STATE OF FLORIDA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Michael W. Sole, *Secretary*

DIVISION OF RESOURCE ASSESSMENT AND MANAGEMENT
Edwin J. Conklin, *Director*

FLORIDA GEOLOGICAL SURVEY
Walter Schmidt, *State Geologist and Chief*

A GEOLOGICAL INVESTIGATION OF THE OFFSHORE AREA ALONG FLORIDA'S NORTHEAST COAST YEAR FOUR (STATE FISCAL YEAR 2005-2006) ANNUAL REPORT SUBMITTED TO THE UNITED STATES DEPARTMENT OF THE INTERIOR MINERALS MANAGEMENT SERVICE

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Daniel C. Phelps (P.G. # 1203), Michelle M. Lachance,
James G. Sparr, and Adel A. Dabous

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EXECUTIVE SUMMARY

The U.S. Minerals Management Service (MMS) and the Florida Geological Survey (FGS) have a long history of studying the marine sediment resources offshore of the State of Florida through cooperative investigations. Currently this includes a multi-year study titled "A Geological Investigation of the Offshore Area Along Florida's Northeast Coast, Under MMS/FGS Cooperative Agreement No. 1435-0001-30757." The study area is that portion of the State of Florida consisting of Nassau, Duval, St. Johns, Flagler and Volusia Counties and their beaches, as well as adjacent federal water from three nautical miles (5.6 kilometers) to 16 nautical miles (29.6 kilometers) offshore. Specific goals of this study include the identification of the location, areal extent and volumes of potentially available restoration-quality sand resources (i.e.: borrow material) underlying federal waters offshore of Nassau, Duval, St. Johns, Flagler and Volusia Counties and the characterization of current beach sediments in the study area.

This report discusses data and interpretations derived from specific tasks conducted in the above study area during Year Four (State Fiscal Year 2005-2006) of the above agreement. This report provides an interim update of ongoing investigations of available restoration-quality sand resources within the study area. This report also references those data presented in previous yearly reports.

Sampling and marine geophysical data collection to date include native beach-sediment sampling, offshore vibracoring, bottom sediment sampling, and seismic profiling. While the task of beach-sediment sample collection on the beaches of Volusia County was conducted by the FGS in Year Three [State Fiscal Year 2004-2005], the analyses of those sediment samples were conducted in Year Four. Seismic reflection profiler data acquired in Year Four were collected in federal waters offshore of Flagler County and the northern portions of Volusia County.

The analyses of sediment samples, and the acquisition and processing of seismic reflection profiler data included in this report during Year Four are summarized as follows:

- *Native Beach Sample Analysis:* A total of 107 samples collected from the beaches of Volusia County in Year Three were described and granulometrically analyzed. Photographs, descriptions and the results of granulometric analyses of those samples are provided in this report.

- *Seabed Sampling and Analysis:* A total of 22 samples collected offshore of Flagler and northern Volusia Counties were described and granulometrically analyzed. Photographs, descriptions and the results of analyses of those samples are provided in this report.

- *Offshore Vibracore Analysis:* Of the vibracores variously collected offshore of Nassau and Duval Counties during the first four years of this study, 104 were analyzed for the purposes of qualifying and quantifying available restoration-quality sand reserves offshore of those counties.

- *Offshore Seismic Reflection Profiler Data:* approximately 234.3 nautical miles (435.2 kilometers) of seismic reflection profile data were collected in federal waters offshore of Flagler and Volusia Counties in Year Four. All of these data were processed, interpreted and plotted along with those data collected in the preceding three years. The seismic reflection profile data collected in Year Four are provided as processed images.

In Nassau County, two features lying east of Amelia Island, approximately 9.5 and 11.3 nautical miles (17.7 and 20.9 kilometers) offshore, respectively labeled A1 and A2, as referenced in

Meisburger and Field (1975), were vibracored in Year Four. A volume of 2.5 million cubic yards (mcy) (1.9 million cubic meters [mcm]) of available restoration-quality sand containing 5% or less fines was estimated for A1. A volume of 9.5 mcy (7.3 mcm) of available restoration-quality sand containing 5% or less fines was estimated for A2. Sediments that are referred to as "fines" are defined as that material which will pass through a 4.00 phi, 0.0025 inch (63 micron) mesh opening, 230 sieve.

In Duval County, the two features referenced in Meisburger and Field (1975), as A3 and A4 were vibracored in Year Four. The FGS, in investigating A3, identified a geomorphologically similar feature lying immediately south of it. For ease of identification, the FGS has labeled these features A3a, (A3 of Meisburger and Field (1975) and Phelps *et al.* (2005)), and A3b. They respectively lie east and southeast of the mouth of the Nassau River approximately 11 nautical miles (17.7 kilometers) offshore. Up to 22.7 mcy (17.4 mcm) of available restoration-quality sand containing 5% or less fines was estimated for A3a. Up to 12.8 mcy (9.8 mcm) of available restoration-quality sand containing 5% or less fines was estimated for A3b.

Feature A4, lying 7 nautical miles (12.9 kilometers) east of the mouth of the St. Johns River, was re-examined in detail and divided north and south into two areas A4a and A4b. Based on 102 vibracores, revised maps of potential sand reserves containing fines fractions of less than 10% and 5% or less are provided for A4b. Analyses of vibracore data and subsequent dredging reports indicate that A4b contains potential reserves of up to 88.1 mcy (67.4 mcm) of available restoration-quality sand containing 5% or less fines and potential reserves of up to 143.7 mcy (109.9 mcm) of available restoration-quality sand containing less than 10% fines. A smaller area within A4b, which lies immediately adjacent to a previously dredged site on A4b, is estimated, based on a fines content of 5% or less and less than 10%, to contain 14.2 mcy (10.9 mcm) and 21.4 mcy (16.4 mcm) respectively of potentially available restoration-quality sand. A borrow site for the USACE's Duval County Shoreline Protection Project was located within the northern portion of that smaller area. Based on 5% or less fines, that borrow site's reserves were estimated to be 1.4 mcy (1.1 mcm) of available restoration-quality sand of which 0.734 mcy (0.561 mcm) have been recovered to date. The remainder of the smaller area is being permitted for future use.

Offshore of Volusia County, Coastal Technology Corporation investigated features identified in Meisburger and Field (1975) from a reconnaissance level vibracoring program. Additional vibracoring was conducted by the company on several of these features.

Seismic stratigraphic analysis of the seismic reflection profiler data indicates the presence, offshore of Flagler and northern Volusia Counties, of areas of anomalous dip in the subsurface which exhibit no relief on the seafloor. Similar features were also observed in those data collected in previous years. These features are believed to be related to the dissolution of underlying strata. Specific conjectured collapse features, vertically persistent to the base of the seismic reflection profiler data recorded, appear to be of limited areal extent and are not expressed bathymetrically.

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INTRODUCTION

Beach erosion is a constant concern in Florida (Clark, 1993). Within the study area, which encompasses the northeastern coast of Florida, beaches comprising over 30 percent of the coastline, (totaling about 44 statute miles [71 kilometers]), are classified as Critically Eroding Beaches (Clark, 1993). Shore protection options, in many portions of the region, are limited by extensively urbanized coastal sectors which have substantial commercial and residential development proximal to the beach. Such conditions make the option of asset relocation or abandonment generally unpalatable. The shore protection measure of choice is the periodic placement of sand along the beach. As coastal development of the state proceeds at an ever increasing pace and readily available onshore sources of suitable borrow material are found to be unavailable, depleted, or uneconomical, offshore sand bodies are increasingly sought after as sources of beach restoration-quality sand. To address this burgeoning need, the Minerals Management Service (MMS) of the United States Department of the Interior and the Florida Department of Environmental Protection's (FDEP) Florida Geological Survey (FGS) entered into a multi-year cooperative agreement (Cooperative Agreement # 1435-0001-30757) to investigate the available restoration-quality sand resources offshore of the northeastern coast of Florida. This investigation has been conducted in coordination and consultation with the U.S. Army Corps of Engineers (USACE). Its purpose is to locate and characterize both the areal extent and volume of restoration-quality sand resources lying in federal waters offshore which are available for beach renourishment along the shorelines of Nassau, Duval, St. Johns, Flagler and Volusia Counties. This goal is being accomplished through the use of seismic reflection profiling, seabed sampling, beach-sediment sampling, and offshore vibracoring. These data will be entered into the Reconnaissance Offshore Sand Search database (http://Ross.urs-tally.com) being developed by URS Corporation for the FDEP Bureau of Beaches and Coastal Systems (BBCS).

This report briefly reviews those data acquired in the study's Years One (State Fiscal Year 2002-2003), Two (State Fiscal Year 2003-2004) and Three (State Fiscal Year 2004-2005) as presented in Phelps *et al.* (2003, 2004 and 2005) respectively. Additionally, it documents the findings of the Year Four investigations. It both provides and discusses in detail those data obtained and/or analyzed in Year Four (State Fiscal Year 2005-2006) and presents conclusions drawn from those data acquired and analyzed in all four years and makes recommendations regarding data to be collected in the future.

Information derived from this study will assist the MMS in making decisions concerning the future use of the available restoration-quality sand deposits . Additionally, identifying and inventorying suitable offshore restoration-quality sand resources will serve to expedite sand replenishment of beaches adversely impacted by hurricanes and/or winter storms in future years.

This report includes photographs and granulometric analyses of samples collected by the FGS both on the beaches of Volusia County and offshore of Flagler and Volusia Counties as well as vibracores collected in federal waters offshore of Nassau and Duval Counties. It provides core boring logs of selected vibracores collected offshore of Nassau and Duval Counties. Additionally, seismic profiler data collected in Year Four in federal waters offshore of Flagler County and the northern portion of Volusia County as well as selected data from previous years is presented. This information can be accessed using one of the following methods:

1. Through the "on-disk" ArcGIS Project. The ArcGIS Project contains links to web pages and PDF files of vibracores, beach samples, seabed samples, and seismic lines residing on the DVD. There are two ways to view the ArcGIS Project:

a. From the ArcMap Project
You must have ArcMap 8.x or later in order to open the ArcMap Project. If you do not have this software, please use the ArcPublisher Project (see below).

b. From the ArcPublisher Project
You must load ArcReader in order to view the ArcPublisher Project. This free viewer can be obtained from the ESRI website at http://www.esri.com/software/arcgis/arcreader/download.html.

2. From the appropriate indices within the DVD.

3. From the pertinent appendices within this report text.

DEFINITIONS

The study area is that portion of the State of Florida consisting of Nassau, Duval, St. Johns, Flagler and Volusia Counties and their beaches as well as adjacent federal water from three (3) nautical miles (5.6 kilometers) to sixteen (16) nautical miles (29.6 kilometers) offshore. The study area is shown in Figure 1.

Grab samples of beach sediments are herein referred to as "beach samples". Figure 2 shows a beach sample being collected in Volusia County. The individual sites selected for the collection of multiple beach samples are herein referred to as "beach sampling locations". The beach sampling locations utilized are shown on Figure 1. Photographs of individual beach samples as well as photographs of beach sampling sites can be found in Appendix A. Grab samples of surficial seabed sediments are herein referred to as "seabed samples". The locations of these seabed samples are shown on Figure 1. Photographs of individual seabed samples can be found in Appendix B.

The process of the collection of vertical sediment cores offshore, as utilized in this study, is herein referred to as "vibracoring". Those vibracores taken for analysis by FGS are herein referred to as "FGS vibracores". Photographs of FGS vibracores can be found in Appendix C. Those vibracores taken for and analyzed by the US Army Corps of Engineers (USACE) are herein referred to as "USACE vibracores". The locations of the vibracores collected in the study area are shown on Figure 1. Sediment samples obtained from vibracores at specific depths below the seabed are referred to herein as "vibracore samples".

Sediment analysis conducted to characterize a beach, seabed or vibracore sample's grain size distribution is referred to herein as "granulometric analysis". This analysis is graphically displayed on grain size determination (GSD) curves. GSD curves created from beach, seabed, and FGS vibracore samples can be found in Appendices A, B, and C respectively. GSD curves for USACE vibracores can be found in Appendix D. The sediment fraction referred to herein as "fines" is that material which will pass through a 4.00 phi, 0.0025 inch (63 micron) mesh opening, # 230 sieve.

Depictions of vibracores, illustrating sedimentological change with depth, are referred to herein as "core boring logs". An example of such a core boring log is shown as Figure 3. Core boring logs utilized in this report for FGS vibracores can be found in Appendix C. Core boring logs for USACE vibracores can be found in Appendix D. Geographically oriented depictions of multiple core boring logs, used to illustrate both lateral and vertical sedimentological change, are referred to herein as "cross sections". An example of such a cross section is shown as Figure 4.

The instrument used to collect geophysical profiles of sub-seabed sediments, variously referred to in the scientific literature as a sub-bottom profiler, a sub-surface acoustic profiler, and a continuous seismic reflection profiler is herein referred to as a "seismic reflection profiler". The signal source of the seismic reflection profiler generates repetitive impulses. The returning reflections off the seabed and stratigraphic horizons within the sub-seabed sediments are received on hydrophones as pressure pulses. This data collection process, variously referred to in scientific literature as continuous seismic reflection profiling, subsurface acoustic profiling, and sub-bottom profiling is herein referred to as "seismic profiling". The seismic reflection profiler records produced through that process, either in digital or analog format, are referred to herein as "seismic profiles". An example of a seismic profile is illustrated as Figure 5. The seismic profiles produced in Year Four can be found in Appendix E. The map trace of an individual seismic profile, as depicted on Figure 1, is referred to as a "seismic line". The assemblage of seismic lines, as depicted on Figure 1 is referred to as a "seismic grid". Individual seismic lines within the seismic grid lineating in a predominately east-west direction, as they run parallel to the regional dip of strata, are referred to as "dip lines". In contrast, individual seismic lines within this seismic grid lineating in a predominately north-south direction, as they run perpendicular to the regional dip of strata and/or along and thus parallel to the crest of linear bathymetric highs, are referred to as "strike lines". Individual seismic lines which intersect multiple dip lines facilitating the direct lateral correlation, from seismic profile to seismic profile of various reflectors are referred to as "tie lines".

Maps included in this document use either the North American Datum of 1983, herein cited as "NAD83", or the World Geodetic System of 1984, herein cited as "WGS84", as the datum. Projection for maps within this document is a Florida Department of Environmental Protection customized Albers Equal Area Conformal Conic herein referred to as "Albers". Global Positioning System instrumentation used to collect geographic global positioning fixes and/or reference points are referred to as "GPS" instrumentation, fixes or points as applicable.

All "unit conversion factors", English to the International System of Units, i.e. Le Système International d'Unités, (SI) and SI to English, used in this report can be found listed on Table 1. These conversion factors were obtained from Eshbach and Souders (1975). Within the body of this report, when recourse to quantification of distance, weight or volume is required, quantifications are first expressed in English units followed, enclosed in parentheses, by their expression in SI units.

PREVIOUS WORK

As previously reported in Phelps *et al.* (2005), Meisburger and Field (1975, 1976) discussed the results of their investigations of the Florida inner continental shelf from Cape Canaveral to the Florida/Georgia border. In their studies, they collected and analyzed more than 1,153 nautical miles (2,137 kilometers) of high resolution seismic profiles and data from 197 vibracores acquired in the late 1960's as part of the Inner Continental Shelf Sediment and Structure (ICONS) Program. Nocita *et al*. (1991) further analyzed vibracores collected for the ICONS Program and, based on low mud to high sand ratios, suggested that the region had several sites with low mud content that might be potential borrow sites for beach renourishment purposes. LaPlace (1993) analyzed in detail 20 vibracores and 215 nautical miles (399 km) of seismic profiles collected offshore of St. Augustine for the ICONS study. As discussed in the Years Two and Three reports (Phelps *et al.,* 2004, 2005), this study suggested that the remnants of an earlier barrier island complex were locally preserved offshore of central and northern St. Johns County. These studies discussed the geomorphology and shallow sub-bottom structure of the continental shelf as well as the surficial and sub-bottom sediments in the study area. As a result of a literature review, granulometric analysis of seabed and vibracore samples, and stratigraphic analysis of the seismic reflection profiler data, several features with a high potential for the occurrence of beach restoration-quality sand in federal waters offshore of Nassau, Duval, St. Johns, Flagler and Volusia Counties were identified. Electrical resistivity surveying, conducted in Year Three offshore of southern Duval County, was conducted by Dredging Exploration Mining Consultants (DEMCO). A copy of their report (Brabers, 2004) was included as an appendix in the

Year Three report (Phelps *et al.,* 2005).

FIELD PROCEDURES AND LABORATORY ANALYSIS

The exploratory phase of Year Four of this program involved the use of seismic profiling offshore of Flagler County and northern Volusia County, the analysis of beach samples from Volusia County collected in Year Three, the collection of seabed samples offshore of Flagler and Volusia Counties and the collection and/or analysis of vibracores collected offshore of Nassau, and Duval Counties. Vibracores were collected offshore of Nassau and Duval Counties by Alpine Ocean Seismic Surveys Incorporated (Alpine) with onboard oversight by FGS personnel. Figure 6 is a photograph of Alpine's vessel, the R/V Atlantic Twin, used for vibracoring, and Figure 7 shows Alpine's vibracoring operations aboard that vessel. Alpine's report (Alpine, 2005) on vibracoring for the FGS conducted on 20-21 October, 2005, is found in Appendix F. Independent of the FGS, Alpine and Continental Shelf Associates collected vibracores offshore of Volusia County as part of Coastal Technology Corporation's (Coastal) investigation of potential off shore reserves of available, restoration-quality sand suitable for beach nourishment in Volusia County. Their reconnaissance report is included in Appendix G. Several of the features they initially vibracored were considered by Coastal to be particularly promising. Subsequently, these features were extensively vibracored by Coastal. A copy of Coastal's final report is included in Appendix G .

Seismic lines for the seismic profiling program conducted offshore of Flagler and northern Volusia Counties were laid out as a reconnaissance seismic grid, with a north/south line spacing of one nautical mile, (1.85 kilometers) (Figure 1) between dip lines. The seismic grid lies in federal waters from 3 nautical miles (5.6 km) to over 15 nautical miles (27.8 km) offshore. North-south trending tie lines were collected offshore of Flagler and northern Volusia Counties. The reconnaissance grid spacing was a continuation of the Years One, Two and Three seismic grid conducted offshore of Nassau, Duval and St. Johns Counties. The grid provides sufficient density to determine where additional supplementary seismic profiling and later reconnaissance seabed sampling might be conducted in future years.

As previously discussed in the Years One, Two and Three reports (Phelps *et al.,* 2003, 2004, 2005), a simple alphanumeric scheme was utilized to identify loose sediment samples. All beach samples discussed in this report are identified with a two letter designation representing the county, such as VO for Volusia County. This is followed by consecutive beach location numbers, 01, 02, 03, 04 etc., and completed by a two letter designation indicating the sample's placement on the beach profile. More specifically, samples collected from the swash zone, beach berm, mid-beach and back-beach are designated SS, B, MB and BB, respectively. For example, a sample collected in Volusia County at sample location 1 in the swash zone would be delineated as VO-01-SS.

All samples collected offshore with a "clam-shell" dredge sampler, are labeled with the beginning two letter geographic codes referenced above, followed by a multi digit sample number and the two letter designator "CG" for clamshell grab. Thus, a seabed sample collected offshore of Flagler County might be designated FG-101-CG.

The numbering scheme utilized in these reports for the analyzed vibracores varies depending on whether they were collected in:

- Year Two by the FGS either independently of the USACE or, if in support of the USACE, either using the survey's research vessel *R/V GeoQuest* or an independent contractor, Athena Technologies Inc. (Athena), with onboard oversight by FGS personnel.

- Year Three by Challenge Engineering and Testing, Inc., using Alpine Ocean Surveys (Alpine) as a subcontractor, under direct contract to the USACE.

- Year Four by the FGS, either independently of the USACE or in support of the USACE, using the survey's research vessel *R/V GeoQuest* or by the FGS's contractor Alpine Ocean Surveys (Alpine), with onboard oversight by FGS personnel.

The vibracores collected independently of the USACE by the FGS or the FGS's contractor Alpine in Years Two and Four are designated with a V for vibracores, followed by either DU for Duval or NA for Nassau to identify the adjacent county, and a unique core number. For example, the first vibracore collected offshore of Duval County in 2005 would be VDU05-01. For a complete description of vibracores collected by the FGS in previous years please see the FGS's Year Two and Year Three reports to the MMS (Phelps *et al.,* 2004, 2005).

Those vibracores collected by Athena in 2003, as detailed in the Year Two report (Phelps *et al.,* 2004), the vibracores collected in 2004 and 2005 by Challenge and the USACE, using Alpine as a subcontractor, and those vibracores collected in 2005 by the FGS in support of the USACE using Alpine as a contractor are designated in the following manner:

- They are identified as CB, for core boring, then DU, for Duval County, followed by either 03, 04, or 05 depending on whether they were collected in 2003, 2004, or 2005.

- These identifiers are followed by a subsequent numerical designator referring to the location number which is followed in some cores by a letter designation of A, AJ, BJ, CJ and R.

- The designator A, when it appears alone, indicates that that core is the second attempt at that location.

- The designators AJ, BJ and CJ refer to cores from locations that required jetting, which in the case of BJ and CJ indicate multiple jetting and vibracoring repetitions, to achieve sufficient penetration at a specific location.

- The designator R appearing on the "Drilling Logs" and "Gradation Curves" supplied by Wolf Technologies, represents a composite vibracore synthesized by them from the results of multiple jetting and vibracoring repetitions.

Beach Sample Collection

Beach sample locations visited in Year One were spaced one statute mile (1.6 kilometers) apart where practicable. Sampling locations in Years Two and Three were spaced at an approximate one statute mile (1.6 kilometers) interval and at every fifth beach monument survey point (BBSC, FDEP) where practicable. These sample locations are shown on Figure 1. Table 2 ties beach monument survey points to beach sampling locations. A total of 107 beach samples were collected in Volusia County, from November 15 to 17, 2004, from a total of 55 sampling locations.

As was reported in the Year Three report (Phelps *et al.,* 2005), while it was intended that at each sampling location beach samples would be collected from the swash zone, the beach berm, mid-beach and back beach, due to the narrowness of the beach, only swash zone and back beach samples were collected at most locations. At some locations, where the beach was extremely narrow, only a swash zone sample was collected. At a few limited locations, typically where the sea beat against a sea wall, no samples were acquired. GPS readings were obtained for each of the sampling points. At each sampling point within an individual sampling location, three individual replicate samples, each totaling approximately two ounces (56.7 grams) of sediment, were obtained for granulometric analysis. Samples were collected by scooping sediments from the surface to an approximate depth of one inch (25.4 millimeters) below the beach surface at each sample point using an approximately two ounce (56.7 gram) scoop. Photographs and analyses for the beach samples collected in Year Three on the beaches of Volusia County can be found in Appendix A.

Seabed Sample Collection

Based on geophysical data interpretation, seabed sample sites for Year Four were chosen to emphasize those areas with indicated potential for restoration-quality sand accumulation. Grain size distribution and percent carbonate content were determined for all seabed samples collected in Year Four. Granulometric analysis results can be found in Appendix B. Additional seabed sample locations, indicative of restoration-quality sand accumulations based on analysis of bathymetric and seismic reflection profiler data, may be investigated further during future years.

Sample collection offshore of Flagler and northern Volusia Counties was performed on September 29, 2005. Samples were recovered in Year Four using the FGS's 24 foot (7 meter) Carolina Skiff (Figure 8) and the smaller of the two "clam shell" dredge samplers illustrated in Figure 9. Water depths at the sample locations were obtained using an onboard echosounder. A total of 22 seabed samples were obtained - 19 seabed samples from offshore Flagler County and three seabed samples from offshore of northern Volusia County. Photographs of the seabed samples collected in Year Four by the FGS can be found in Appendix B.

Sediment Sample Processing

The sieve nest used in sample processing (Figure 10) by the FGS is described in Table 3. All granulometric analyses were conducted using the general guidelines of the American Society for Testing and Materials (2000a, 2000b) and specific procedures advanced by the FGS sedimentology laboratory (Balsillie, 1995, 2002a, 2002b; Balsillie and Tanner, 1999; Balsillie *et al.,* 1999; Balsillie *et al.,* 2002a; Balsillie *et al.,* 2002b; Balsillie and Dabous, 2003). Each sample was initially weighed after oven drying. The sample was then wet sieved through a 230 sieve (0.63 mm or 4 phi), oven dried and reweighed with the weight loss being assigned to the fine fraction. The sample was then dry sieved with the portion of the pan fraction obtained during dry sieving also assigned to the fine fraction. The sample was then digested with a 4 M hydrochloric acid solution to remove the carbonate fraction, rinsed, oven dried, resieved and weighed again.

Prior to preliminary dry sieving those samples exhibiting a significant percentage of fines were further characterized. After wet sieving (4 phi fraction) to separate the fine fraction, a pipetting technique, using methodology in Folk (1974) and Galehouse (1971), was employed to determine the amounts of silt and clay present. The significance of fines in identifying sediments for beach nourishment is discussed below.

Cumulative grain size distribution curves reflect the total grain size distribution (GSD) of each sediment sample. The weight of the fine fraction, consisting of the weight loss from wet sieving plus weight of the fraction passing through the sieve nest to the pan, was assigned to the finer than 4 phi fraction. Separate GSDs were determined for the carbonate and non-carbonate fractions of each beach and offshore sample along with the combined GSD for each sample. A link is provided in the grain size analysis column of the indices for beach and seabed samples, and FGS vibracore (Appendices A, B and C respectively).

For beach samples, a set of three samples was taken at each site. Sample #1 of the set was processed as described above. Sample #2, subsequent to being dried, was described and photographed. These descriptions and photographs can be accessed via the index under the photograph column and in Appendix A. Sample #3 of the set was dried; of these, eleven were randomly selected and processed like sample #1, for the purpose of granulometric analysis quality control. The results of the granulometric analyses are provided in Appendix A. Those samples not selected for processing were archived in the FGS's vibracore and sediment sample repository.

For seabed samples, the procedures described above for beach samples were followed, with the exception that the seabed samples obtained were split using a sample splitter to obtain a suitable sample volume for sediment processing.

Restoration-Quality Sand Parameters

It is important to note that the thickness of available restoration-quality sand is determined in part by the percent fines content. Thus, restoration-quality sand resources are often limited vertically by the depth at which the fines content exceeds 5%, as specified in Chapter 62-41.007(5J) of Florida Administrative Code (Florida Administrative Code, 2001), unless the fines content on the beach to be renourished exceeds 5% and then only up to that percentage. With these provisos in mind, reserve estimates of restoration-quality sand at various sites offshore of Duval and Nassau Counties have been provided at both less than 10% and at 5% or less fines.

Grain Size Distribution (GSD) Curves

GSD curves are presented in the respective indexes for beach, seabed and vibracore samples. A GSD of the raw sample as well as separate GSDs for the carbonate and non-carbonate fractions of each sample obtained by the FGS are provided, the carbonate data being derived from the weight difference between the raw and digested samples for each grain size. Only raw sample GSDs are available for the vibracores processed by USACE contractors.

Sediment Processing Quality Control

As a quality control check, replicate samples were processed separately for eleven of the beach samples and the granulometric results compared with those obtained from the first samples to test similarity of the grain size distributions. Comparison of the distribution medians yields a mean discrepancy of 0.023 phi units for the raw samples and 0.035 phi units for the fully processed siliciclastics indicating no significant difference found between the distributions of the first and replicate samples. Graphical comparisons of initial and replicate samples can be seen in Appendix H.

Vibracore Processing

Initially, the cores were cut into two foot long segments, and then split in half longitudinally. Samples were taken from the top of the core and sequentially at two foot intervals down the length of the core until the bottom of the core was reached, as well as taken above and below significant stratigraphic changes. This was done by removing a plug of approximately 50 grams of sediments from each of those points. These samples were processed individually as described above. The results of their granulometric analysis are provided in Appendix C. The grain size distribution curves are provided with the analysis (Excel spreadsheet). A link is provided in the grain size analysis column on the index for vibracores. The unsampled halves of the cores were photographed and archived.

Seismic Reflection Profiling

Seismic reflection profiler surveys carried out in Years One through Four offshore of Nassau, Duval, St. Johns, Flagler and Volusia Counties were conducted by towing sound pulse generating and receiving instruments behind a survey vessel traversing predetermined survey track lines at a set vessel speed of four knots. The sound pulse generator was initiated at a fixed rapid rate and the returning reflections were received by a hydrophone array. The reflections were recorded digitally and amplified, fed to a chart recorder, and graphically plotted in two-way signal travel time on the boat as an analog paper record. The sonic velocity utilized in plotting the seismic reflection profiler analog data was 4,921.2 feet per second (ft/sec) (1,500.00 meters per second [m/s]), i.e. the average velocity of sound in sea water. Horizontal control is achieved by simultaneously recording a GPS fix for each pulse.

The digital data set recorded typically comprises two files for each line; a geophysical response file (.tra), which also contains the GPS data, and a data acquisition parameters file (.par). The geophysical response file for each line was subsequently processed in-house at the FGS to produce a graphics (.jpg) file and a navigational file (nav.).

Seismic Reflection Profiler Data Collection

Approximately 234 nautical miles (435 kilometers) of seismic reflection profiler data were acquired in Year Four, with the bulk of these data being acquired offshore of Flagler County in federal waters, i.e. greater than three nautical miles offshore. The data collection program consisted of 28 east-west (dip) lines and 9 north-south, 1 northeast-southwest and 12 northwest-southeast strike lines. Some strike lines cross and thus tie multiple dip lines while others extend from adjacent dip lines' end and start points. Locations for the east-west lines were chosen on minutes of latitude to provide an approximate one nautical mile (1.9 kilometers) north-south grid. Figure 1 displays the location of all seismic reflection profiler data collected to date.

It was noted by Freedenberg *et al*. (2002), in their studies to the south, that the highest quality sand accumulations were associated with bathymetric highs. The length of dip lines and the placement of the tie lines offshore of Flagler and Volusia Counties were therefore determined by distance from the shore, the eastward extent of bathymetric highs, and, in the case of strike lines, the strike of the crest of those highs as determined from available bathymetric data.

The seismic profiles recorded for this study were collected aboard the FGS vessel R/V GeoQuest, (Figure 11). Signal energy for the survey conducted in Year Four was provided by an Applied Acoustic Engineering boomer sled towed approximately 30 feet (9.1 meters) behind the survey vessel. This instrument is shown on Figures 12 and 13 on the deck and under tow respectively. For the Applied Acoustic Engineering sled an Innovative Transducers, Inc. streamer cable was deployed for signal detection. Figures 13 and 14 respectively show how such a sled and streamer are physically deployed while Figure 15 provides a diagram of how the entire system was deployed. The sled-mounted Applied Acoustic Engineering boomer signal source was towed at an approximate speed over the seabed of 4 knots, fired at a shooting interval of 500 milliseconds with record lengths of 100 or 120 milliseconds. A boomer generates its signal via the use of a rapidly moving electromagnetically controlled plate that imparts a pulse into the water column. For the Year Four survey, the boomer was configured so that most of the source energy had a frequency of 4 kHz. All field records were retained on CD disks in Year One and DVD disks in Years Two, Three and Four for long term storage and are available for general distribution.

Limitations imposed by equipment, safety, and personnel availability initially constrained the time window for seismic reflection profiler data acquisition in Year Four. These data could only be acquired during day-light hours and over a 2 week period in a time of the year not particularly notable for good sea conditions in the study area. The data quality of the seismic reflection profiles obtained during the marine geophysical survey in Year Four was impacted by occasional marginal/adverse sea conditions.

Computer Processing of Seismic Reflection Profiler Data

As was the case for data acquired in previous years, processing of the seismic reflection profiler data collected or acquired in Year Four was accomplished using the Sonar Web Pro software package developed by Chesapeake Technologies, Incorporated. Individual seismic reflection profiler lines were processed such that the graphics files created produce images with west to the left on all east/west trending lines and north to the left on all north/south trending lines. This orientation facilitates the comparison of individual lines and is in keeping with standard practices and conventions generally used in seismic data processing. In the case of those lines which approach 45 degrees to the parallels and meridians, northwest and southeast, or southwest and northeast are used, with west always to the left.

The sonic velocity utilized in data processing was 4921.2 ft/sec (1500.00 m/s), i.e. the average velocity of sound in sea water. While this is in keeping with standard practice in the processing of seismic reflection profiler analog records, the actual sonic velocity in the near seafloor sediments investigated, due to their higher density relative to sea water, progressively increases with depth and probably averages nearer to 5,905.44 ft/sec (1,800.00 m/s).

As previously discussed in our Year Three Report (Phelps et al., 2005), this assumption is based on sonic velocities reported in Meisberger and Field (1975). They divided the sequence they investigated into three velocity layers. The uppermost layer, lying from 0 to 90 feet (0 to 27.5 meters) below mean sea level (MSL), was estimated to exhibit a sonic velocity approximating that of sea water. The second layer, extending downward from 90 feet (27.5 meters) below MSL, to its base ranging from 200 to 900 feet (61 to 274 meters) below MSL, was estimated to exhibit sonic velocities ranging from 5,169 to 6,300 ft/sec (1,576 to 1,920 m/s). The third layer extending downward from the base of the second layer to below the base of their recorded data was estimated to exhibit sonic velocities ranging from 7,218 to 9,514 ft/sec (2,200 to 2,900 m/s).

The top of this third layer probably lies near or below the base of our recorded data. Given the unavailability of sonic velocity data specific to the water and sediments actually surveyed, 4,921.2 ft/sec (1,500.00 m/s) was deemed an acceptable compromise value for sonic velocity. Within the geophysical consulting industry, this velocity is typically used as the default value in the processing of such data. The resulting seismic profiles are thus roughly comparable to geologic cross sections. Depths to the seabed are considered to be the most accurate with depths to specific horizons displayed on individual seismic profiles progressively displayed deeper than their actual depth below the seabed. The depth scales provided on individual seismic profiles are considered to be the best approximations achievable given the available data and computer software, and the depth markers provided on the seismic reflection profiler sections are therefore approximations. All digital data collected has been retained so that more sophisticated processing might be applied in the future. All of the seismic reflection profiler data collected in Year Four can be accessed in Appendix E.

OVERVIEW OF WORK

Years One, Two and Three

The following is a history of accomplishments in Years One, Two and Three:

- A bibliography identifying previous work in the study area, as well as more general publications germane to the study was compiled.
- Over 234 nautical miles (435 kilometers) of seismic reflection profiler data were collected

offshore of Nassau, Duval, St. Johns and Flagler Counties and interpreted to determine locations thought to be favorable for the occurrence of restoration-quality sand.

- A beach sampling program was initiated to establish a baseline characterization of native beach sands in Nassau, Duval, St. Johns, Flagler and Volusia Counties. This included 97 beach locations in those counties from which 233 points were sampled.
- A total of 18 seabed samples were collected.
- Three push cores were collected on the ebb tidal delta of the Nassau River.
- A total of 52 vibracores were collected offshore of Nassau and Duval Counties with 11 vibracores collected by the FGS and 41 collected by the FGS subcontractor Athena.
- An additional 3 vibracores were collected by Athena in the mouth of the St. Johns River.
- Descriptions were made and grain size distributions determined for beach and seabed sediment samples, push cores and vibracores.
- A radiocarbon date from a sample at 16.8 feet (5.1 meters) below the seabed was obtained from one of the vibracores collected by the FGS.
- The computer processing of all seismic reflection profiler data collected in Years One, Two and Three was completed.
- A preliminary seismic stratigraphic analysis of the seismic reflection profiler data collected was completed.

Year Four

The following tasks were accomplished for Year Four:

- A total of 22 seabed samples collected offshore of Flagler and northern Volusia Counties were described and granulometrically analyzed.
- Of the vibracores collected offshore of Nassau and Duval Counties during the first four years of this study, 104 were analyzed for the purposes of qualifying and quantifying available restoration-quality sand reserves offshore of those counties.
- Approximately 234 nautical miles (435 kilometers) of seismic reflection profile data were collected offshore of Flagler and Volusia Counties in Year Four, with the bulk of these data being collected offshore of Flagler County. All of these data were processed, interpreted and plotted together with those data collected in the preceding three years.

INTERPRETATIONS

Concerning the shoals offshore in the study area it is important to note that, in previous studies along the central east Florida coast (Freedenberg *et al.,* 2002), the FGS determined that the highest quality sand accumulations were associated with bathymetric highs. Seismic stratigraphic analysis of the seismic reflection profiles and granulometric analysis of vibracore sediment samples were the predominant tools used to examine such features in the study area.

Offshore of Nassau and Duval Counties

As shown on Figure 1, analyses of the seismic reflection profiles obtained in Years One, Two, Three, and Four have identified near shore features of interest offshore of Nassau and Duval Counties. As previously discussed in Phelps *et al.* (2003, 2004, 2005), these features were interpreted to be a complex of channels and disturbed sediments that comprise the remains of channels and ebb tidal delta/estuarine complexes associated with the ancestral St. Johns, Nassau and St. Mary's Rivers. This interpretation is consistent with Meisburger and Field's (1975) findings which showed that while portions of the "channel" they identified were sand-rich, other portions contained a significant admixture of finer grained material. The data suggest that a mantle of reworked sediments of variable thickness, unsuitable for beach restoration use, is superimposed on these features. A program of vibracoring, conducted in coordination with the USACE, was initiated to define locations where this mantle is absent or sufficiently thin that use of the underlying sand is possible. This mantle is present offshore of Duval County as a shoal lying seaward of the Duval/Nassau County boundary region originally identified in Meisburger and Field (1975) as A4. Because this shoal was determined to contain sufficient suitable sand-rich sediments for beach replenishment projects in the past, it was selected as one of this study's vibracoring targets.

The FGS further analyzed the seismic reflection profiler data available in Nassau and Duval Counties. The seismic reflection profile sections shown as Figures 16, 17, 18 and 19 cross features A1/A2, A3a, A3b and A4 respectively. Figure 19, in an earlier version, was previously provided in Phelps *et al.* (2005).

Meisburger and Field (1975) noted several features of interest offshore of Nassau County. Two of these features, identified by them respectively as a "low linear shoal" (A1 on Figure 20), and as a "low linear ridge atop a bank shoal" (A2 on Figure 20), lie approximately 9.5 and 11.3 nautical miles (17.7 and 20.9 kilometers) offshore, respectively. These features were vibracored by Meisburger and Field (1975) between August 1966 and February 1967 for the Inner Continental Sediment and Structure (ICONS) study. Feature A2 was subsequently vibracored by the FGS in Year Two with a single vibracore collected. Additional vibracoring to investigate features A1 and A2 was conducted in 2005 with the collection of one vibracore in A1 and two more vibracores in A2. Figure 21 is the cross section B – B' that extends through A1 and along the axial ridge of A2. Figure 16 is the seismic reflection profiler line ND51A that extends through A1 and along the axial ridge of feature A2 with all of the pertinent vibracores collected to date projected onto it.

Area A1

In the single vibracore collected in area A1, VNA05-01, a restoration-quality sand thickness of approximately 7.1 feet (2.2 meters), consisting of sands with less than 5% fines, was observed lying above sediments unsuitable for beach renourishment. After the area designated by Meisburger and Field (1975) as A1 was redefined, as shown on Figure 22, segmented 2-D areas were calculated using ArcGIS. Using geometric constructs, the known thickness, and the calculated area, an approximate reserve volume was calculated. Thus, at a fines content of 5% or less, a volume of 2.5 mcy (1.9 mcm) of potentially available restoration-quality sand was estimated for A1. Based as they are on a single vibracore and due to their relatively thin extent in that vibracore, the reserves estimates for A1 should be considered speculative and are subject to revision when and if future vibracoring is accomplished.

Area A2

Data from four vibracores were used in estimating the volume of potentially available restoration-quality sand in feature A2. However, two of those vibracores, ICONS vibracore 76 and vibracore VNA-04, only penetrated 3 and 6 feet (0.9 and 1.8 meters) respectively. The remaining two vibracores collected, VNA05-02 and VNA05-03, showed restoration-quality sand thicknesses, with less than 5% fines, of approximately 12.3 and 16.0 feet (3.8 and 4.9 meters) respectively lying above unsuitable sediments. After the area designated by Meisburger and Field (1975) as A2 was redefined, as shown on Figure 22, segmented 2-D areas were calculated using ArcGIS. Using geometric constructs, the known thicknesses, and the calculated areas, an approximate reserve volume of restoration-quality sand was calculated. At a fines content of 5% or less, a volume of 9.5 mcy (7.3 mcm) of potentially available restoration-quality sand was estimated for A2. Based as they are on only two fully penetrating vibracores (20 feet [6 meters] in depth), the reserves estimates for A2 should be considered speculative and subject to revision when and if future vibracoring is accomplished.

Area A3

Vibracoring to investigate this feature lying approximately 11 nautical miles (17.7 kilometers) offshore of northern Duval County (feature A3 of Meisburger and Field (1975) shown on Figure 20) and a geomorphologically similar feature lying immediately to the south of it was conducted in Year Four by the FGS using Alpine Ocean Surveys Incorporated as a contractor. As shown on Figure 22, the FGS, for ease of identification, has labeled these features A3a and A3b respectively. In Year 4, two vibracores were obtained from A3a and one vibracore was obtained from A3b. Figure 23 depicts cross section C - C' across A3a. This cross section is illustrated on Figure 1. The locations of the cores forming cross section C - C', are annotated on seismic reflection profile 04b40, and shown in Figure 17. Seismic reflection profile 04b39, shown in Figure 18 crosses the feature A3b.

From Figure 1, Figures 17 or 18 can be accessed by placing the cursor on and clicking on "04b40" (the identifier for seismic reflection profile line 04b40, Figure 17), or "04b39" (the identifier for seismic reflection profile line 04b39, Figure 18). To access cross section C to C' (Figure 23) place the cursor on and click on the "C". Cross section C - C' (Figure 23) runs northwest to southeast and lies on the axial crest of feature A3a. The vibracores depicted on this cross section, except for vibracore 191 which was collected in the late 1960's as part of the ICONS study, were collected in Year Four. Data from the cores collected in Year Four on feature A3 can be accessed via either Appendix C, or Figure 1,. Depths to the base of estimated reserves of restoration-quality sand containing less than 10% and less than 5% fines are shown on Figure 23.

In area A3a, the two vibracores collected, VDU05-03 and VNA05-02, showed restoration-quality sand thicknesses (with less than 5% fines) of approximately 12.8 and 11.2 feet (3.9 and 3.4 meters) , respectively before penetrating unsuitable sediments. After the area designated by Meisburger and Field as A3 was redefined as A3a, as shown on Figure 22, segmented 2-D areas were calculated using ArcGIS. Using geometric constructs, the known thicknesses, and the calculated areas, an approximate reserve volume of restoration-quality sand was calculated. An assumed maximum sand thickness of 11 feet (3.4 meters) was used with the zero sand thickness boundary established by the -60 foot (-18 meter) bathymetric contour.

Based on these limits and a fines content of 5% or less a volume of 22.7 mcy (17.3 mcm) of potentially available restoration-quality sand was estimated in the area. Based as they are on two vibracores, these reserves should be considered speculative and subject to revision when and if future vibracoring is accomplished.

In the single vibracore collected in area A3b (VDU05-01), a sand thickness (with less than 5% fines) of approximately 16.6 feet (5.1 meters) was observed lying above unacceptable sediments. Segmented 2-D areas were calculated using ArcGIS. Using geometric constructs, the known thickness, and the calculated area, an approximate reserve volume of restoration-quality sand was calculated. An assumed maximum sand thickness of 16 feet (5 meters) was used with the zero sand thickness boundary established by the -60 foot (-18 meter) bathymetric contour. As the bathymetric contours do not close on the northwestern margin an arbitrary boundary in that direction was assumed for the purposes of reserve calculations.

Calculations yield an estimate of 12.8 mcy (9.8 mcm) of potentially available restoration-quality sand with a fines content of 5% or less for this area. Based on a single vibracore, these reserves should be considered speculative and subject to revision when and if future vibracoring is accomplished.

Area A4

As reported in the Years Two and Three reports (Phelps *et al.,* 2004, 2005), the shoal 8 miles (12.9 kilometers) east of the St. Johns River's mouth (identified as area A4 on Figures 20 and 22), was selected for investigation because it had previously been dredged as a source of sediments for beach replenishment. See Figure 1 for an outline of the previously dredged area.

Illustrated on Figure 19 is an interpretation of a seismic profile which crosses, from west to east, the southern portion of A4. This interpretation is based on Meisburger and Field (1975), Scott (1988), Odum *et al.* (1997), Kindinger *et al.* (2000) and Davis *et al.* (2001). The inferred base of Recent marine sediments is depicted in green with the seabed delineated as the red horizon above it. The sequence delineated corresponds to Unit A of Meisberger and Field (1975). Between the green horizon and the blue horizon, (based on Meisberger and Field (1975)) and published interpretations of seismic reflection profiles to the south (Kindinger *et al.,* 2000) and seismic reflection profiles and log analysis picks to the west (Odum *et al.,* 1997) and (Davis *et al.,* 2001) respectively, are Pliocene and Pleistocene undifferentiated sands, clays, and shell. As reported in Phelps *et al.*, (2005) the top of this sequence is age dated in FGS's vibracore VDU-01 with a measured radiocarbon age of 14,160 +/- 60 YBP, a conventional radiocarbon age of 14,140 +/- 60 YBP, and a calibrated (95% probable [2 sigma]) age of from 16570 to 17320 YBP. Contained within this sequence, as seen in the vibracores, are occasional laterally discontinuous thin beds of highly weathered limestone and sandstone. Examples of this can be seen in the various vibracores displayed in the cross section shown as Figure 4. This sequence corresponds to Unit B of Meisberger and Field (1975). The blue horizon, an erosional unconformity in this seismic reflection profile section, is believed to be at or near the top of the Hawthorn Group based on analysis of seismic reflection profiles to the south (Kindinger *et al.,* 2000) as well as seismic reflection profiles (Odum *et al.,*1997) and well log analysis (Davis *et al.,* 2001) to the west. The black horizon shown on this seismic reflection profile section is interpreted to be a reflector within the Hawthorn Group. The lowest red horizon delineated on this section is interpreted to be at or above the top of the Ocala Limestone based on seismic reflection profiles (Odum *et al.,*1997; Davis *et al.,* 2001) as well as well log analysis to the west. Note that the white reflector shown on this section is the first water bottom multiple and as such is purely an artifact of data collection.

As was discussed in the Year Three report, the identification of several features with a high potential for the occurrence of beach restoration-quality sand in federal waters offshore of southern Duval County in area A4 prompted an extensive joint FGS and USACE vibracoring program in Year Four to define offshore restoration-quality sand sources meeting both immediate and near term needs. This investigation includes the collection, by Challenge, using Alpine as a subcontractor for core collection, and Southern Earth Sciences for core processing, of an additional 50 vibracores and 49.5 nautical miles (91.7 kilometers) of electrical resistivity data immediately adjacent to the east and south of the sand borrow area. Using these data, the USACE's consultant, Challenge, through their subcontractor DEMCO, estimated an average available restoration-quality sand thickness of 9.5 feet (2.9 meters) and a volume of 22.9 mcy (17.5 mcm) of possible reserves of restoration-quality sand lying in the immediate vicinity both east and south of the previously dredged area (Brabers, 2004). These investigations were more narrowly focused within the area vibracored in Year Two. This additional vibracore data set suggests that localized occurrences of beds of cobble-sized shell, not encountered in the vibracores previously collected, may adversely impact sediment usability in some areas. Additional vibracoring of feature A4 was completed in Year Four during which 6 additional vibracores were collected.

Figure 4 depicts the vibracore-based cross section labeled A - A', respectively on Figures 1 and 24. From Figure1, individual core logs and granulometric data can be accessed by placing the cursor on the individual core identifiers and clicking on them. From Figure 1, Figures 4 and 19 can be accessed by placing the cursor on and clicking on the "A" for cross section A to A' and "nd43" (which is the identifier for seismic reflection profiler line 43. Cross section A - A' runs west to east and lies to the south of the area previously dredged. The vibracores depicted on the seismic refection profiler line and the cross section were collected in Years Two, Three and Four. Data from these cores can also be accessed via Appendix D. Depths to the base of postulated reserves of restoration-quality sand containing 5% or less fines and less that 10% fines are shown on the cross section.

Although a substantial number of cores collected in Years Two, Three and Four in area A4 contained available restoration-quality sand to the limit of penetration (20 feet [6.1 meters]), a number of these cores consisted of smaller thicknesses of restoration-quality sand which is underlain either by clay or limestone. In calculating reserves of available restoration-quality sands, an effort was made by the FGS to include in those calculations only those sequences which were described, sampled and analyzed granulometrically rather than basing available restoration-quality sand reserve calculations on vibracore visual descriptions alone. As was previously discussed in Phelps, *et al.,* (2005), this is an important distinction to make as the vibracores, as described, typically exhibit sands to greater depths than were analyzed, albeit often with an admixture of clay and/or silt as a minor component. Thus, our available restoration-quality sand reserve calculations are based primarily on the granulometric analysis of specific sedimentary units within the vibracores and secondarily on lithologic descriptions. Lithologic descriptions were used to establish the base of sedimentary units. After running an Inverse Distance Weighted Surface Interpolation (IDWSI) of usable sand thickness via ArcGIS for cores both inside and just outside the boundary designated by Meisburger and Field (1975) as A4, approximate limits for both 10% and 5% fines were defined. While variance within the calculated surface does occur, there are 2 distinct areas within A4, designated as A4a and A4b.

From the much more limited vibracore data available, the northern region, A4a, is characterized by a thinner layer of potentially usable sands. There is little to no data available for the ICONS vibracores. However, where such sands do exist in those vibracores, it is unknown as to what depth they may extend. Of the vibracores for which complete information is available, the restoration-quality sands identified were no greater than 6 feet (1.8 meters) thick and appeared to be discontinuous. North of area A4a, within the boundary Meisburger and Field (1975) designated A4, there is no evidence to support the presence of any amount of usable sands.

Between A4a and A4b, is a region of unusable surficial sediments. Where vibracored, these sediments contain greater than 10% fines. There are several vibracores on the boundaries of both A4a and A4b as well as one in the region between, CB-DUC-03-33, that are characterized by 2-7 feet (0.61-2.13 meters) of restoration-quality sands above a layer of limestone. This limestone measures 13 feet (4 meters) at its thickest in CB-DUC-03-32. It should be noted that core CB-DUC-03-33 was not included in either areas A4a or A4b. This vibracore is located in a seafloor depression and it is believed that its upper most 3.5 feet (1.1 meters) of restoration-quality sand is contiguous with a stratigraphically lower layer of economically unavailable sands seen in neighboring vibracores.

To the south in area A4b, there are substantial reserves of restoration-quality sand. The southeastern boundary of A4b seems to extend beyond what Meisburger and Field (1975) considered usable. To be conservative, the -55 foot (17 meter) bathymetric contour was primarily used for this newer boundary. The -55 foot (17 meter) bathymetric contour was similarly used on A4b's south central edge as well.

Total reserves of potentially available restoration-quality sand lying in the area designated as A4b were calculated to be 143.7 mcy (109.9 mcm) and 88.1 mcy (67.4 mcm) at less than 10% and 5% or less fines respectively. Figures 24 and 25 are sand thickness maps of these reserves. Within A4b the area of proposed future reserves (outlined in blue on Figures 1, 24 and 25) lying immediately adjacent to the area dredged prior to 2005, was estimated at less than 10% and 5% or less fines respectively, 21.4 mcy (16.4 mcm) and 14.2 mcy (10.9 mcm) of probable restoration-quality sand. The area dredged in 2005 (outlined in red on Figures 1, 24 and 25) is estimated to contain 2.2 mcy (1.7 mcm) at less than 10% fines or 1.4 mcy (1.1 mcm) at 5% or less fines of probable restoration-quality sand. Between 6 June, 2005 and 8 August, 2005, subsequent to the vibracoring upon which these estimates were based, within the area dredged in 2005 an estimated 0.734 mcy (0.561 mcm) were hauled from an offshore borrow site and placed along 5.7 miles (9.2 kilometers) of the Duval County shoreline (Olsen, 2005). Olsen Associates further reports that comparison of their pre- and post-construction surveys suggests that the offshore borrow area experienced a net volume decrease on the order of 0.9257 mcy (0.7078 mcm) (Olsen 2005). A copy of the Olsen report can be viewed in Appendix I. Using a volume of 0.9257 mcy (0.7078 mcm) as the amount either removed or made unavailable by dredging in 2005, area A4b is estimated to contain a remaining 142.8 mcy (109.2 mcm) and 87 mcy (66.5 mcm) of available restoration-quality sand based on a content of less than 10% fines and on 5% or less fines respectively. The area of proposed future reserves is estimated to contain a remaining 20.5 mcy (15.7 mcm) and 13.3 mcy (10.2 mcm) based on a content of less than 10% fines and on 5% or less fines respectively. The area dredged in 2005 is estimated to contain a remaining 1.3 mcy (1.0 mcm) and 0.5 mcy (0.4 mcm) based on a content of less than 10% fines and on 5% or less fines respectively. Based on a succession of grids of increasingly more closely spaced vibracores, confidence in these reserve estimates becomes progressively stronger as one proceeds from those of area A4b through the area of proposed future reserves and into the area dredged in 2005.

Area A5

As discussed in Phelps, *et al.* (2005), Meisburger and Field (1975) postulated the existence of over 5.0 mcy (3.8 mcm) of restoration-quality sand in a channel deposit two to three nautical miles (4.8 to 6.4 kilometers) east of the mouth of the St. Johns River (see area A5 located on Figure 20). This feature was subsequently extensively cored by the USACE but never utilized.

Offshore of St. Johns County

Meisburger and Field (1975) noted two features of primary interest in the study area offshore of St. Johns County north of St. Augustine. Their findings are discussed in detail in Phelps, *et al.* (2005). The first feature, shown as A6 on Figure 26 is estimated by them to contain approximately 178 mcy (136.1 mcm) of restoration-quality sand. The second feature is shown as A7 on Figure 26. They estimated the volume of available restoration-quality sand in the second feature to be 7.4 mcy (5.7 mcm). The USACE has recently collected vibracores from these features. When that data becomes available the FGS will re-estimate the volumes of available restoration-quality sand these features may contain.

Offshore of Flagler County

Meisburger and Field (1975) noted a feature of primary interest identified as A8 on Figure 27, in the study area between 10 to 15 nautical miles (16.1 to 24.1 kilometers) offshore of Flagler Beach, Flagler County. Despite its distance offshore, this shoal would appear to have a strong potential as a restoration-quality sand borrow site for Flagler County beach restoration. As discussed in Phelps, *et al.* (2005), this feature is a linear shoal lying sub-parallel to the present coastline with approximately the same orientation and distance from the coast as features A2, A3a and A3b lying offshore of Nassau and northern Duval Counties. This feature lies on the margin of an area where subsurface acoustic profiler data was collected in Year Three. It was traversed along its axis by a single northwest/southeast tie line collected in that year as well as crossed by several dip lines collected in Year Four. As reported in Phelps, *et al.* (2005), Meisburger and Field (1975), based on their vibracore 140, recovered in the center of this linear shoal, describe this feature as consisting of clean sand and state it is over 10 feet (3.0 meters) thick with mean diameters ranging from 0.0113 to 0.0121 inches [0.287 to 0.308 millimeters (1.7 to 1.8 phi)]. They judged prospects to be very good for locating suitable borrow material in this ridge, and that if the entire ridge was of suitable material the estimated reserve is 39 mcy (29.8 mcm) (Meisburger and Field, 1975).

Offshore of Volusia County

As shown on Figure 27, Meisburger and Field (1975) noted a number of features of interest offshore of Volusia County. Feature A9 is described by them as an irregular low relief shoal containing over 11 feet (3.4 meters) of clean uniform medium sand with an average mean diameter ranging from 0.0113 to 0.0121 inches (0.287 to 0.308 millimeters [1.7 to 1.8 phi]). Based on a single core, probable reserves of sand were estimated to be 61 mcy (46.6 mcm).

Alpine, operating as a subcontractor to Coastal, collected 30 vibracores from features offshore of Volusia County late in 2004. Coastal provided a reconnaissance report, provided in Appendix G, (Parkinson, 2005), of their investigations to the Ponce DeLeon Port Authority. Coastal subsequently narrowed their investigations to B11, the northern third of B12 and southern third of B13 which they further investigated by acquiring 28, 29 and 29 additional vibracores respectively. Coastal's final report, provided in Appendix G (Parkinson and Budde, 2006) detail their resultant findings. The estimated reserves of beach restoration-quality sand meeting the criteria of 5% or less fines available in several of the A and B series features described by Meisburger and Fields (1975) and modified by Parkinson and Budde (2006) are provided in Table 4. Personal communication with personnel at Coastal suggests that additional supplementary work offshore of Volusia County was conducted by them in 2006.

In the geological section offshore of Nassau, Duval and St. Johns Counties, as reported in Phelps *et al.* (2004, 2005), and seen offshore of Flagler County and in the northern portions of Volusia County (included in the Year Four seismic grid) are areas of anomalous dip as well as clearly identifiable buried depressions in the seafloor sediments. All of these features are interpreted to be the result of karst processes (Popenoe *et al.,* 1984). Analysis of data associated with these features by the FGS strongly suggests that they have a dissolution collapse origin. Such features can be seen on seismic reflection profile lines 05B10 and 05B20. These features are vertically persistent to the base of the seismic reflection profiler data recorded. Seismic reflection profile lines 05B21 and 05B22, while of lower quality, reveal similar collapse features as well.

SUMMARY

Years One, Two and Three

As a result of the seismic stratigraphic analysis conducted, several features were identified as having a high potential for the occurrence of available restoration-quality sand in federal waters offshore of Duval County. The results of this analysis were discussed with representatives of the U.S. Army Corps of Engineers, Jacksonville District Office, and a copy of the preliminary work map delineating those features was provided to them. From those data, they selected a number of locations in the study area for vibracoring in Years Two, and Three. The results of the tasks completed in Years One, Two and Three of this investigation are detailed in Phelps *et al.* (2003), Phelps *et al.* (2004), and Phelps *et al.* (2005), respectively.

Year Four

Beach-sediment samples were collected at the outset of the Year Four field season. Seabed samples were collected offshore of Flagler and Volusia Counties. Results of the offshore sample analyses were used to aid in the selection of vibracoring locations. These sediment samples were brought to the FGS laboratory for sample description and granulometric analysis. Data from these samples can be found in Appendix B. As was performed on Years One, Two and Three samples, granulometric analysis was conducted using the general guidelines of the American Society for Testing and Materials (2000a, 2000b) and specific procedures were followed by the FGS sedimentology laboratory (Balsillie, 1995, 2002a, 2002b, Balsillie and Tanner, 1999; Balsillie *et al.,* 1999; Balsillie *et al.,* 2002a; Balsillie *et al.* 2002b; Balsillie and Dabous, 2003). It is intended that all sample descriptions and granulometric data will be entered into the Reconnaissance Offshore Sand Search database (http://Ross.urs-tally.com) being developed by URS Corporation for the FDEP's BBCS. Photographs and granulometric analyses of the beach and sea bed sediment samples collected in Year Three can be found in Appendices A and B respectively. Photographs, core logs, and granulometric analyses of vibracores are found in Appendix C for FGS collected and in Appendix D for USACE collected cores. Some selected cores from 2003 and 2004 are also documented in Appendix D.

The following is a summary of work accomplished in Year Four:

- Approximately 234 nautical miles (435 kilometers) of seismic reflection profile data were collected offshore of Flagler and northern Volusia Counties.
- From offshore Flagler and northern Volusia Counties, a total of 22 seabed samples were collected, described and analyzed and their grain size distributions were analyzed.
- A total of 107 samples from 55 beach sampling locations in Volusia County were described and their grain size distributions were analyzed.
- The granulometric results from a total of 7 vibracores collected in Years Two and Four from the seafloor offshore of Nassau and northern Duval County were analyzed, and an analysis of the potential available restoration-quality sand resources on three features was prepared.
- The granulometric results from a total of 104 vibracores collected in Years Two, Three and Four from the seafloor offshore of southern Duval County were analyzed, and a detailed analysis of the potential available restoration-quality sand resources was prepared.

- The computer processing of all seismic reflection profiler data collected or acquired in Year Four was completed.
- A preliminary seismic stratigraphic analysis of the seismic reflection profiler data collected offshore of Flagler and northern Volusia Counties was completed.

Additional seabed sampling locations, based on the seismic reflection profiler data, are currently being chosen. These samples may be collected in future years. Work in future years will further investigate submerged lands beneath federal waters offshore of Nassau, Duval, St. Johns, Flagler and Volusia Counties.

CONCLUSIONS

Several features with a high potential for the occurrence of available beach restoration-quality sand in federal waters offshore of Nassau and Duval Counties have been identified. Offshore of Nassau County two features, lying east of Amelia Island approximately 9.5 and 11.3 nautical miles (17.7 and 20.9 kilometers) offshore, labeled respectively A1 and A2, as referenced in Meisburger and Field (1975) were investigated with three vibracores in Year 4. Based on criteria of 5% or less fines content, analysis of the available vibracore data by the FGS suggests possible total offshore reserves of available restoration-quality sand associated with features A1 and A2 are 2.5 mcy (1.9 mcm) and 9.5 mcy (7.3 mcm) respectively.

Two features, offshore of Duval County, labeled A3 and A4 by Meisburger and Field (1975) were investigated in Year 4. The FGS, for ease of reference, has relabeled A3 as A3a and has labeled an additional feature, lying immediately to its south, A3b. A3a and A3b both lie approximately 11 nautical miles (17.7 kilometers) offshore of northern Duval County. In Year 4 two vibracores were obtained from A3a and one vibracore was obtained from A3b. Based on fines contents of 5% or less 22.7 mcy (17.4 mcm) of potentially available restoration-quality sand was estimated for A3a and using the same criteria reserves of 12.8 mcy (9.8 mcm) were estimated for A3b.

In the course of the FGS's investigations, its findings were discussed with representatives of the USACE Jacksonville District Office. As a result of those discussions, the FGS and the USACE have identified the feature A4, located offshore of southern Duval County, to be of particular interest. Area A4b, using 0.9257 mcy (0.7078 mcy) as the amount either removed or made unavailable by dredging in 2005, is estimated to contain a remaining 142.8 mcy (109.2 mcm) and 87 mcy (66.5 mcm) of available restoration-quality sand based on a content of less than 10% fines and on 5% or less fines respectively. The area of proposed future reserves (outlined in blue on Figures 1, 24 and 25) is estimated to contain a remaining 20.5 mcy (15.7 mcm) and 13.3 mcy (10.2 mcm) based on a content of less than 10% fines and on 5% or less fines respectively. The area dredged in 2005 (outlined in red on Figures 1, 24 and 25) is estimated to contain a remaining 1.3 mcy (1.0 mcm) and 0.5 mcy (0.4 mcm) based on a content of less than 10% fines and on 5% or less fines respectively.

RECOMMENDATIONS

The FGS recommends that, when available, data from the 45 vibracores USACE recently collected offshore of St. Johns County (including approximately 17 from feature A6, 2 from feature A7, and 7 from feature B8 identified in Meisburger and Field (1975)) be made available to the FGS. Upon analysis of these vibracores, the FGS will re-estimate the volumes of restoration-quality sand available offshore of St. Johns County.

Future years' tasks should include the collection and analysis of bottom samples as well as the analysis of seismic reflection profiler data already collected offshore of central and southern Volusia County. Future analysis should also include a review of the recent vibracores collected by the USACE offshore of St. Johns County as well as the extensive vibracoring program recently completed offshore of Volusia County by Coastal. It is further recommended that a program of beach sampling to characterize the existing beach sediments be conducted on the beaches in the northern half of Brevard County in Year Four for the purposes of comparing those un-renourished beaches with renourished beaches further north. Additionally, it is recommended that the FGS continue discussions with the USACE during their dredging-area selection process regarding proposed projects to occur in the vicinity of St. Augustine and Flagler Beach in St. Johns and Flagler Counties, respectively.

It is recommended that data collected on the Florida northeastern inner continental shelf be integrated with the data previously collected in the FGS's Florida central-eastern inner continental shelf study reported in Freedenberg *et al.* (2002). This would be accomplished in part by tying the seismic reflection profiler grid to be collected in future years of this study with the grid previously collected offshore of southern Brevard County in previous studies on the central Florida east coast (Freedenberg *et al.,* 2002).

The research recommendations outlined above will facilitate the further investigation of the beach and near shore coastal areas of:

- Volusia County to evaluate and quantify offshore available restoration-quality sand resources for the purpose of beach restoration in the immediate future.

- Nassau, northern Duval, St. Johns and Flagler Counties to evaluate potential offshore available restoration-quality sand resources for anticipated future need.

- Northern Brevard County beaches to evaluate potential offshore available restoration-quality sand resources for anticipated future need and to characterize the sediments on those un-renourished beaches.

The accomplishment of these goals would also facilitate a more detailed investigation and understanding of the geomorphology, shallow structure, and sediments of the Florida northeastern and central inner continental shelf.

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