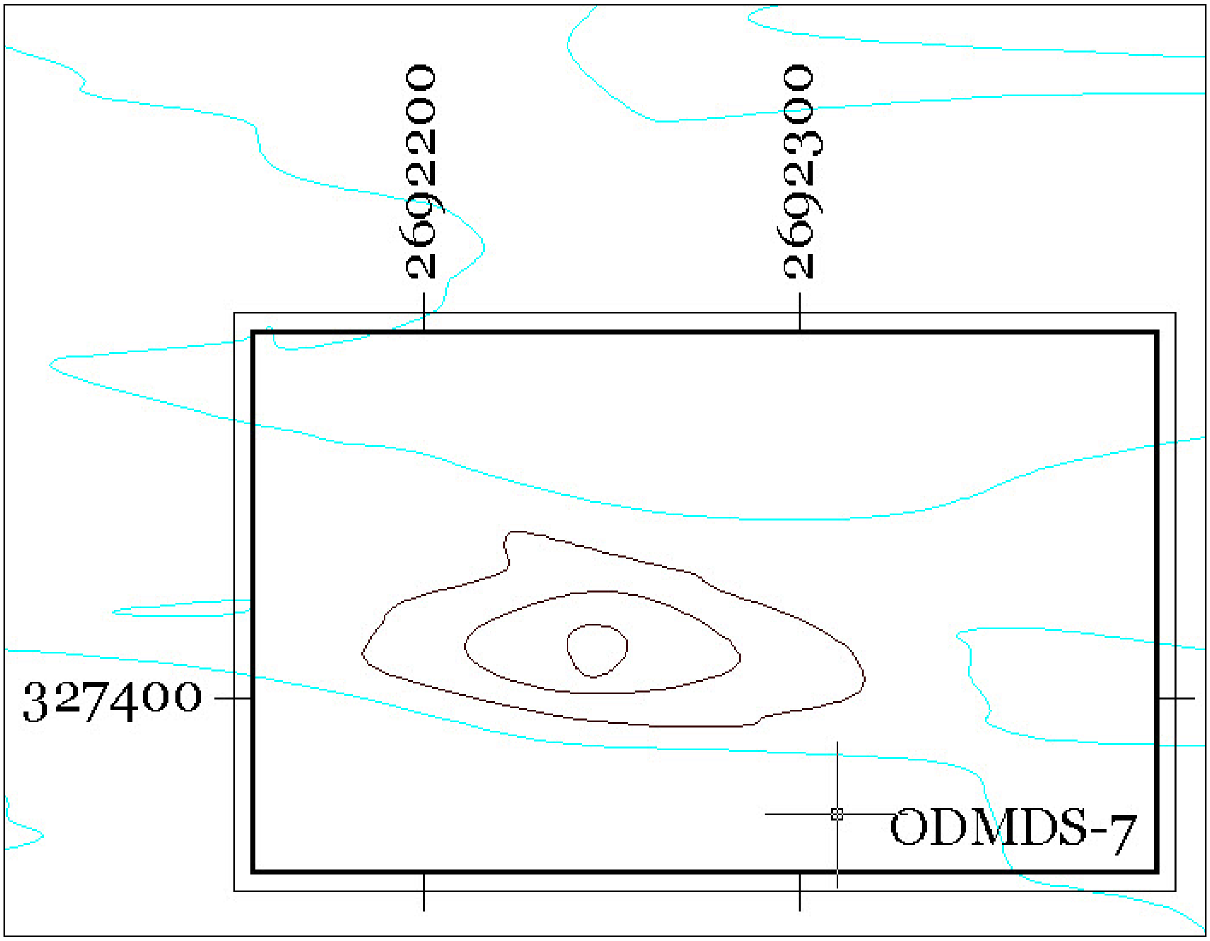


Figure 12. Target ODMDS Magnetic Contour Signature.

ODMDS-8
NC State Plane x=2691834 y=328491

Target ODMDS-8 consisted of multi-component magnetic anomaly detected on two survey lines with a maximum magnetic intensity of 42 nT (Figure 13). No acoustic target signature was recorded in association with the target.

The broad multi-component characteristics of the magnetic anomaly suggest that it could be related to more than one ferrous object lying in close proximity. Because this type of magnetic signature has the potential to be associated with a submerged cultural resource, this target was selected for diver identification and assessment during the target identification portion of this project.

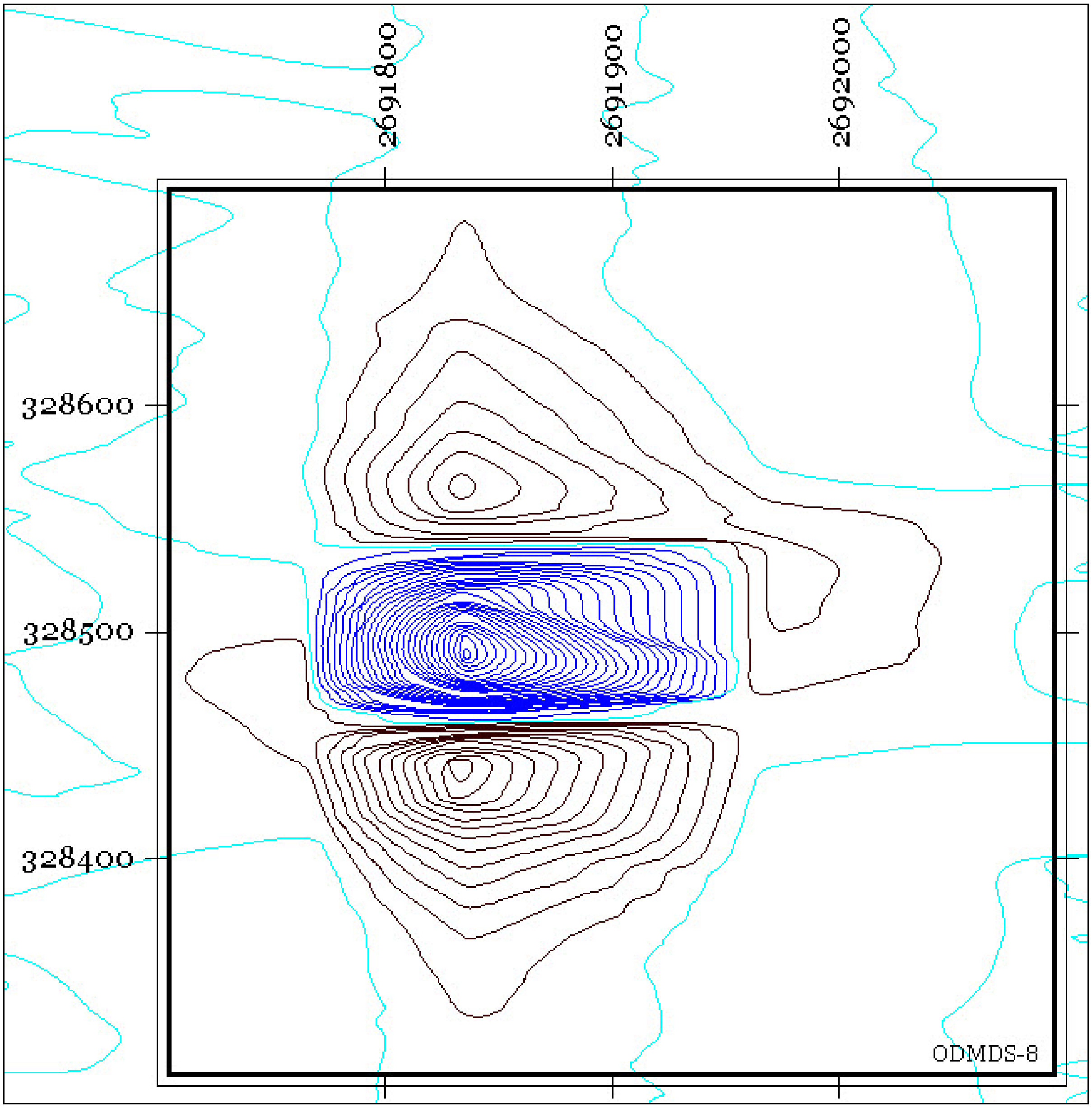


Figure 13. Target ODMDS-8 Magnetic Contour Signature.

ODMDS-9

NC State Plane x=2691951 y=332672

Target ODMDS-9 consisted of a broad single dipolar magnetic anomaly detected on two survey lines with a maximum magnetic intensity of 10 nT (Figure 14). No acoustic target signature was identified in association with the magnetic anomaly.

The simple dipolar characteristic of the target signature suggests that it was created by a single object such a pipe or other linear object. No additional investigations or mitigation are recommended

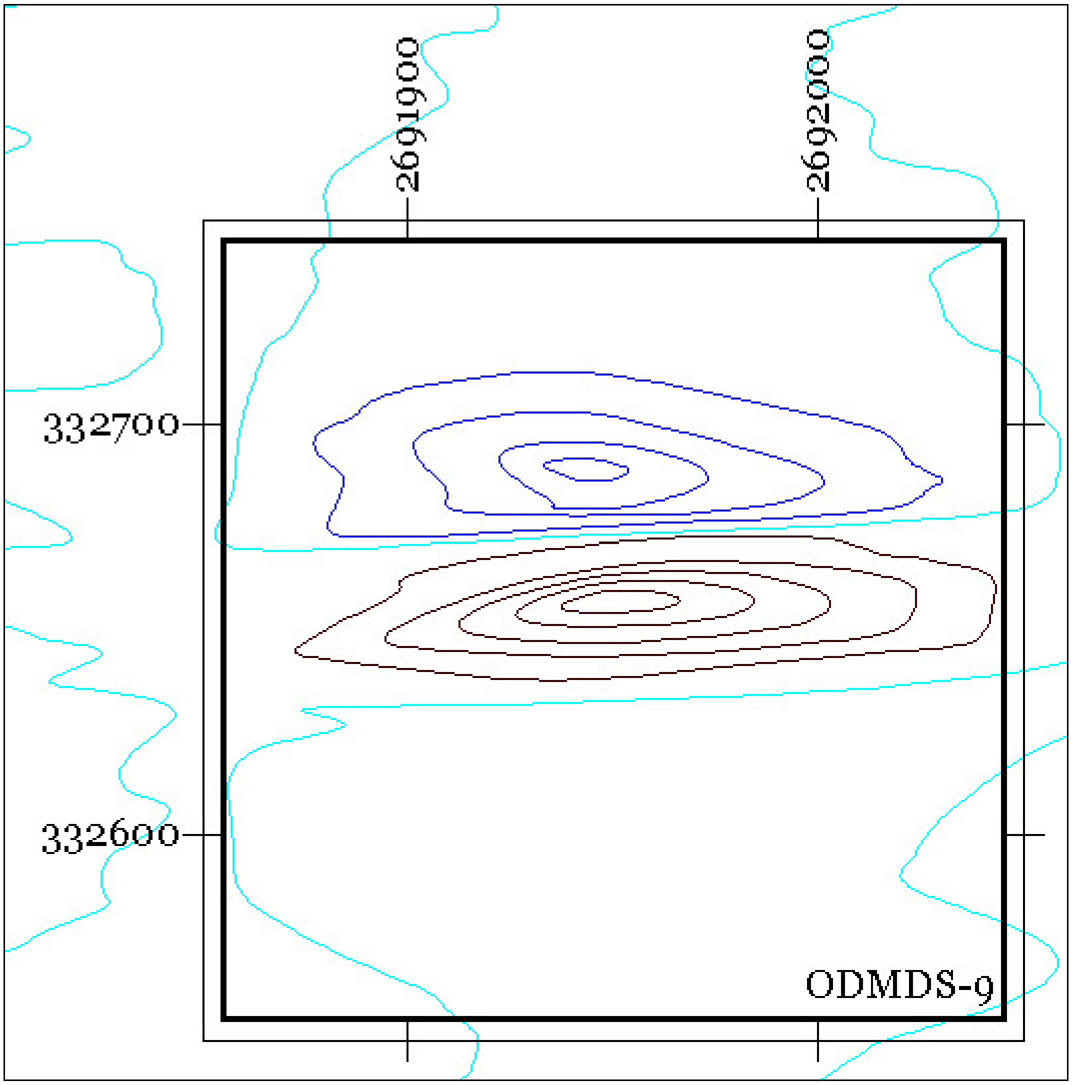


Figure 14. Target ODMDS-9 Magnetic Contour Signature.

ODMDS-10
NC State Plane x=2691471 y=332058

Target ODMDS-10 consisted of a broad single dipolar magnetic anomaly detected on two survey lines with a maximum magnetic intensity of 6 nT (Figure 15). No acoustic target signature was identified in association with the magnetic anomaly.

The simple dipolar characteristic of the target signature suggests that it was created by a single object such a pipe or other linear object. No additional investigations or mitigation are recommended.

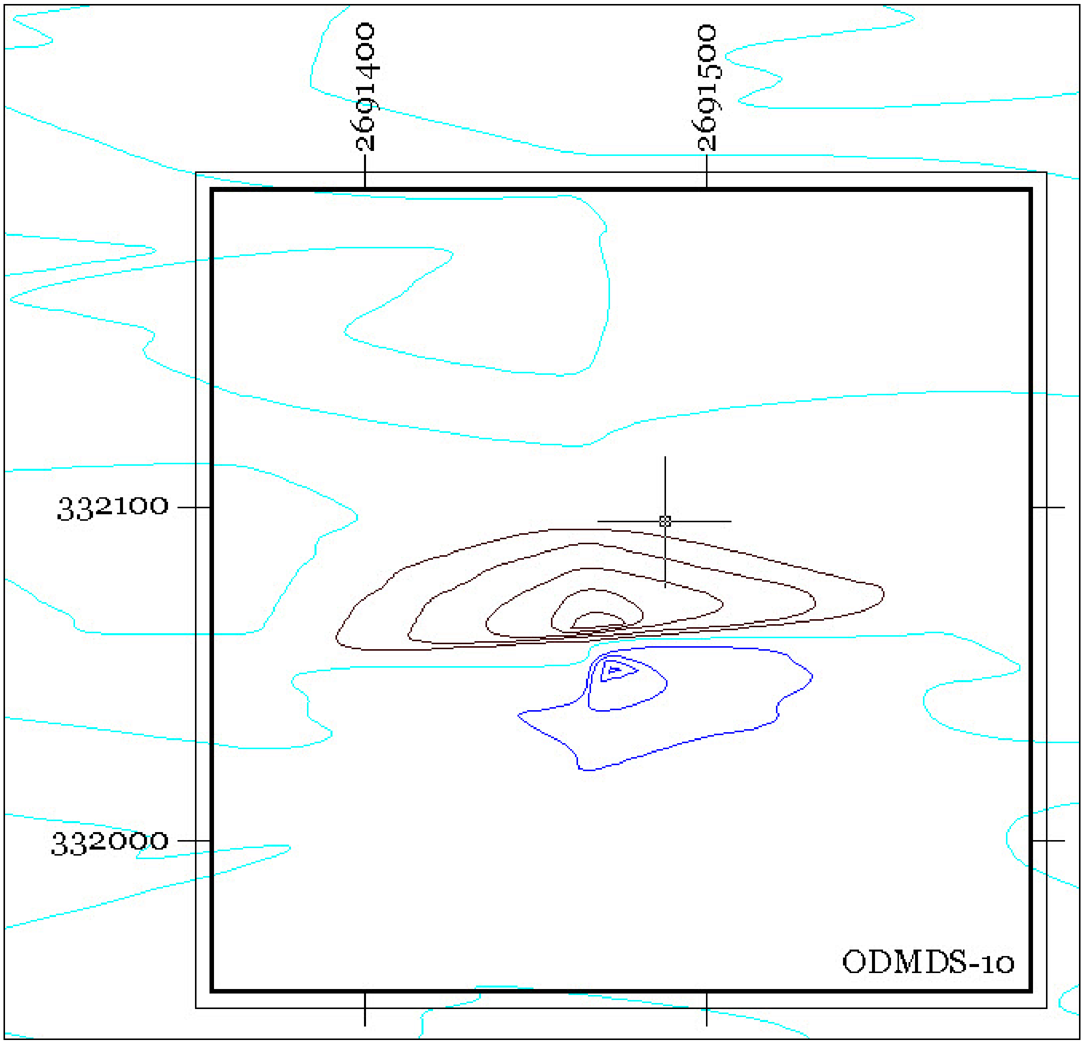


Figure 15. Target ODMDS-10 Magnetic Contour Signature.

ODMDS-11
NC State Plane x=2690067 y=328602

Target ODMDS-11 had a single dipolar magnetic signature on two survey lines with a maximum magnetic intensity of 8 nT (Figure 16). Acoustic records indicate at least one linear object as well as other debris protruding above the bottom in same vicinity as the magnetic anomaly (Figure 17).

Although this type of magnetic signature would appear to have limited potential to be associated with a significant submerged cultural resource, the addition of an acoustic signature made the target good candidate for target identification. Target ODMDS-11 was selected for diver identification and assessment during the target identification portion of this project.

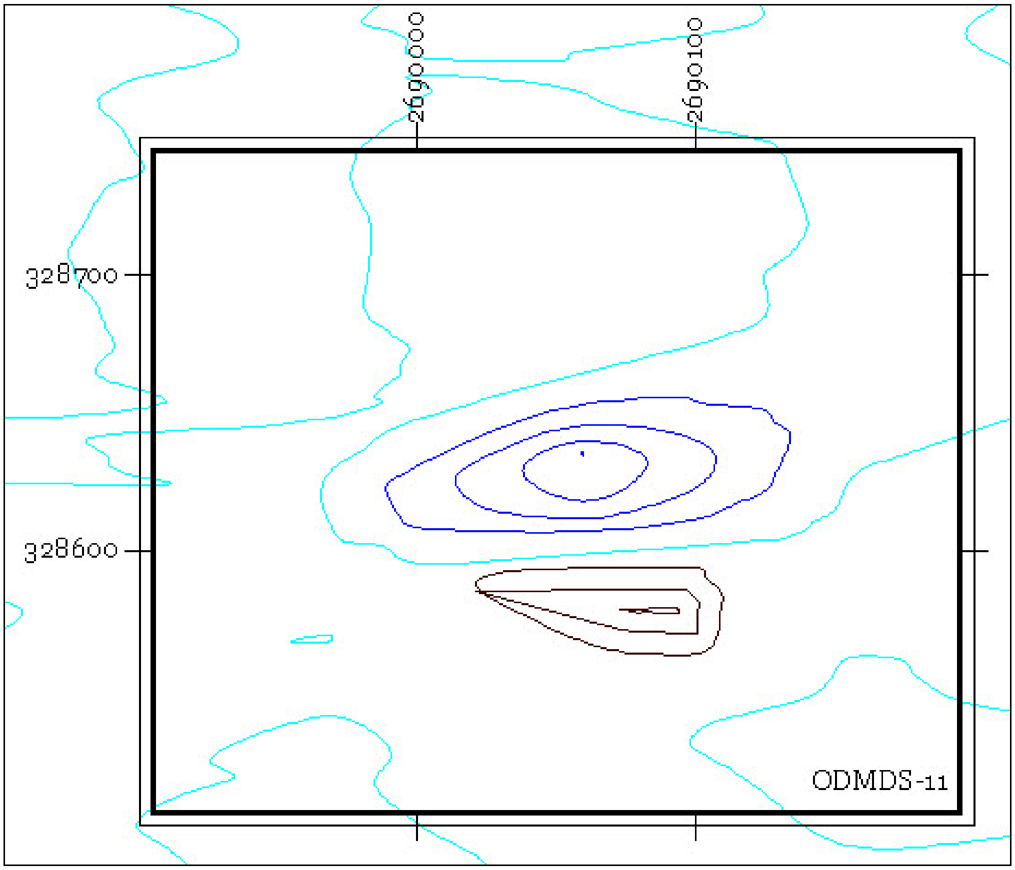


Figure 16. Target ODMDS-11 Magnetic Contour Signature.

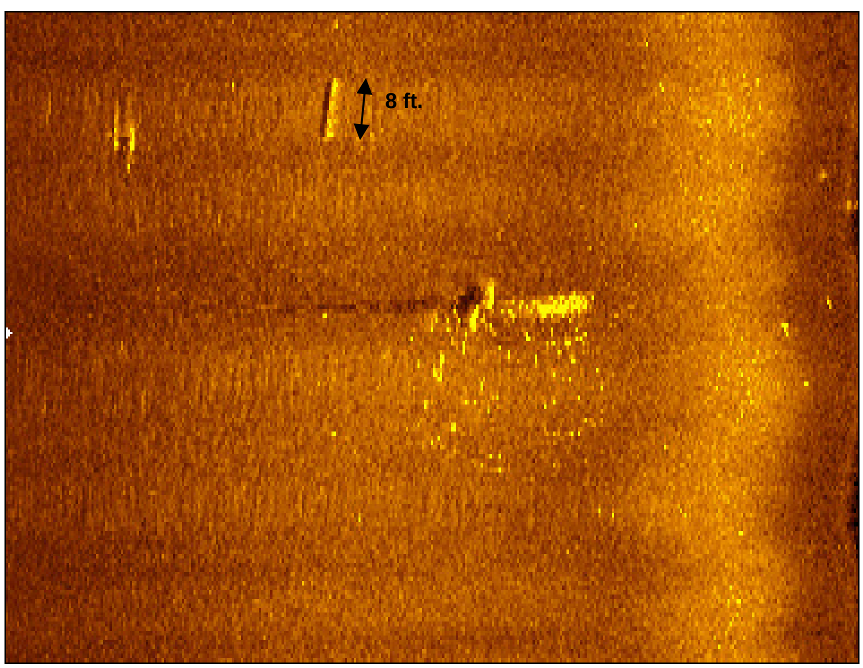


Figure 17. Target ODMDS-11 associated Sonar Signature.

ODMDS 12

NC State Plane x=2689758 y=329159

Target ODMDS-12 had a single dipolar magnetic signature on a single survey line with a maximum magnetic intensity of 5 nT (Figure 18). A scatter of material including linear objects protruding above was recorded on acoustic records in association with the magnetic signature (Figure 19).

Although this type of magnetic signature would appear to have limited potential to be associated with a significant submerged cultural resource, the addition of an acoustic signature made the target good candidate for identification. Target ODMDS-12 was selected for diver identification and assessment during the target identification portion of this project.

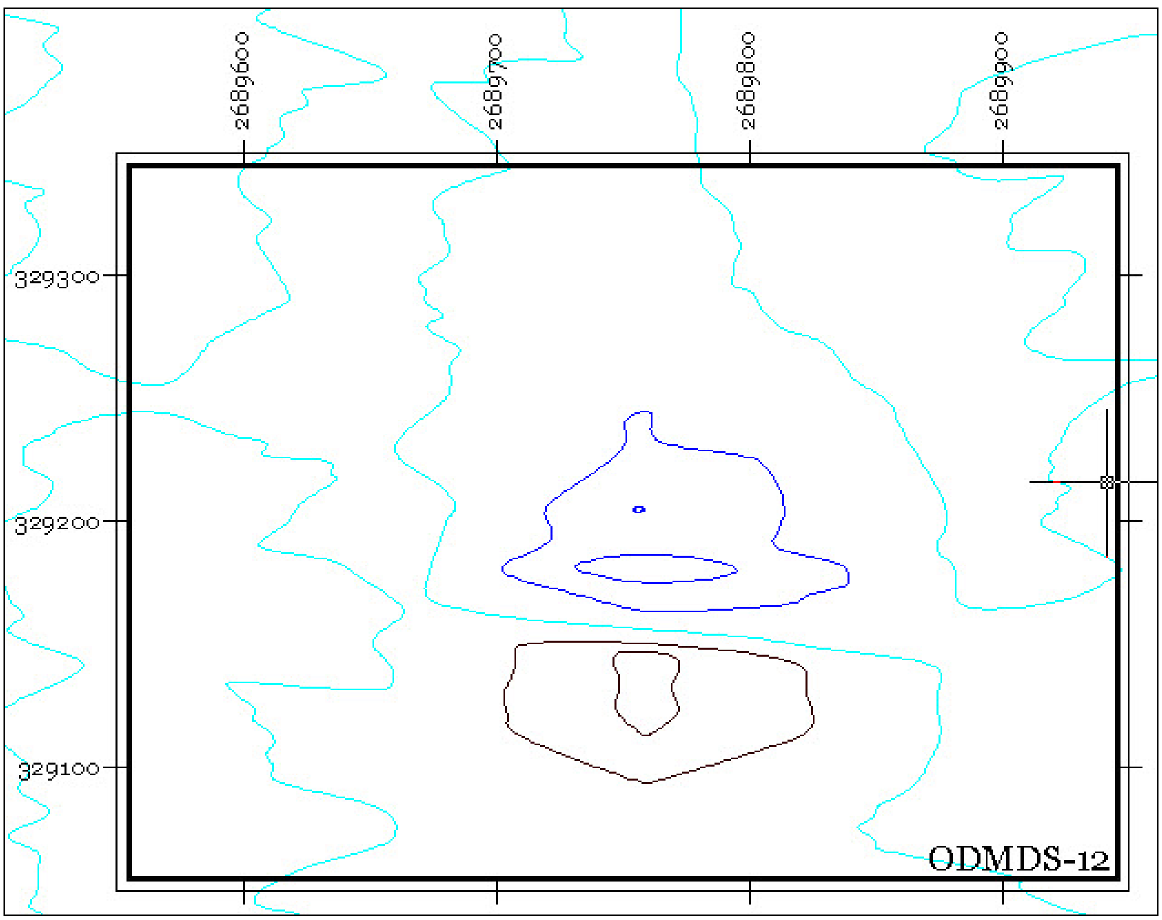


Figure 18. Target ODMDS-12 Magnetic Contour Signature.

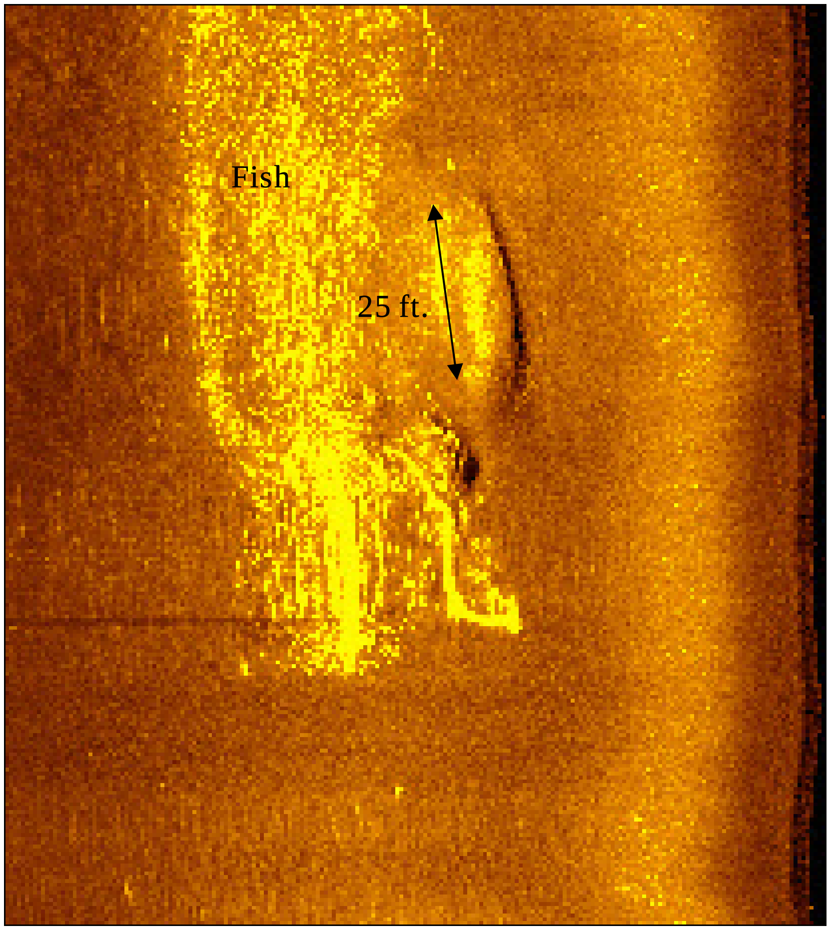


Figure 19. Sonar Signature associated with ODMDS-12.

ODMDS-13
NC State Plane x=2689458 y=331823

Target Cluster Q2-13 consisted of two dipolar magnetic anomalies on three survey lines with a maximum magnetic intensity of 11 nT (Figure 20). No acoustic target signature was recorded in associations with the magnetic anomalies. The intensity, proximity, and characteristics of the targets' signatures suggest they may be related or at least similar ferrous objects.

Although they may be related, the individual anomalies appear emanate from a single source each with limited potential to be associated with a significant submerged cultural resource. No additional underwater archaeological investigation or mitigation is recommended.

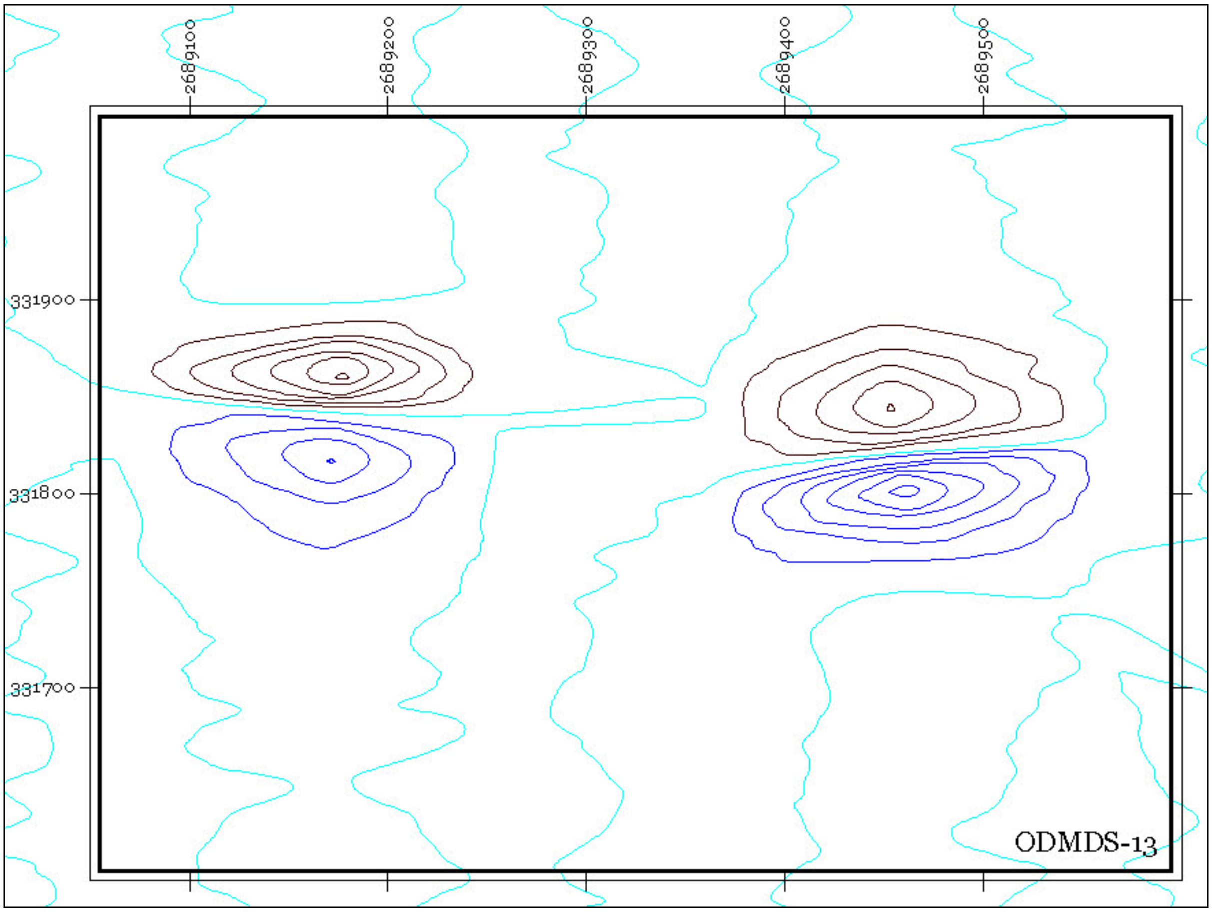


Figure 20. Target Cluster ODMDS-13 Magnetic Contour Signature.

ODMDS-14
NC State Plane x=2688258 y=331380

Target ODMDS-14 had a dipolar magnetic signature with an intensity of more than 4 nT (Figure 20). A large mound of sand/sediment was identified on acoustic records associated with the magnetic anomaly.

Based on the mound in the sonar signature the target appears to be associated with a relatively recent dredge material disposal site. No additional investigation or mitigation is recommended.

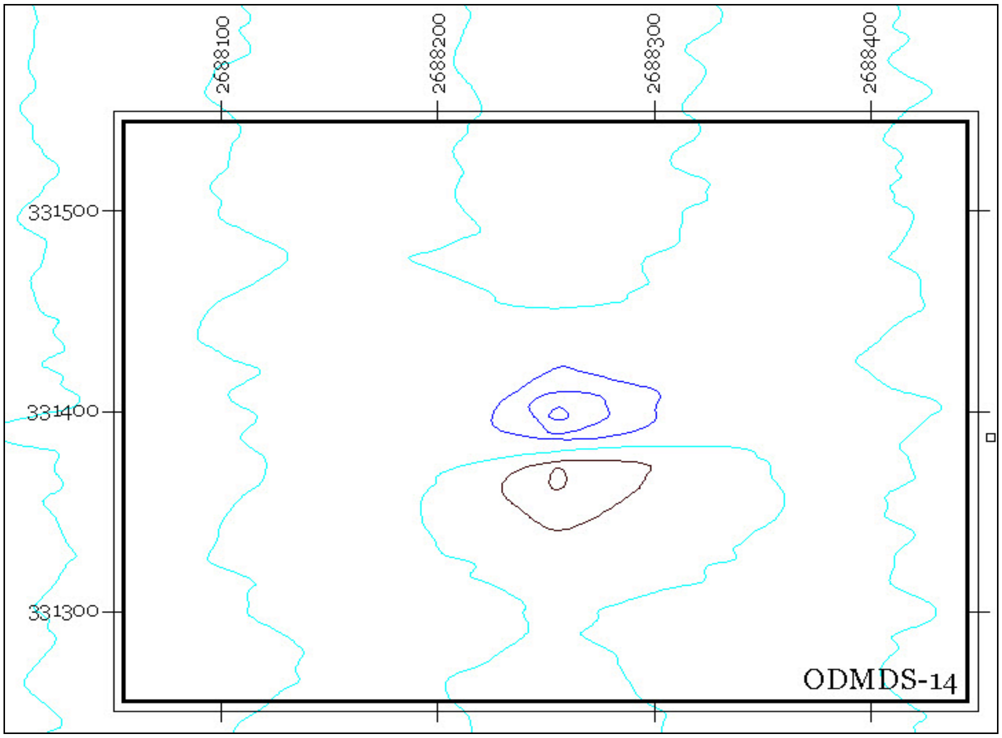


Figure 21. Target ODMDS-14 Magnetic Contour Signature.

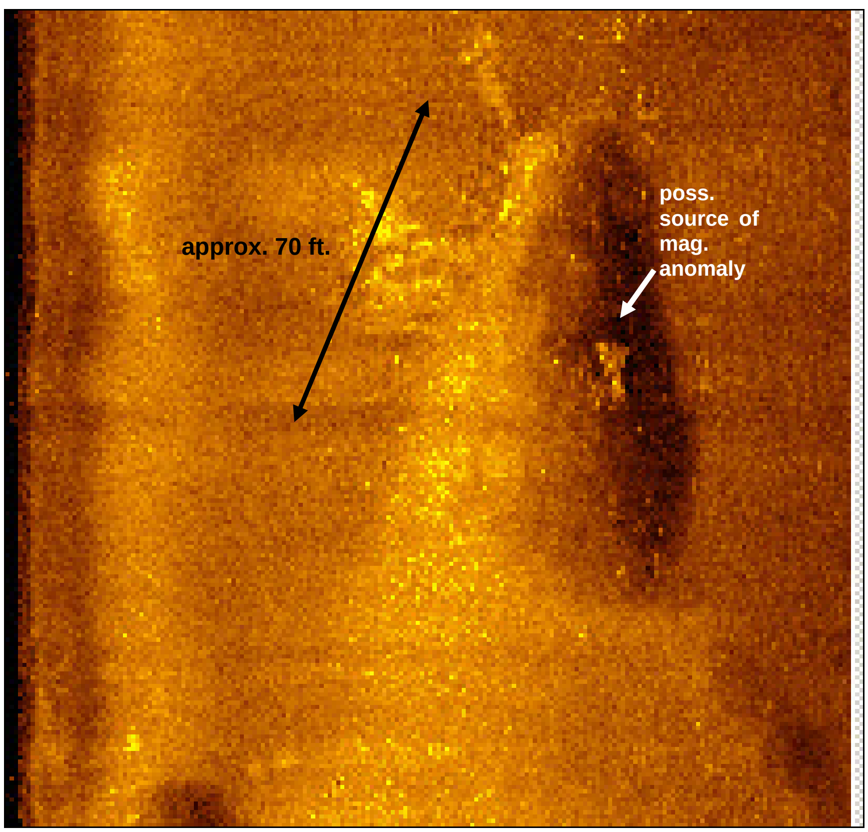


Figure 22. Target ODMDS-14 Magnetic Contour Signature.

ODMDS-15
NC State Plane x=2686524 y=332863

Target ODMDS-15 consisted of multi-component magnetic anomaly detected on two survey lines with a maximum magnetic intensity of 6 nT (Figure 23). No acoustic target signature was recorded in association with the target.

Broad multi-component characteristics can be related to more than one ferrous object or objects lying in close proximity. In some circumstances this type of magnetic signature has the potential to be associated with a submerged cultural resource; however this targets location within an offshore shore dredge disposal area makes it more likely to be associated with ferrous debris. No additional underwater archaeological investigation or mitigation is recommended

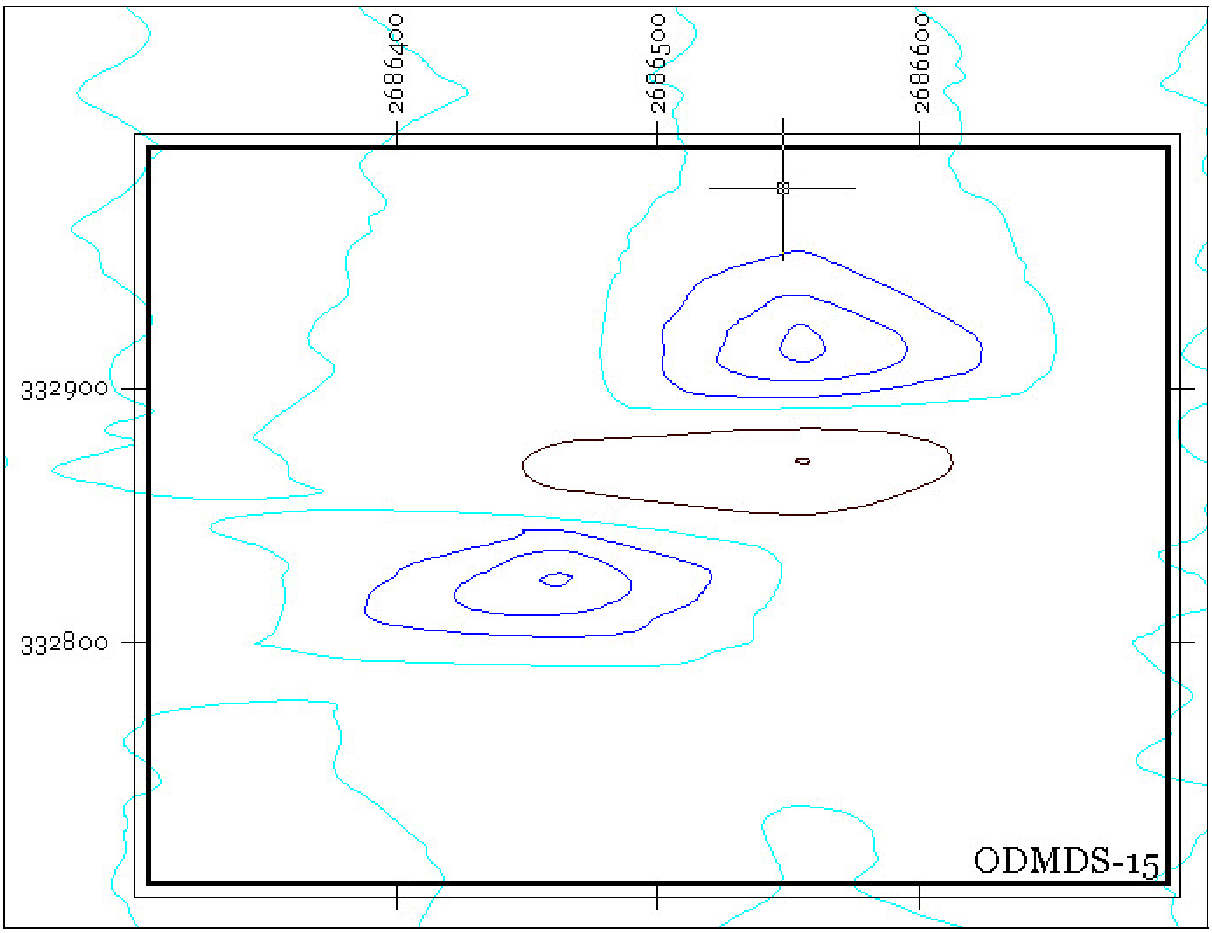


Figure 23. Target ODMDS-15 Magnetic Contour Signature.

ODMDS-16
NC State Plane x=2685354 y=325494

Target ODMDS-16 consisted of two monopolar magnetic anomalies recorded along a two survey lines with a maximum magnetic intensity of more than 2 nT (Figure 24). No acoustic target signature was identified in association with the magnetic anomalies. The target appears to be one or more associated objects possibly a section of wire rope. No additional underwater archaeological investigation or mitigation is recommended.

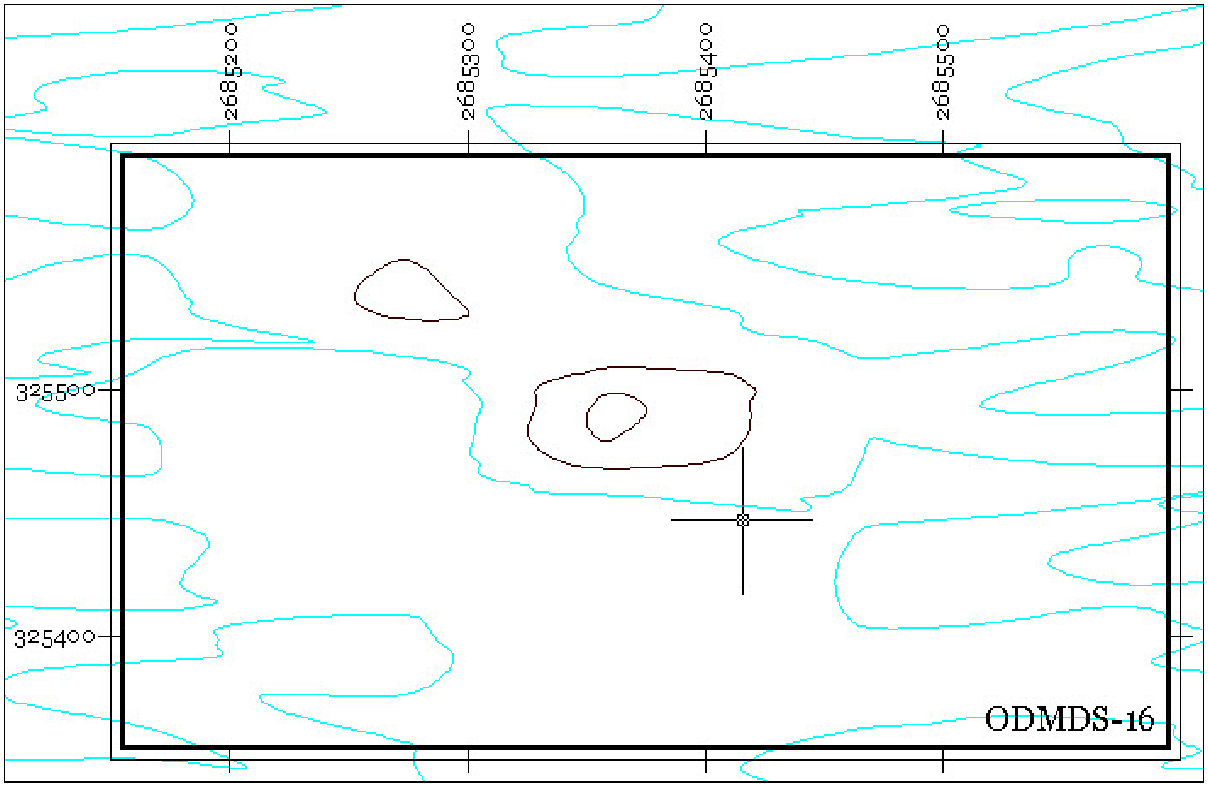


Figure 24. Target Cluster Q2-16 Magnetic Contour Signature.

ODMDS-17
NC State Plane x=2685258 y=332187

Target ODMDS-17 consisted of a single dipolar magnetic anomaly on a single survey line with a maximum magnetic intensity of 9 nT (Figure 25). No acoustic target signature was identified in association with the magnetic anomalies.

The simple dipolar characteristic of the targets signature suggests that it was created by a single object such a pipe or other linear object with limited potential to be associated with a significant submerged cultural resource. No additional investigation or mitigation is recommended.

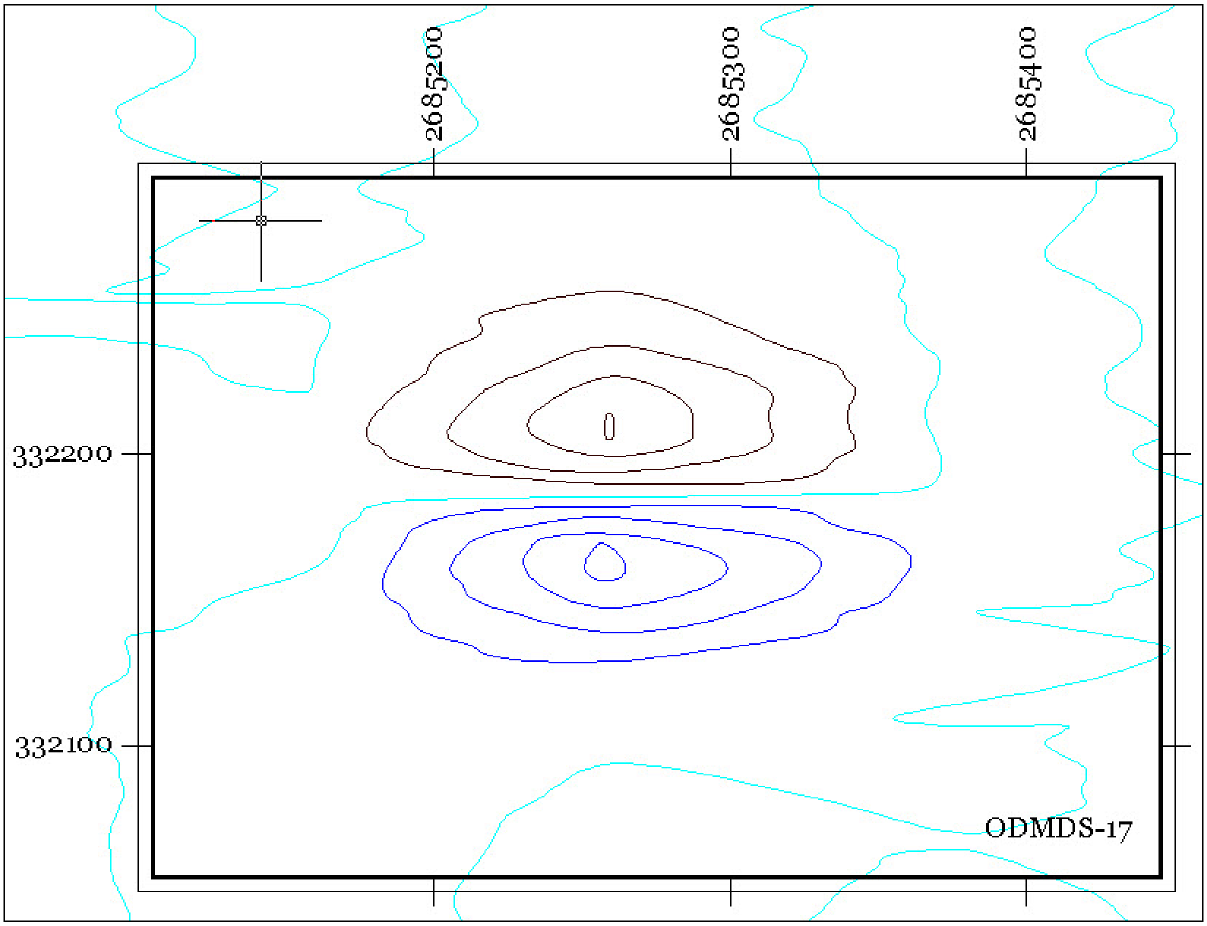


Figure 25. Target ODMDS-17 Magnetic Contour Signature.

ODMDS-18
NC State Plane x=2685275 y=330778

Target ODMDS-18 consisted of a single dipolar magnetic anomaly on a single survey line with a maximum magnetic intensity of 8 nT (Figure 26). No acoustic target signature was identified in association with the magnetic anomalies.

The simple dipolar characteristic of the targets signature suggests that it was created by a single object such a pipe or other linear object with limited potential to be associated with a significant submerged cultural resource. No additional investigation or mitigation is recommended.

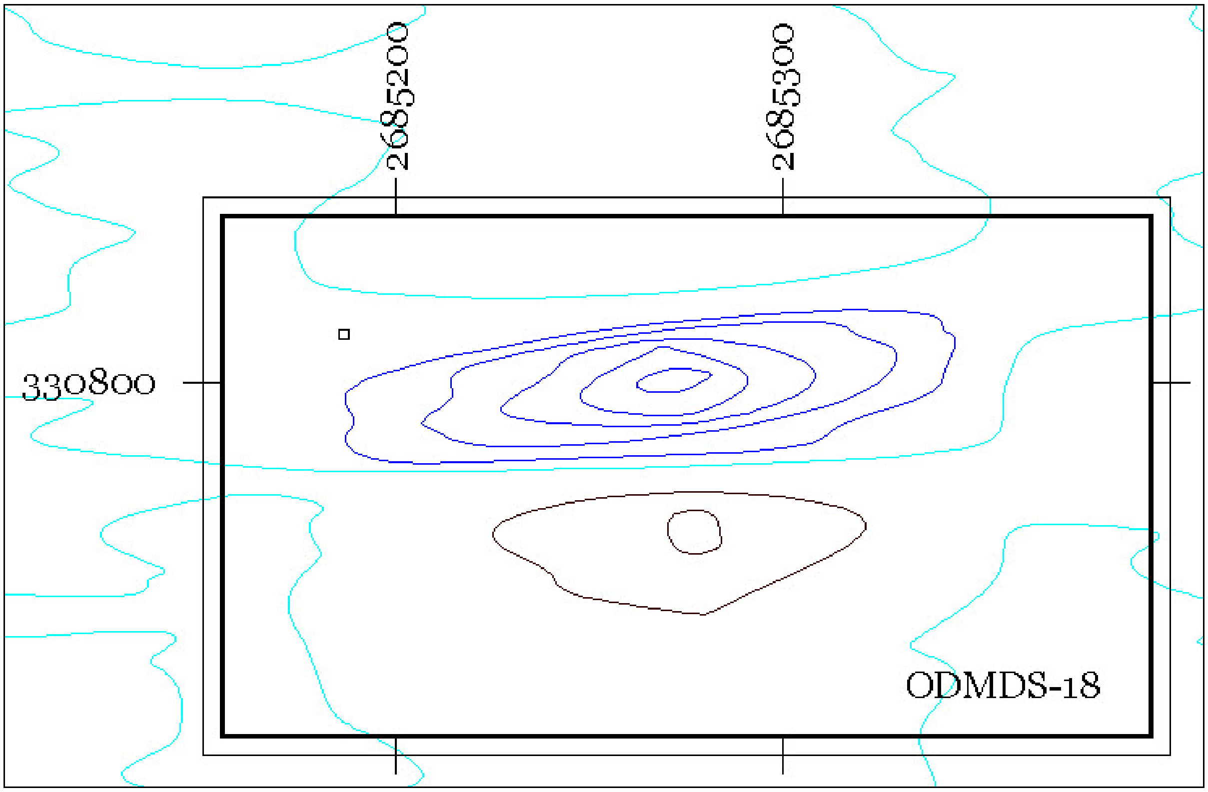


Figure 26. Target ODMDS-18 Magnetic Contour Signature.

ODMDS-19

NC State Plane x=2684952 y=329756

Target ODMDS-19 was a monopolar magnetic anomaly recorded along a single survey line with a maximum magnetic intensity of more than 3 nT (Figure 27). No acoustic target signature was identified in association with the magnetic anomaly.

The simple monopolar characteristic of the targets signature suggests that it was created by a single ferrous object with limited potential to be associated with a significant submerged cultural resource. No additional investigation or mitigation is recommended.

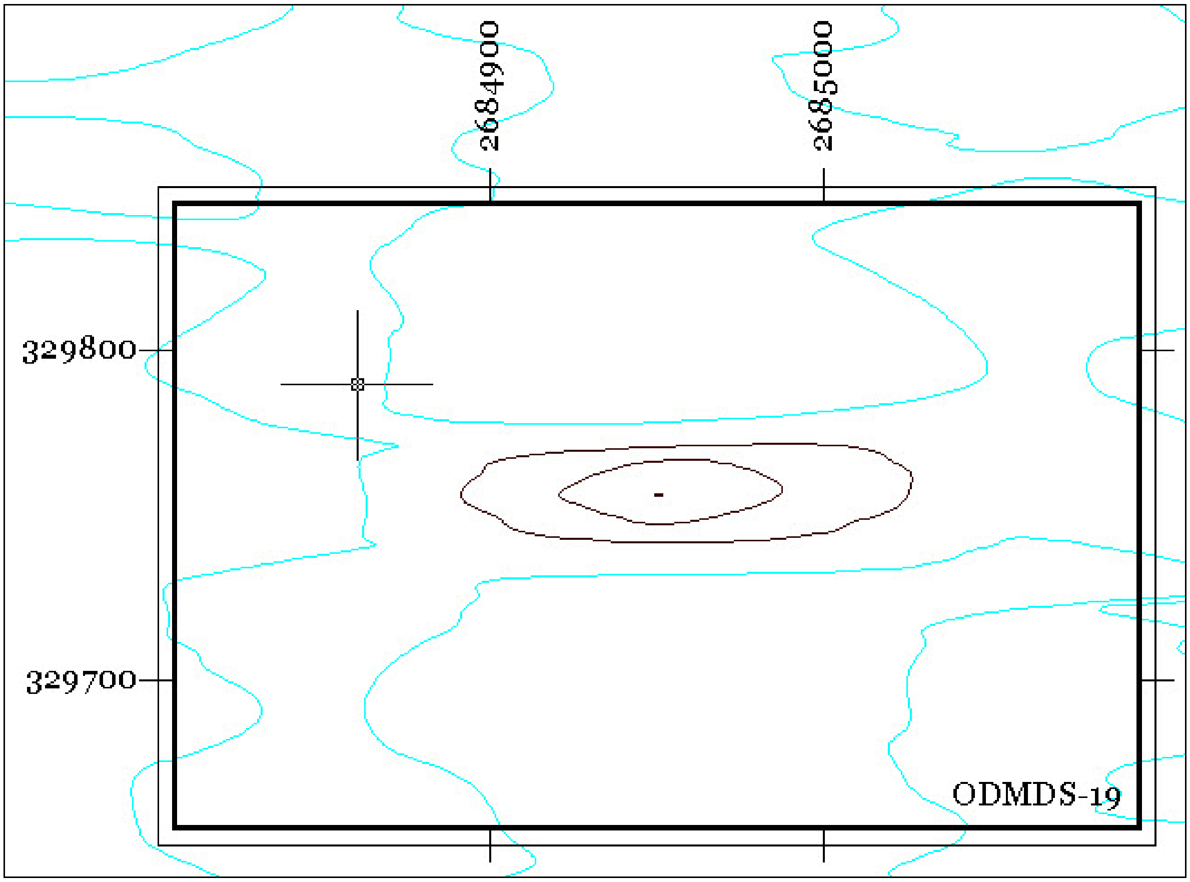


Figure 27. Target ODMDS-19 Magnetic Contour Signature.

ODMDS-20

NC State Plane x=2684659 y=330275

Target ODMDS-20 consisted of a single dipolar magnetic anomaly on a single survey line with a maximum magnetic intensity of 6 nT. No acoustic target signature was identified in association with the magnetic anomaly.

The simple dipolar characteristics of the targets signature suggests that it was created by a single object such a pipe or other linear object. No additional investigations or mitigation are recommended.

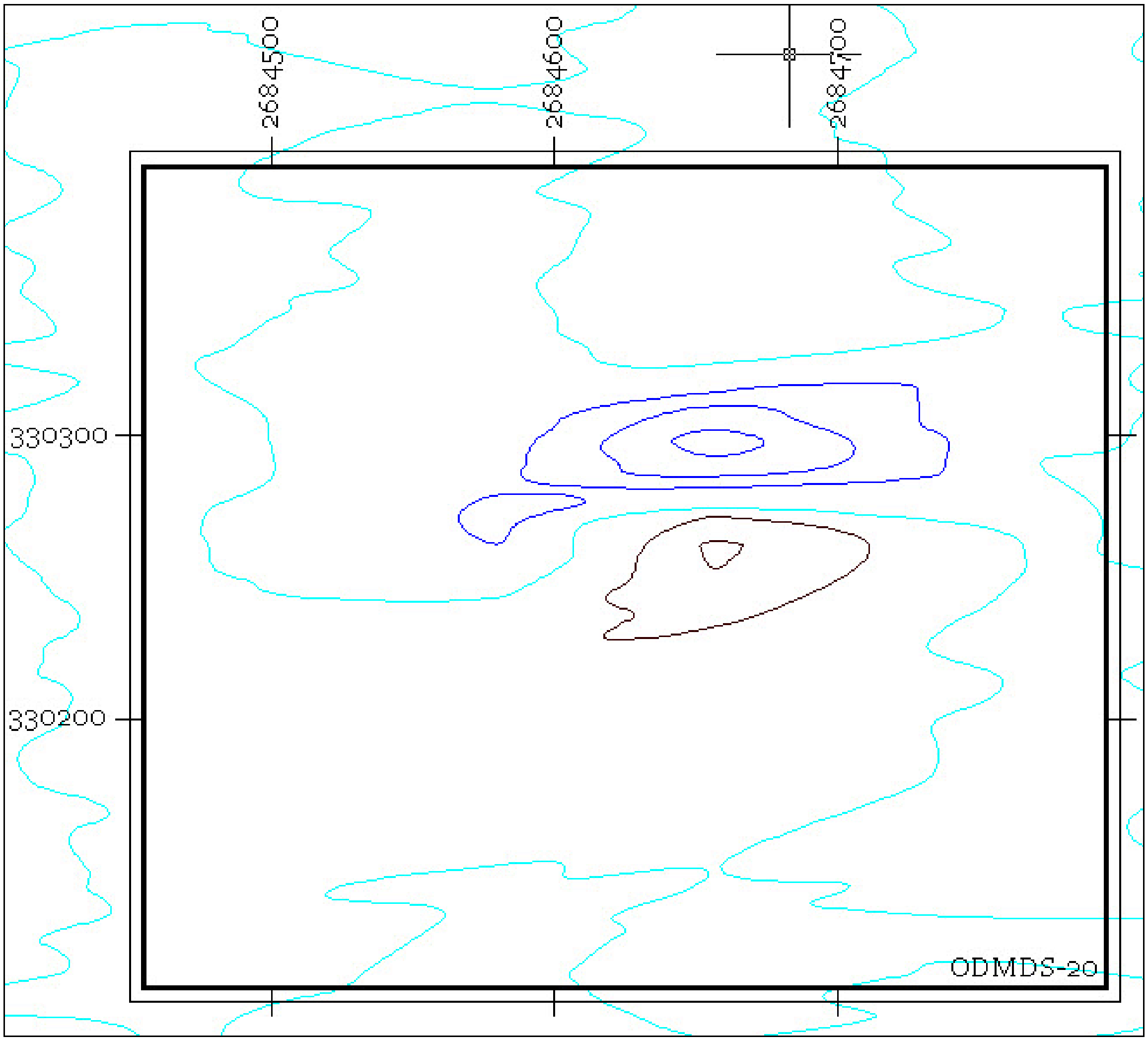


Figure 28. Target ODMDS-20 Magnetic Contour Signature.

ODMDS-21
NC State Plane x=2684164 y=328818

Target ODMDS-21 single dipolar magnetic anomaly on a single survey line with a maximum magnetic intensity of 9 nT (Figure 29). A single linear object approximately 8 feet in length and protruding above the bottom was recorded on acoustic records in association with the magnetic signature (Figure 30).

Although this type of magnetic signature would appear to have limited potential to be associated with a significant submerged cultural resource, the addition of an acoustic signature made the target good candidate for identification. Target ODMDS-21 was selected for diver identification and assessment during the target identification portion of this project.

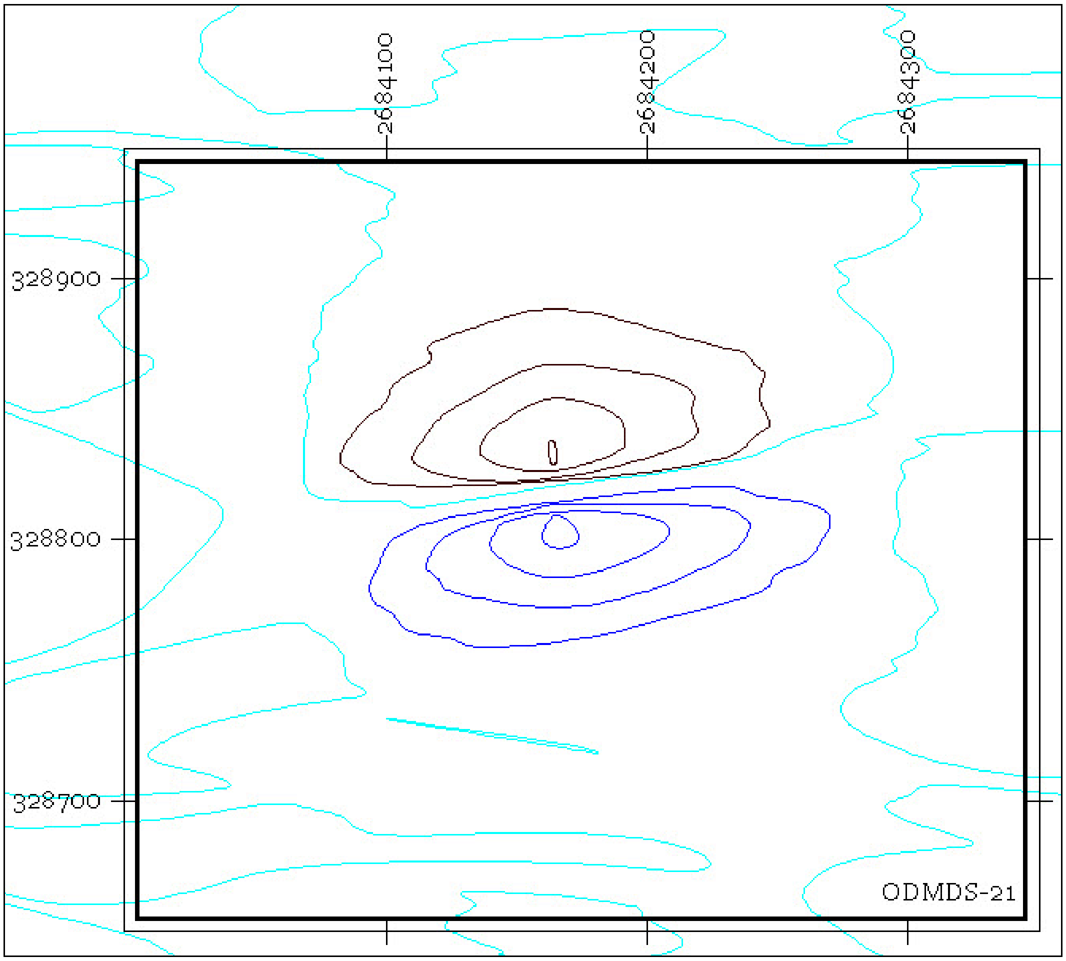


Figure 29. Target ODMDS-21 Magnetic Contour Signature.

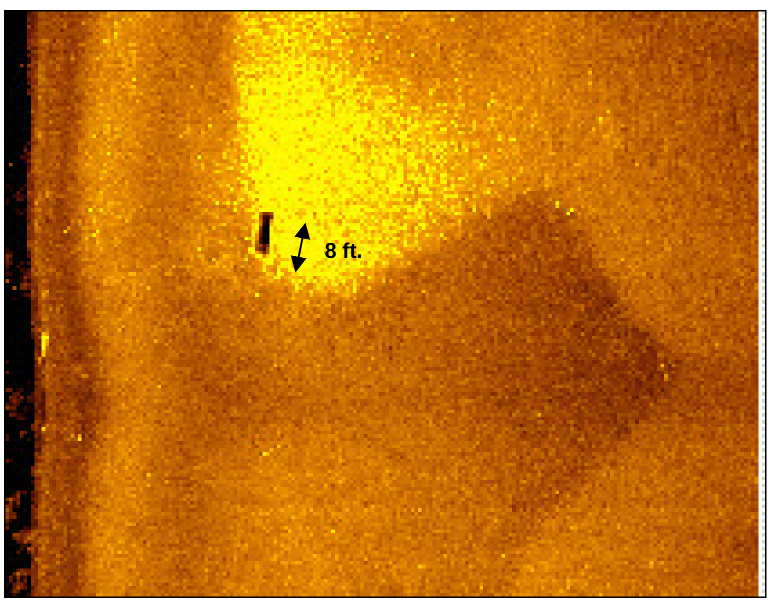


Figure 30. ODMDS-21 Acoustic Target Signature.

ODMDS-22
NC State Plane x=2684346 y=327360

Target ODMDS-22 consisted of broad dipolar magnetic anomaly on two survey lines with a maximum magnetic intensity of 5 nT (Figure 22). No acoustic target signature is associated with the magnetic signature.

Although very broad the simple dipolar characteristic of the targets signature suggests that it was created by a single object such a linear object with limited potential to be associated with a significant submerged cultural resource. No additional investigation or mitigation is recommended.

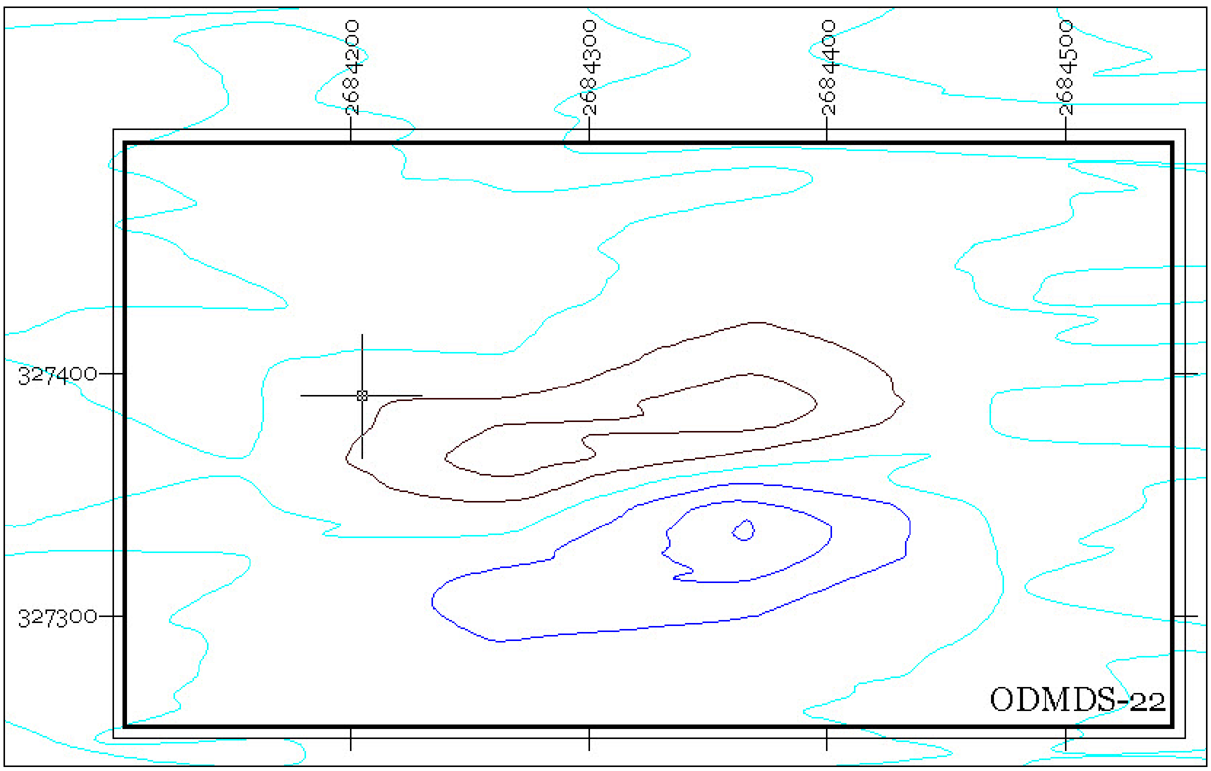


Figure 31. Target ODMDS-22 Magnetic Contour Signature.

ODMDS-23
NC State Plane x=2684477 y=325366

Target ODMDS-23 consisted of broad monopolar magnetic anomaly on two or three survey lines with a maximum magnetic intensity of 3 nT (Figure 32). No acoustic target signature is associated with the magnetic signature.

Although very broad the simple monopolar characteristics of the targets signature suggests that it was created by a single object. No additional investigation or mitigation is recommended.

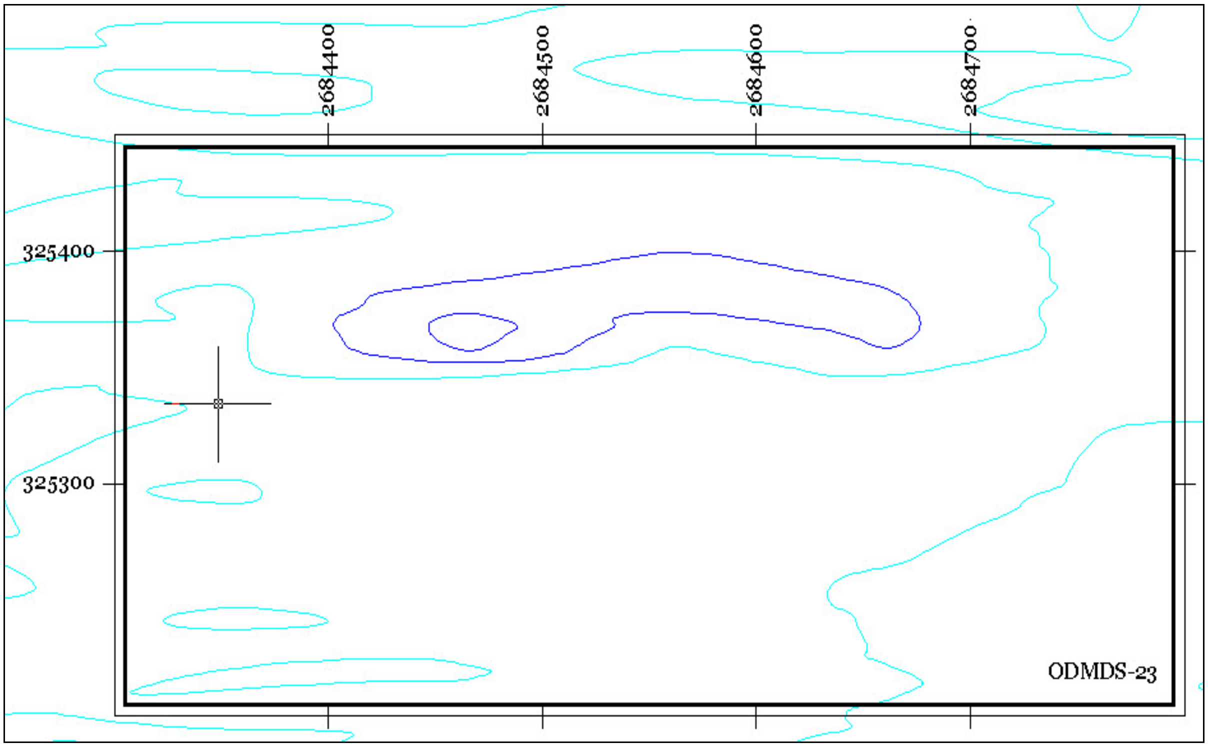


Figure 32. Target ODMDS-23 Magnetic Contour Signature.

ODMDS-24
NC State Plane x=2683689 y=327949

Target ODMDS-24 consisted of broad multi-component magnetic anomaly on two survey lines with a maximum magnetic intensity of 10 nT (Figure 33). No acoustic target signature is associated with the magnetic signature.

The broad multi-component characteristics of the magnetic anomaly suggest that it could be related to more than one ferrous object lying in close proximity. Because this type of magnetic signature has the potential to be associated with a submerged cultural resource, this target was selected for diver identification and assessment during the target identification portion of this project.

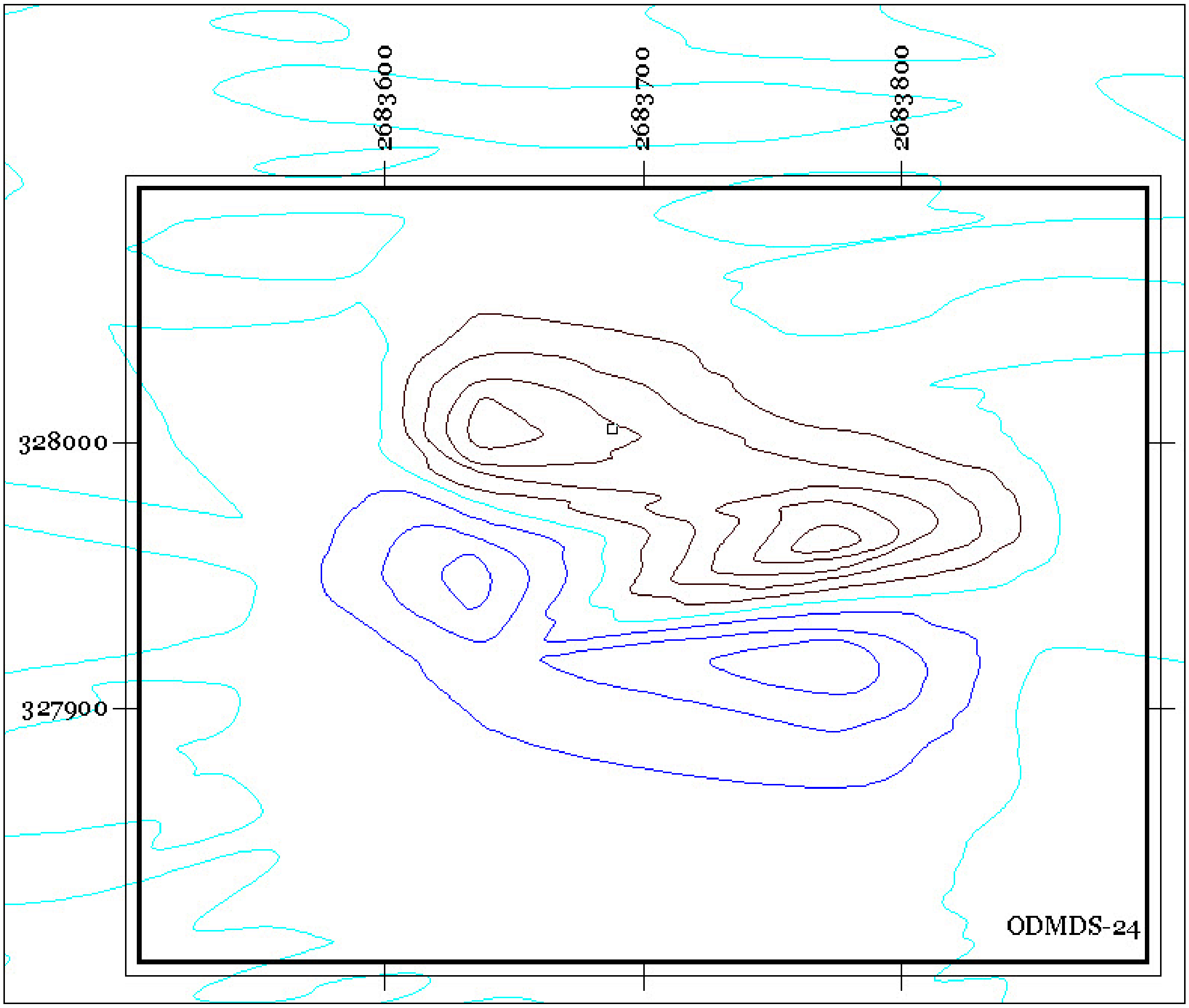


Figure 33. Target ODMDS-24 Magnetic Contour Signature.

ODMDS-25
NC State Plane x=2682463 y=327117

Target ODMDS-25 consisted of a mostly dipolar magnetic anomaly detected on a single survey line with a maximum magnetic intensity of 6 nT (Figure 34). No acoustic target signature was recorded in association with the target.

The simple dipolar characteristics of the targets signature suggests that it was created by a single object such a pipe or other linear object. No additional investigations or mitigation are recommended.

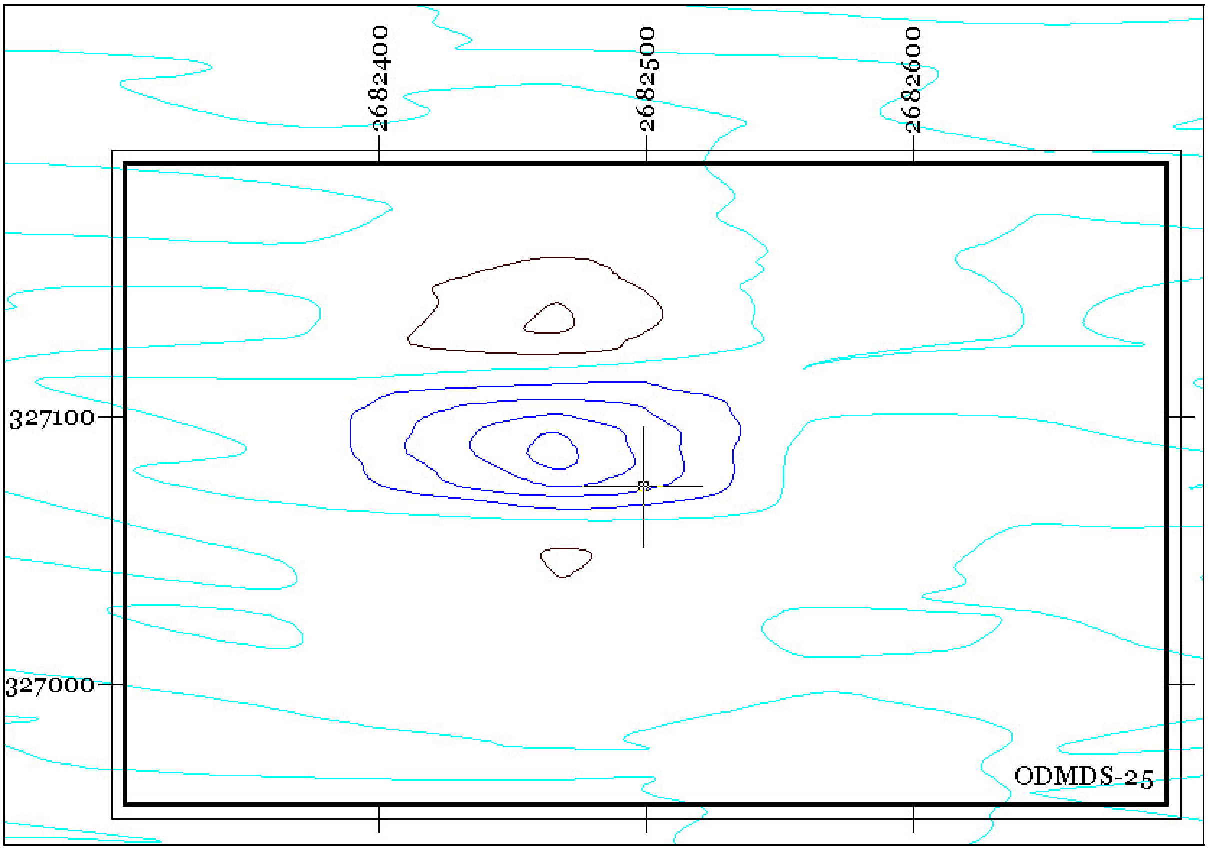


Figure 34. Target ODMDS-25 Magnetic Contour Signature.

IDENTIFICATION OF SELECTED TARGETS

One of the primary goals for the this project was the identification and assessment of 10 previously recorded remote sensing targets found during a 2007 remote sensing survey also conducted by M-AT under contract with US Army Corps of Engineers, Wilmington District. The report entitled *An Archaeological Remote Sensing Survey of Bogue Banks Offshore Borrow Areas, Carteret County, North Carolina* was finalized in 2008 (Hall 2008).

As part of the Carteret County's long range beach nourishment EIS nine (9) remote sensing targets from the 2007 underwater archaeological survey in Borrow Area Q2 and one target (1) from Borrow Area Y were selected to be identified and archaeologically assessed for this investigation. An additional six (6) targets were also selected following completion of the ODMDS remote sensing survey creating a total of 16 targets to be identified.

M-AT's underwater archaeology team conducted the target identification survey from a 25-foot long survey vessel/dive platform. Target relocation was achieved using the survey software HYPACK's navigation program and DGPS positioning to return to the North Carolina State Plane coordinates for each target location.

At each target's location the vessel was maneuvered into a position as close as possible to target coordinates and a buoy was deployed to mark its position. In some cases, such as complex target clusters, either a side scan sonar or a marine magnetometer was used to further resolve target positions or to select particular anomalies within the group. Once the position was marked by a buoy the survey vessel was anchored over that location and a diver was deployed. In the cases of a buried target (indicated by a magnetic anomaly) underwater archaeologists typically employed a handheld underwater proton-precession magnetometer to find the exact location of the anomalies' signature on bottom. Once confirmed, the marker buoy was move to that location on the bottom. Next, if no evidence of the target was identified on the ocean floor, a 10-foot-long ¾-inch hydraulic probe was used to penetrate the bottom in a concentrated probing pattern around the buoy weight until the ferrous object was found.

In some cases objects such as wire rope or pipe, could be effectively identified during the probing process. In other cases where the target could not be identified by simple probing, a 4-inch handheld induction dredge - powered by a 2½-inch fire pump, was employed to excavate down to the material creating the magnetic anomaly. Test excavations to depths below about five feet proved to be difficult and somewhat dangerous. At depths over three feet it was necessary to widen and terrace the test hole to keep the sometimes vertical walls from sloughing in on divers. For this reason test excavations over five-feet-deep were avoided if it was possible to reasonably identify the source of the anomaly by hydraulic probing.

Borrow Area Q2 Target Identification

From Borrow Area Q2 targets Q2-20, 21, 23, 24, 28, 29, 30, 31, and 32 were selected for identification. Only target Q2-30 had an accompanying acoustic signature (Figure 36).

Borrow Area Q2 Targets Selected for Identification:

Q2-20-Cluster
NC State Plane x=2692898 y=337662
Original Target Description:
Target Q2-20 was recorded as a cluster of multi-component and smaller dipolar anomalies on five survey lines with a maximum magnetic intensity of 145 nT (Figure 35). No acoustic target signature was identified in association with the magnetic anomalies.

Q2-20
Testing Location: x=2692852 y=337668
Testing Results:
After probing and excavation of one of the magnetic anomalies within the cluster the target was identified, as 1-inch wire rope buried 5 feet below the bottom.

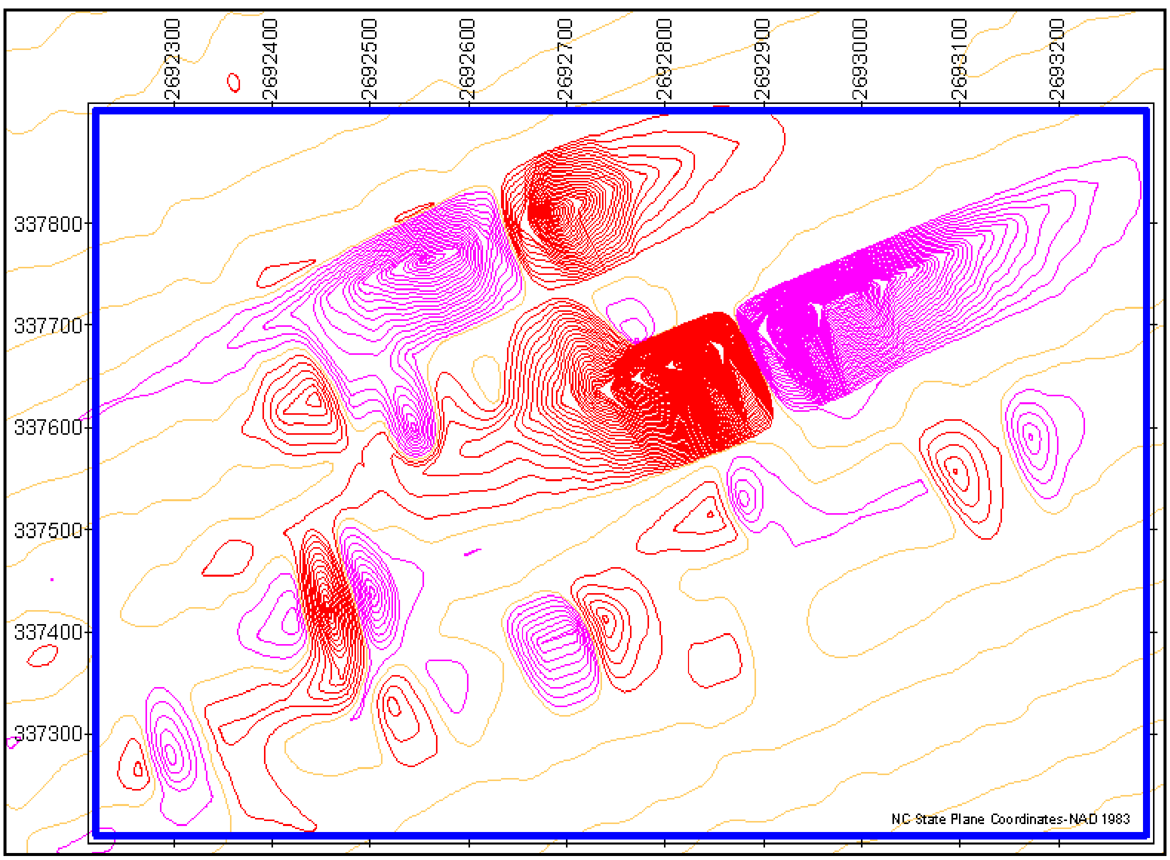


Figure 35. Target Cluster Q2-20 Magnetic Contour Signature.

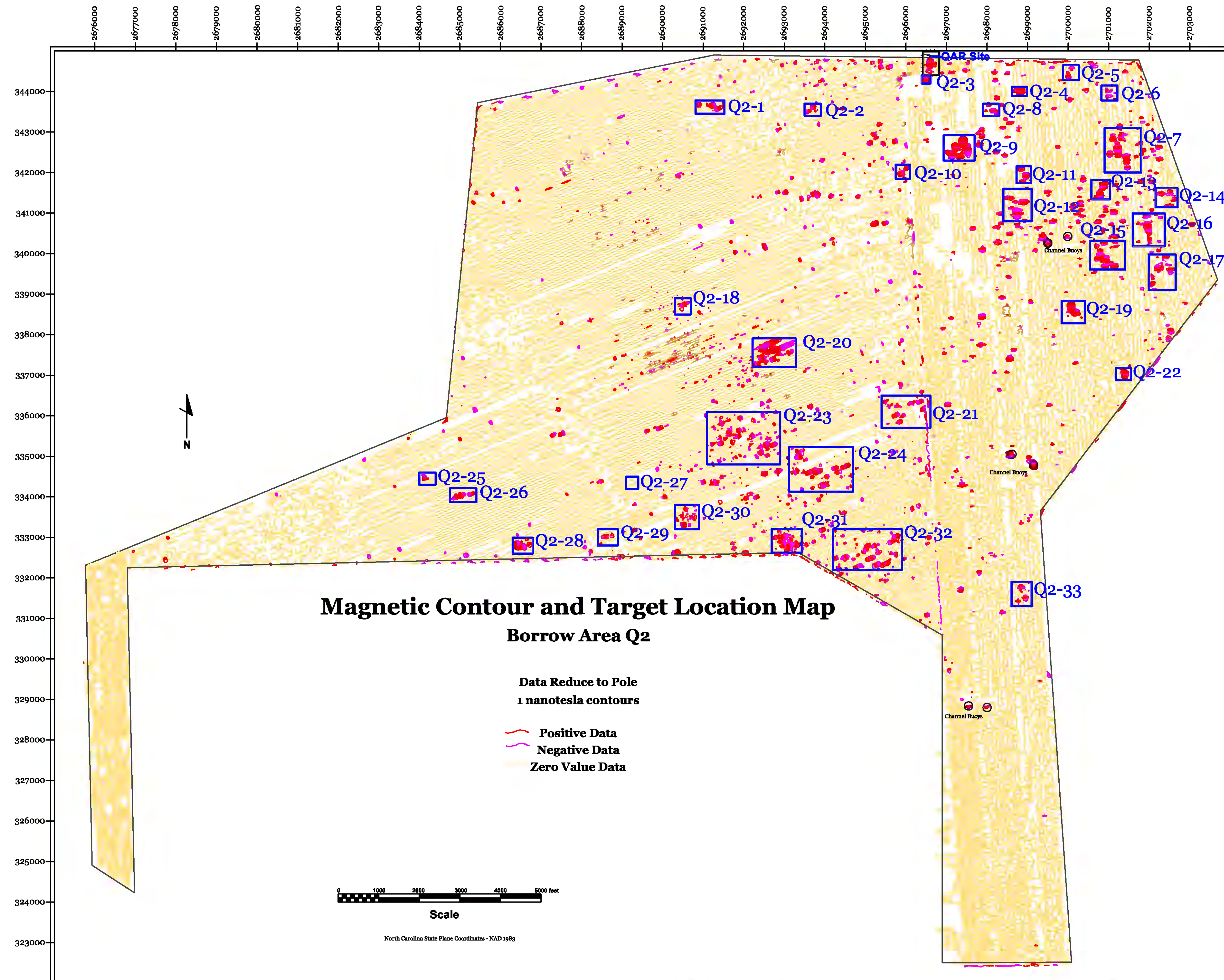


Figure 36. Magnetic Contour and Target Location Map Borrow Area Q2.

Q2-21-Cluster
NC State Plane x=2696327 y=336350
Original Target Description:
Target Cluster Q2-21 consisted of several widely scattered dipolar magnetic anomalies on 8 survey lines with a maximum magnetic intensity of 10 nT (Figure 37). No acoustic target signature was identified in association with the magnetic anomalies.

Q2-21
Testing Location: x=2696168 y=336326
Testing Results:
After probing and excavation, a portion of the target cluster was identified as a steel belted automobile tire buried 7 feet. In addition, divers also believe they encountered some small diameter wire rope at a depth of approximately 9 feet and in the immediate vicinity of the tire.

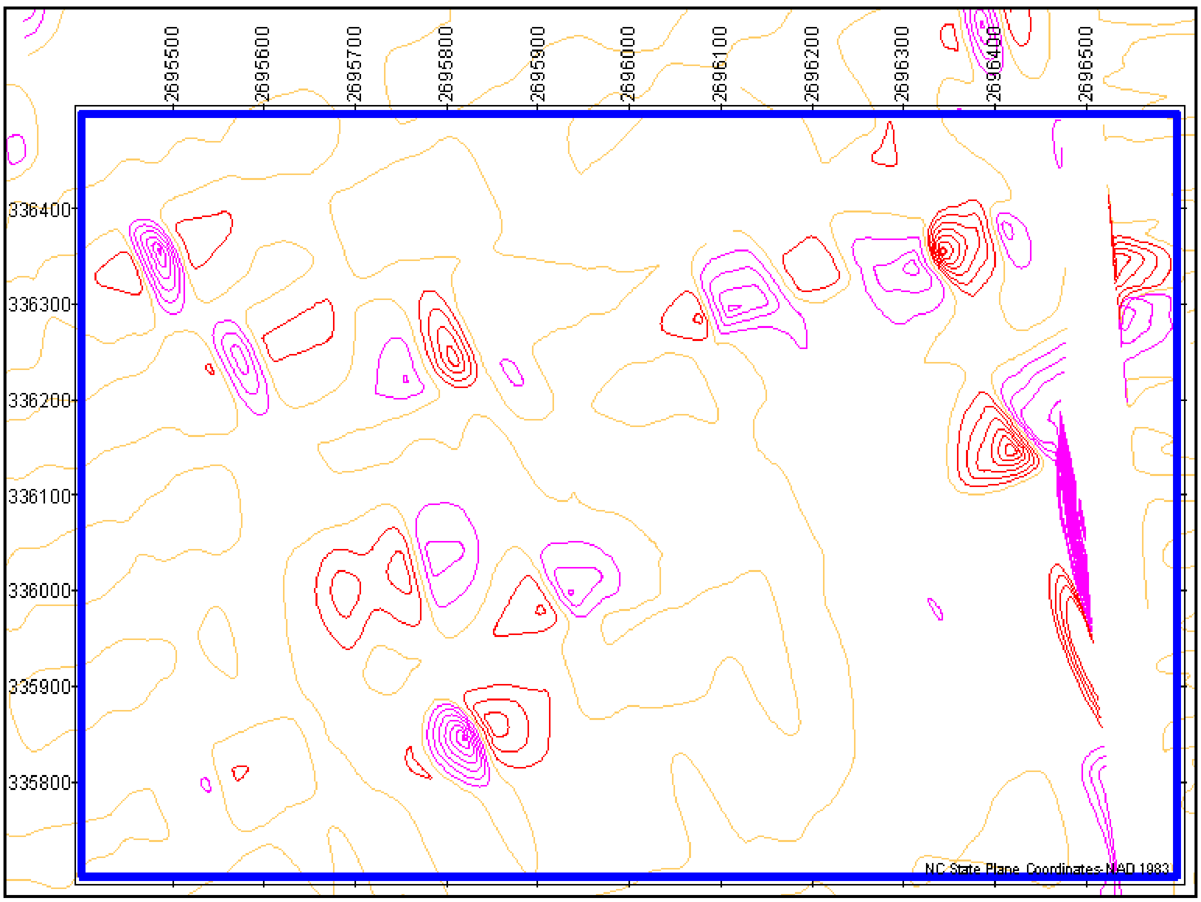


Figure 37. Target Cluster Q2-21 Magnetic Contour Signature.

Q2-23-Cluster

NC State Plane x=2691870 y=33495

Original Target Description:

Target Cluster Q2-23 consisted of widely scattered multi-component and dipolar magnetic anomalies on 12 survey lines with a maximum magnetic intensity of 48 nT (Figure 38). No acoustic target signature was identified in association with the magnetic anomalies.

Q2-23

Testing Location: x=2691900 y=335635

Testing Results:

After probing of one of the magnetic anomalies within the target cluster was identified a concrete pipe or piling 12 to 16-inches in diameter buried approximately 6 to 7 feet below the bottom. No excavation was conducted due to the depth of the object.

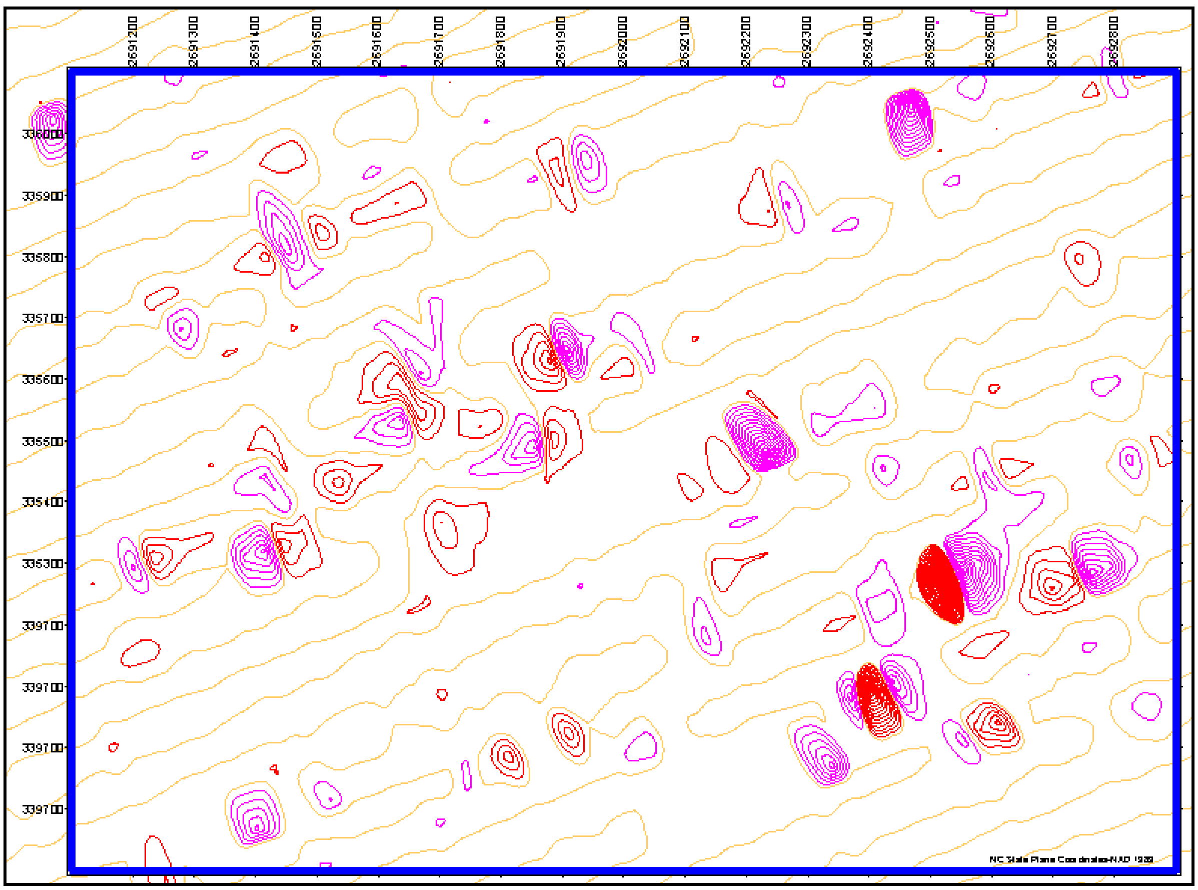


Figure 38. Target Cluster Q2-23 Magnetic Contour Signature.

Q2-24-Cluster
NC State Plane x=2693811 y=334618
Original Target Description:
Target Cluster Q2-24 consisted of widely scattered multi-component and dipolar magnetic anomalies on 13 survey lines with a maximum magnetic intensity of 44 nT (Figure 28). No acoustic target signature was identified in association with the magnetic anomalies.

Q2-24
Testing Location: x=2693810 y=334625
Testing Results:
After probing and excavation of one of the anomalies within the target cluster a 2-inch wire rope with an associated 2-inch steel ring was identified. The object was possibly a tow bridle or lift-sling buried 4 to 5 feet below the bottom.

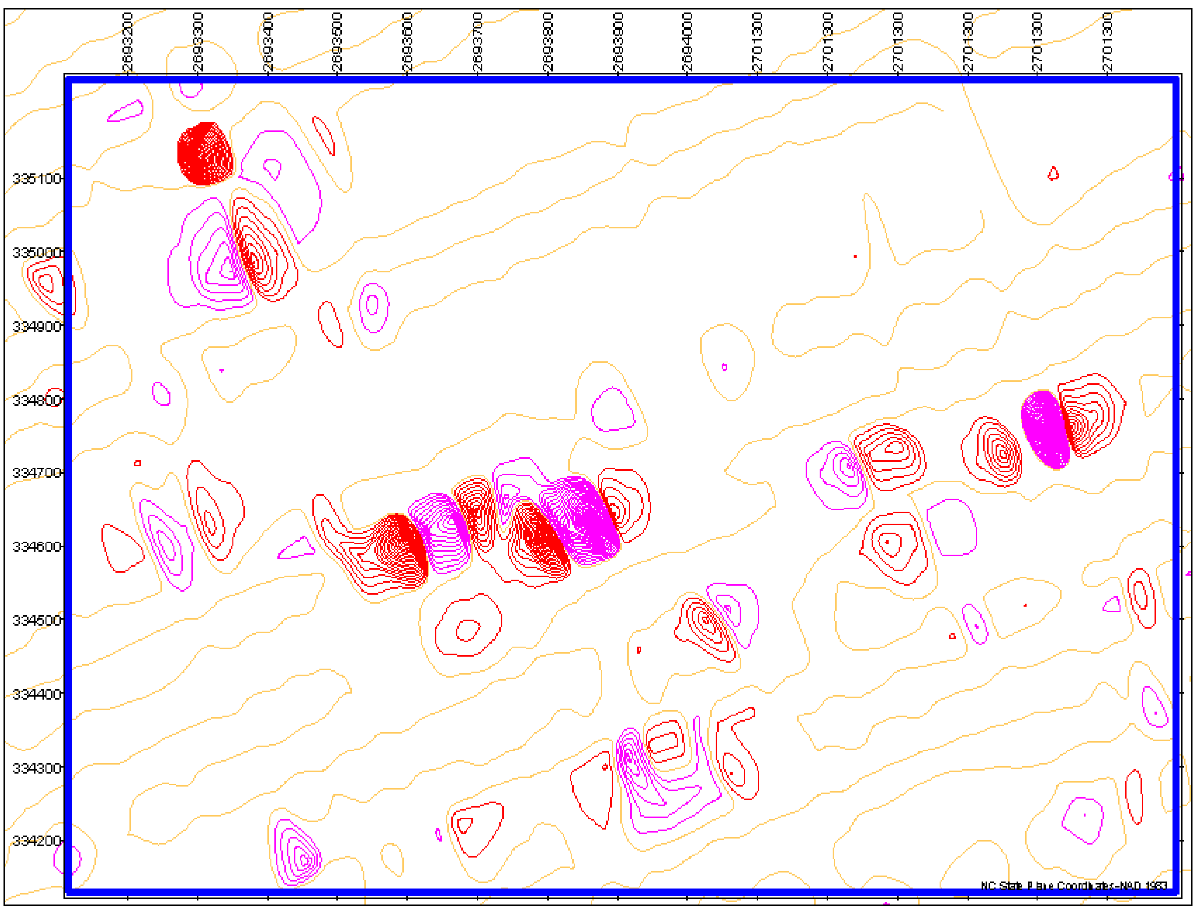


Figure 39. Target Cluster Q2-24 Magnetic Contour Signature.

Q2-28-Cluster
NC State Plane x=2696546 y=332769
Original Target Description:
Target Cluster Q2-28 consisted of multi-component anomaly on three survey lines with a maximum magnetic intensity of 20 nT. No acoustic target signature was identified in association with the magnetic anomalies.

Q2-28
Testing Location: x=2686441 y=332821
Testing Results:
Probing and excavation was conducted at of one of the magnetic anomalies within the Q2-28 target cluster. The anomaly was identified as what appeared to be concrete rubble with rebar reinforcement. The concrete rubble was buried 4 to 6 feet. Also identified (probing only) was some type of steel plate or flat steel object over 2 feet in width and buried approximately 8 feet deep.

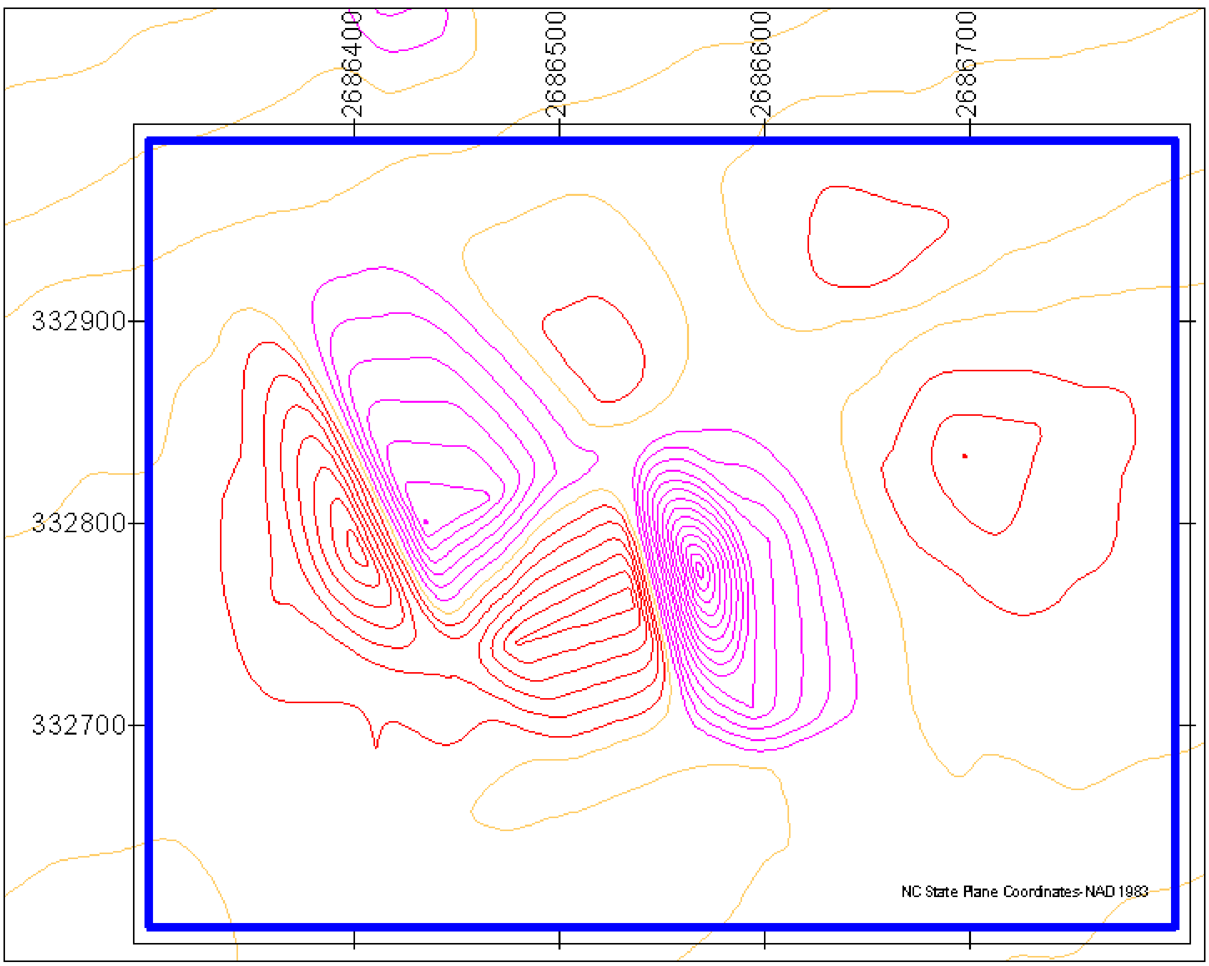


Figure 40. Target Cluster Q2-28 Magnetic Contour Signature.

Q2-29-Cluster
NC State Plane x=2688551 y=333005
Original Target Description:
Target Cluster Q2-29 consisted of two low intensity dipolar anomalies on two survey lines with a maximum magnetic intensity of 12 nT. No acoustic target signature was identified in association with the magnetic anomalies.

Q2-29
Testing Location: x=2688423 y=333026
Testing Results:
Target Q2-29 was relocated on the bottom with a handheld magnetometer then extensively probed down to 10 feet below the bottom. No identification of the object creating the magnetic anomaly was made. The object was either buried deeper than ten feet or was small enough to be missed by concentrated probing.

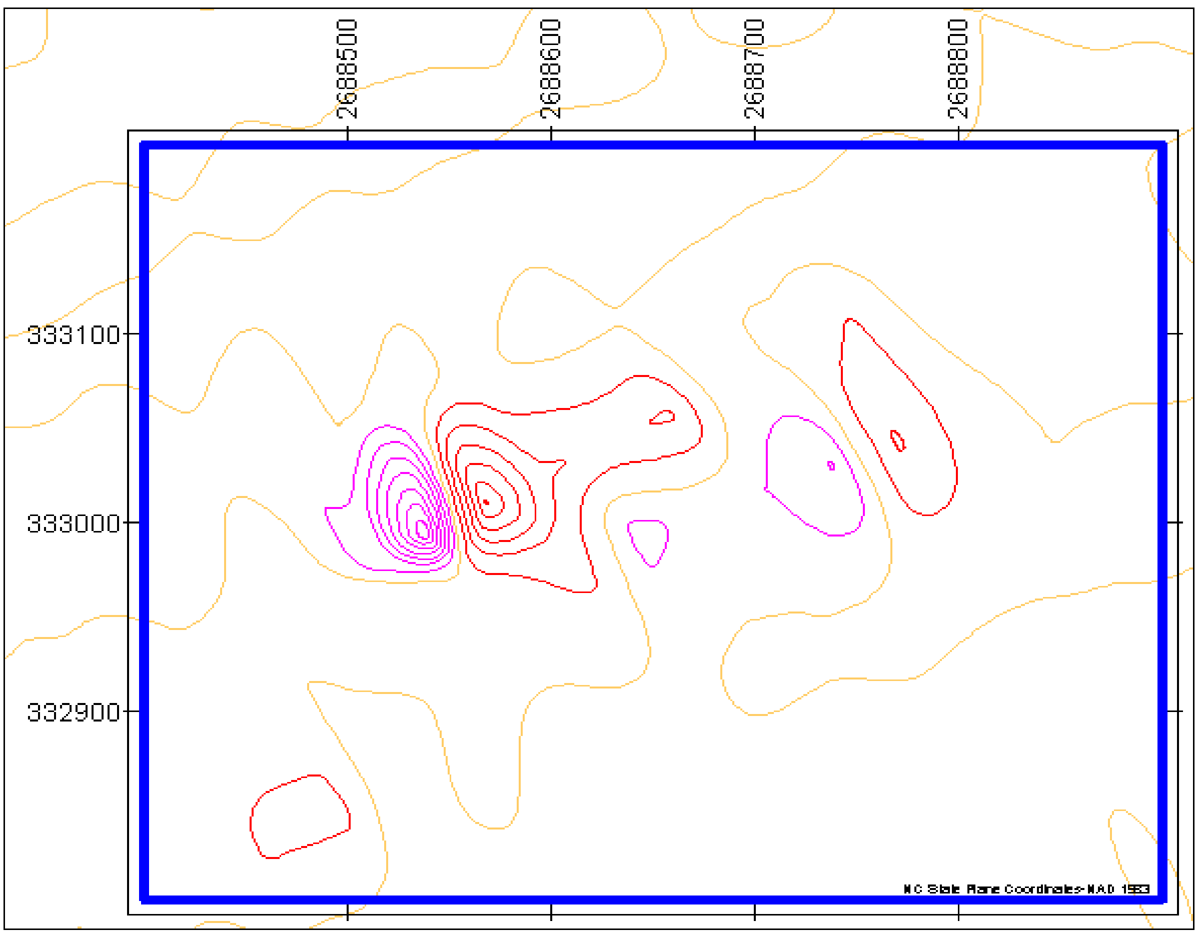


Figure 41. Target Cluster Q2-29 Magnetic Contour Signature.

Q2-30-Cluster
NC State Plane x=2690490 y=333515
Original Target Description:
Target Cluster Q2-30 consisted of multi-component and dipolar magnetic anomalies on six to eight survey lines with a maximum magnetic intensity of 16 nT. Acoustic records associated with the anomalies show a pile of linear objects over 70 feet in length by 20 feet wide exposed just above the bottom.

Q2-30
Testing Location: x=2688423 y=333026
Testing Results:
Target Q2-30 was relocated on the bottom with a handheld magnetometer then extensively probed down to 10 feet below the bottom. No identification of the object creating the magnetic anomaly was made. The object was either buried deeper than ten feet or was small enough to be missed by concentrated probing. The sonar image originally found associated with the magnetic anomaly appears to have been created by a large size school of fish. Although and interesting shipwreck shaped image it appears to have been only coincidental to the anomaly cluster.

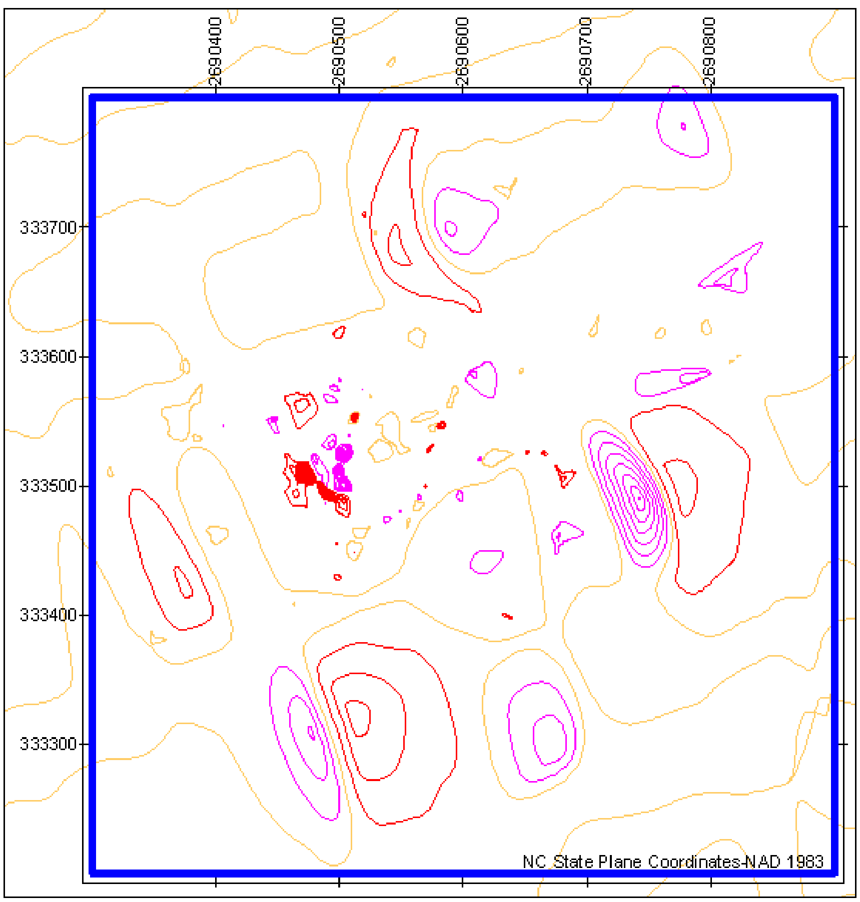


Figure 42. Target Cluster Q2-30 Magnetic Contour Signature.

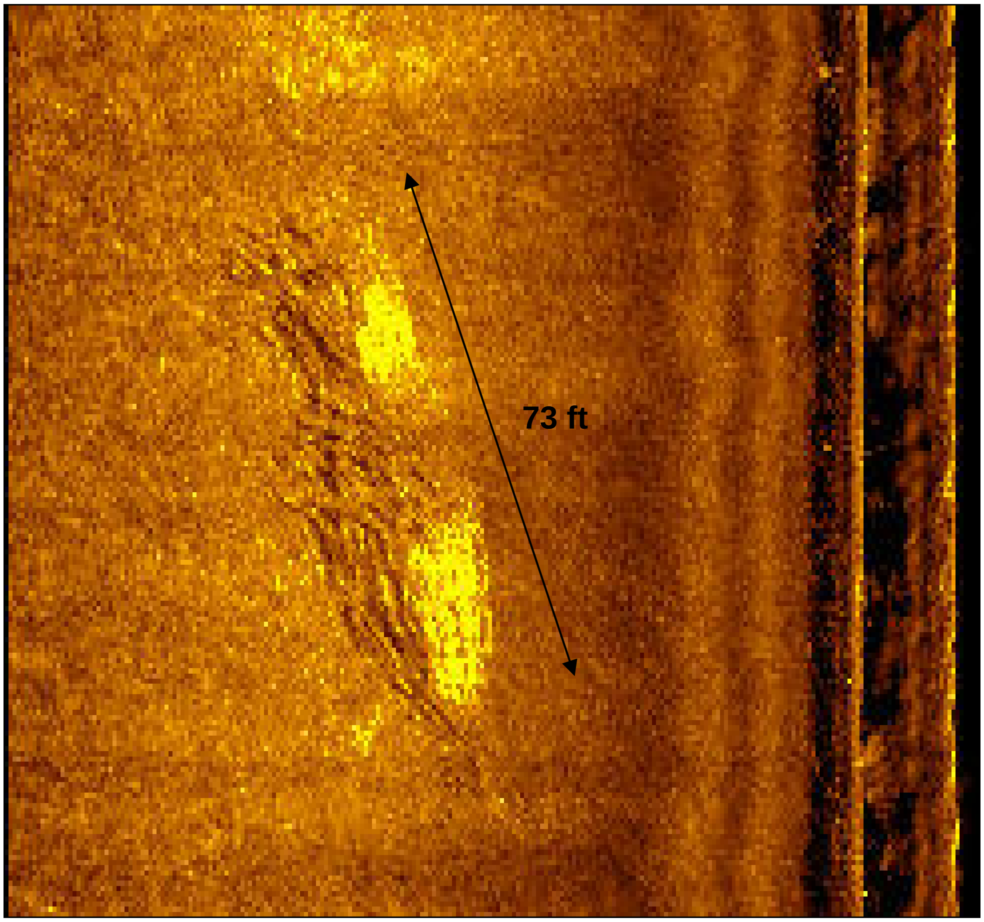


Figure 43. Target 30 – Acoustic Target Signature.

Q2-31-Cluster
NC State Plane x=2693045 y=332856
Original Target Description:
Target Cluster Q2-31 consisted of multi-component and dipolar magnetic anomalies on four to six survey lines with a maximum magnetic intensity of 24 nT. No acoustic target signature was identified in association with the magnetic anomalies.

Q2-31
Testing Location: x=2693141 y=332815
Testing Results:
After extensive probing of one of the magnetic anomalies within the target cluster was identified as approximately 1-inch wire rope buried approximately 6 to 7 feet below the bottom. No excavation was conducted due to the depth of the object.

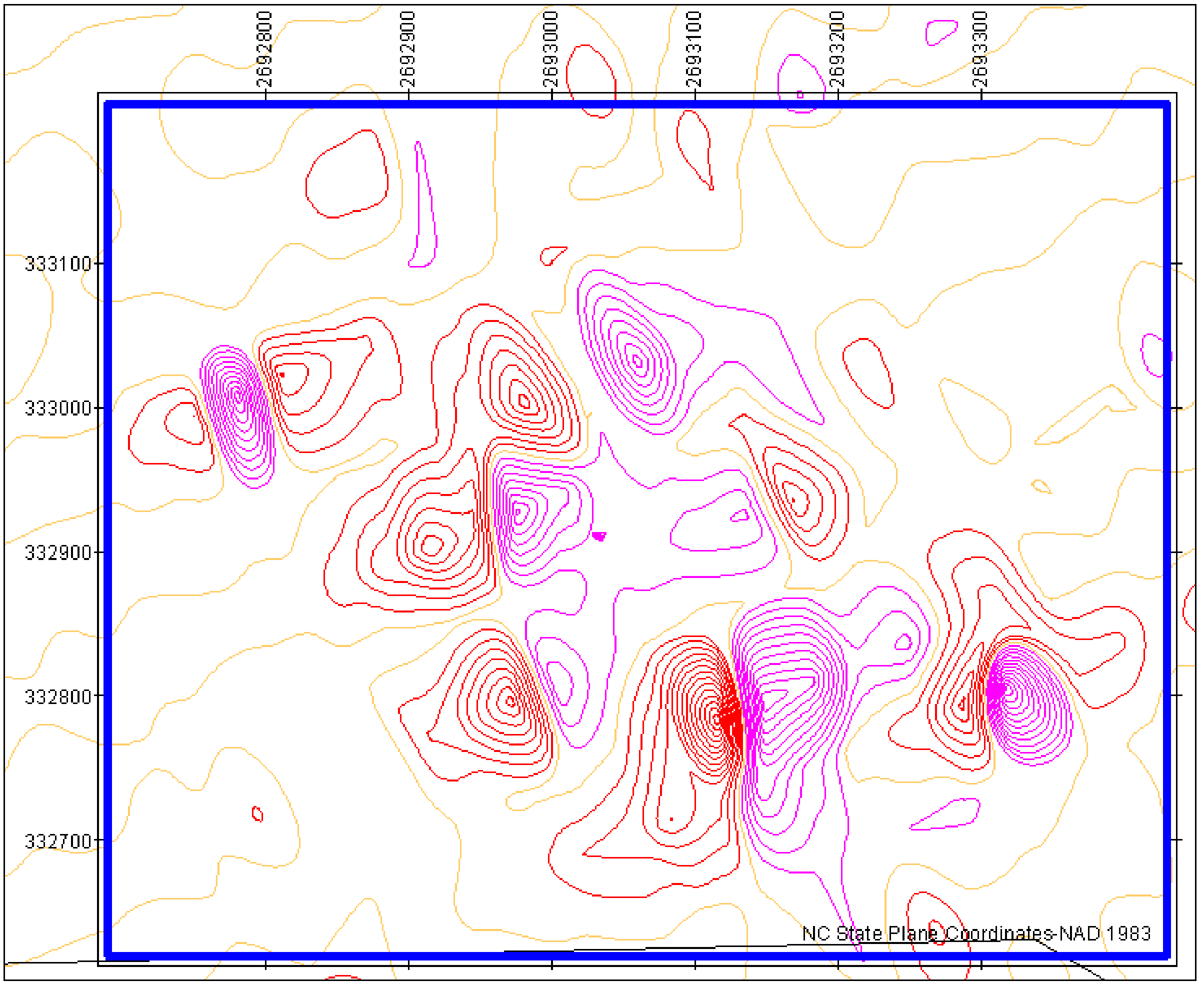


Figure 44. Target Cluster Q2-31 Magnetic Contour Signature.

Q2-32-Cluster
NC State Plane x=2695255 y=332311
Original Target Description:
Target Cluster Q2-32 consisted of multi-component and dipolar magnetic anomalies on 12 to 14 survey lines with a maximum magnetic intensity of 38 nT. No acoustic target signature was identified in association with the magnetic anomalies.

Q2-32
Testing Location: x=2694528 y=332526
Testing Results:
After extensive probing of one of the magnetic anomalies within the target cluster was identified as a coil of either wire rope or steel wire buried approximately 8 feet below the bottom. No excavation was conducted due to the depth of the object.

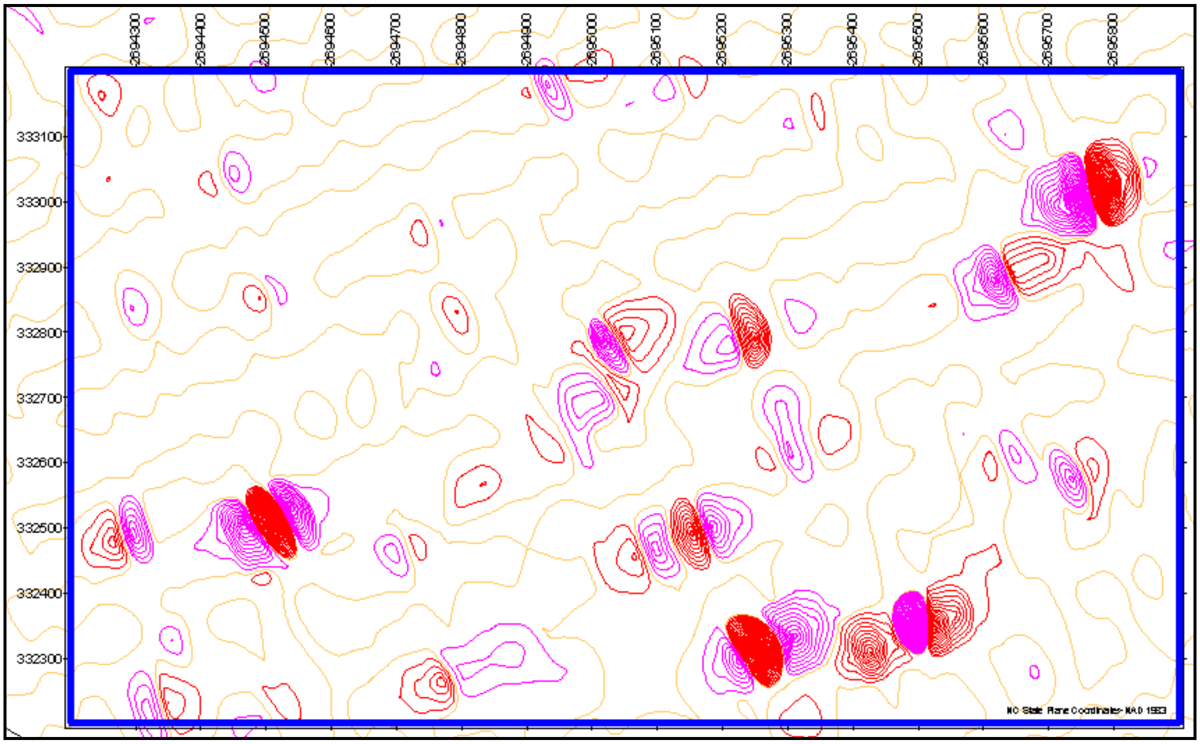


Figure 45. Target Cluster Q2-32 Magnetic Contour Signature.

Borrow Area Y Target Identification

In Borrow Area Y there was only one target: Y-1 (Figure46).

Y-1
NC State Plane x=2690477 y=333505
Original Target Description:
Target Y-1 consisted of multi-component magnetic anomaly with maximum magnetic intensity of 16 nT (Figure 47). Acoustic records associated with the anomaly identified an unusually shaped object (much like an historic steam boiler) approximately 16 feet long by 7 feet wide (Figure 48).

Y-1
Testing Location: x=2690475 8 y=332490
Testing Results:
Divers identified the target as what appears to be a natural sandstone rock outcrop covered with various types of soft and hard corals. A small modern anchor and chain a few feet north of outcrop may responsible for the magnetic signature originally found associated with the target. Surrounding the rock outcrop the bottom was covered by a thin veneer of sand and scattered soft corals (Figures 49–52).

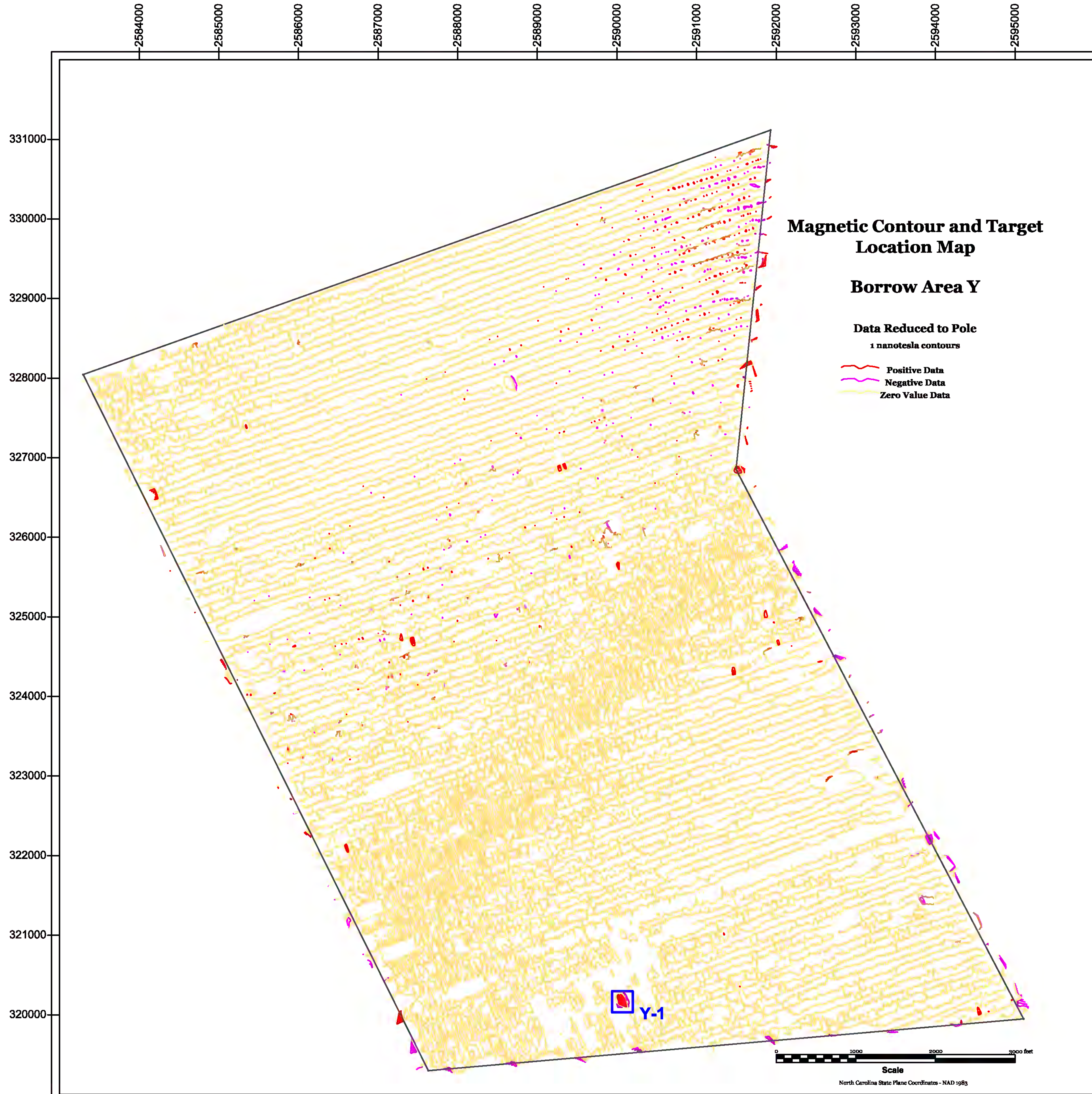


Figure 46. Magnetic Contour and Target Location Map Borrow Area Y.

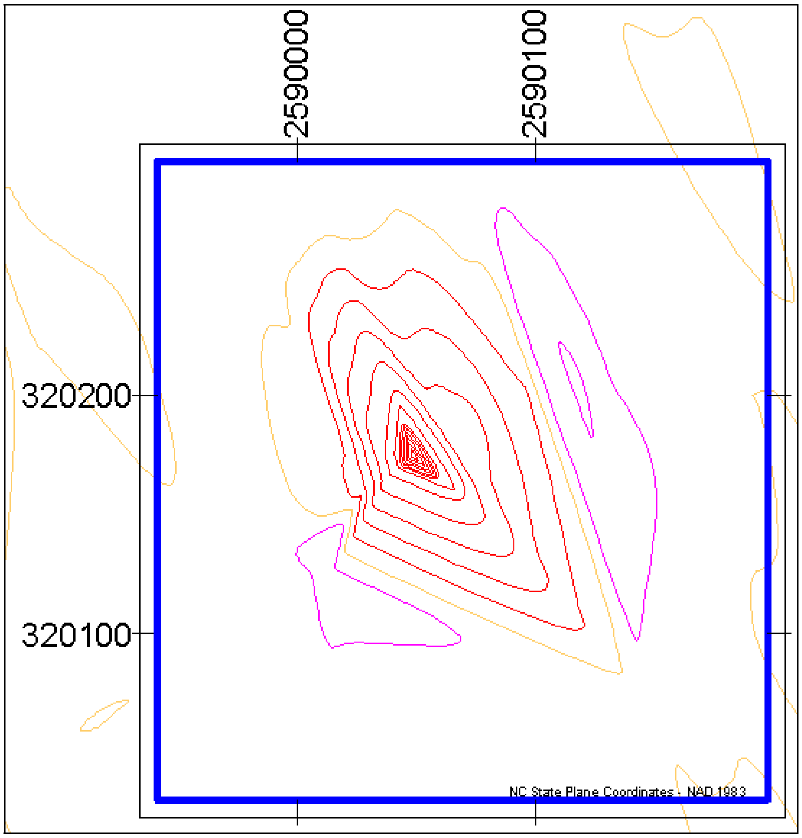


Figure 47. Target Y-1 Magnetic Contour Signature.

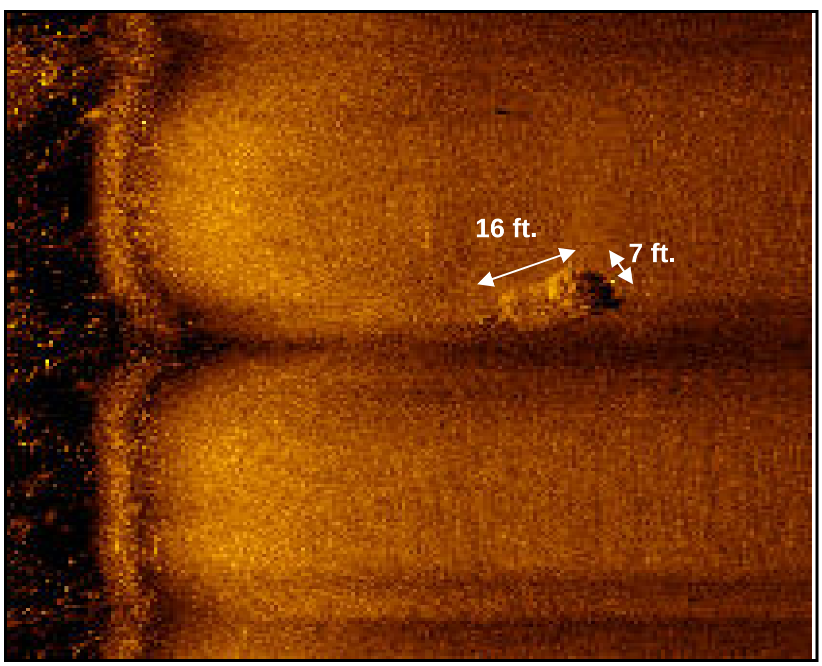


Figure 48. Target Y-1 Acoustic Target Signature.

Although visibility was limited on the day of the site investigation, below are some images captured off of video taken at Target Y-1:

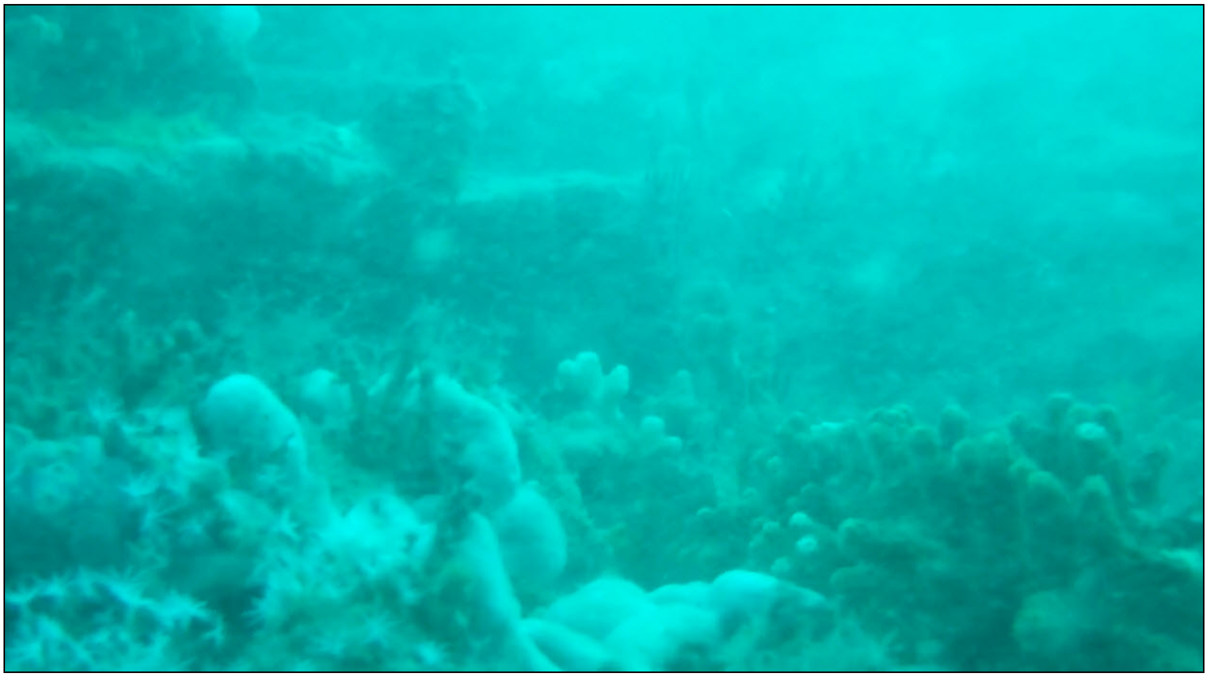


Figure 49. Target Y-1 sandstone outcrop and corals

Figure 50. Target Y-1 hard corals over three feet in diameter on rock outcrop.

Figure 51. Target Y-1 close-up of hard corals

Figure 52. Target Y-1 corals with fish.

Borrow Area ODMDS Target Identification

Of the 25 target/anomalies recorded in the ODMDS Borrow Area six were select for diver identification during this project: ODMDS targets 2, 8, 11, 12, 21 and 24 were investigated by underwater archaeologist (see Figure 4). Original target descriptions, contours and sonar signatures for the ODMDS Survey area are presented in the remote sensing section of this report.

ODMDS Targets Selected for Identification:

ODMDS-2
Testing Location: x=2694963 y=332711

Testing Results:
During probing the anomaly was identified as a single linear ferrous object 6 or 8-inches in diameter and buried approximately 7 feet. Divers were unable to determine the length of the object. The object was determined to be rounded or oval in shape possibly a section of steel pipe or bar. After concentrated probing within a 15-foot radius of the object no other objects were encountered down to a depth of 10-feet below the bottom.

ODMDS-8
Testing Location: x=2691818 y=332495

Testing Results:
During probing the magnetic anomaly was identified as a coil or loop of at least 1½-inch wire rope buried approximately 7 feet below the bottom. No excavation was conducted due to the depth of the object.

ODMDS-11
Testing Location: x=2690068 y=3328605

Testing Results:
Although hampered by poor visibility, divers identified a 6-foot long section of four-inch iron or steel pipe and the remains of a yellow reef buoy.

ODMDS-12
Testing Location: x=2689760 y=329159

Testing Results:
Although hampered by poor visibility, divers partially identified the material producing the targets signatures as 4 to 5 inch braided polypropylene hawser and what was possibly the remains of a homemade a rebar grappling hook.

ODMDS-21
Testing Location: x=2689760 y=329159

Testing Results:
Identified by a diver on the bottom as an approximately 8-foot long by 12-inch in diameter steel pipe or cylinder. The walls of the cylinder were at least 3-inches thick.

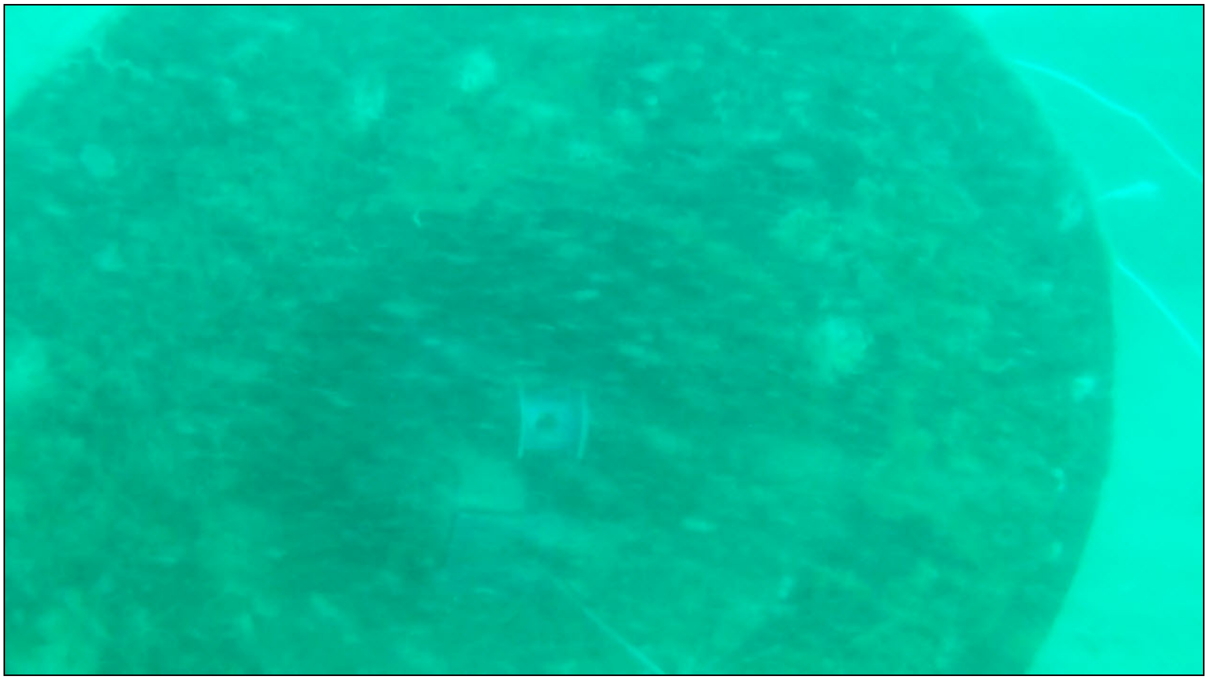


Figure 53. Target ODMDS-21 end view of steel cylinder.

ODMDS-24 Testing Location: x=2691818 y=332495

Testing Results:
During probing the magnetic anomaly was identified as a coil or loop of at least 1-inch wire rope buried approximately 5 to 6 feet below the bottom. No excavation was conducted due to the depth of the object.

CONCLUSIONS AND RECOMMENDATIONS

At the completion the archaeological remote sensing survey of the ODMDS Borrow Area a total of 25 individual and clustered magnetic anomalies were identified. Of these anomalies five were found to be associated with a sonar target signature. A total of six (6) of the 25 were recommended for addition investigations. These included Targets ODMDS-2, 8, 11, 12, 21, and 24. The remaining 19 targets were classified as unlikely to have the potential to be associated with a significant submerge cultural resource (Appendix B - Table of Remote Sensing Targets ODMDS Borrow Area)

Following the remote sensing survey of the borrow area Phase II investigations to identify and assess targets commenced. Diving was conducted to identify nine targets in the Q2 Borrow Area, one target in the Y Borrow Area, and six targets in the ODMDS borrow area. At the completion of diving investigations 14 of the 16 targets had been relocated and at least partially identified. Two of the targets in area Q2 were relocated with a handheld underwater magnetometer on the ocean bottom however; these targets were not found after extensive probing down to a depth of ten feet. It would appear that the targets were either deeply buried or physically small enough to be missed by probing (see Appendix C -.Target Identification and Assessment).

All of the targets identified during this project were found to be associated with modern debris that is either related to the present day Ocean Dredge Material Disposal Site or past artificial reef systems such as the tire reefs created in the 1970s. Target Y-1 near Bogue Inlet proved to be associated with a small natural rock outcrop and covered with extensive coral growth. No submerged cultural resources or historic artifacts were identified during the investigations of Borrow Areas Q2, Y-1 or ODMDS.

REFERENCES

Angley, Wilson
1982 *An Historic Overview of The Beaufort Inlet - Cape Lookout Area of North Carolina*. Report on file at the Research Branch, N. C. Division of Archives and History, Raleigh, North Carolina.

1984 *An Historical Overview of Bogue Inlet*. North Carolina Division of Archives and History, Raleigh, NC.

Berman, Bruce D.
1972 *Encyclopedia of American Shipwrecks.* The Mariners Press, Boston.

Hall, Wes
2008 *An Archaeological Remote Sensing Survey of Bogue Banks Offshore Borrow Areas, Carteret County, North Carolina.* Report on File at U.S. Army Corps of Engineers, Wilmington District

Hill, Mrs. Fred.
1975 *Historic Carteret County, North Carolina*. Carteret County Historical Research Association, Beaufort, North Carolina.

Konkle, Burton A.
1922 *John Motley Morehead and the Development of North Carolina,*1796-1866. William J. Campbell, Philadelphia.

Lytle, William M. and Forrest R. Holdcamper.
1975 *Merchant Steam Vessels of the United States 1790* - 1868, "The Lytle Holdcamper List." The Steamship Historical Society of America, Staten Island, New York.

Marx, Robert F.
1975 *Shipwrecks of the Western Hemisphere, 1492-1825*. New York: David McKay and Co.

Newsome, A. R. (editor)
1929 A Miscellany from the Thomas Henderson Letter Book, 1810-1811. *North Carolina Historical Review*.

Newton, J. G., O. N. Pilkey, and J. O. Blanton
1971 Wreck lists and charts in North Carolina Department of Conservation and Development. Division of Mineral Resources. *An Oceanographic Atlas of the Carolina Continental Margin.* Prepared at Duke University Marine Laboratory at Beaufort, North Carolina, from research supported by the North Carolina Board of Science and Technology, the United States Science Foundation, and the United States Geological Survey.

Paul, Charles L.
1970 Beaufort, North Carolina: Its Development as a Colonial Town. *North Carolina Historical Review No. 47, October, pp. 370-387.*

Shomette, Donald G.
1973 *Shipwrecks of the Civil War.* Donic Ltd., Washington, D. C.

Stick, David
1952 *Graveyard of the Atlantic: Shipwrecks of the North Carolina Coast.* The University of North Carolina Press, Chapel Hill, NC.

1958 The Outer Banks of North Carolina. The University of North Carolina Press, Chapel Hill, North Carolina.

Tubby, Raymond
2000 *Historical and Archaeological Investigation of the 1750 Spanish Plate Fleet Vessel El Salvador.* Unpublished Masters thesis, East Carolina University.

United States Congress, Senate Executive Document, No. 78, 33rd Congress, 1st Session.

Watts, Gordon P. Jr. et al.
1975 *Report of the Activities of the 1975 Field School in Underwater Archaeology, Cape Lookout Vicinity.* Unpublished report by Underwater Archaeology Unit, prepared for the North Carolina Department of Cultural Resources and the University of North Carolina at Wilmington.

Watts, Gordon P. Jr.
1992 *A Remote Sensing Survey and Reconnaissance Investigations to Identify and Assess Targets Located Along Range A, a Bar Channel Widener, a Channel Extension, and Two Spoil Deposits at Beaufort, Inlet North Carolina.* Report on file Environmental Resources Branch U.S. Army Corps of Engineers District, Wilmington, North Carolina

1997 *Underwater Remote Sensing Survey and Diver Inspection near Beaufort Inlet, North Carolina*. Report on file Environmental Resources Branch U.S. Army Corps of Engineers District, Wilmington, North Carolina

www.ah.dcr.state.nc.us/QAR
2007 *An Historical Overview of the Beaufort – Cape Lookout Area*. Archives and History, Division of Cultural Resource, State of the North Carolina web site.

www. ncstateports.com
2007 History of North Carolina State Ports Authority. North Carolina State Port Authority Web Site. Internet world wide web.

APPENDIX A - SHIPWRECKS IN THE VICINITY OF BOGUE BANKS

Name of Vessel	Type	Tons	Cause	Date Lost D-M-Y	Place	Comments	Reference
							6
Queen Anne's Revenge	ship	?	grounded	06-??-1718	Topsail Inlet/Beaufort Inlet		6
Adventure	sloop	?	grounded	06-??-1718	Topsail Inlet?Beaufort Inlet		6
El Salvador	snow	?	grounded	08-30-1750	Cape Lookout - South		3,4,6
Susannah	schooner	?	grounded	04-02-1753	At entrance to Old Topsail Inlet		4,6
unknown	brig	?	grounded	10-19-1769	At Old Topsail Inlet		6
unknown	brig	?	ran ashore	??-09-1769	Below Topsail Inlet		6
Betsy	sloop	?	grounded	01-01-1771	At Old Topsail Inlet		5,6
Hero	schnooner	?	grounded	02-09-1790	Beaufort Bar		5,6
Polly	sloop	?	unknown	07-16-1793	Ashore near Beaufort		5,6
unknown	brig	?	grounded	09-17-1814	Beaufort Bar		6
Antelope	schooner	?	grounded	03-10-1815	Near Beaufort		6
Eagle	brig	?	unknown	03-10-1815	Near Beaufort		6
Orleans	brig	?	unknown	03-10-1815	Near Beaufort		*6*
Harriot	ship	?	unknown	06-25-1817	Bogue Banks near Beaufort		*6*
Santa Maria	ship	?	grounded	03-22-1819	Beaufort Bar		6
Tionel	schooner	?	grounded	04-12-1842	West of Beaufort Bar		2
Delaware	schooner	?	unknown	28-12-1844	4 mi. SW Beaufort Bat		1
Colonel Hanson	schooner		ran ashore	04-09-1846	Bogue Banks	run ashore at Swansboro	1
Walter J. Doyle	schooner		unknown	03-??-1852	Beaufort Bar		2,3,4
Sun	schooner		unknown	01-13-1854	Beaufort Inlet		2,3,4
Charles M. Creese	schooner		unknown	09-??-1857	Beaufort Inlet		3
unknown	schooner		grounded	11-??-1863	Bogue Inlet		1
Pevensey	steamer	543	ran ashore	06-09-1864	Bogue Banks	iron hull blockade runner	2,3,
Quinnebaugh	steamer	186	stranded	07-20-1865	Shackleford Banks		4
Fearless	steamer	128	stranded	11-15-1866	Beaufort		4
Jonas Sparks	schooner	?	unknown	04-14-1867	Beaufort Bar		2,3,4
Katy Wentworth	schooner	294	unknown	18-11-1886	Bogue Banks	1 live lost	2,3,4
Bronx	sloop	24	unknown	06-21-1892	3 miles SW Beaufort		2,34
Carrie L. Davis	schooner	?	ran ashore	??-??- 1902	Bogue Inlet	total loss of cargo and vessel	1
Thomas L. James	schooner	?	ran ashore	??- ??- 1902	Bogue Inlet	total lost of cargo	1
Governor Safford	steamer	307	ran ashore	24-07-1908	near Bogue Inlet		1
Clifton	steamer	256	stranded	18-05-1909	Beaufort	built 1864	4
M.B. Davis	schooner	18	foundered	8-12-1917	near Bogue Inlet		1
Maside	steamer	39	unknown	12-14-1920	2 mi. S of Fort Macon		2
Louise Howard	schooner	173	unknown	14-04-1921	3 mi. S of Fort Macon station		1
Alela	power yacht	70	burnt	20-05-1923	2 mi. NE of Fort Macon station	built 1913	2,4
Juno	tug	62	foundered	22-07-1923	Beaufort	built 1876	4
Morris and Cliff	schooner	132	foundered	16-01-1926	near Bogue Inlet		1,2
W.E. Hutton	tanker	4359	sunk	18-03-1942	off Bogue Inlet	sunk by German Submarine	1,2
Senateur Duhamel	trawler	133	unknown	19-12-1942	34 41' 09"N, 76° 43' 18"W	built 1923	2
Libertad	cargo	93	foundered	08-12-1952	Beaufort Inlet		2
Doswell S. Edwards	cargo	93	foundered	12-08-1952	Beaufort Inlet	built 1926	2

Reference Sources to Shipwreck List

1. Angley, Wilson. *An Historical Overview of Bogue Inlet*, Research Branch, North Carolina Division of Archives and History.

2. Wreck lists and charts in North Carolina Department of Conservation and Development. Division of Mineral Resources. *An Oceanographic Atlas of the Carolina Continental Margin*. By J. G. Newton, O. N. Pilkey, and J. O. Blanton, 1971. Prepared at Duke University Marine Laboratory at Beaufort, North Carolina, from research supported by the North Carolina Board of Science and Technology, the United States Science Foundation, and the United States Geological Survey.

3. Stick, David. *Graveyard of the Atlantic: Shipwrecks of the North Carolina Coast*. Chapel Hill: The University of North Carolina Press, 1952.

4. Berman, Bruce D. *Encyclopedia of American Shipwrecks,* Boston, Mass.: The Mariners Press, 1972.

5. Marx, Robert F. *Shipwrecks of the Western Hemisphere*, 1492-1825. New York: David McKay and Co., 1975.

6. www.qaronline.org. *Eighteen Century Shipwrecks in the vicinity of Beaufort Inlet Area*. Archives and History, Division of Cultural Resource, State of the North Carolina web site

APPENDIX B - TABLE OF REMOTE SENSING TARGETS ODMDS BORROW AREA

An Archaeological Remote Sensing and Target Identification Survey of Bogue Banks Offshore Borrow Areas Q2, Y1 and ODMDS, Carteret County, North Carolina

Target	**NC - State Plane Coord.**	**Mag/max nT/ +/- 1 nT influence**	**Sonar ID**	**Recommendations / Avoidance Buffer**
ODMDS-1	x=2696456 y=331126	Mono/48nT/+/- 100 ft	n/a	no additional investigations
ODMDS-2	x=26951441 y=332875	clust. dipol/multi/5-20 nT/200 ft	n/a	**add. uw invest/ ID.this project**
ODMDS-3	x=2694491 y=330904	clust. dipol,mono/1-4 nT/40 -80ft.	linear obj over 600 ft. –wire rope	no additional investigations
ODMDS-4	x=2693245 y=329310	mono/4 nT/100 ft	n/a	no additional investigations
ODMDS-5	x=2693107 y=332650	2x -dipol/10 nT/75 ft	n/a	no additional investigations
ODMDS-6	x=2692702 y=327105	broad multi/10 nt/200 ft.	n/a	no additional investigations
ODMDS-7	x=2692246 y=327412	mono/3 nT /100 ft.	n/a	no additional investigations
ODMDS-8	x=2691834 y=328491	multi/42 nT /250 ft.	n/a	**add. uw invest/ID. this project**
ODMDS-9	x=2691951 y=332672	dipol/10 nT /125 ft.	n/a	no additional investigations
ODMDS-10	x=2691471 y=332058	dipol/6 nT /120 ft.	n/a	no additional investigations
ODMDS-11	x=2690067 y=328602	dipol/8 nT /100 ft.	wide scat obj.1-linear 6ft.	**add. uw invest/ID this project**
ODMDS-12	x=2689758 y=329159	dipol/5 nT/100 ft.	scat. objects w/ linear 35ft +	**add. uw invest/ID. this project**
ODMDS-13	x=2689458 y=331823	cluster 2-dipol/5 nT/125 ft.	n/a	no additional investigations
ODMDS-14	x=2688258 y=331380	dipol/4 nT/75 ft	mound 70 feet w/obj. /dump site	no additional investigations
ODMDS-15	x=2686524 y=332863	multi/6 nT /150 ft	n/a	no additional investigations
ODMDS-16	x=2685354 y=325494	mono/2 nT/100 ft	n/a	no additional investigations
ODMDS-17	x=2685258 y=332187	dipol/9 nT/100 ft	n/a	no additional investigations
ODMDS-18	x=2685275 y=330778	dipol/8 nT/100 ft	n/a	no additional investigations
ODMDS-19	x=2684952 y=329756	mono/3 nT/100 ft	n/a	no additional investigations
ODMDS-20	x=2684659 y=330275	dipol/6 nT/110 ft	n/a	no additional investigations .
ODMDS-21	x=2684164 y=328818	dipol/9 nT/125 ft	Linear obj. 8 ft.	**add. uw invest/ID. this project**
ODMDS-22	x=2684346 y=327360	broad dipol/5 nT/200 ft	n/a	no additional investigations
ODMDS-23	x=2684477 y=325366	mono/3 nT/200 ft	n/a	no additional investigations
ODMDS-24	x=2683689 y=327949	multi/10 nT/220 ft	n/a	**add. uw invest/ID. this project**
ODMDS-25	x=2682463 y=327117	dipol/6 nT/100 ft	n/a	no additional investigations

APPENDIX C - TARGET IDENTIFICATION AND ASSESSMENT

An Archaeological Remote Sensing and Target Identification Survey of Bogue Banks Offshore Borrow Areas Q2, Y1 and ODMDS, Carteret County, North Carolina

Target	**Coord. Of Object or Testing**	**Findings**	**Recommendations**
Q2-20	x=2692852 y=337668	1-inch wire rope buried 4 to 5 ft. excavated.	No addition investigation or mitigation
Q2-21	x=2696168 y=336326	auto tire buried 5 ft excavated- wire rope at 9 ft probed	No addition investigation or mitigation
Q2-23	x=2691900 y=335635	12 to 16-inch concrete pipe or pile buried 6 -7 feet.	No addition investigation or mitigation
Q2-24	x=2693810 y=334625	2-inch wire rope w/steel ring poss. bridle or sling	No addition investigation or mitigation
Q2-28	x=2686441 y=332821	concrete rubble w/rebar buried 5-6 ft. flat steel at 8 ft (probe)	No addition investigation or mitigation
Q2-29	x=2688423 y=333026	neg. identification. Concentrated probing down to 10 feet	No addition investigation or mitigation
Q2-30	x=2688423 y=333026	neg. identification. Concentrated probing down to 10 feet	No addition investigation or mitigation
Q2-31	x=2693141 y=332815	1-inch? wire rope buried 7 -8 ft.	No addition investigation or mitigation
Q2-32	x=2694528 y=332526	wire rope/steel wire buried 8 ft. size unknown (probed)	No addition investigation or mitigation
Y-1	x=2690475 y=332490	sandstone rock outcrop w/soft and hard corals /sm. anchor	No addition investigation or mitigation
ODMDS-2	x=2694963 y=332711	6 to 8 inch pipe/bar undetermined length buried 7 ft (probed)	No addition investigation or mitigation
ODMDS-8	x=2691818 y=332495	2-inch wire rope loop/coil buried 7 ft (probed)	No addition investigation or mitigation
ODMDS-11	x=2690068 y=328613	yellow reef buoy with 6 ft long 4 dia pipe	No addition investigation or mitigation
ODMDS-12	x=2689760 y=329173	4-5 inch poly hawser /rebar grapple hook remains	No addition investigation or mitigation
ODMDS-21	x=2684164 y=328818	8ft. long /3-inch thick walled pipe/cylinder	No addition investigation or mitigation
ODMDS-24	x=2691818 y=332495	1-inch wire rope in loop/coil. buried 5-6 ft (probed)	No addition investigation or mitigation