CHARACTERIZATION OF SEDIMENTS IN FEDERAL WATERS OFFSHORE OF NEW JERSEY AS POTENTIAL SOURCES OF BEACH REPLENISHMENT SAND

Phase II, Year 2 Final Report

Minerals Management Service

Cooperative Agreement # 14-35-0001-30751

by

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INTRODUCTION

The purpose of this Cooperative Agreement is to obtain basic geological, economic, and environmental data on sand deposits offshore of New Jersey in Federal waters that have potential as beach replenishment sand sources. The New Jersey Geological Survey, in cooperation with Rutgers University, Richard Stockton College, and the Division of Engineering and Construction (DEC) in New Jersey Department of Environmental Protection (NJDEP), has continued to identify and characterize suitable sand sources. During Phase I, 150+ line miles of seismic data and twenty vibracores were collected in Federal waters offshore of Townsends Inlet, NJ (Plate 1). Coastal areas were ranked according to severity of beach erosion, and relevant data from previous studies were compiled and summarized.

Phase II, Year 2 has encompassed several tasks, including: 1) analysis of the seismic and vibracore data; 2) comparison of sediment needs and availability; 3) comparison of onshore vs. offshore sand resources and dredging in State vs. Federal waters; and 4) investigation of environmental effects of extracting sand resources. The bulk of work for this year is reported in the Masters Thesis by Smith (1996) characterizing the sand shoals offshore of Townsends Inlet based on analysis of the analog seismic data and the vibracores. A copy of the thesis was submitted to the Minerals Management Service in November, 1996. Drs. Gail Ashley and Robert Sheridan served as thesis advisors to Peter Smith and oversaw all work on the project based at Rutgers. Matthew Goss assisted with collection of seismic data and vibracores, and worked with Smith on processing the vibracores at the Rutgers Core Library. Frederick Muller researched and compiled seismic and core data from the New York and Philadelphia Districts of the U.S. Army Corps of Engineers (USACE) and from several private-sector sources.

Task 4 was completed in reports by Rutgers Institute of Marine and Coastal Sciences on studies of fish populations at Beach Haven Ridge, site of the LEO-15 observatory (Hales and others, 1995, Able and Hagan, 1995). These studies provide a general picture of the faunal distribution on and near the Beach Haven Ridge shoal. A larger environmental study at the shoals offshore of Townsends Inlet is beyond the scope of this study.

The remaining tasks reported below include parts of Task 1 and 2, i.e. interpretation and volumetric analysis of the digital seismic data, and Task 3, comparison of onshore vs. offshore sand resources and dredging in State vs. Federal waters. The interpretation and volumetric analysis of the digital seismic data was completed by Jeffrey Waldner and David Hall. Jane Uptegrove compiled data on onshore and offshore sources of sand. Zehdreh Allen-Lafayette prepared Plate 1, "Identified Potential Beach Replenishment Sand Sources, onshore and offshore New Jersey". Eugene Keller assisted with locating data on beach replenishment contracts, on file at Divison of Engineering and Construction, NJDEP.

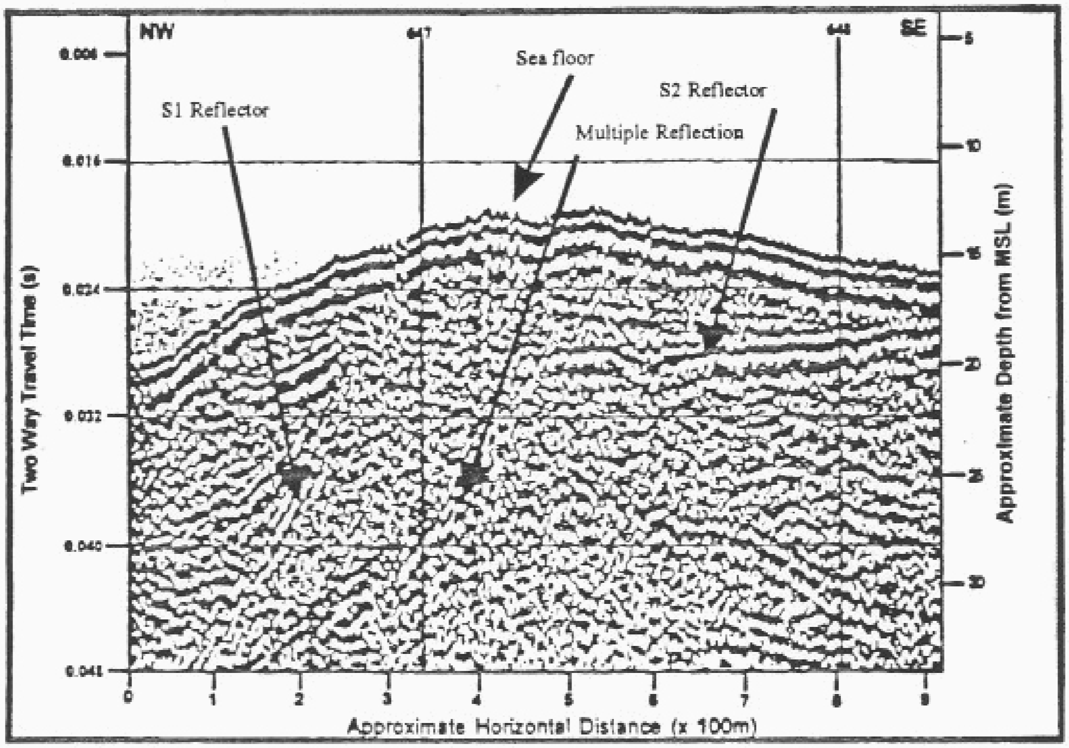
TASKS 1 AND 2 -- ANALYSIS OF NEW DATA AND VOLUME ESTIMATES

Interpretation and volumetric analysis of digital seismic data

More than 150 line-miles of high-resolution continuous profiling seismic data were collected in the study area. Digital and analog data records are collected simultaneously by the seismic system. The analog format (paper recorder) consists of an ORE Geopulse source-receiver plotting to an EPC graphic data recorder. The analog paper output permitted real-time analysis of the data and made possible cursory interpretation while the survey was underway. For digital recording, the hydrophone output passes to an engineering-type land seismograph which autosaves the digital records to an internal hard disk. In many ways the analog output produces sufficient detail to conduct a complex seismic facies analysis. For a small incremental cost, the digital system affords advantages over the analog system in archiving data, geographical positioning, and signal processing. Details of the acquisition methodology and digital data reduction operations are in the Phase I report (Uptegrove and others, 1994) and Smith (1996).

Smith (1996) performed vibracore analyses, seismic interpretation, sequence analysis and volumetric estimates of the sand resource based on the analog seismic data. By contrast, this report presents volumetric analysis of the beach sand resource derived from the digital data. The digital seismic data are enhanced using such processing routines as: trace sorting, residual static corrections, digital frequency filtering, and muting and gain scaling routines using EAVESDROPPER, a common-midpoint (CMP) processing software developed by the Kansas Geological Survey (Kansas Geological Survey, 1993; Bennett and Chung, 1986; Somanas and others, 1987). Figure 1 shows a sample of analog and digital data.

Based on seismic sequence, facies analysis, and vibracore data, Smith (1996) determined that sand resources were primarily concentrated in the shore-detached sand ridges in the study area, specifically the Inner Sand Ridge and Avalon Shoal ridge. He also detailed the geomorphic development of these sand ridges. Smith developed criteria for measuring borrow sand resource volumes from the seismic interpretation and vibracore data. Smith determined that suitable borrow material is limited in the shoal features because sand volume thins at the edges of the ridges and the lower 6.6 feet (2 meters) of sediment above the S2 regional unconformity consists of unsuitable coarse, poorly sorted sediments. To calculate sand volumes, Smith confines the



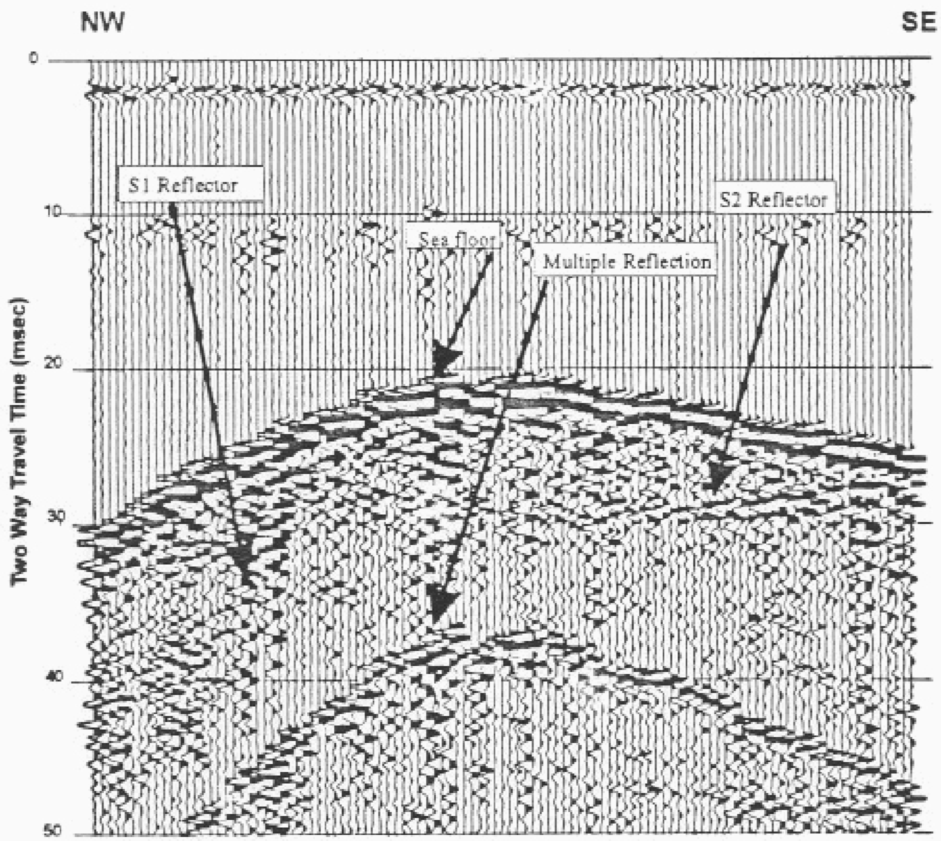


Figure 1. Analog (above) and Digital (below) seismic profile data traversing the same sand ridge along seismic line TI-12N. Both profiles identify the S2 reflector which marks the sequence boundary between Holocene sediments and older Tertiary deposits. Seismic sequence analysis and analog interpretation is described in Smith (1996).

boundary area to the 16.4-ft (5-meter) contour above the S2, obtains the remaining volume between the 16.4-ft (5-meter) and 6.6-ft (2- meter) contour, and includes the remaining volume of the sand ridge above the 16.4-ft (5-meter) contour (Figure 2).

Geodetic positions for both the analog and digital data sets were generated using a differential Global Positioning System (G.P.S.). Locations are correlated to each digital record for exact positioning. The analog data are limited to fixes situated at approximately 5-minute intervals. For the entire survey area, the analog data contain 550 fix positions. Smith's (1996) depth and isopach maps for the analog data are based on the calculated depth at each fix position.

By contrast, maps produced from interpretation of the digital data are generated by digitizing profiles and correlating each trace number to G.P.S. position. Accordingly, the digital data have greater geodetic resolution than the analog data. The maps of the digital seismic data are based on 50,770 points for the water bottom and 41,066 for the S2 unconformity. A flow chart detailing the data reduction to generate the maps from the digital data is shown in Figure 3. The Water Bottom Relief map is contoured in units of two-way seismic traveltime rather than feet, as shown in Figure 4. This pseudo-bathymetric map shows the location of the Inner Sand Ridge and Avalon Shoal. Inasmuch as depth in feet was not crucial at this stage, the traveltimes are not converted to linear units until the isopach map is contoured. The contoured surface of the S2 unconformity is not shown in this report but was used in the generation of the isopach maps. All data sets are contoured using SURFER version 5.01(Golden Software, Inc., 1994) software.

The isopach map showing the thickness between the S2 unconformity and the water bottom unconformity is shown in Figure 5. The isopach was generated by computing the

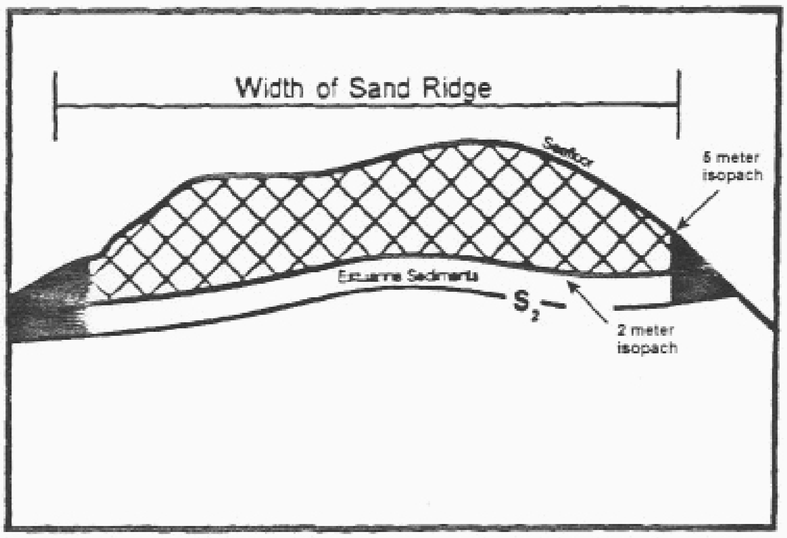


Figure 2. Schematic for calculating borrow sand volumes (hatchured area) from seismic profile data using criteria developed by Smith (1996) (modified from Smith, P. C., 1996).

START

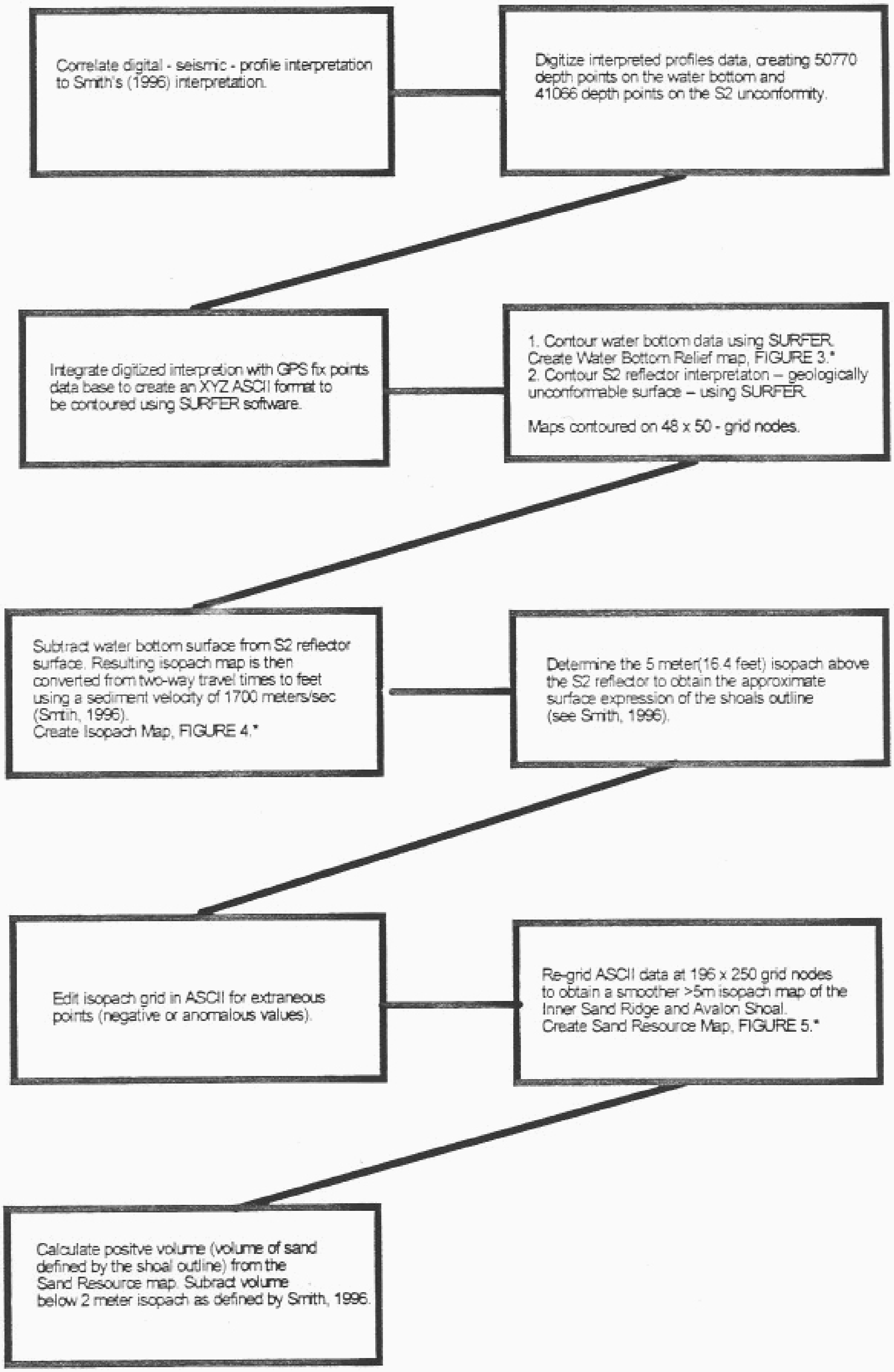


Figure 3. Digital data interpretation flow diagram.
* denotes figure used in text.

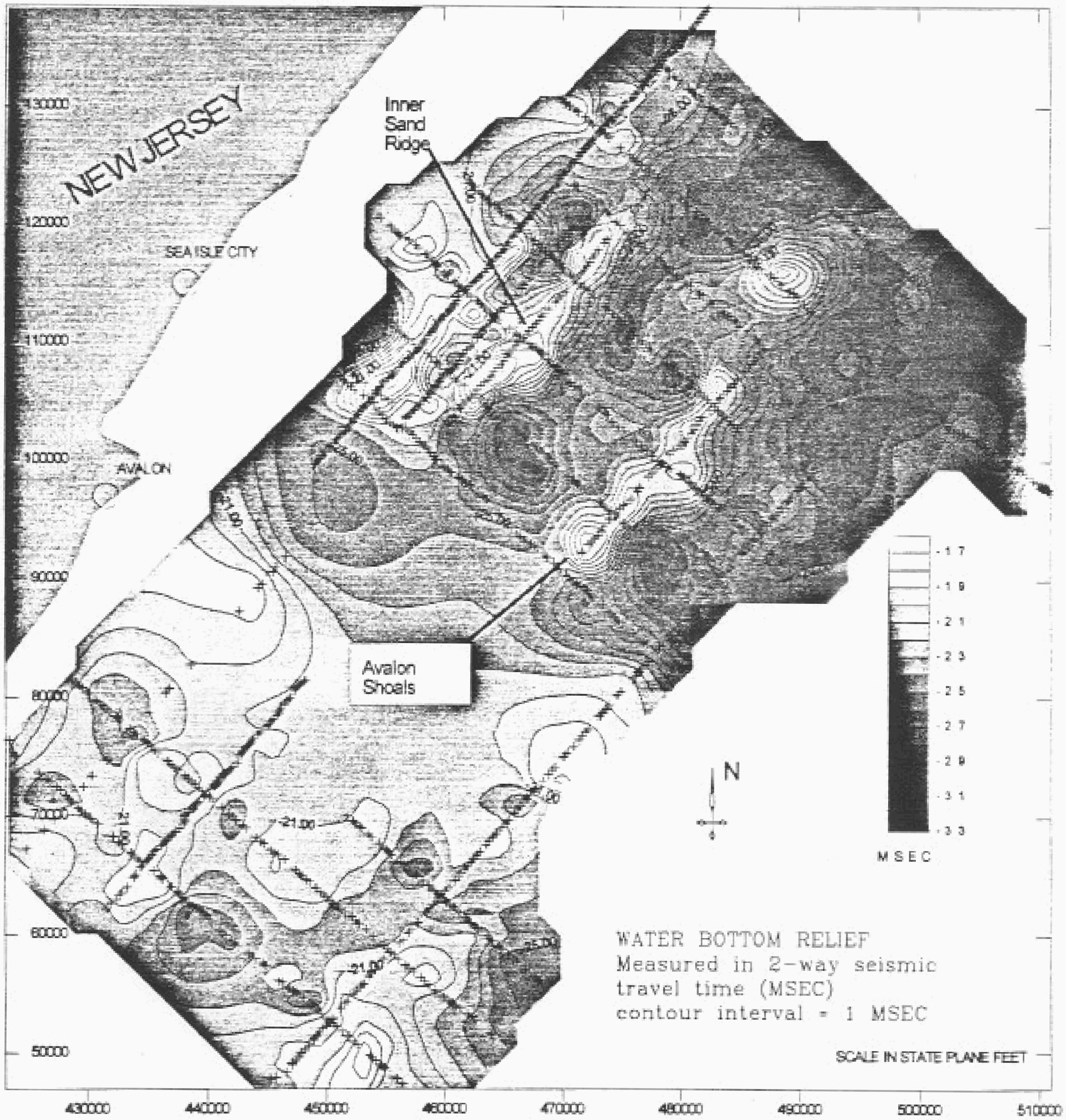


Figure 4. Water bottom relief map showing sand shoals, X's are every15th GPS position.

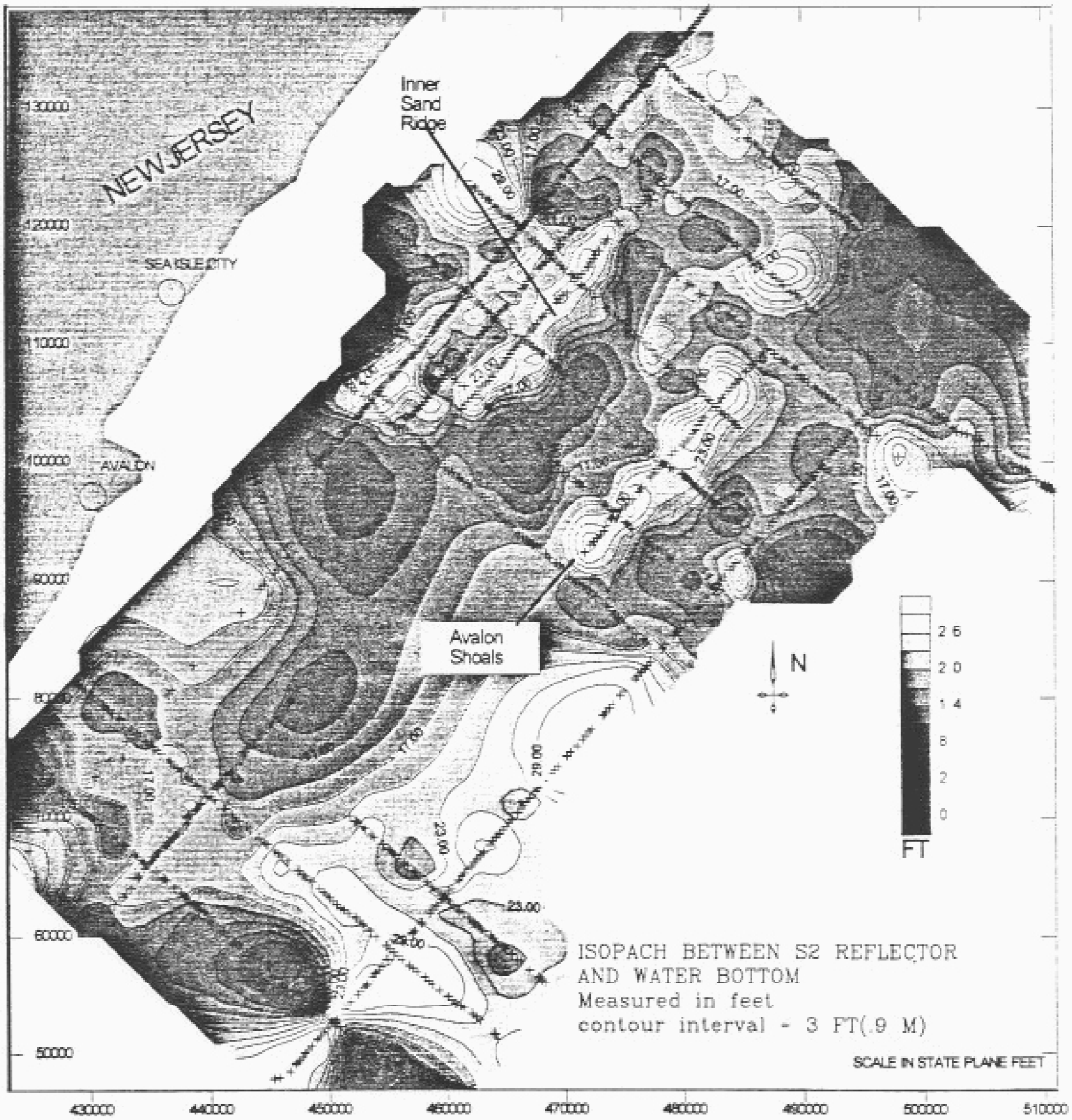


Figure 5. Isopach map between the S2 unconformity and the water bottom seismic reflectors. X's show every 15th GPS fix position.

difference between the two surfaces in two-way seismic traveltime units (milliseconds), and subsequently converted those measurements to thickness in feet using a sediment velocity of 5577.4 feet/second (1700 meters/second).

The Sand Resource Map (Figure 6) shows the orientation and lateral extent of the targeted sand shoals (Inner Sand Ridge and Avalon Shoals) using the 16.4-ft (5-meter) isopach as the perimeterof the shoals. The volumes using Smith's criteria are calculated with the aid of the volumetric function in the SURFER (Golden Software, Inc., 1994) contouring program. The volumes for the analog and digital data sets are compared below.

Sand Resource Volumes	Inner Sand Ridge (cubic yards)	Avalon Shoal Sand Ridge (cubic yards)	Total Sand Resource Volume (cubic yards)
Analog Data	63,300,000	48,800,000	112,100,000
Digital Data	50,616,000	74,247,000	124,863,000

Table 1. Sand volumes calculated using the two data sets.

Differences in the volumes obtained by the analog and digital data are primarily due to the number of geodetic positions, the irregularities of the surface boundaries, and differences in the contouring parameters, resulting in distinctly different contour maps. The digital data have 100 times more data points, making possible more accurate vertical and horizontal resolution. The higher resolution digital data reveal that the Inner Sand Ridge consists of two distinct features. To match most closely the area outlined by Smith (1996), digital data volumetric calculation was performed only on the continuous narrow ridge, resulting in a smaller volume than that calculated by Smith. Conversely, the Avalon Shoal is a wider and thicker feature in the digital data, resulting in a larger volume.

CONCLUSIONS

This study shows that the digital seismic data have the capability to enhance overall

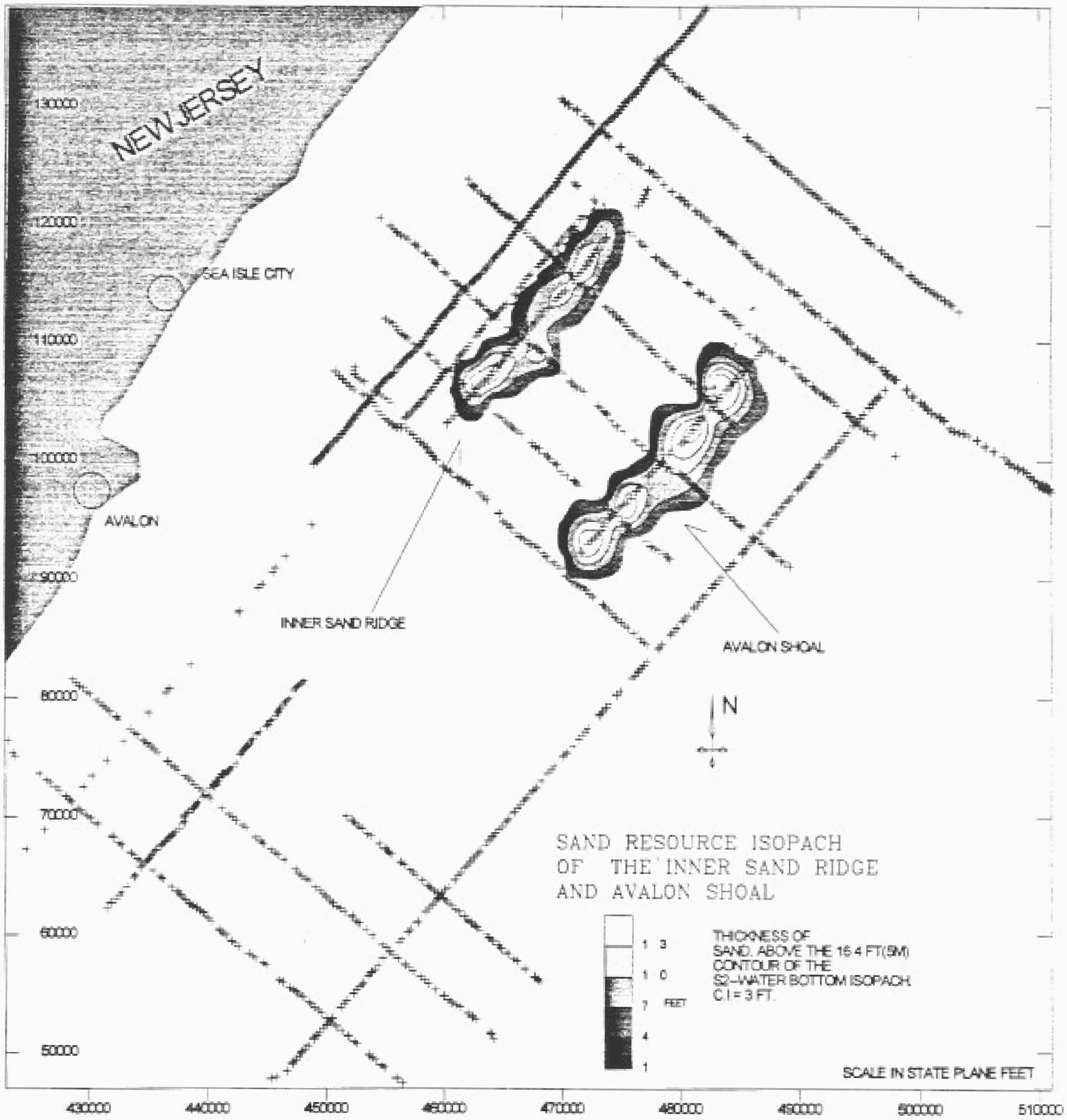


Figure 6. Map showing the sand resource above the 16.4 ft (5 m) isopach.
X's show every 15th GPS fix position.

quality of sand resource volume estimates from reconnaissance surveys. Acquisition and processing technology are constrained largely by the computer capabilities in accommodating large volumes of data. Today's rapid rate of technological advances in microcomputer technology is improving both the capacity and cost of an already effective technique.

TASK 3 -- COMPARISON OF ONSHORE AND OFFSHORE SAND SOURCES

Economic factors influencing beach replenishment costs

Contracts for beach replenishment sand show a wide range of prices per cubic yard of sand delivered. Some contracts some are funded by the municipalities (e.g. Avalon Twp.), whereas others are part of larger projects managed by the USACE and the DEC (Atlantic City, Cape May).

Some contracts include work on hard structures (e.g. groins) or emplacement of experimental structures (e.g. artificial reefs/breakwaters). In these cases, the price for the beach replenishment sand may be lower to meet a contract dollar limit. Other factors causing differences in the unit cost of sand are the proximity of the sand source to a beach fill site or the ability of the contractor to arrange to haul materials on the return from the site.

A record of recent contracts on file at DEC reveals lower costs for dredged sand than for sand from onshore (also known as upland) sources (Table 2). Of 24 recorded contracts issued between 1979 and 1997, 17 supply sand from dredged material and 7 supply sand from upland sources. With prices adjusted for inflation and listed in 1992 dollars, the arithmetic mean price of onshore material is $5.02 per cubic yard (cu. yd.); the arithmetic mean price of dredged material is $4.42 per cu. yd., 12 percent less than onshore material. Large-volume projects typically utilize dredged rather than onshore material. Since the implementation

Table 2. Cost of beach replenishment: recent contracts with the New Jersey Department of Environmental Protection supplying sand from dredged material and upland sources

MUNICIPALITY	YEAR	AMOUNT IN CUBIC YARDS	CONTRACTOR	COST IN DOLLARS PER CUBIC YARD		COST IN DOLLARS PER CUBIC YARD CORRECTED FOR INFLATION		
						DEFLATION/ INFLATION FACTOR*	(VALUE IN 1992 DOLLARS)	
				DREDGED MATERIAL	UPLAND SOURCE		DREDGED MATERIAL	UPLAND SOURCE
Sea Bright	1995	5,000,000	Weeks	5.00		1.076	4.65	
Monmouth Beach	1996	3,410,000	T.L. James	5.00		1.099	4.55	
Long Branch	1997	4,600,000	Weeks	6.30		1.126 **	5.60	
Harvey Cedars	1994	485,000	R.W. Vogel, Inc.		7.09	1.05		6.75
Atlantic City	1983	32,400	Hanselman, Inc.		4.71	0.732		6.43
"	1986	1,000,000	American Dredging Co.	4.72		0.806	5.86	
Longport Borough	1990	129,000	Gates	4.58		0.936	4.89	
Ocean City	1979	118,900	Environmental Dredging Co.	1.58		0.553	2.86	
"	1982	1,217,700	American Dredging Co.	3.40		0.702	4.84	
"	1989	200,000	Gates	4.58		0.897	5.11	
"	1994	600,000	Weeks	4.83		1.05	4.60	
"	1995	1,400,000	Weeks	3.29		1.076	3.06	
"	1995	500,000	Weeks	3.40		1.076	3.16	
Strathmere	1984	520,000	American Dredging Co.	4.90		0.759	6.46	
Sea Isle City	1984	800,000	American Dredging Co.	3.83		0.759	5.05	
"	1987	150,400	American Dredging Co.	2.90		0.831	3.49	
"	1992	390,000	American Dredging Co.	3.00		1	3.00	
"	1995	27,600	Earthwork Assocs.		4.21	1.076		3.91
Avalon	1987	1,379,100	American Dredging Co.	1.66		0.831	2.00	
North Wildwood	1989	97,000	Great Lakes	5.41		0.897	6.03	
Lower Township	1986	29,000	Earthwork Assocs.		3.67	0.806		4.55
Cape May Point	1985	25,000	Earthwork Assocs.		3.67	0.786		4.67
"	1992	35,000	Albrecht and Huen		2.64	1		2.64
"	1995	10,000	Albrecht and Huen		6.66	1.076		6.19
COUNT				17	7		17	7
MINIMUM				1.58	2.64		2.00	2.64
ARITHMETIC MEAN				4.02	4.66		4.42	5.02
MAXIMUM				6.30	7.09		6.46	6.75
SAMPLE STANDARD DEVIATION				1.29	1.64		1.28	1.51

* Deflation/Inflation factors from the Chain-type Price Index for Gross Domestic Product, developed by the Bureau of Economic Analysis, Dept. of Commerce, available in the Survey of Current Business.

** Projection for index increases from 1996-2000 are derived from the FY 1998 Budget Economic Assumptions.

of the Army Corps of Engineers' Northern Coastal Area Replenishment Project (Sea Bright, Monmouth Beach and Long Branch), offshore dredged material is by far the principal beach replenishment sand source in New Jersey.

Mineralogic and textural compatibility of sediments

Grain size of quartz sand on the New Jersey coast fines to the south (McMaster, 1954; Uptegrove and others, 1994). McMaster(1954) reported a median grain size of 0.4 to 0.5 millimeters (mm), medium to coarse sand, at Sandy Hook, diminishing to a median grain size of 0.1 to 0.2 mm, fine sand, at Cape May. Gravel (grain size >2 mm) content in sediments offshore of Ocean and Monmouth Counties is greater than in sediments offshore of Cape May and Atlantic Counties (Amato, 1994). The mineralogic composition also changes along the coast. For example, glauconitic sands eroded from headlands consisting of the Cretaceous Navesink Formation, the Red Bank and Tinton Sands and the Tertiary Hornerstown, Vincentown, Manasquan and Shark River Formations in the northern coastal area are incorporated into the northern beach sands. To the south (from Mantoloking to Cape May Point), sands reworked from submerged Coastal Plain sediments mingle with eroded onshore sediments to form a chain of barrier islands. Along the coast from Point Pleasant southward, the beaches consist of progressively less material derived from the northern headlands.

Regarding accessory minerals in potential offshore sand, sediments in the vicinity of Atlantic City and Ventnor are richer in ilmenite and leucoxene than elsewhere along the coast; and sands in the northern offshore area have more garnet, pyroxene and amphibole (Uptegrove and others, 1994).

Borrow material from upland pits may originate as marine, fluvial, glacial or lacustrine sediments. The grain-size distribution in these sediments would vary accordingly.

Ideally, borrow material should be the same size, or slightly coarser than the native material on the beach to be nourished (USACE, 1984, 1996). If the borrow material has a significantly smaller grain size, the beach will be out of equilibrium with the local wave and current environment, and will be quickly eroded (USACE, 1996). The overfill factor (Ra) and renourishment factor (Rj) as defined in the USACE's Shore Protection Manual (USACE, 1984) are positively affected if borrow material is of the same size or slightly coarser than the native material. The overfill factor estimates the volume of fill material needed to produce one cubic yard of stable beach material after reaching equilibrium, defined by the USACE (1996) as the condition in which the beach and native materials are compatible. The renourishment factor is a measure of the stability of the placed borrow material relative to the stability of the native beach sand (USACE, 1996). Ideally, mineralogy and color should match the native material.

Identified onshore sand sources

Long-distance hauling of aggregate is costly. This study limited identified onshore sand sources to those within 15 miles of the coast in Monmouth County or within a 15-mile radius of major access routes to the barrier islands in Ocean, Atlantic and Cape May Counties. The accompanying Plate 1, "Identified potential beach replenishment sand sources, onshore and offshore New Jersey", shows the location of these sand and gravel quarries. Quarries in Plate 1 with hyphenated labels are keyed to Table 3, a listing of sand and gravel quarries and/or owners within the 15-mile limit. Contractors listed in Table 2 can be cross-referenced with contractors listed in Table 3. For instance, Earthwork Associates (labeled C-4, C-20, C-33, and C-35 on Plate 1), located in Dennis, Upper, Middle, and Upper Townships, respectively in Cape May

Table 3. Sand and gravel pits located within a 15-mile radius of the coast or major access routes to barrier islands in Cape May, Atlantic, Ocean and Monmouth Counties, New Jersey. Map numbers (Map I.D. no.) correspond to labels for onshore pits on Plate I, "Identified potential beach replenishment sand sources, onshore and offshore New Jersey". Data from Bell and others (1991).

Map I.D. no.	Owner or Name	Municipality	County	Geologic Formation/ Description of Materials/ Comments	Reference
C-1	Albrecht and Huen Inc.	Dennis	Cape May	na	U.S. Bureau of Mines (1976), Johnson (1979), N.J. Bureau of Mine Safety (1991)
C-3	Cape Concrete Co.	Dennis	Cape May	na	N.J. Bureau of Mine Safety (1991)
C-4	Earthwork Associates	Dennis	Cape May	na	U.S. Bureau of Mines (1976), Johnson (1979), N.J. Bureau of Mine Safety (1991)
C-17	Albrecht and Huen	Middle	Cape May	na	U.S. Bureau of Mines (1976), Johnson (1979), N.J. Bureau of Mine Safety (1991)
C-20	Earthwork Associates	Upper	Cape May	na	N.J. Dept. of Transportation (1982), N.J. Bureau of Mine Safety (1991)
C-21	Action Supply	Upper	Cape May	Cape May/washed quartz pebbles and sand for construction use/ mined with dredge to a depth of 30 ft.	N.J. Dept. of Transportation (1982), Martens (1956), N.J. Bureau of Mine Safety (1991)
C-25	Tuckahoe Sand and Gravel	Upper	Cape May	Cape May/construction-grade sand and gravel	N.J. Dept. of Transportation (1982), U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991)
C-26	The Morie Company	Upper	Cape May	construction-grade sand and gravel/ formerly Tuckahoe Sand and Gravel	N.J. Dept. of Transportation (1982), U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991)
C-30	Albrecht and Huen	Middle	Cape May	na	N.J. Bureau of Mine Safety (1991)
C-31	Albrecht and Huen	Middle	Cape May	na	N.J. Bureau of Mine Safety (1991)
C-32	Albrecht and Huen	Middle	Cape May	na	N.J. Bureau of Mine Safety (1991)
C-33	Earthwork Associates	Middle	Cape May	na	N.J. Bureau of Mine Safety (1991)
C-34	Daley's Pit	Upper	Cape May	na	N.J. Bureau of Mine Safety (1991)
C-35	Earthwork Associates	Upper	Cape May	na	N.J. Bureau of Mine Safety (1991)

Table 3, continued

A-30	J. Monfredo, Inc.	Galloway	Atlantic	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991), Johnson (1979)
A-42	Frank Santora	Hamilton	Atlantic	Bridgeton, Cohansey/both formations mined for sand; clay is present major product, for use in landfill covers	N.J. Bureau of Mine Safety (1991)
A-53	Anthony J. Puggi	Egg Harbor	Atlantic	na	N.J. Bureau of Mine Safety (1991)
A-54	Bob's Gravel Pit	Egg Harbor	Atlantic	na	N.J. Bureau of Mine Safety (1991)
A-55	Ole Hansen and Sons	Egg Harbor	Atlantic	na	N.J. Bureau of Mine Safety (1991)
A-59	Ole Hansen and Sons	Estell Manor	Atlanitc	na	N.J. Bureau of Mine Safety (1991)
O-2	Johnson Sand and Gravel	Barnegat	Ocean	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991), Johnson (1979)
O-5	F.M. Moon, Inc.	Barnegat	Ocean	construction-grade sand and gravel	N.J. Bureau of Mine Safety (1991)
O-7	Tanner Trucking	Barnegat	Ocean	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991), Johnson (1979)
O-9	Fisher Brothers Sand and Gravel	Berkeley	Ocean	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991)
O-22	Ralph Clayton and Sons	Jackson	Ocean	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991), Johnson (1979)
O-29	Stavola Sand and Gravel	Jackson	Ocean	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991), Johnson (1979)
O-30	Atlantic Sand and Gravel	Lacey	Ocean	formerly Gravatts Sand and Gravel	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991)
O-31	Brick Wall Corp.	Lacey	Ocean	formerly Parker Sand and Gravel	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991)
O-32	French Contracting Co.	Lacey	Ocean	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991), Johnson (1979)

Table 3, continued

O-34	Parker Construction Co.	Lacey	Ocean	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991), Johnson (1979)
O-35	Parker Construction Co.	Lacey	Ocean	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991), Johnson (1979)
O-42	Tuckerton Sand and Gravel	Little Egg Harbor	Ocean	5 ft. of light-yellow to nearly white, sandy gravel; small amount of clay present	Martens (1956), N.J. Geological Survey (1899-1937), N.J. Bureau of Mine Safety (1991)
O-44	Brick Wall	Manchester	Ocean	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991)
O-57	Alpha Omega Equities	Barnegat	Ocean	location uncertain	N.J. Bureau of Mine Safety (1991)
O-59	Bob Kalsch	Eagleswood	Ocean	location uncertain	N.J. Bureau of Mine Safety (1991)
O-61	Lacey Sand and Gravel	Lacey	Ocean	location uncertain	N.J. Bureau of Mine Safety (1991)
O-62	Clayton Sand and Gravel	Lakewood	Ocean	na	N.J. Bureau of Mine Safety (1991)
O-63	Heritage Minerals	Manchester	Ocean	na	N.J. Bureau of Mine Safety (1991)
O-65	Cox and Cox	Eagleswood	Ocean	na	N.J. Bureau of Mine Safety (1991)
O-66	Mt. Holly Concrete	Little Egg Harbor	Ocean	na	N.J. Bureau of Mine Safety (1991)
M-21	Herbert Sand	Howell	Monmouth	na	U.S. Bureau of Mines (1976), N.J. Bureau of Mine Safety (1991), Johnson (1979)
M-91	Fred McDowell	Freehold	Monmouth	location uncertain	N.J. Bureau of Mine Safety (1991)
M-92	Howell Sand and Gravel	Howell	Monmouth	na	N.J. Bureau of Mine Safety (1991)
M-93	Manco, Inc.	Matawan	Monmouth	location uncertain	N.J. Bureau of Mine Safety (1991)
M-101	Seaview Corporate Park	Ocean	Monmouth	location uncertain	N.J. Bureau of Mine Safety (1991)
M-102	Stavola Construction Corp.	Ocean	Monmouth	na	N.J. Bureau of Mine Safety (1991)
M-103	Stavola Construction Corp.	Tinton Falls	Monmouth	na	N.J. Bureau of Mine Safety (1991)

County (Table 3), supplied beach fill at Sea Isle City, Lower Township, and Cape May Point (Table 2). Only some of the quarries listed on Plate 1 and in Table 3 have provided beach replenishment sand.

Decline in onshore sand sources

Historic data on the location of sand and gravel quarries in the four coastal counties (Bell and others, 1991) indicate a decline in the number of open pits during the last 100 years. In Cape May County, the number of abandoned *vs.* active sites is 18:14; in Atlantic County, it is 15:7; in Ocean County, the number is 33:20; and in Monmouth County, the number of abandoned *vs.* active quarries is 59:7. Urban pressures, particularly in Monmouth County, have converted sand and gravel quarries to housing developments and shopping malls. The decline in upland sources has the potential to inflate the per unit cost of upland sand.

Environmental impact of onshore sand mining

Environmental impacts of onshore sand mining and transport to the replenishment site include: 1)the resultant pits at the mining site after excavation, with associated water drainage problems, marred landscape, elevation of ambient temperature of the adjacent area, destruction of wildlife habitat, and creation of hazardous unstable sand banks; and 2)transportation impacts between the quarry and the replenishment site, including wear-and-tear on road surfaces and increased air pollution, traffic, and noise during the period of emplacement. Also, placement of trucked-in sand requires construction of ramps between nearby streets and the beach to provide vehicle access. This ramp material is typically a highway construction grade sand, composed of more gravel and clay than a beach sand. It is graded over with beach sand. However, during storms, this construction sand may be exposed or eroded, resulting in a mixing with the beach sand.

Aesthetic value

Public perception of a replenishment project, including the aesthetic value of the replenishment material affects the success of a project, if not the actual cost. Emplacement of an iron-stained orange sand from an upland source on the beach at Harvey Cedars, Long Beach Island, New Jersey in 1994 generated a rash of complaints from property owners and public officials (Asbury Park Press, 1994a, 1994b). Where recently emplaced, iron leaching from the stained sand can discolor clothing.

Identified offshore sand sources

Identified sand sources in more than 30 shoals/areas in both nearshore and farther offshore waters total approximately 1.3 billion cubic meters (1.8 billion cubic yards). As reported in the Phase-I report of this study, several previous studies identified offshore sand source areas, particularly in the vicinity of Cape May, Absecon Inlet, Barnegat Inlet, and the New York Bight. Shoals reported in these studies are shown on Plate 1. Labels correspond to shoal identification numbers in the Cape May and Central New Jersey Coast studies (Meisburger and Williams, 1980; Meisburger and Williams, 1982), and to the Shoal ID labels in Tables 4 and 5, respectively. Since some of the studies are several decades old, shoal-specific data need to be reviewed and updated if particular shoals are selected for development.

In their study of shoals offshore of Cape May, Meisburger and Williams (1980) found 18 sites containing nearly 1.09 billion cubic meters (1.43 billion cu. yds.) of sand (Plate 1, Table 4). All but two of the sites (CM-1 and CM-2) are linear and arcuate shoals of Holocene age consisting of clean, quartz sand of marine origin. The shoals are about 6 meters (20 feet) thick and appear to rest on a pre-Holocene fluvial surface composed of dense silty sand and gravel. The six shoals closest to Cape May (CM-A, CM-B, CM-C, CM-E, CM-F, CM-J) and area CM-1

Shoal ID	Water Depth (ft)	Area (x 10^6 yd^2)	Deposit thickness (ft)	Estimated volume (x 10^6 yd^3)
CM-A	6 to 30	10.914	5	18.182
CM-B	6 to 12	3.555	5 to 10	6.499
CM-C	12 to 38	14.617	5 to 20	41.079
CM-D	10 to 40	38.962	5 to 15	89.265
CM-E	23 to 33	6.765	5 to 10	14.644
CM-F	22 to 34	5.990	5 to 10	13.163
CM-G	18 to 42	29.417	5 to 20	84.328
CM-H	44 to 53	20.099	5 to 20	53.230
CM-I	40 to 60	33.778	5 to 20	120.860
CM-J	18 to 42	54.222	5 to 20	189.554
CM-K	20 to 60	125.580	5 to 30	617.477
CM-L	26 to 60	25.383	5 to 25	94.943
CM-M	44 to 65	3.901	5 to 20	10.794
CM-N	50 to 65	8.543	5 to 10	20.979
CM-1	6 to 30	na	na	est. 14.5
CM-2	39 to 53	na	na	est. 20.6

Table 4. Sand shoals offshore of Cape May, New Jersey identified in Meisburger and Williams (1980). Shoal IDs correspond to shoal labels on Plate I, "Identified potential beach replenishment sand sources, onshore and offshore New Jersey". Shoal CM-A on Plate I includes Area CM-1 (Meisburger and Williams, 1980). Areas CM-1 and CM-2 are not discernible topographic or seismic features. Sand volumes for these areas are based solely on vibracore analysis and are only estimates.

contain a total of about 216 million cubic meters (283 million cu. yds.) of sand. Several of these shoals have been developed as borrow areas for Cape May beach replenishment.

Meisburger and Williams (1982) found an estimated 172 million cubic meters (225 million cu. yds.) of suitable sand in 15 areas offshore of Central New Jersey from Avalon to Barnegat Inlet (see Plate 1). Data on these shoals can be found keyed to Plate 1 in Table 5.

Smith (1996) characterized two shoals offshore of Avalon, New Jersey, one of which (the Inner Sand Ridge) is encompassed by area BI-L of Meisburger and Williams (1982). In his report to the Minerals Management Service (Cooperative Agreements #14-35-0001-30666 and #14-35-0001-30751), Smith calculates a total of 85.7 million cubic meters (112.1 million cubic yards) of suitable sand in the Inner Sand Ridge and Avalon Shoal (TI-1 and TI-2 on Plate 1 and in Table 6). Borrow areas for the Beach Erosion Control Project for the northern coastal area, Sea Bright to Ocean Township, New Jersey (Section I) and Asbury Park to Manasquan, New Jersey (Section II), are depicted in lieu of designated potential sand source areas in the New York Bight apex (Plate 1, Table 7).

Environmental impact of offshore dredging

Environmental impacts of offshore dredging and pumping to the replenishment site include the disruption of benthic habitat. In particular, surf clams are identified as at risk. Disruption of habitat may affect other species as well, including fin fish that feed on nutrients associated with benthic communities.

In an effort to assess the recruitment rates of the benthic organisms, one of the Belmar borrow areas is currently being monitored by Bureau of Shell Fisheries, NJDEP. In another effort to characterize the benthic and fin fish communities in offshore waters, Rutgers Institute of Marine and Coastal Sciences inventoried species on Beach Haven Ridge (as part of Year 3 of

Shoal ID	Water depth (m)	Area (x 10^6 m^2)	Avg. deposit thickness (m)	Estimated volume (x 10^6 m^3)
BI-A	2 to 9	4.87	1.5	11.14
BI-B	9 to 13	2.76	1.2	5.90
BI-C	9 to 13	3.97	1.5	12.72
BI-D	9 to 13	5.96	1.8	25.18
BI-E	6 to 9	1.67	1.8	4.44
BI-F	7 to 11	4.30	1.5	8.38
BI-G	7 to 11	8.34	1.8	28.50
BI-H	9 to 11	1.46	2.1	4.54
BI-I	9 to 13	4.07	1.8	14.92
BI-J	9 to 15	6.03	1.5	14.70
BI-K	15 to 16	9.36	1.8	27.84
BI-L	9 to 15	2.41	2.4	5.86
BI-M	9 to 16	2.34	2.5	5.94
BI-N	9 to 11	0.49	2.7	1.32
BI-O	9 to 11	0.24	2.3	0.56

Table 5. Sand shoals offshore of Central New Jersey identified in Meisburger and Williams (1982). Shoal IDs correspond to shoal labels on Plate I, "Identified potential beach replenishment sand sources, onshore and offshore New Jersey". Area BI-L encompasses the Inner Sand Ridge, one of two shoals located offshore of Townsends Inlet and characterized in Smith (1996), Minerals Management Service Agreements #14-35-0001-30666 and #14-35-0001-30751.

Shoal ID	Shoal Name	Water Depth (m)	Volume (x 10^6 m^3)	Volume (x 10^6 yd^3)
TI-1	Inner Sand Ridge	7.01 to 15.2	48.4	63.3
TI-2	Outer Sand Ridge (Avalon Shoal)	10.9 to 14.3	37.3	48.8

Table 6. Shoals located offshore of Townsends Inlet and characterized in Smith (1996), Minerals Management Service Agreements #14-35-0001-30666 and #14-35-0001-30751. Shoal IDs correspond to shoal labels on Plate I, "Identified potential beach replenishment sand sources, onshore and offshore New Jersey".

Borrow ID	Name	Replenishment Project	Volume (x 10^6 yd^3)	Reference
SB-1	Sea Bright-88	Section I	54.5	U.S. Army Corps of Engineers (1989)
BA-2	Belmar #2	Section I	1.48	U.S. Army Corps of Engineers (1989)
BA-4	Belmar #4	Section I	1.5	U.S. Army Corps of Engineers (1989)
SB-1	Sea Bright-89	Section II	24.33 to 33.01	U.S. Army Corps of Engineers (1993)
BA-3	Belmar #3	Section II	1.01	U.S. Army Corps of Engineers (1993)
BA-5	Belmar #5	Section II	2.9	U.S. Army Corps of Engineers (1993)
BA-6	Belmar #6	Section II	2.19	U.S. Army Corps of Engineers (1993)

Table 7. Designated borrow areas for the Beach Erosion Control Project for the northern coastal area, Sea Bright to Ocean Township, New Jersey (Section I) and Asbury Park to Manasquan, New Jersey (Section II). Borrow IDs correspond to labels on Plate I, "Identified potential beach replenishment sand sources, onshore and offshore New Jersey".

the New Jersey Cooperative Study) to provide a baseline census for a typical shore-detached sand ridge in water depths of 15 meters (Able and Hagan, 1995; Hales and others, 1995). Innovative dredging techniques, including discontinuous dredge patterns to preserve bathymetric high areas may diminish disruption of benthic habitat.

Natural nearshore shoal-fields serve as protection from storm waves and they serve as source areas for longshore sand transport and onlapping of sand on beaches during the spring and summer. Dredging nearshore shoals affects the buffering and protective functions of these shoal fields. The extent of this impact is as yet not well quantified. Dredging sand shoals farther offshore may have less impact on natural sand source systems and thereby conserve storm wave protection. This matter deserves further study including modeling of the storm wave and natural sand source systems, as in the models developed for New Jersey tidal inlets (e.g. Ashley, 1987).

Nearshore *versus* farther offshore dredging

There is insufficient data to compare the costs of nearshore (within 3 miles) and farther offshore (beyond the 3-mile limit) dredging. However, a combination of currently available technology and Jones Act restrictions on foreign-owned dredges operating in U.S. waters effectively limits dredging to maximum water depths of approximately 20 meters (66 ft). Plate 1 designates the area of less-than-20-meters water depth beyond the 3-mile State-Federal boundary (stippled pattern). This represents the present-day effective area of operations for dredging in Federal waters. If the technology for dredging at greater depth improves, this area will extend farther offshore. Most of the identified sand shoals are within 12 miles of the coast (see Plate 1). Some shoals straddle the 3-mile State/Federal boundary (Plate 1), as also occurs in Maryland and Delaware.

CONCLUSIONS

Offshore dredging is more economical than accessing upland sources by about 12 percent. Offshore dredging is able to realize an economy of scale. The size of current and projected beach-replenishment projects in New Jersey require source areas on the scale of the Sea Bright borrow areas. Onshore areas, subject to urban pressures, continue to diminish and will be unable to provide the volumes of material needed in the future at a competitive price.

Identified sand sources in more than 30 shoals/areas in both nearshore and farther offshore waters total approximately 1.3 billion cubic meters (1.8 billion cubic yards). These sources include the Inner Sand Ridge and Avalon Shoal characterized by Smith (1996) as part of MMS Cooperative Agreements #14-35-0001-30666 and #14-35-0001-30751. Several identified shoals are located straddling the 3-mile State/Federal boundary.

Environmental impacts are unavoidabable in both terrestrial and marine settings. Onshore sand and gravel quarries create environmental changes affecting water drainage, degradation of natural areas, disruption of traffic due to transport and road-bed wear, air pollution, and potential hazards to the public. Offshore dredging disrupts benthic habitat and impacts the sand buffer and storm-wave protective functions of offshore shoal fields. Environmental monitoring of dredge sites is at a beginning stage. NJDEP and Rutgers University have ongoing monitoring of shoals for recruitment of surf clams and other fauna. As more data are amassed, the environmental impact in the offshore will be characterized more accurately.

Future work

In Phase II, Year 3, NJGS will perform side-scan and magnetometer surveys of the Inner Sand Ridge and Avalon Shoal offshore of Townsends Inlet. Dr. Robert Sheridan and Michael Kearsley of Rutgers University will re-examine the volume analysis of suitable sand in the two shoals using synthetic seismograph models. Also, NJGS will produce a digital database of the information generated by the cooperative study. The database will be in GIS format using ArcView™ software and will be issued on compact disc.

In related work, NJGS will participate with the Delaware and Maryland Geological Surveys in proposing a cooperative vibracoring contract. The purpose of this project will be to realize an economy of scale in contracting for drilling vibracores to further identify sand sources in Federal waters offshore of these three states.

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Roger Amato of the Minerals Management Service provided technical and administrative guidance for the study. The study was funded under Cooperative Agreement #14-35-0001-30751. I.G. Grossman of NJGS edited the report.

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IDENTIFIED POTENTIAL BEACH REPLENISHMENT SAND
SOURCES, ONSHORE AND OFFSHORE NEW JERSEY
EXPLANATION
Fifteen-mile buffer area.
Land outside buffer area.
Water between three-mile and twelve-mile limits.
Borrow area with study identification number (see Table 6).
Shoal area with study identification number (see Tables 3, 4 and 5).
Inner Sand Ridge and Avalon Shoal Ridge.
Water depth of less than twenty meters beyond the three-mile State/Federal boundary.
County border.
State border.
Fifteen-mile buffer
C-7 Sand and gravel pit with study identification number (see Table 2).
Data compiled from Bell and others (1991), Meisburger and Williams (1980, 1982), National Ocean Survey (1972, 1975, 1979), Smith (1996), U.S. Army Corps of Engineers (1989, 1993), on file at New Jersey Geological Survey, Trenton, NJ.
Cartography by Z. Allen-Lafayette, 1996.
NEW YORK
PENNSYLVANIA
NEW JERSEY
MARYLAND
DELAWARE
ATLANTIC OCEAN
Raritan Bay
Delaware Bay
MONMOUTH COUNTY
OCEAN COUNTY
ATLANTIC COUNTY
CAPE MAY COUNTY
Sandy Hook
Sea Bright
Monmouth Beach
Long Branch
Ocean Township
Asbury Park
Manasquan
Point Pleasant
Mantoloking
Barnegat Inlet
Harvey Cedars
Atlantic City
Ventnor
Longport
Ocean City
Strathmere
Sea Isle City
Townsends Inlet
Avalon
North Wildwood
Cape May City
Lower Township
Cape May Point
Coastline buffer
J. Stanley Tunney/Thomas A. Mathis Bridges buffer
The Causeway, Long Beach Island Bridge buffer
Ventnor City buffer
Avalon Borough buffer
Wildwood City buffer
Cape May Point buffer
three-mile limit
twelve-mile limit
75°00'
74°00'
40°00'
39°00'
0 5 10 15 statute miles
0 5 10 15 nautical miles
RATES OF VOLUME CHANGE, 1986-1992
EXPLANATION
Gains and losses of beach sand (in cubic yards per foot per year)
Losses
More than 4
2+ to 4
0 to 2
Gains
More than 4
2+ to 4
0 to 2
No data available
Reach boundary
0 10 20
miles
Changes in sand budget based on data from Farrell and others, 1993. Measurements made to depth of 12-20 feet NGVD of 1929 (National Geodetic Vertical Datum of 1929).