GEOPHYSICAL AND GEOTECHNICAL INVESTIGATIONS TO IDENTIFY SAND RESOURCES FOR BEACH NOURISHMENT ON SAND KEY, PINELLAS COUNTY, FLORIDA

Prepared by:

Coastal Planning & Engineering, Inc.

Beth M. Forrest, Ph.D.
Melany Larenas, P.G.
Beau Suthard, MSc
Jeffrey L. Andrews, PSM, CH

Prepared for:

Pinellas County

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Abstract

In 2008, Pinellas County and the St. Louis and Jacksonville Districts of the United States Army Corps of Engineers (USACE), authorized Coastal Planning & Engineering, Inc. (CPE) to conduct a sand search investigation to identify at least three (3) areas spaced along Sand Key that would best serve the County and the USACE in the next renourishment of Sand Key. This investigation builds on work previously conducted by the USACE that covered nine (9) study areas (A through I) (USACE, 1997, 2004). Study Areas A through I were subsequently re-evaluated by CPE in the 2007 Constructability Analysis, at which time up-to-date State standards were applied to estimate the volume of potentially beach compatible material in these areas (Forrest *et al.*, 2007). The County directed CPE to collect geophysical data from areas at the north (USACE Study Areas I and D), central (USACE Study Areas F and G) and south (USACE Study Area H) parts of the key. In 2008 reconnaissance level data was collected across the five (5) study areas. The survey plan was modified during the reconnaissance survey and design level data was collected within the most promising areas. Vibracores were then collected from the areas most likely to contain the greatest volume of beach quality material (Study Areas D and H). Although Area G was not expected to contain significant volumes of beach compatible material, Pinellas County directed CPE to investigate Area G in the hopes of finding additional material as it is centrally located to the project.

The 2008 investigations confirmed the results of the 2007 constructability analysis. Study Areas D and H contained beach quality material, however, they did not contain sufficient volumes of material to support the next renourishment of Sand Key. No additional material was identified within Area G. In response, CPE was contracted by Pinellas County in 2009, to conduct Phase II and III investigations to identify additional material. Pinellas County directed CPE to conduct a reconnaissance geophysical survey within Study Areas A, B and C, despite the low probability of identifying additional material. Due to the low probability of identifying additional material in these areas, several prominent sand ridges in the vicinity of the USACE Study Areas were also investigated. Vibracores were collected from locations selected based on the results of the reconnaissance geophysical survey. The geophysical data, coupled with analysis of the vibracores was used to determine sediment quality and to ascertain the presence of material unsuitable for dredging. Three (3) new sand resource areas, designated Areas J, K and L, were identified during the Phase II investigation. These three (3) areas were presented to Pinellas County and the FDEP BBCS, who expressed a preference for developing areas J and L. In addition to these areas, Pinellas County authorized a cultural resource investigation of a small area outside of Study Area D, which was previously investigated in 2008 as well as the new sand resource areas.

Eight (8) borrow areas that contain potentially beach compatible material were designed in or around areas D, H, J and L. Three (3) borrow areas, containing an estimated 72,000 cy of potentially beach compatible material were developed within Study Area D (Borrow Area D1, D2 and D3). Three (3) borrow areas containing an estimated 817,300 cy of potentially beach compatible material were developed within Study Area H (Borrow Areas H1, H2 and H3). A single borrow area containing 305,300 cy of potentially beach compatible material was developed within Study Area J. A single borrow area containing 1,480,600 cy of potentially beach compatible material was developed within Study Area L.

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INTRODUCTION

Pinellas County is located on Florida's Gulf of Mexico coast. Sand Key is a highly developed coastal barrier island located along the central west coast of Florida between Clearwater Pass and Johns Pass (Figure 1). It is a 14-mile long island that stretches from Florida Department of Environmental Protection (FDEP) monuments R-51 to R-125. Sand Key includes Madeira Beach, Redington Beach, North Redington Beach, Redington Shores, Indian Shores, Indian Rocks Beach, Belleair Shores, Belleair Beach and Clearwater Beach.

The barrier islands in Pinellas County have a history of shoreline erosion caused by storms, wave action and currents. With the exception of the north and south ends of Sand Key, most of the island is classified as critically eroded (FDEP, 2009). The critically eroded area (R-56 to R-115.4) extends 11.3 miles and has threatened development and recreational interests in the communities of Belleair Beach, Belleair Shores, Indian Rocks Beach, Indian Shores, Redington Shores, North Redington Beach, Redington Beach and the north end of Madeira Beach (FDEP, 2009) (Figure 1).

Beach restoration projects, as well as concrete and wooden bulkheads, extend throughout the eroded area. Since the late 1960s, several segments of Sand Key have been nourished. Redington Beach was nourished in 1988. A volume of 529,150 cy of sand was placed along a 1.6 mile stretch of beach between R-99 and R-107 (USF, 1988; Lin and Dean, 1989). Indian Rocks beach was nourished in 1990 with 1,300,000 cy of sand placed between R-71 and R-85 (USF, 1993). Indian Shores was nourished in 1992. Over the course of the 1992 project, sand was placed along a 2.3 mile stretch of shoreline between R-86 and R-98 (Davis and Wang, 1997). During the Sand Key nourishment of 1998, 2,612,166 cy of material was placed between R-56 and R-66, and between R-72 and R-107 (USACE, 2002). In 2005, 2 million cy of sand was placed along nearly 9 miles of Sand Key. The project area included Sand Key, Belleair Beach, Indian Rocks Beach, Indian Shores, Redington Shores and North Redington Beach. With the exception of the 1988 Redington Beach project, the primary source for these past nourishment projects has the north side of the main Egmont Channel (Figure 1) within the ebb-tidal delta. The Redington Beach project used the Johns Pass ebb-tidal shoal (Lin and Dean, 1989). The roundtrip distance between the Egmont Channel ebb-tidal delta and the northern end of Sand Key is approximately 45 miles. Use of this borrow area, for nourishment projects on Sand Key, is not cost effective because of the significant distance that fill material needs to be transported before placement on the beach.

In 1994, the United States Army Corps of Engineers (USACE) conducted a sand resource survey offshore of Sand Key in an attempt to identify closer, less costly sand resources to be used as borrow areas for future nourishment projects. Over the course of the survey, they identified nine (9) study areas containing potentially beach compatible material. These areas were designated Study Areas A through I. These areas were further analyzed and in 2004 the USACE developed twenty (20) borrow areas within the nine (9) study areas (USACE, 2004) (Figure 2).

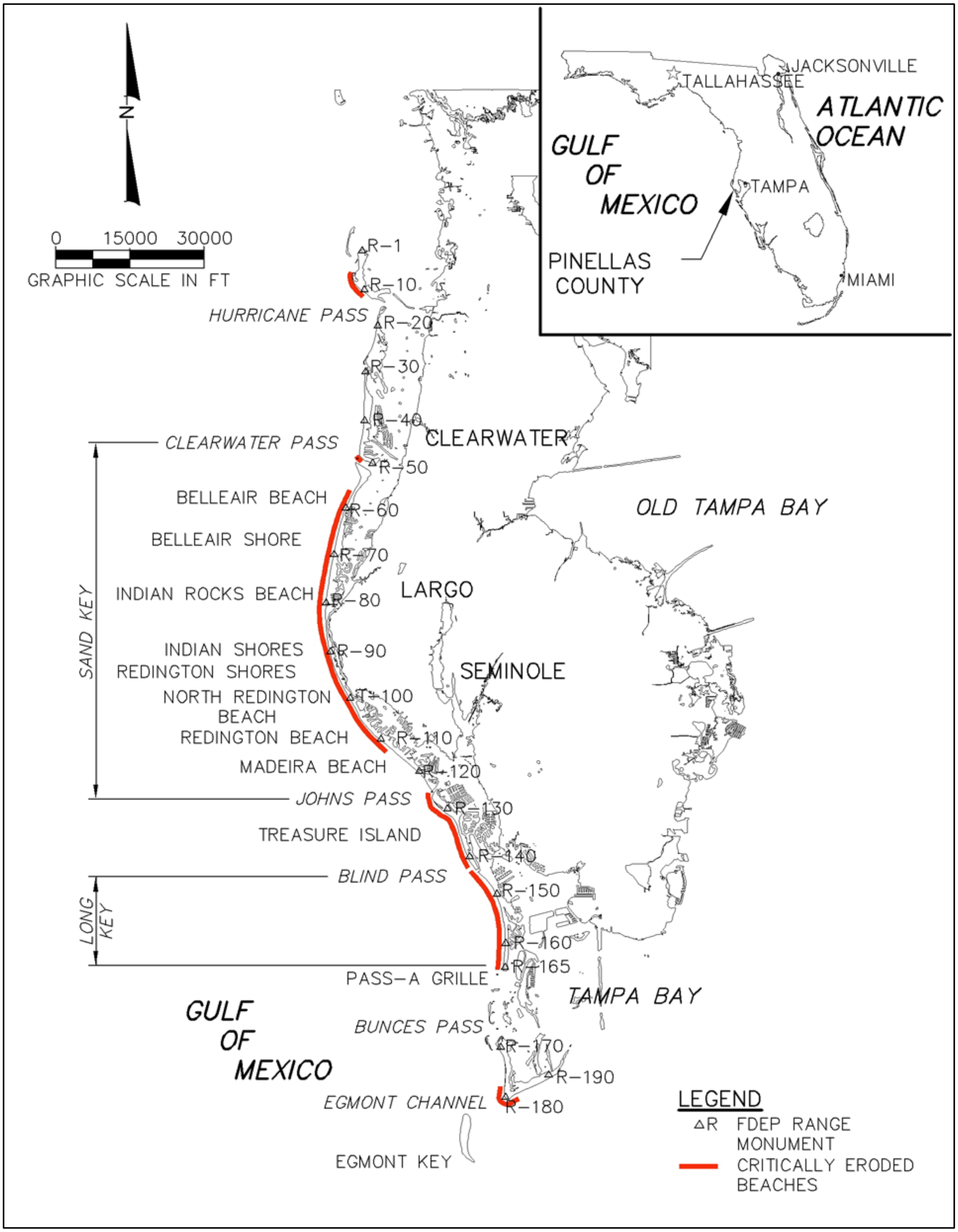


Figure 1. Pinellas County Map showing the location of critically eroded beaches.

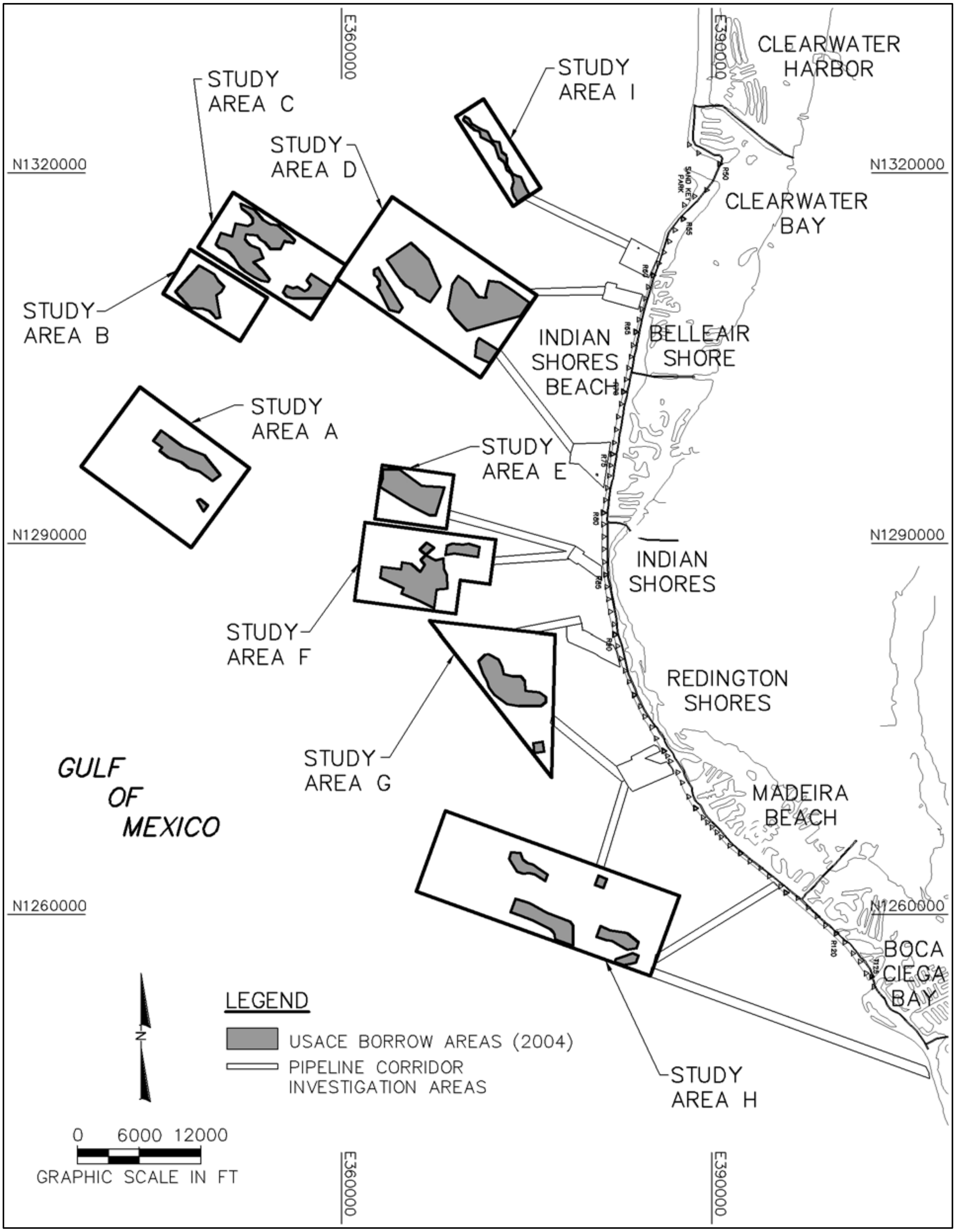


Figure 2. Figure showing historic areas of investigation (general/boxes) and developed borrow areas.

In 2007, Coastal Planning & Engineering, Inc. (CPE) re-evaluated Study Areas A through I and the borrow areas within these study areas, using current FDEP sediment quality standards and guidelines (Forrest *et al*., 2007). This constructability analysis indicated that only three (3) of the study areas would provide significant volumes of sand for Sand Key. These areas were Study Areas C, D and H, which contained an estimated 326,400 cy, 467,400 cy and 585,600 cy of dredgeable material, respectively. It was recommended that additional geophysical and vibracore data be collected within these three (3) areas to meet current state guidelines and to verify that the sand within these areas is beach compatible. Further investigation of several prominent ridge features in the vicinity of the USACE study areas was also recommended.

Following the constructability analysis, CPE conducted a Phase III design level marine sand search investigation. The goal was to identify at least three (3) areas spaced along Sand Key that would best serve the County and the USACE in the next renourishment of Sand Key. In 2008, CPE was directed by Pinellas County to conduct design level geophysical investigations to verify and supplement the data originally collected by the USACE in Study Areas D, F, G, H and I. Based on the data that was collected, it appeared that Study Areas D and H were the most likely to contain beach quality material. Pinellas County also recommended that Study Area G be further investigated due to its central location to the project area even though substantial quantities of beach-compatible sand were not expected within Area G. This investigation confirmed that approximately 889,400 cy of potentially beach compatible material is located within Areas D and H and that no significant volume of potentially beach compatible material was located within Area G. The volume of potentially beach compatible material identified during this investigation was not sufficient for the next renourishment of Sand Key. This prompted new investigations to identify additional material.

In 2009, in an effort to locate additional material, Pinellas County authorized CPE to conduct Phase II reconnaissance and Phase III design-level geophysical and geotechnical investigations. Cultural resource investigations were also authorized for, and conducted in any borrow areas developed outside of the previously-cleared 1994 USACE study areas (Appendix 1). Reconnaissance-level geophysical and geotechnical data was collected during a Phase II investigation. This investigation focused on the USACE study areas and the prominent ridge features extending beyond these areas. Upon review of the reconnaissance data, three (3) promising areas were identified (Areas J, K and L). These areas were presented to the Bureau of Beaches and Coastal Systems (BBCS) and Pinellas County who decided to focus subsequent investigation efforts on Areas J and L. Additional remotely sensed data (*i.e.* seismic reflection profiles, sidescan sonar imagery and magnetometer surveys) and vibracores were collected during a Phase III investigation, which included a cultural resource investigation within Areas J, L and the small area extending outside of USACE Study Area D. Areas J and L were found to contain approximately 1,785,900 cy of potentially beach compatible material.

This report presents the results of the 2008 and 2009 geophysical and geotechnical investigations and cultural resource investigations that led to the development of Borrow Areas D, H, J and L. General investigation sequencing is discussed first followed by a description of the geological background of the area, previous investigations and characterization of the existing beach. A description of the 2008 and 2009 geophysical and geotechnical field activities is then provided, along with analysis of results from these activities and definition of the characteristics of the identified sand resources and borrow area development.

INVESTIGATION SEQUENCING

A systematic approach to marine sand searches has been developed over the years by the CPE Coastal Geology and Geomatics team (*e.g.* Finkl, Khalil and Andrews, 1997; Finkl, Andrews and Benedet, 2003; Finkl, Benedet and Andrews, 2005; Finkl and Khalil, 2005). In a comprehensive marine sand search, CPE typically divides the investigation into three (3) sequential phases (Figure 3). This phased approach can be modified to meet the scope of the investigation and accommodate the level of work previously performed. Regardless of the phases executed during a sand search, the CPE investigation sequencing is preserved in order to maintain efficiency and completeness to provide confident results.

Phase I investigations typically consist of a comprehensive review of the recipient beach and sediment resources offshore of the project area. This desktop study examines previously collected information within the geologic context of the search area in order to identify features having the highest potential of containing beach-compatible sand. The geological background of the area is assessed to identify the geomorphic features that may contain material suitable for the project. Information related to previously investigated areas, potential sand resources and borrow areas, is compiled and related back to the geomorphic features. Geophysical and geotechnical data previously collected within these areas, as well as any reports discussing the findings, are then reviewed. Based on this analysis, deposits potentially containing beach-compatible material are identified. The results of Phase I are used to define the areas that will be surveyed during Phase II investigations.

Phase II investigations usually consist of reconnaissance level geophysical and geotechnical surveys. A joint geophysical investigation (typically collecting seismic reflection profiles, sidescan sonar images, magnetometer and bathymetric data) is conducted at reconnaissance line spacing to assess the thickness of potential sand resources. The wide reconnaissance line spacing is designed to cover large expanses of seafloor. Therefore, the data coverage achieved during Phase II investigations may not be sufficient to develop a detailed sand thickness (isopach) map. The geophysical data collected during this phase is used to design a vibracore investigation plan. Vibracores are collected to determine the sediment characteristics within the areas identified through remote sensing. Typically a limited number of cores are collected to groundtruth each potential sand resource. Sand resources within the investigation area are then analyzed using GIS procedures that integrate the seismic reflection profile and vibracore data to provide an estimate of deposit thickness and sedimentary characteristics. Beach samples may also be collected during this phase to characterize the existing beach in terms of grain size, color and composition (*i.e.* how well the potential borrow area sediment matches the existing beach material). The Phase II results are reviewed within the context of beach compatibility to identify potential resource areas that will undergo design level investigations during Phase III.

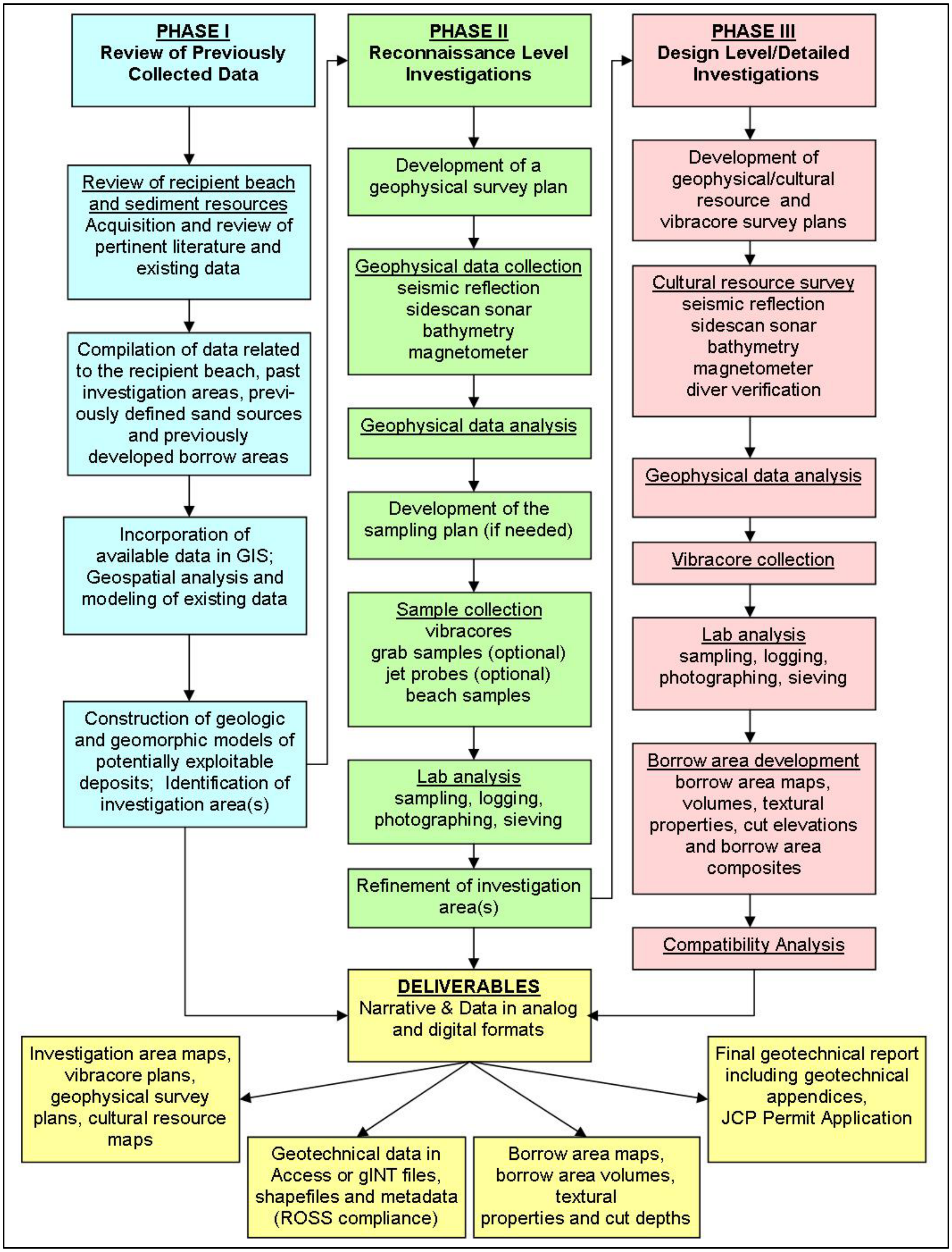


Figure 3. Flow diagram showing the general investigation sequence followed by CPE during a typical marine sand search investigation.

Phase III typically consists of design level geotechnical and geophysical investigations, a cultural resource investigation, and borrow area design. A joint seismic, sidescan sonar, magnetometer and bathymetric survey is conducted within the potential sand resource area(s). The data collected is used to identify possible cultural or environmental resources for avoidance and to develop isopach (sediment thickness) maps for borrow area design. These results are also used to target areas for additional vibracoring. In order to conform to standard geological and engineering practice, fulfill permitting requirements, and conduct geophysical and geotechnical surveys in an expeditious manner, vibracores are collected to provide a maximum spacing of 1000 ft. (industry standard spacing) within the potential resource area. Preliminary borrow area boundaries and excavation depths are developed from the data collected during the Phase I, II and III investigations.

A final cultural resource investigation is required to permit borrow areas for use. During this investigation, additional geophysical data is collected within the borrow area(s) to achieve a total combined line spacing of 30 m (approximately 98 ft.). A qualified marine archaeologist is required to be on the survey vessel at all times during the cultural resource investigation. The geophysical data is used to identify any cultural resources, submerged hazards or any other features that would affect borrow area delineation and dredging activities. Based on the results of the cultural resource investigation, the marine archaeologist compiles a report that includes recommendations for buffers around any potentially significant magnetic anomalies. The final borrow area design is then modified to take the recommended buffers into account.

Since these sand search investigations were designed to supplement work previously conducted by the USACE, a full Phase I investigation was not conducted. A Phase III design level investigation was conducted in 2008. The results of the 2008 investigation called for an additional sand search. Therefore, in 2009, Phases II and III geophysical and geotechnical investigations were conducted. These investigations focused on the USACE study areas and the prominent ridge features extending beyond these areas, as directed by Pinellas County and BBCS. Where appropriate, cultural resource investigations were also conducted.

GEOLOGICAL BACKGROUND

Developing an understanding of the geologic setting of the project area is important because it provides contextual information that sets limits to potential sand resources. A description of the regional geologic setting defines the framework bedrock seafloor surfaces and the sediments that sit on them. The nature of a sedimentary deposit determines sand quality, distribution, and its potential use for beach nourishment. It is thus necessary to understand the general continental shelf environments because the distribution of beach-quality sands on the seabed is not random, but spatially organized. This information is typically compiled during the Phase I investigation. However, since these sand search investigations focused primarily on study areas and borrow areas previously identified by the USACE, a Phase I investigation was not conducted.

Much of the subsurface of Florida consists of layers of limestone that form a relatively flat-topped structure known as the Florida Platform (Bryan *et al*., 2008) (Figure 4). The Florida Platform, which includes both submerged continental shelf and subaerial land areas, extends southward from the North American continental land mass and separates the Atlantic Ocean from the Gulf of Mexico. The Florida Platform was constructed undersea as calcium carbonate (remains of various sea organisms) was deposited on underlying bedrock (Bryan *et al.*, 2008).

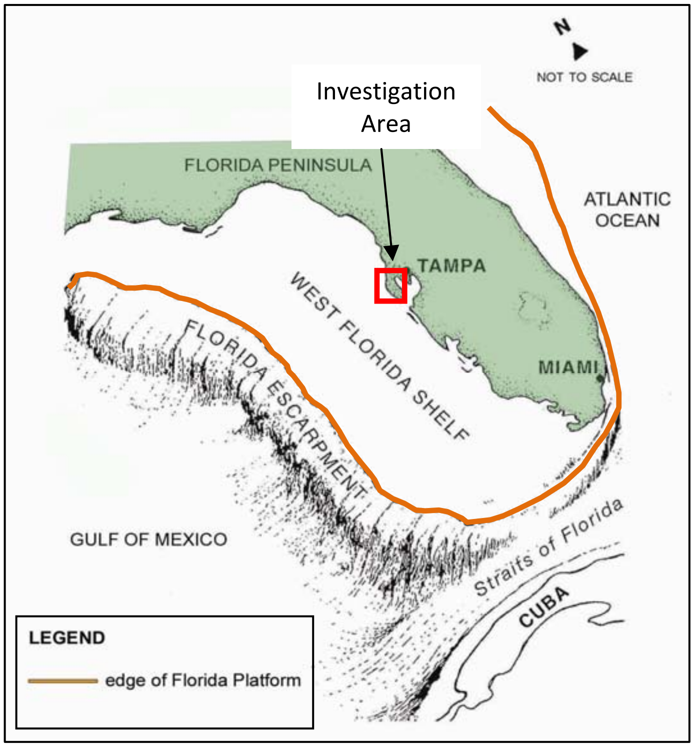


Figure 4. Oblique view of the Florida Platform, which comprises the perimeter landmass and Atlantic and Gulf continental shelves. The study area lies on the west coast of Florida, on the West Florida Shelf (modified from Bryan *et al.*, 2008).

The Florida Peninsula is the subaerially exposed part of the Florida Platform and forms the eastern rim of the Gulf of Mexico Basin (Figure 4). It was constructed between the middle Jurassic (180 Million Years Ago (MYA)) and the late Miocene (5 MYA) and is comprised of a thick sedimentary sequence predominantly composed of carbonates and anhydrites. During the initial evolution of the Florida Peninsula, sediments began to cover late Triassic to early Jurassic (c. 205 MYA) mafic volcanic suites that make up the crystalline basement rocks (White, 1970; Winston, 1971). Development of the thick sedimentary cover that makes up the Florida Peninsula was also associated with the early Jurassic embayment of the Gulf of Mexico basin, with its center of deposition passing through the southern archipelago (chain of islands formed tectonically) and paralleling the west coast, (Winston, 1992). During the same time or during a later emergence, there appears to have been a tilting of the plateau along its longitudinal axis causing a partial submergence of the west coast and uplift of the east coast. This partly accounts for the wide estuaries and offshore channels found along the west coast of Florida but not along the east coast.

The Florida Peninsula is the portion of the State of Florida that lies above sea level (Figure 4). It represents the subaerially exposed part of the platform. More than half of the

Florida Platform remains submerged beneath the Gulf of Mexico and a minor portion submerged beneath the Atlantic Ocean (Bryan *et al*., 2008). Since the early Jurassic, the extent of exposed platform has varied. More of the platform was exposed during times of low sea level. At the height of the Pleistocene (1.8 MYA to 10,000 years ago) Great Ice Age, the exposed peninsula was twice as wide as it is presently (Bryan *et al*., 2008). During times of high sea level (*i.e.* during the Cretaceous when the sea reached some of its highest levels), most of the platform was submerged. During the Paleocene and Eocene (65 MYA to 34 MYA), the platform remained completely submerged under a shallow tropical sea approximately 500-miles long and 400-miles wide.

This warm, clear water environment during the Paleocene and Eocene was similar to the modern Bahama Banks in that the sediments produced were almost entirely calcium carbonate (Chen, 1965). During such times of submergence, approximately 4000 ft. (in north central Florida) to 20,000 ft. (in southernmost Florida) of carbonate and marine sediments were deposited. These sediments eventually lithified to create the limestone formations that underlie Florida. The pronounced eustatic sea-level lowstand that occurred during the late Oligocene and early Miocene in response to a global cooling trend, and which was one of the most rapid and extreme drops in the world sea level (see, for example, discussions in Finkl and Fairbridge, 1979; Fairbridge and Finkl, 1980), had a profound influence on marine carbonate rocks in Florida. Lowered sea levels exposed carbonate sequences to non-marine phreatic and vadose hydrologic conditions, while at the same time inducing erosion.

Surface runoff physically and chemically eroded early Oligocene carbonates to produce subdued karst topography of the type described by Sweeting (1973) and White (1988). Extensive groundwater dissolution created cavern systems in Eocene and older rocks, which were precursors to the karst terrain that later developed. Neogene marine transgressions buried and infilled many of the caverns with fine-grained sediments that were reduced from calcareous platform rocks or accumulated as a result of eolian processes. These infilling sediments sometimes included concentrations of marine and non-marine vertebrate fossils (Randazzo, 1997) that significantly increased particle size. Dissolution of carbonate rocks on the Florida platform caused notable changes in rock fabric that were accompanied by the development of different types of pore spaces. Moldic, vugh, and interparticle pore types are the most common and give the carbonates a “honeycomb” habit to produce porous, sharp-edged, and irregular surfaces. Extensive dissolution created larger cavities such as caves and caverns as well as sinkholes and solution pits (*e.g.* Sweeting, 1973; Randazzo, 1997; White, 1988). When eroded by marine processes, the carbonate rocks of the porous and solution-holed seafloor produce gravel-sized fragments that are commonly washed up on beaches after storms (Hine *et al.*, 1998).

The western coast of Florida is part of a large primary geological feature referred to as the eastern Gulf of Mexico Sedimentary Basin, which is further divided into the North Gulf Coast Sedimentary Province and the Florida Peninsula Sedimentary Province (Schmidt and Clark, 1980). The Florida Peninsula, a large carbonate platform containing a thick, non-clastic sedimentary sequence predominantly composed of carbonates and anhydrites, was constructed between the Middle Jurassic (180 MYA) and the Late Miocene (5 MYA). This ancient carbonate platform forms the proximal portion of the west Florida shelf-slope system and exerts large-scale control on coastal geomorphology, the availability of sediments, and wave energy (Hine *et al.*, 2003). During the same time or during a later emergence, there appears to have been a tilting of the plateau along its longitudinal axis causing a partial submergence of the West Coast, partly accounting for the wide estuaries and offshore channels found along the west coast of Florida.

The underlying antecedent topography of the Tertiary (2–65 MYA) limestone surfaces, as well as their hardground exposures, significantly influence the orientation and geographic location of Holocene (last 10,000 years) barrier islands and sand ridges along the west coast of Florida, as discussed by Evans *et al.* (1985) and Hine *et al.* (1986). Coastal orientation is generally NW-SE along the southwest coast of Florida. However, there are major offsets at Indian Rocks (Pinellas County), Sanibel Island (Lee County) and Cape Romano (Collier County). The underlying pre-Quaternary (1.8 MYA) surface is composed of irregular karstic limestones that partially control barrier island development, position, and tidal inlet opening (Gibeaut and Davis, 1988; Stapor *et al.*, 1991). The present coastal barrier islands likely formed close to their present location during the latest, relatively stable, stages of the Holocene transgression approximately 4,000 to 5,000 years ago (Bland, 1985; Davis, 1997; Evans *et al.*, 1985). Historic shoreline data for recently evolved coastal barrier islands and stratigraphic data based on core logs from older barrier islands indicate that they formed in response to a gentle wave climate that transported sediments onshore to shallow water where they shoaled upward to intertidal and supratidal levels (Locker *et al*., 2003).

PREVIOUS INVESTIGATIONS

The following are summaries of several marine surveys and geotechnical studies previously conducted near Sand Key. This information was compiled during CPE's 2007 constructability analysis and was evaluated within the context of the geologic framework to formulate the investigations that were subsequently conducted by CPE in 2008 and 2009.

USACE Study Area Identification & Borrow Area Development

A survey extending 5 miles offshore of Sand Key was conducted in the early 1980s. This survey, which is described by Gelfenbaum *et al.* (1995), identified two (2) types of sand deposits; a 2.4 ft. thick sand cover over most of the study area and a series of 15 ft. thick sand ridges extending perpendicular to the shore. These deposits were further investigated in 1994 by the U.S. Geological Survey (USGS) in a cooperative effort with the USACE. Two (2) initial areas of investigation were identified for geophysical and vibracore surveys (Figure 5). Area A was 1 mile wide by 12 miles long and extended from just north of Johns Pass to just south of Clearwater Pass.

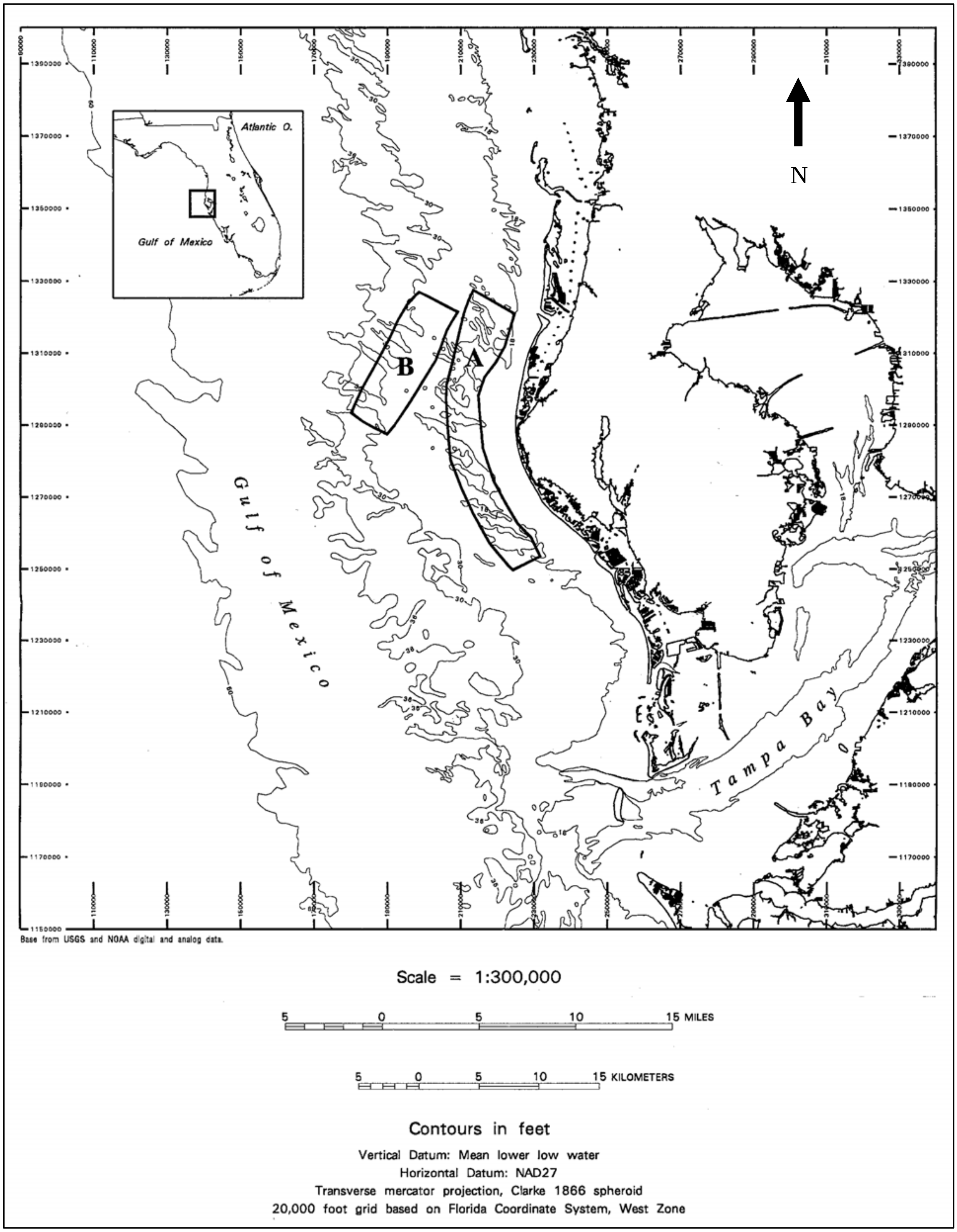


Figure 5. 1994 sand survey initial areas of investigation (from Gelfenbaum *et al.,* 1995). The initial area of investigation was broken into subareas A and B.

Area B was 1 mile wide by 6 miles long and was located offshore of Area A, along the northern part of Sand Key.

Gelfenbaum *et al.* (1995) provide a description of the geophysical data collected during the reconnaissance-level sand resource survey. Approximately 135 nautical miles of reconnaissance-level seismic reflection and sidescan sonar data was collected in October 1994 using the Florida Institute of Oceanography vessel *R/V Suncoaster*. Tracklines, at 1,000 ft. spacing, were run across Areas A and B. Navigation was by differential GPS with an estimated accuracy of 20-30 ft. The reconnaissance seismic data was collected using a HUNTEC Sea Otter boomer source and an ITI 10 channel streamer with a 5 ft. separation between the source and streamer. The seismic data was collected and processed using an Elics Delph 2 digital acquisition and processing package. The seismic reflection data was used to map sediment thickness in the two (2) survey areas. The sediment thickness maps generated from this data were used to identify potential vibracore target areas. Sidescan sonar data was collected using an EG&G 272 TD towfish operating at 100 kHz with a total swath of 984 ft. The reconnaissance sidescan data was used to map the spatial extent of unconsolidated sediment and potential hardbottom throughout the study area.

Based on the results of the reconnaissance geophysical surveys, a plan for reconnaissance-level vibracore collection was developed. Twenty-two (22) vibracores were collected by the USGS in 1994. Vibracore spacing ranged from approximately 2,500 ft. to 15,000 ft. Core penetration ranged from 2 ft. to 14 ft. and recovery ranged from 0 ft. to 12.5 ft. The longest cores (>7 ft.) were collected from the northern and inshore part of the study area. Eight (8) of the cores contained limestone fragments at their bases. Three (3) cores contained blue-gray clay at their bases. The lithology of the cores is described in Gelfenbaum *et al.* (1995). Several lithologies are represented in the cores. The dominant lithology is clean fine-grained quartz sand, which is found at the top of most of the cores. The thickest accumulations of this sand were found in cores collected from the northern part of the study areas. A mixture of quartz sand and blackened grains appeared to be common in the southern part of the study areas. A couple of the northern cores had dark brown to black, organic rich sediment that occurs as thin layers at the base of the cores. Several cores from the northern part of the study sites, had thin layers of light colored lime mud at their bases. Sixty-two (62) samples were collected from the vibracores and analyzed. Grain size distributions were determined using the sieve and pipette method. Mean grain size and standard deviations were determined by the moment method.

An additional one hundred and forty-six (146) vibracores were collected by Ardaman & Associates in 1996. The cores were re-logged by CPE and logs, photographs, granularmetric reports and grain size distribution curves/histograms are provided in Appendices 4, 5, 6 and 7, respectively. Vibracore logs and grain size distribution curves are provided in Appendices 4 and 7, respectively. With some exceptions, these vibracores were collected at a maximum core spacing of 1000 ft. Generally, the uppermost several feet of each core was fine-grained gray sand. The silt/clay content appears to increase with depth in each core, with green and brown clay found towards the base of several of the cores. Most of the cores contained trace to little gravel scattered throughout. The nature of the gravel-sized material found in most of the cores was not characterized. This material could be sandstone or limestone fragments, or it could be shell.

The data collected during the reconnaissance geophysical and vibracore surveys discussed above was used to identify nine (9) study areas (designated A through I) which are shown in Figure 2. In 2001, Dial Cordy and Associates, Inc. was contracted by the USACE to conduct a biological survey of these nine (9) study areas. Over 15,000 acres of seafloor was mapped using towed video and GPS mapping. Transects were established in each study area at 500 ft. intervals. The point at which each survey transect crossed a change in habitat was determined from video analysis. Points were then incorporated into a database and ArcView GIS was used to generate resource maps. Diver surveys were used to characterize representative areas of potential hardbottom. The results of the biological survey are summarized in Dial Cordy and Associates, Inc. (2002).

Following the biological mapping, the USACE then refined the nine (9) study areas into twenty (20) potential borrow areas (Figure 2). Borrow area design involved the placement of a 400 ft. buffer around the hardbottom mapped during the reconnaissance sidescan survey (USACE, 2004). All study areas are underlain by rock. To minimize the risk of encountering this rock, each borrow area was designed to maintain a 4 ft. thickness of sand above the underlying rock. The sand above the 4 ft. buffer was then reviewed for textural characteristics and degree of similarity to the native beach (USACE, 1997). The grain size distributions, mean grain size and sorting were taken into account. The elevation of any undesirable material was noted. An excavation elevation was determined by placing a 2 ft. buffer above the undesirable material and a borrow area composite was then created using the Ardaman and Associates cores collected in 1996. Cut thicknesses and volumes were then calculated for each borrow area using the cut elevations. The final design cut thicknesses ranged from 0 ft. (Study Area E) to 15 ft. (Study Area D). It was estimated by the USACE that Study Areas A through I contain a total volume of 5,735,000 cy of beach compatible sand.

CPE 2007 Sand Key Sand Source Investigation Constructability Analysis

In 2007, CPE was contracted by Pinellas County to re-evaluate the dredge cuts and volumes for the twenty (20) borrow areas developed by the USACE, using current Florida Department of Environmental Protection (FDEP) sediment quality standards and guidelines. The goal was to quantify the volume of potential beach quality material available and to identify areas that would best serve the County and the USACE in the next renourishment of Sand Key. CPE's re-evaluation is discussed in Forrest *et al.* (2007). The recommendations made by CPE are briefly described below. Detailed recommendations are provided in Forrest *et al.* (2007).

CPE reviewed the nine (9) study areas and the vibracore logs and determined that some of the material that was considered beach compatible when it was originally analyzed, does not meet current state standards as provided in Rule 62B-41.007(2)(j) F.A.C. CPE recommended that the USACE dredge cut elevations be revised to incorporate the current FDEP regulations for beach-compatible sand. Recommendations for revised dredge cut elevations were determined by reviewing the material contained in the vibracores collected from each study area. The cores collected by Ardaman and Associates in 1996 were used to establish recommended dredge cut elevations for each borrow area. The USGS cores were used to check consistency with the Ardaman and Associates cores. The State currently recommends the placement of a two-foot buffer between any beach compatible material and any underlying non beach compatible material. Therefore, the elevation of material not meeting current State guidelines was noted and a two-foot buffer was added above the unsuitable material. The State also recommends the maintenance of a 400-ft buffer between the borrow area and the local hardbottom to minimize hardbottom impacts. Although the borrow areas designed by the USACE did incorporate a buffer, the placement of this buffer was based on the reconnaissance-level data collected during the sand search survey and not from the Dial Cordy hardbottom survey. The 2001 Dial Cordy hardbottom survey, although only verified by spot dives, indicates that hardbottom encroaches on several of the USACE designed borrow areas. The presence of hardbottom should have been fully diver verified, resulting in the identification and implementation of an appropriate hardbottom buffer based on environmental mapping and not reconnaissance-level sand search data. This oversight resulted in overestimation of potential beach-compatible sand volumes by neglecting to account for impacts to potential borrow areas due to hardbottom buffers.

The revised cut elevations were compared to LIDAR bathymetry to estimate the thickness of potential beach quality material in each borrow area. The limits of each USACE designed borrow area were then refined to encompass only areas thick enough to efficiently dredge (a minimum 2-ft. cut thickness). Each borrow area was further refined to include only areas having a minimum 150-ft. wide swath, which is the space required for most cutterhead dredges to operate efficiently.

These revisions led to a reduction in the volume of dredgeable material from the original estimates made by the USACE. This reduction was due to the application of current state guidelines and analysis of the dredgeability of the borrow areas. State guidelines place restrictions on sediment grain size (in terms of allowable gravel and silt content), and provide recommendations for the placement of buffers above any material considered unsuitable for beach placement. The distribution of sand remaining after the current state standards were applied significantly reduced the volume estimates. This was because in many of the borrow areas some or all of the potentially beach quality material is too thin or discontinuous to effectively dredge. The volume estimates did not take into account the placement of a 400-ft buffer around potential hardbottom, as the actual hardbottom coverage had not been verified. The presence of hardbottom in or around the borrow areas may result in a further reduction in available volume. Seismic reflection data was not collected. Therefore, isopach data was not incorporated into the borrow area design. Incorporation of seismic data could, therefore, result in an additional reduction in volume. These estimates did not take into account an assessment of the compatibility of the material with the native beach. The available volume may be further reduced if material not compatible with the native beach is present.

CPE's constructability analysis indicated that Study Areas A, B, E, F, G and I are not likely to be viable sand sources. The three (3) most promising sources of beach compatible material are Study Areas C, D and H. Although these three (3) areas likely contain potentially beach compatible material and are located directly offshore of the anticipated project area, they will likely fail to provide the 2.0 million +/- cy needed for Sand Key's next nourishment.

Historic National Ocean Service (NOS) bathymetry from the National Oceanographic and Atmospheric Administration (NOAA) covering the nine (9) study areas shows what appear to be a series of prominent sand ridges offshore of the project area. These ridges are oriented roughly northwest/southeast and range from approximately 3,000 to 30,000 ft. in length. Several of these ridges were targeted by the USACE but extended beyond the limits of their study areas. Additional volume may be obtained by further investigating these areas. The most promising ridges are highlighted in Figure 6. CPE's final recommendations included focusing future efforts on refining Study Areas C, D, and H by collecting additional data to meet state standards and expanding the investigation area to include the offshore sand ridges identified on the NOAA bathymetry.

Beach Characterization

The suitability of a sand source for beach nourishment is directly linked to the characteristics of the recipient beach. State and federal regulatory agencies require that sand resources for nourishment be "beach compatible", that is, "similar" to sand existing in the project area. Qualities such as grain size, silt content, color, and mineralogical content are taken into account. It is, therefore, important to accurately characterize existing beach sediments during a sand search investigation. This allows researchers to target potential sand resources that are most similar to the recipient beach. The quality of material that can be placed on Florida's beaches, is governed by Rule 62B-41.007(2)(j) F.A.C. which states that:

> *To protect the environmental functions of Florida's beaches, only beach compatible fill shall be placed on the beach or in any associated dune system. Beach compatible fill is material that maintains the general character and functionality of the material occurring on the beach and in the adjacent dune and coastal system. Such material shall be predominately of carbonate, quartz or similar material with a particle size distribution ranging between 0.062 mm (4.0ϕ) and 4.76 mm (-2.25ϕ) (classified as sand by either the Unified Soils or the Wentworth classification), shall be similar in color and grain size distribution (sand grain frequency, mean and median grain size and sorting coefficient) to the material in the existing coastal system at the disposal site and shall not contain:*
>
> *1. Greater than 5 percent, by weight, silt, clay or colloids passing the #230 sieve (4.0ϕ);*
> *2. Greater than 5 percent, by weight, fine gravel retained on the #4 sieve (-2.25ϕ);*
> *3. Coarse gravel, cobbles or material retained on the 3/4 inch sieve in a percentage or size greater than found on the native beach;*
> *4. Construction debris, toxic material or other foreign matter; and*
> *5. Not result in cementation of the beach.*
>
> *If rocks or other non-specified materials appear on the surface of the filled beach in excess of 50% of background in any 10,000 square foot area, then surface rock should be removed from those areas. These areas shall also be tested for subsurface rock percentage and remediated as required. If the natural beach exceeds any of the limiting parameters listed above, then the fill material shall not exceed the naturally occurring level for that parameter.*

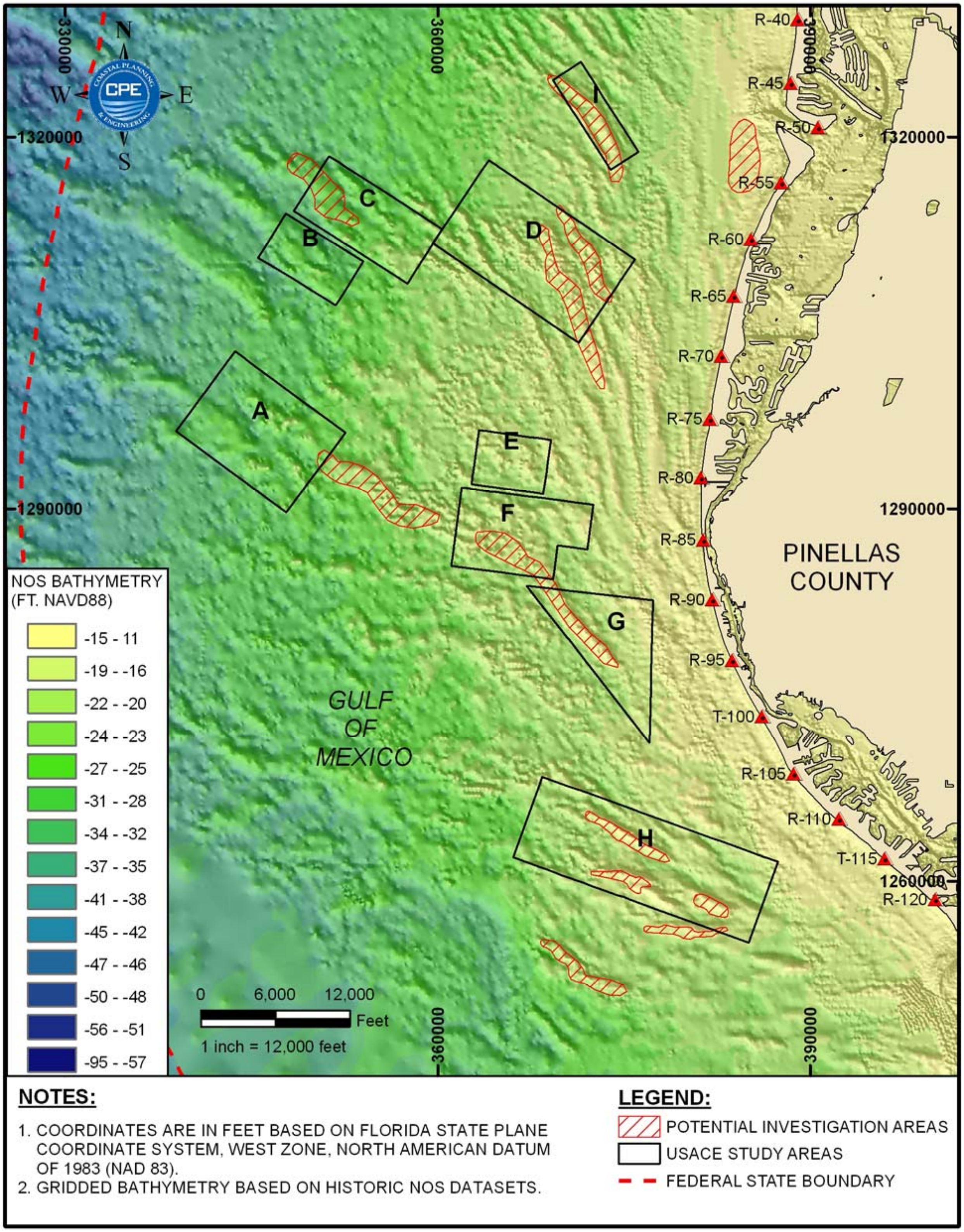


Figure 6. Potential investigation areas identified based on CPE's re-evaluation of the USACE study areas and borrow areas.

The primary source for these past Sand Key nourishment projects has been the Egmont Shoal Borrow Area, which has a mean grain size of 0.18 mm and is primarily composed of clean fine quartz sand (USACE, 2006). Based on the past use of this material, sand similar in nature to the Egmont Shoal Borrow Area should be considered to be compatible.

In 1980, samples representing the native beach were collected at 2-mile spacing along the length of Pinellas County (USACE, 1997). This native beach survey included sample collection along eight (8) profile lines on Sand Key (USACE, 1997). These profile lines covered the entire gulf shoreline of Sand Key. Locations of the profiles relative to FDEP range monuments were not provided. Based on the analysis of these samples, Sand Key's native beach has a mean grain size of 0.19 mm (2.39 ϕ), is poorly sorted, has a silt content of 3.6% (percent passing the #230 sieve), a shell content of 13% (based on a visual estimate) and an average carbonate content of 18%. Munsell color was not determined.

Beach samples were not collected by CPE during the 2008 or 2009 investigations. CPE strongly recommended conducting a compatibility analysis to determine compatibility between the beach and potential sand resources and to provide optimum project performance. However, Pinellas County did not wish to include a compatibility analysis in CPE's sand search investigation, opting instead to utilize the University of South Florida (USF) and the USACE to perform compatibility analyses. Therefore unforeseen sand compatibility issues may result.

Pinellas County did not have any requirements (i.e. color, carbonate content, shell content) that needed to be met beyond the required state and federal regulatory agency standards. Therefore, sands meeting current state standards are considered potentially beach quality and were targeted during this sand search investigation.

PHASE II AND III INVESTIGATIONS

Equipment and Methods

Due to the scope and precision required by modern sand search protocols, a wide range of geophysical and geotechnical survey methods are required. The investigations included bathymetric, sidescan sonar, seismic reflection profiling and magnetometer surveys as well as determination of sediment composition and thickness via vibracoring. The bathymetric, sidescan sonar, seismic reflection profiling and magnetometer surveys were conducted concurrently using the setup illustrated in Figure 7. The collection and processing of this data is described below. The geophysical and geotechnical equipment used during the investigations is listed in Table 1 and described below.

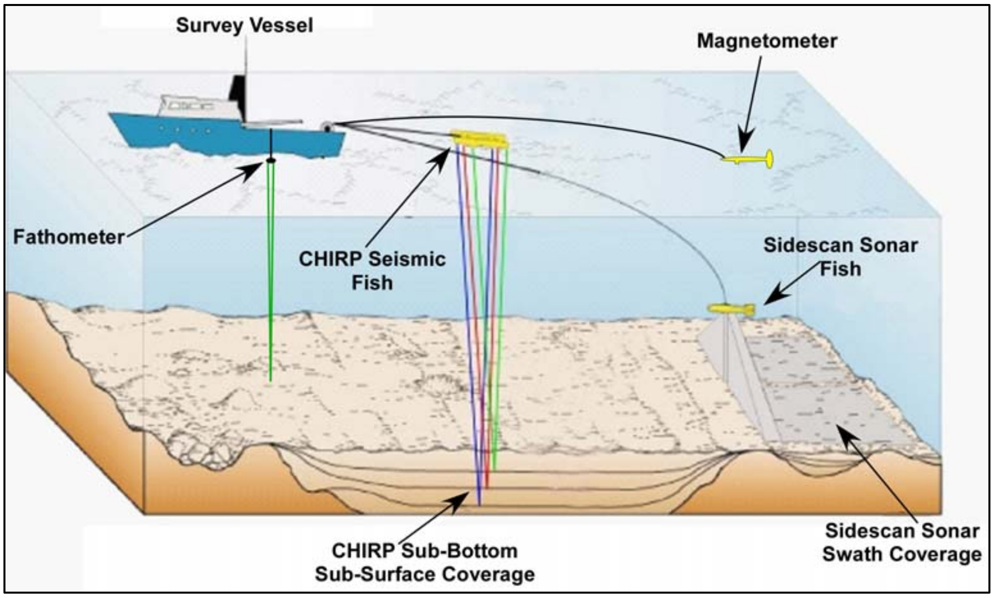


Figure 7. Schematic diagram showing the deployment of a joint seismic reflection profile, bathymetric, magnetometer and sidescan sonar survey.
(Modified from: http://woodshole.er.usgs.gov/operations/sfmapping/seismichist.htm)

Table 1. *Equipment used during the 2008 and 2009 geophysical and geotechnical investigations.*

Equipment Type	Description
Navigation	Trimble Real Time Kinematic (RTK) Global Positioning System (GPS) interfaced with Hypack Inc.'s Hypack 2008 ® software
Sounder (Bathymetry)	Odom Hydrographic Systems, Inc. "Hydrotrac" Hydrographic Echo Sounder
Sub-bottom Profiler (seismic reflection)	EdgeTech X-STAR SB-512i Sub-bottom Profiler
Sidescan Sonar	Edgetech 4200-HFL Sidescan Sonar
Vibracores	271B Alpine Pneumatic Vibracore BH-4 style vibrator apparatus (single piston, pneumatically driven vibrator)
Magnetometer	Geometrics G-882 Digital Cesium Marine Magnetometer interfaced with Hypack 2008® software

Navigation Systems

The navigation and positioning system deployed for the 2008 and 2009 surveys was a real-time kinematic (RTK) global positioning system (GPS) with dual frequency receivers. RTK GPS relies on a base station and transmitter placed on a survey point with a known elevation and horizontal position. The base station for the surveys was set on the roof of "Reflections", a condominium located on Indian Rocks Beach, as this location provided the clear horizon needed to minimize phase-measurement effects caused by multi-pathing. The base station position for the RTK GPS system was surveyed and established prior to survey operations. Horizontal and vertical positioning checks were conducted before and after the survey at existing monuments located within the project area to confirm survey accuracy. The base station transmits carrier phase and Doppler shift corrections via radio link to a receiver onboard the survey vessel. The receiver on the survey vessel can then apply the carrier phase and Doppler shift corrections to the position of the vessel as measured by GPS satellites.

The vertical accuracy of control data meets the accuracy requirements set forth in Section 01000 of the BBCS Monitoring Standards for Beach Erosion Control Projects and Chapter 61G17-6, F.A.C. of ± 0.16 ft. The horizontal accuracy of the control data meets the Geospatial Positioning Accuracy Standards, Range VIII of a maximum ± 0.66 ft. as stated in section 01000. In order to achieve required accuracy the topographic and hydrographic surveys were controlled using 2nd order FDEP "A" monuments. GPS data was collected at 1 Hz or faster to minimize position interpolation when assigning the position to the various geophysical data.

Hypack Inc.'s Hypack 2008 ® Data Collection and Processing Program

Navigational, magnetometer, and depth sounder systems were interfaced with an onboard computer, and the data was integrated in real time using Hypack Inc.'s Hypack 2008® software. Hypack 2008® is a state-of-the-art navigation and hydrographic surveying system. The location of the fish tow-point on the vessel in relation to the RTK GPS was measured, recorded and entered into the Hypack 2008® survey program. The length of cable deployed between the tow-point and each towfish was also measured and entered into Hypack 2008®. Hypack 2008® uses these values to calculate the estimated position of each towfish in real time. Online screen graphic displays include the pre-plotted survey lines, the updated boat track across the survey area, adjustable left/right indicator, as well as other positioning information such as boat speed, quality of fix measured by Position Dilution of Precision (PDOP), and line bearing. The digital data is merged with positioning data (RTK GPS), video displayed and recorded to the acquisition computers hard disk for post processing and/or replay.

Bathymetric Survey

The Odom Hydrographic Systems, Inc.'s Hydrotrac, a single frequency portable hydrographic echo sounder, was used to perform the bathymetric surveys. The Hydrotrac operates at frequencies of 24, 33, 40, 200, 210, or 340 kHz and is a digital, survey-grade sounder. A 210 kHz transducer was used for the bathymetric survey.

Prior to the start of each survey, a reconnaissance survey of the second order FDEP monuments was conducted to confirm that the survey control was in place and undisturbed. RTK GPS was used to locate and confirm the survey control for this project (Appendix 2). To achieve the required accuracy, the hydrographic surveys were controlled using second order FDEP monuments.

Horizontal and vertical RTK GPS positioning checks and sounder calibration were performed periodically throughout the surveys (typically at the beginning and end of each survey day). The sounder was calibrated via bar-checks and a sound velocity probe. The DIGIBAR PRO sound velocity meter is used to find the average sound velocity needed to calibrate the Hydrotrac sounder prior to performing the bar-check. Bar checks were performed from a depth of 5 ft. to the maximum depth of the survey area. Analog data showing the results of the bar check calibration is displayed on the sounder charts at 5 ft. increments during descent of the bar.

Real-time navigation software (Hypack), was used to provide navigation to the helm in order to minimize deviation from the online azimuth. This software provides horizontal position to the sounding data allowing real-time review of the data in plan view or cross section format. A Trimble RTK GPS and a TSS Motion Compensator were used onboard the survey vessel to provide instantaneous tide corrections as well as heave, pitch and roll corrections.

Soundings were collected at intervals sufficient to provide an accurate depiction of the seafloor. Cross lines (tie lines) were collected to verify survey accuracies.

Upon completion of the field work, data was edited and reduced with CPE's internal software programs and Hypack 2008®. The observed tide data was compared to local predictions and other regional gauges for verification purposes. The offshore raw digital data was viewed and edited in Hypack 2008®. Digitized data was scanned for noise and compared to the analog record. False soundings were removed and a comma delimited ACSII file was created and exported.

Magnetometer Survey

High-resolution magnetic remote sensing is needed to identify any metallic objects that could represent a potential cultural resource or hazard to construction. A Geometrics G-882 Digital Cesium Marine Magnetometer, capable of a plus or minus 0.1 gamma resolution, was used to perform a cursory investigation of magnetic anomalies within the potential sediment sources (Figure 8). Magnetometer surveys were conducted to establish the presence, and subsequent exclusion zones around any potential underwater wrecks, submerged hazards, or any other features that would affect borrow area delineation and dredging activities. Magnetometer data was also collected to meet the requirements of the *de minimus* exemptions (Appendix 3).

To produce a magnetic record of sufficient resolution, the sensor was deployed and maintained in the water column at a depth of 4 to 10 ft. below the water surface. However, during the cultural resource survey it was towed without floats under the direction of the Tidewater Atlantic Research (TAR) archaeologist. As a result, the towing depth was variable. A computer recorder provided a continuous permanent record of the magnetic background and target signatures. Positioning data generated by the navigation system was tied to magnetometer records by regular annotations to facilitate target location and anomaly analysis. Annotations include line number, date and time of start and end of each line, and target identification.

Upon completion of the general magnetometer surveys, the data was examined by a marine archaeologist, who provided the locations of magnetic anomalies. The magnetic anomalies were avoided during subsequent geotechnical (vibracore) investigations by a 400 ft. buffer.

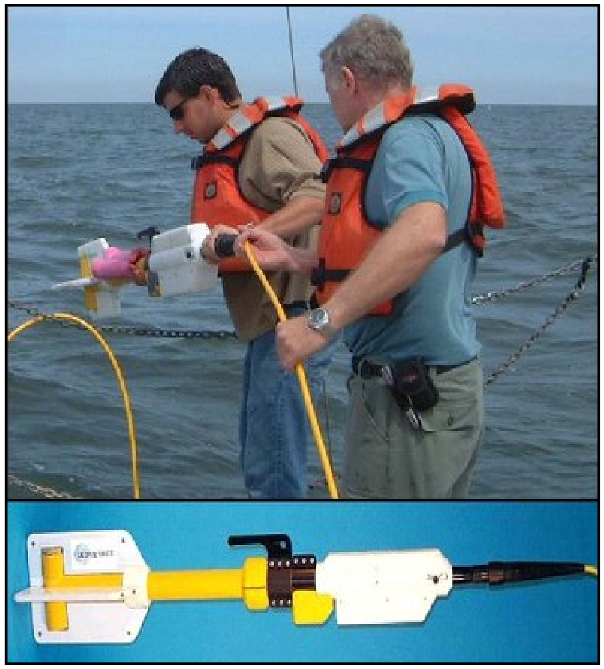


Figure 8. Geometrics G-882 Digital Cesium Marine Magnetometer used to investigate magnetic anomalies within the potential sediment sources.

Seismic Reflection Profile Surveys

"Chirp" sub-bottom seismic-reflection data was used to show sedimentary stratigraphy and identify potential project-compatible sediment resources. The use of chirp sub-bottom data allows common stratigraphic layers to be mapped throughout the study area while determining the thickness and extent of potential project-compatible sediment.

An EdgeTech X-STAR SB-512i was used to conduct the seismic reflection profile surveys (Figure 9). The X-STAR Full Spectrum Sonar is a versatile wideband FM sub-bottom profiler that collects digital normal incidence reflection data over many frequency ranges. This instrumentation generates cross-sectional images of the seabed (to a depth of up to 50 ft. in this survey). The X-STAR SB-512i transmits an FM pulse that is linearly swept over a full spectrum frequency range (also called a "chirp pulse"). The tapered waveform spectrum results in images that have virtually constant resolution with depth. The Chirp systems have an advantage over 3.5 kHz and "boomer" systems in sediment delineation because the reflectors are more discrete and less susceptible to ringing from both vessel and ambient noise. The full-wave rectified reflection horizons are cleaner and more distinct than the half-wave rectified reflections produced by older analog systems.

The X-STAR SB-512i, the newest model in the EdgeTech suite of Chirp Full Spectrum Sub-bottom towfish, differs from the older X-STAR SB-512 (which had four (4) 6" diameter transducers) by having a single 13" diameter low frequency transducer and a single 6.5" diameter high frequency transducer. The new low frequency transducer provides more low frequency energy at all pulse settings, which allows deeper penetration of seafloor sediments while at the same time maintaining the high resolution of the original configuration.

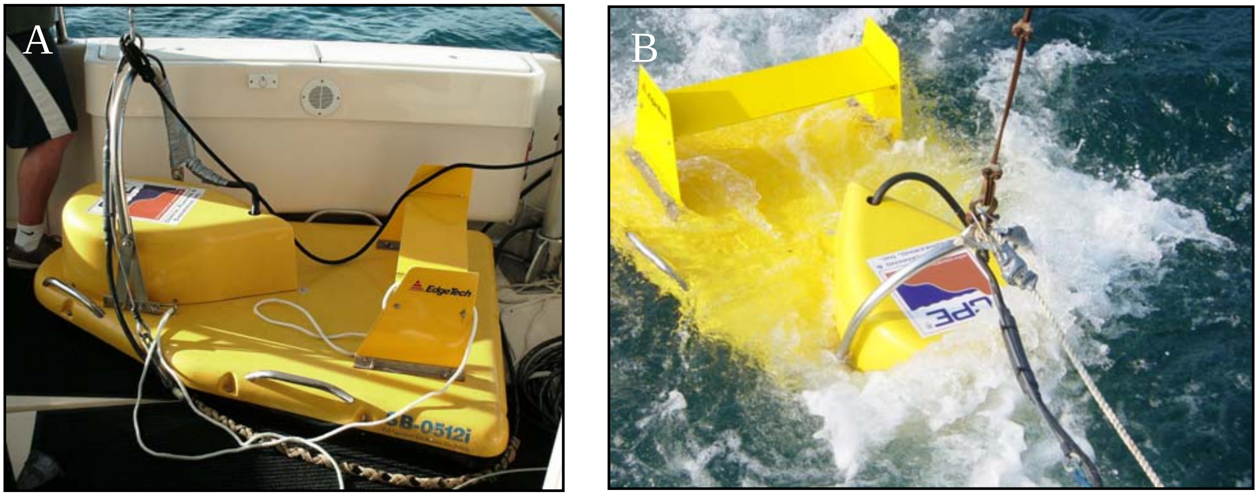


Figure 9. EdgeTech X-STAR SB-512i sub-bottom profiling system. (A) shows the sub-bottom profiling system prior to deployment. (B) shows the system after deployment.

In order to minimize noise related to the survey vessel and sea conditions, the seismic towfish (which operates as both the source and receiver for the sub-bottom system) was deployed and towed behind the research vessel. The sub-bottom system was interfaced with RTK GPS via Hypack 2008® navigational software. The location of the fish tow point (as referenced to the RTK GPS antenna), together with the length of cable deployed from the tow point, were entered into Hypack 2008® in order to account for the fish layback and provide accurate positioning of the seismic fish during the survey. The sub-bottom system was operated by the Discover-SB® software program. At the start of the sub-bottom profiling survey, the sweep frequencies of the outgoing pulse together with the different gain settings available within Discover-SB® were adjusted to obtain the best possible resolution for the survey. The data was continuously bottom-tracked to allow for the application of real-time gain functions in order to have an optimal in-the-field view of the data. Automatic gain control (AGC) was used to normalize the data by strengthening quiet regions/soft returns while simultaneously reducing/eliminating overly strong returns by obtaining a local average at a given point. A time-varying gain (TVG) was used to increase the returning signal over time in order to reduce the effects of signal attenuation.

All sub-bottom data was recorded on the acquisition computer's hard disk and transferred to a USB memory stick and/or portable hard drive at the end of each survey day to back-up raw survey data. A printed hardcopy of the data was also produced as the data was collected. Notes regarding line name, time, event, and direction of collection were recorded for the beginning and end of each survey trackline. Post collection processing of the seismic data was completed using Chesapeake Technology, Inc's SonarWiz.MAP +SBP® software. This software allows the user to apply specific gains and settings in order to produce enhanced sub-bottom imagery that can then be interpreted and digitized for specific stratigraphic facies relevant to the project goals.

The first data processing step is to calculate the approximate depth of the reflector below the sound source by converting the two-way travel time (the time in milliseconds that it takes for the "chirp pulse" to leave the source, hit the reflector and return to the source) to feet by utilizing an approximate value for the speed of sound through both the water and underlying geology. For this survey, a detailed hydrographic and geologic sound velocity structure was not available, so CPE geophysicists used an estimated sound velocity of 1.6 meters per millisecond (m/ms) in order to convert two-way travel time to feet. This estimate of the composite sound velocity is based on several assumptions including the speed of sound through water which is typically 1.5 m/ms as well as on the speed of sound through the sediment which can vary from 1.6 m/ms for unconsolidated sediment to >1.7 m/ms for limestone.

CPE geophysicists then processed the imagery to reduce noise effects (commonly due to the vessel, sea state, or other natural and anthropogenic phenomenon) and enhance stratigraphy. This was done using the processing features available in SonarWiz.MAP +SBP®; AGC, swell filter, and a user-defined gain control (UGC). The SonarWiz.MAP +SBP® AGC is similar to the Discover-SB® AGC feature, where the data are normalized in order to remove the extreme high and low returns, while enhancing the contrast of the middle returns. In order to appropriately apply the swell filter and UGC functions, the sub-bottom data was bottom-tracked to produce an accurate baseline representation of the seafloor. Once this was done through a process of automatic bottom tracking (based on the high-amplitude signal associated with the seafloor) and manual digitization, the swell filter and UGC were applied to the data. The swell filter is based on a ping averaging function that removes vertical changes in the data due to towfish movement caused by the sea state. The swell filter was increased or decreased depending on the period and frequency of the sea surface wave conditions, however, special care was taken during this phase to not remove, or smooth over geologic features that are masked by the sea state noise. The final step was to apply the UGC. The SonarWiz.MAP +SBP® UGC feature allows the user to define amplitude gains based on either the depth below the source, or the depth below the seafloor. For this survey, the UGC was adjusted so that the gain would increase with depth below the imaged seafloor (and not the source), mimicking a time-varying gain. The user was able to remove the noise within the water column, increase the contrast within the stratigraphy, and increase the amplitude of the stratigraphy with depth, accounting for some of the signal attenuation normally associated with sound penetration over time.

After data processing, sub-surface data interpretation was performed using SonarWiz.MAP +SBP® software. Using the SonarWiz.MAP +SBP® platform, processed seismic profile lines were opened to digitally display the recorded sub-surface stratigraphy. Using the software's Sonar File Manager, color coded vibracore descriptions were added directly to the seismic profiles. A project-specific color scheme was developed for the vibracores based on the FDEP sediment quality guidelines provided in Rule 62B-41.007(2)(j) F.A.C. Using the vibracore descriptions as a guide, the seismic stratigraphy was interpreted and the depth of the top of marginal to poor quality material was determined. The stratigraphic reflector that best correlated with this layer was digitized.

Using the seafloor and the reflector representing non beach-compatible material (i.e. high silt, clay or rock content), the thickness of the sediment wedge was calculated and exported in order to develop an isopach (sediment thickness) map of each area. The maps that were created were verified by importing and gridding the thickness data in Golden Software Inc's Surfer 8®. After gridding the data, contour maps showing sediment thickness were produced. The contour maps were checked for discrepancies in the data and the proper adjustments were made. Once the data was verified, final thicknesses were exported to be used in the borrow area design process.

Sidescan Sonar Survey

Sidescan data is required to verify the location and extent of unconsolidated sediment and to map ocean bottom features such as benthic habitats, exposed pipelines, cables, underwater wrecks, potential cultural resources, *etc*. Sidescan surveys were conducted to identify features that may affect borrow area delineation, introduce hazards to dredging, or adversely impact the environment.

During this sand search investigation an EdgeTech 4200-HFL sidescan sonar system was used (Figure 10). This system uses full-spectrum chirp technology to deliver wide-band, high-energy pulses coupled with high resolution and good signal to noise ratio echo data. The sonar package included a portable configuration with a laptop computer running EdgeTech's Discover® acquisition software and a 300/600 kHz dual frequency towfish running in high definition mode. Dual frequency provides a more complete sidescan return that aids interpolation at the outer portions of the swath, which in turn provides a more complete data set.

During the investigations, the sidescan was towed from the survey vessel at a position and depth that limited exposure to sources of interference and provided the best possible record quality. The survey was conducted in such a manner to achieve total bottom coverage within the survey area. The line spacing was set up so that we obtained 100% overlap (*i.e.* all areas of the seafloor were covered twice). The digital sidescan data was merged with positioning data (RTK GPS via Hypack 2008®). Position data appeared in the video display and was logged to disk for post processing and/or replay. The acoustic data was recorded digitally.

Figure 10. EdgeTech 4200-HFL sidescan sonar system.

Post collection processing of the sidescan data was completed using Chesapeake Technology, Inc's SonarWiz.MAP software. This software allows the user to apply specific gains and settings in order to produce enhanced sidescan imagery that can be interpreted and digitized for specific benthic habitat features and debris throughout the survey area. The first step in processing was to import the data into the software and bottom track the data. Bottom tracking is achieved using an automated bottom tracking routine and in some cases manual bottom tracking. This step provides the data with an accurate baseline representation of the seafloor and eliminates the water column from the data.

After bottom tracking, the data was processed to reduce noise effects (commonly due to the vessel, sea state, or other anthropogenic phenomenon) and enhance the seafloor definition. In most cases automatic time-varying gain (TVG) is sufficient to provide the best imagery. Time-varying gain divides the data into parallel swaths and equalizes backscatter of each swath to create a normalized image highlighting contrast change throughout the image, which creates a better mosaic and allows the processer to pick out areas with similar acoustic properties. In areas with high levels of noise in the data it was necessary to apply automatic gain control (AGC) which normalizes the data by strengthening quiet regions/soft returns while simultaneously reducing/eliminating overly strong returns by obtaining a local average at a given point. Once the data was sufficiently processed a mosaic was produced in the form of a geotiff along with an interpretation of bottom features such as potential benthic habitat and manmade debris in the form of a shapefile. The classification scheme presented in Table 2 was used.

Bottom features were digitized on a line-by-line basis to allow for comparison of features along adjacent lines. The digitized features were imported into ArcGIS 9.3, along with the final mosaic for further analysis. Once they were imported into the GIS platform, final composite digitized features were created based on the line by line analysis performed in the sidescan processing platform.

Table 2. *Sidescan sonar bottom feature classification.*

Bottom Feature	Description
Hardbottom	High confidence areas of rock outcrops on the seafloor that appear to be continuous or cover a majority of the digitized area. High confidence is based on these features having been identified and digitized on multiple lines.
Possible Hardbottom	Rock outcrops on the seafloor that appear to be continuous over a majority of the digitized area. These features are digitized based on the interpretation of one sidescan line.
Scattered Hardbottom	High confidence areas of rock outcrops on the seafloor that do not appear continuous or are sparsely distributed throughout the digitized area. High confidence is based on these features having been identified and digitized on multiple lines.
Possible Scattered Hardbottom	Rock outcrops that do not appear to be continuous or appear to be sparsely distributed throughout the digitized area. These features are digitized based on the interpretation of one sidescan line.
Secondary Unknown Feature	Bottom type is unclear and an accurate interpretation cannot be made. Generally these areas require groundtruthing to make an accurate interpretation. These features are digitized based on the interpretation of one sidescan line.
Edge of Data	Edge of the sidescan data.
Sand Wave	Features interpreted to be sand waves.
Sand Patch	Small sand areas within larger areas digitized as other features.
Wreck	Feature interpreted to be a wreck.

Vibracore Survey

Vibracores were collected to obtain continuous physical samples of the material within the potential sand resources. They are used to characterize the physical properties of the material and groundtruth the seismic data. Prior to collecting vibracores in State waters for this investigation, a vibracore *de minimus* exemption had to be obtained. A *de minimus* exemption is issued in lieu of a permit, when the proposed activity will have insignificant impacts. In order to do this, a Joint Environmental Resource Permit (ERP) application was submitted to the Florida Department of Environmental Protection (FDEP) Bureau of Beaches and Coastal Systems (BBCS) for review. This application required a general project description and a map outlining the area of investigation within which the proposed vibracoring would take place. The application was also forwarded to the Bureau of Survey and Mapping, Division of State Lands, the U.S. Army Corps of Engineers (USACE) and the Florida Division of Historical Resources (SHPO) for review and comment.

A *de minimus* exemption was granted by the BBCS on 1 May 2008 to collect up to seventy (70) vibracores offshore of Sand Key within the Pinellas County Aquatic Preserve as part of the 2008 geotechnical investigation at Sand Key (Appendix 3). A second d*e minimus* exemption was granted by BBCS on July 22, 2009 to collect up to sixty (60) vibracores from proposed borrow areas as part of the 2009 geotechnical investigation at Sand Key (Appendix 3). A condition of both *de minimus* exemptions required that a joint seismic, sidescan sonar, magnetometer and bathymetric investigation be conducted prior to vibracoring. As a condition of the *de minimus* exemption, this data must be reviewed by a qualified marine archaeologist. Vibracores must be collected within 50 ft. of the as-run survey lines and avoid magnetic anomalies identified during the geophysical investigation. A 200-ft. radius avoidance buffer was established around all magnetic anomalies regardless of potential significance.

For areas located in Federal waters, prior to conducting geotechnical and geophysical surveys, CPE was required to apply for a permit for Geophysical Prospecting for Mineral Resources or Scientific Research on the Outer Continental Shelf Related to Minerals Other than Oil, Gas, and Sulphur and a permit for Geological Prospecting for Mineral Resources or Scientific Research on the Outer Continental Shelf Related to Minerals Other than Oil, Gas, and Sulphur. Geophysical and geological permits were granted by the Minerals Management Service (MMS) (Appendix 3). The geological permit required the avoidance of two (2) magnetic targets that could be significant archaeological resources by a minimum 200 ft. radius buffer.

In 2008, a total of forty (40) vibracores were collected by Alpine Ocean Seismic Survey for Challenge Engineering & Testing, Inc. using a 271B Alpine Pneumatic Vibracore configured to collect undisturbed sediment cores up to 20 ft. in length (Figure 11a). If core penetration ceased at a depth of less than 15 ft., the sampled portion was removed from the pipe, a new liner inserted, and a jet pump hose was attached just below the vibracore head. The rig was, again, lowered to the bottom and jetted into the sediment just above refusal depth. The jet was then turned off and the vibrator resumed collecting the lower part of the core.

In 2009, vibracores were collected by CPE using a diver-operated vibracore system, configured to collect undisturbed sediment cores up to 20 ft. in length (Figure 11b). The diver operated vibracore system employed scientific divers and a pneumatic vibracore system. The BH-4 style vibrator apparatus is a single piston, pneumatically driven vibrator that is retrofitted to a 3-inch galvanized steel pipe. An air hose array provides compressed air from a compressor on the deck of the support vessel.

a)

b)

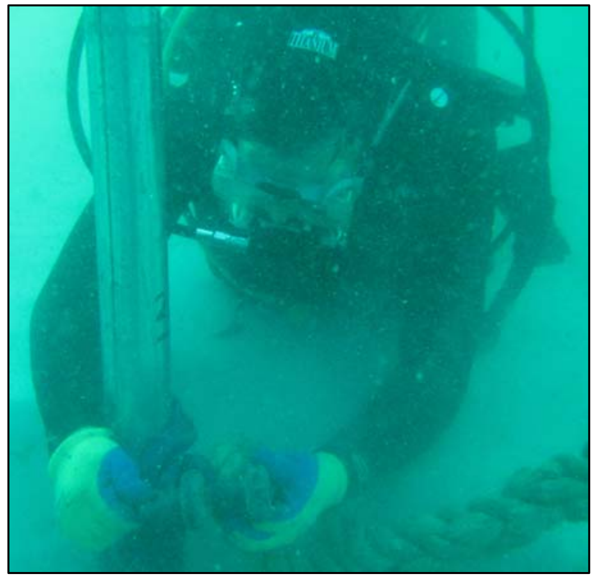


Figure 11. a) Deployment of the 271B Alpine Pneumatic vibracore off the RV *Atlantic Twin* during the 2008 geotechnical investigation. b) The BH-4 vibracore apparatus being deployed during the 2009 geotechnical investigation.

Upon removal of the vibracores, they were measured, marked and cut into 5-ft. sections. The cores were then labeled, and transported to CPE's office in Boca Raton, Florida. There, the vibracores were split and logged by describing sedimentary properties by layer in terms of layer thickness, color, texture (grain size), composition and presence of clay, silt, gravel, or shell and any other identifying features (Figure 12). Wet Munsell color was determined in accordance with American Society for Testing and Materials Standard Materials Designation D2488-00 for description and identification of soils (visual-manual procedure) (ASTM, 2009). The vibracores were digitally photographed against an 18% gray background. This is the standard reference value against which all camera light meters are calibrated. Use of an 18% gray background is preferred by the FDEP as it provides a known reference color. Sediment samples were obtained from irregular intervals based on distinct layers in the sediment sequence. The unsampled half of each core was then archived.

Figure 12. Vibracore logging, sub-sample collection and Munsell color determination being conducted at CPE's office in Boca Raton, Florida.

Sediment Grain Size (Mechanical) Analysis. During sieve analysis, the visually estimated percentage of shell on the #5 and #7 sieves was noted. Dry Munsell color was also noted. Sieve analyses were conducted on all sediment samples in accordance with American Society for Testing and Materials Standard Materials Designation D422-63 for particle size analysis of soils (ASTM, 2007). This method covered the quantitative determination of the distribution of sand size particles. For sediment finer than the No. 230 sieve (4.0 phi) the ASTM Standard Test Method, Designation D1140-00 was followed (ASTM, 2006). Mechanical sieving was accomplished using calibrated sieves with a gradation of half phi intervals. Additional sieves representing key ASTM sediment classification boundaries were included to meet Florida Department of Environmental Protection (FDEP) standards. Weights retained on each sieve were recorded cumulatively. Grain size analysis determination for samples extracted from the 2008 vibracores was conducted by contractors for the Jacksonville USACE. Grain size analysis was conducted by CPE for vibracore samples extracted from the 2009 vibracores.

Grain size data were entered into the gINT® software program, which computes the mean and median grain size, sorting, and silt/clay percentages for each sample using the moment method (Folk, 1974). Granularmetric reports and grain size distribution curves were compiled for each sample.

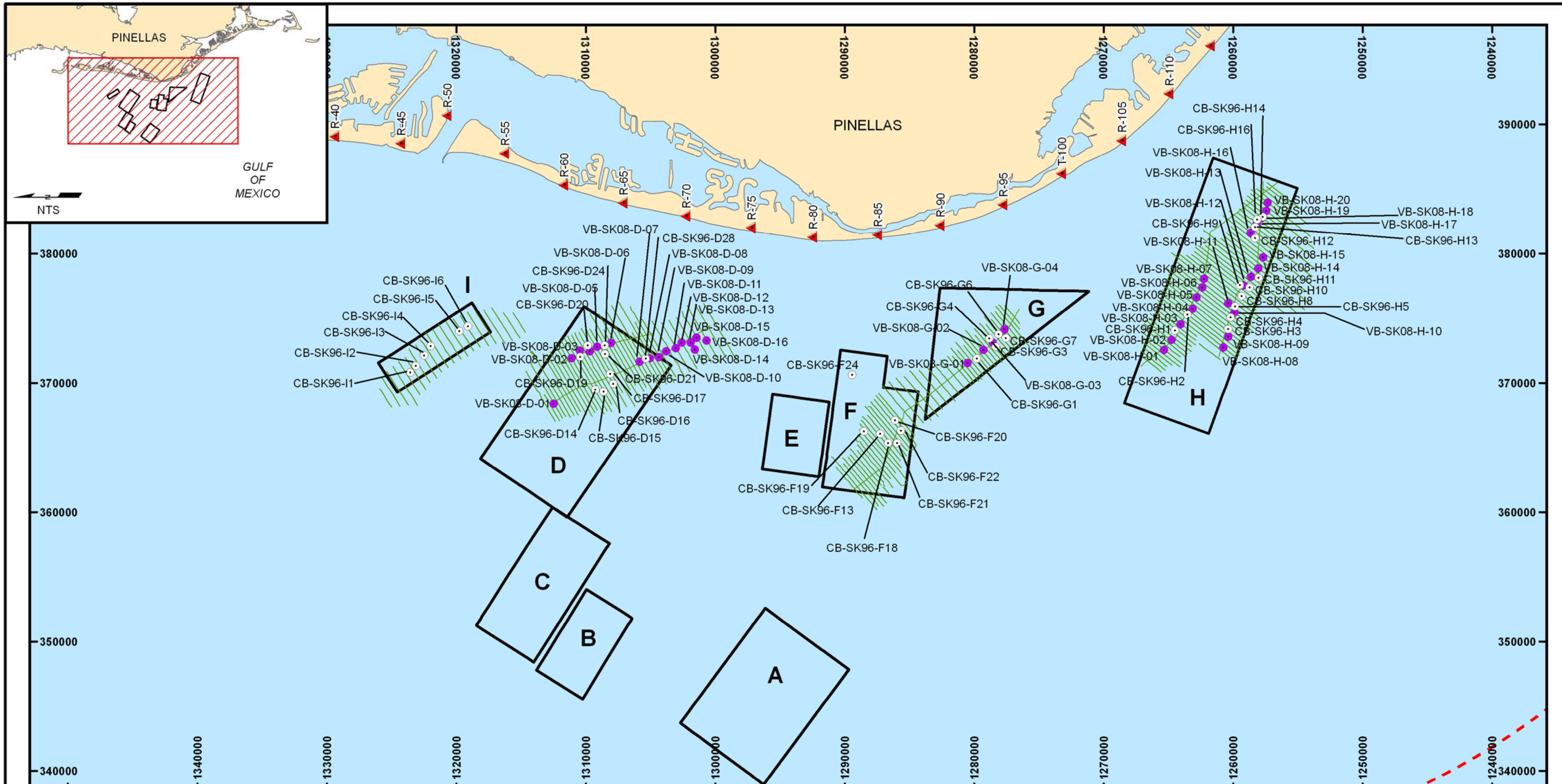
Carbonate Content Determination. Carbonate content determination for samples extracted from the 2008 vibracores was conducted by contractors for the Jacksonville USACE. Carbonate content was determined by percent weight on one hundred and eighty samples (180) using the acid leaching methodology described in Twenhofel and Tyler (1941). Carbonate content was also determined by CPE on sixty-eight (68) samples extracted from the 2009 vibracores using the same methodology. Results were entered into the gINT® software and are displayed on the granularmetric reports.

Investigation Details

In 2008, Pinellas County, together with the St. Louis and Jacksonville Districts of the USACE, authorized CPE to conduct a Phase III design level sand search investigation to identify at least three (3) areas spaced along Sand Key that would best serve the County and the USACE in the next renourishment of Sand Key. The County directed CPE to collect geophysical data from areas at the north (USACE Study Areas I and D), central (USACE Study Areas F and G) and south (USACE Study Area H) parts of the key. A joint seismic reflection profiling, sidescan sonar, bathymetric and magnetometer survey was conducted within these areas (Figure 13). Reconnaissance-level data was initially collected across the five (5) study areas. The survey plan was modified during the reconnaissance survey and design level data was subsequently collected within the most promising areas. Design-level data was not collected from Area I, as based on the reconnaissance data, it was determined that this area was the least promising. The geophysical data was used to develop the design phase vibracore operation. The vibracores collected by Ardaman and Associates in 1996 were incorporated into the vibracore plan to obtain the required 1,000 ft. maximum spacing. A re-analysis of the 1996 Ardaman and Associate cores was undertaken by CPE (Appendix 4).When the depth of the cores was plotted against the CPE 2008 bathymetric the difference in depth varies from +2.5 to -2.4 feet. CPE's Professional Surveyor and Mapper contacted Ardaman and Associates to discuss the control and bathymetric survey methods used for the 1996 cores. No resolution was determined from the conversation. The analysis and borrow area design using these cores are subject to error.

Vibracores were subsequently collected from the areas most likely to contain the greatest volume of beach quality material (Study Areas D and H). Although Area G was not expected to contain significant volumes of beach compatible material, it is centrally located to the project area and therefore a promising target. Pinellas County directed CPE to investigate Area G in the hopes of finding additional beach compatible material. These cores were collected by Challenge Engineering & Testing, Inc. Vibracore locations are shown in Figure 13. CPE's investigations did not include a cultural resource investigation during this phase because the borrow areas developed by the USACE had already been cleared by an earlier cultural resource investigation conducted by the Jacksonville District USACE. Any resources developed outside of these study areas would, however, require a cultural resource investigation.

Based on these investigations, Study Areas D and H were expected to contain beach quality material. However, initial volume estimates confirmed the results of the constructability analysis, which indicated that these areas would not contain a sufficient volume of material to support the next renourishment of Sand Key. No additional material was identified within Area G. In response, CPE was contracted by Pinellas County to conduct Phase II and III investigations to identify additional material. Pinellas County directed CPE to conduct a reconnaissance geophysical survey within Study Areas A, B and C, despite the low probability of identifying additional material. Due to the low probability of identifying additional material in these areas, several prominent sand ridges in the vicinity of the USACE Study Areas were also investigated. In July, 2009, a concurrent magnetometer, seismic reflection profiling, sidescan sonar and bathymetric survey was conducted off the R.V. *AquaQuest.* A total of 101 nautical line miles of Phase II reconnaissance geophysical data were collected. In July, 2009, twelve (12) vibracores were collected from locations selected based on the results of the reconnaissance geophysical survey. Figure 14 shows the location of the Phase II geophysical tracklines and vibracores. The geophysical data, coupled with analysis of the vibracores was used to determine sediment quality and to ascertain the presence of material unsuitable for dredging. Three (3) new sand resource areas, designated Areas J, K and L, were identified during the Phase II investigation. These three (3) areas were presented to Pinellas County and the FDEP BBCS. Both parties expressed a preference for developing areas J and L. Since these three (3) areas, as well as an area adjacent to Study Area D (previously investigated in 2008), lie outside of the USACE study areas, borrow area development would require cultural resource investigation. Pinellas County therefore authorized CPE to conduct a joint Phase III design-level investigation for Areas J and L and cultural resource investigation of Areas J, L, and adjacent to Area D to expedite the borrow-area design process.



NOTES

1) COORDINATES ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, WEST ZONE NORTH AMERICAN DATUM OF 1983 (NAD 83)

LEGEND:

- FDEP RANGE MONUMENTS
- 1996 ARDAMAN AND ASSOCIATES VIBRACORES
- 2008 CHALLENGE ENGINEERING & TESTING INC. VIBRACORES
- 2008 CPE GEOPHYSICAL TRACKLINES
- FEDERAL STATE BOUNDARY
- USACE STUDY AREAS

0 4,000 8,000 Feet

1 inch = 8,000 feet

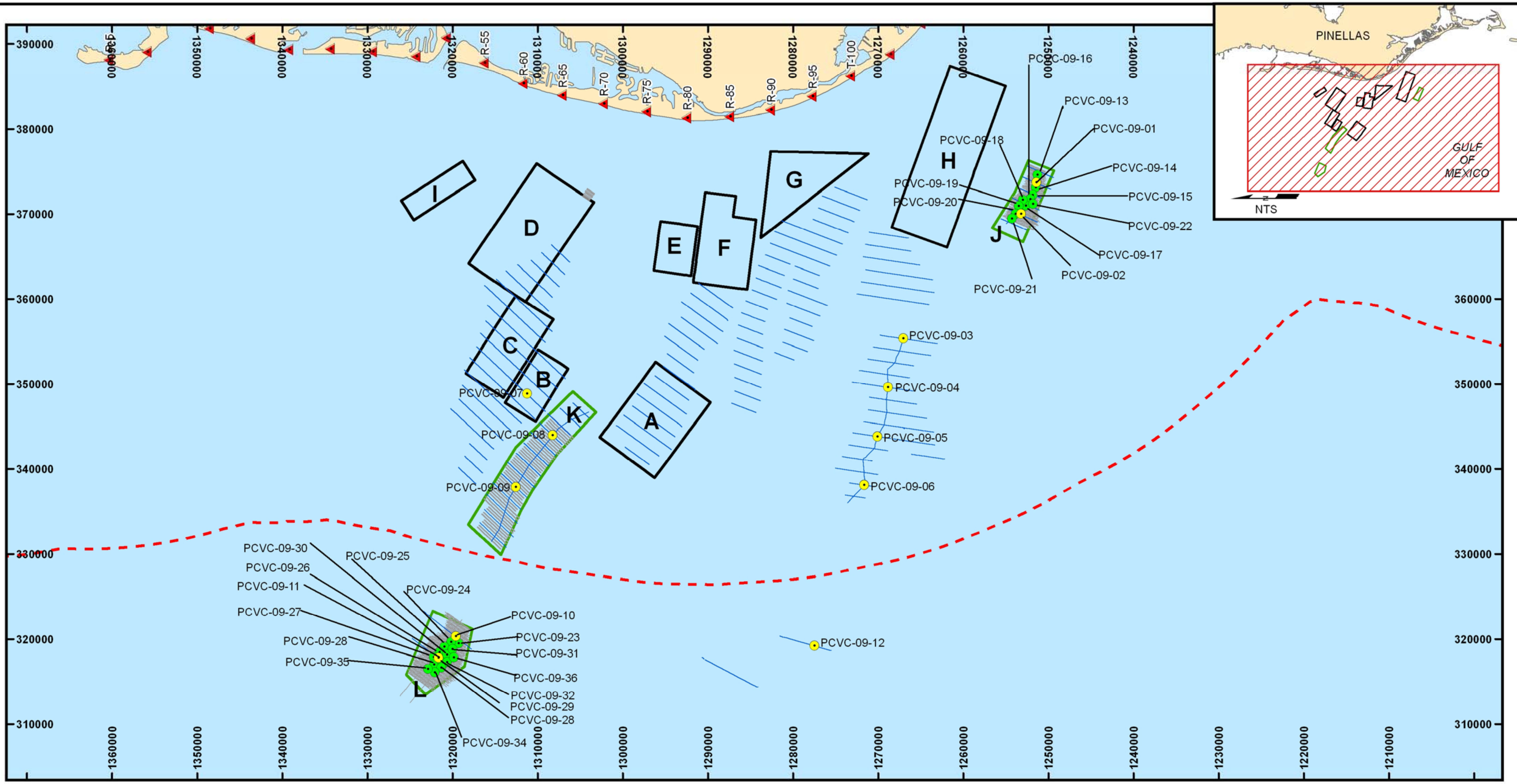
N

TITLE:

FIGURE 13. LOCATION OF GEOPHYSICAL AND GEOTECHNICAL DATA COLLECTED DURING THE 2008 INVESTIGATIONS.

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 11/24/09	BY: BF	COMM NO: 1000030	FIGURE 13



NOTES

1) COORDINATES ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, WEST ZONE NORTH AMERICAN DATUM OF 1983 (NAD 83)

LEGEND:

- 2009 CPE RECONNAISSANCE VIBRACORES
- 2009 CPE DESIGN LEVEL VIBRACORES
- 2009 CPE RECONNAISSANCE GEOPHYSICAL TRACKLINES
- 2009 CPE DESIGN LEVEL/CULTURAL RESOURCE GEOPHYSICAL TRACKLINES
- FEDERAL STATE BOUNDARY
- FDEP RANGE MONUMENTS
- 2009 ADDITIONAL STUDY AREAS
- USACE STUDY AREAS

0 6,000 12,000 Feet

1 inch = 12,000 feet

TITLE:

FIGURE 14. LOCATION OF 2009 RECONNAISSANCE AND DESIGN LEVEL/CULTURAL RESOURCE TRACKLINES AND VIBRACORES.

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 12/02/09	BY: BF	COMM NO: 1000030	FIGURE 14

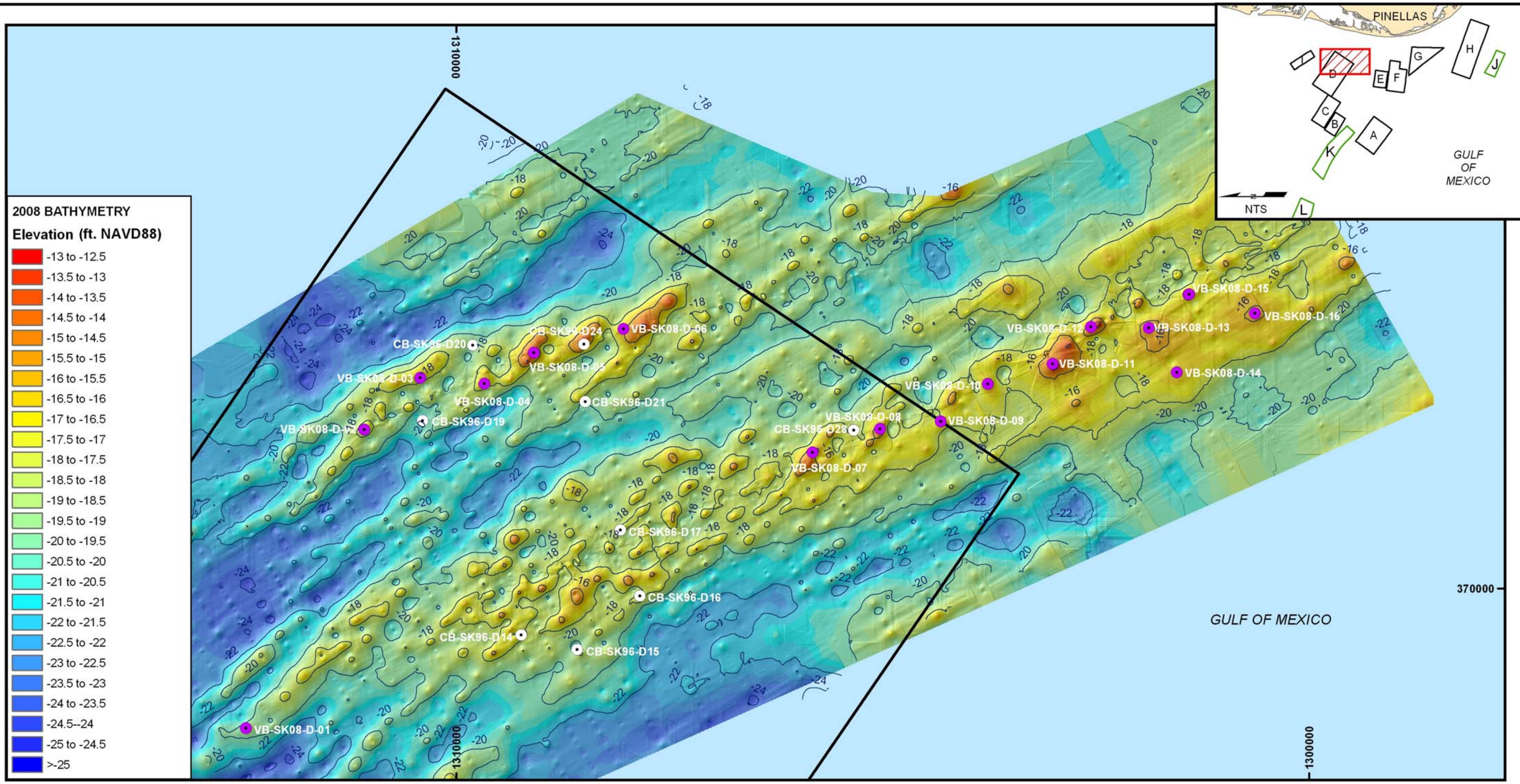
In September 2009, a joint design level and cultural resource investigation was conducted. Design-level geophysical data was collected from Study Areas J, K and L (Figure 14). Cultural resource investigations were conducted in areas J and L and a small area outside of Study Area D. While both Study Areas L and K appeared to have similar white sand deposits, Pinellas County directed CPE to focus the cultural resource level investigation on Area L which is a more promising sand source because the deposit is much wider (approximately 3500 ft.) and thicker than Area K. Design level investigations were previously conducted in USACE Study Area D in 2008 (Finkl *et al.*, 2009). Because this area extends outside of the USACE study area, which was previously cleared for cultural resources, the portion that extends beyond the original study area required a cultural resource investigation, which was conducted in conjunction with the Area J and L cultural resource survey. When combined with the previously collected geophysical data, a total line spacing of 30 m. (approximately 100 ft.) was achieved. The joint seismic reflection profiling, sidescan sonar and magnetometer survey was used to identify potential cultural resources such as artifacts, underwater wrecks, submerged hazards, significant relict landforms or any other features including modern debris that would affect borrow area delineation and dredging activities. A qualified marine archaeologist was onboard at all times during the joint geophysical and cultural resource investigation. Based on the results of the cultural resource investigation, the marine archaeologist recommended the avoidance of several potentially significant magnetic anomalies by the creation of an avoidance buffer zone around each (Appendix 10) (TAR, 2009a; TAR, 2009b).

The geophysical data that was collected was used to map the elevation of marginal to poor quality sediment (*i.e*. silt, clay, rock). The results of the joint design-level and cultural resource geophysical investigation were used to plan vibracore locations for the design-level geotechnical investigation. A 200 ft. radius buffer placed around all magnetic anomalies, regardless of potential significance, was incorporated into the vibracore survey plan. In October, 2009, twenty-four (24) vibracores were collected from areas J and L to meet the maximum 1,000 ft. industry standard spacing guidelines for permitting. Figure 14 shows the location of the vibracores.

Results and Discussion

The results of the geophysical and geotechnical investigations that were conducted in 2008 and 2009 are discussed below. Based on the data that was collected during these investigations, preliminary borrow area boundaries and excavation elevations were developed within Study Areas D, H, J and L.

Following the 2008 geophysical investigations, bathymetric maps of USACE Study Areas D, F, G and H were created (Figures 15, 16 and 17). These maps show the locations of the sand ridges as topographic highs on the seafloor. The ridges range in width from approximately 2,000 ft. in area D to approximately 600 ft. in area H.



NOTES

1) COORDINATES ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, WEST ZONE NORTH AMERICAN DATUM OF 1983 (NAD 83)
2) GRIDDED BATHYMETRIC DATA BASED ON GEOPHYSICAL DATA COLLECTED BY CPE IN 2008

LEGEND:

- 1996 ARDAMAN AND ASSOCIATES VIBRACORES
- 2008 CHALLENGE ENGINEERING & TESTING VIBRACORES
- BATHYMETRY (2FT NAVD88 CONTOUR INTERVAL)
- USACE STUDY AREAS

0 600 1,200
Feet

1 inch = 1,200 feet

N

TITLE:

FIGURE 15. BATHYMETRIC MAP OF STUDY AREA D.

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2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
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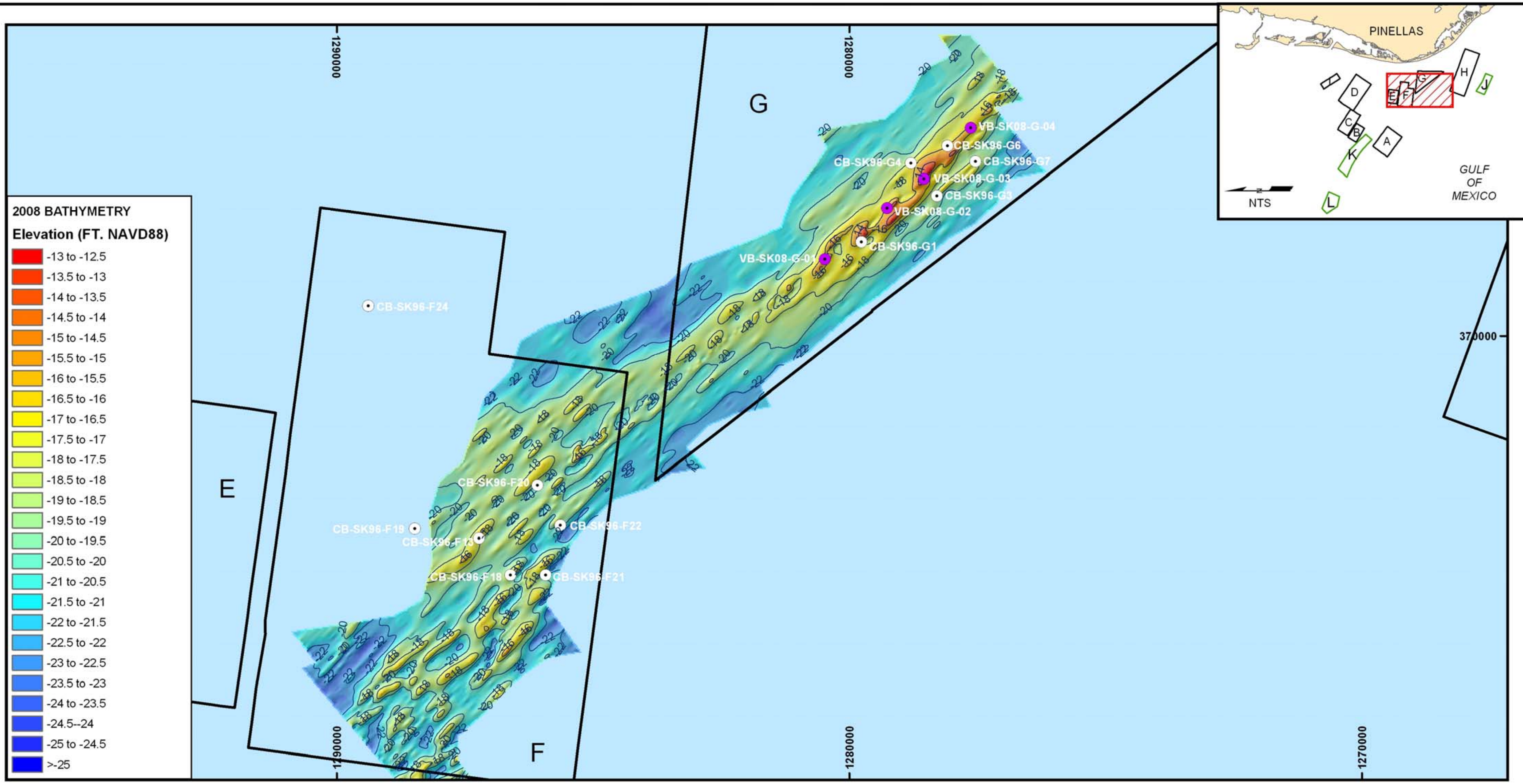
FAX.(561) 391-9116

DATE: 11/12/09	BY: BF	COMM NO: 1000030	FIGURE 15



NOTES

1) COORDINATES ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, WEST ZONE NORTH AMERICAN DATUM OF 1983 (NAD 83)
2) GRIDDED BATHYMETRIC DATA BASED ON GEOPHYSICAL DATA COLLECTED BY CPE IN 2008

LEGEND:

- 1996 ARDAMAN AND ASSOCIATES VIBRACORES
- 2008 CHALLENGE ENGINEERING & TESTING VIBRACORES
- BATHYMETRY (2FT NAVD88 CONTOUR INTERVAL)
- USACE STUDY AREAS

0 1,000 2,000 Feet

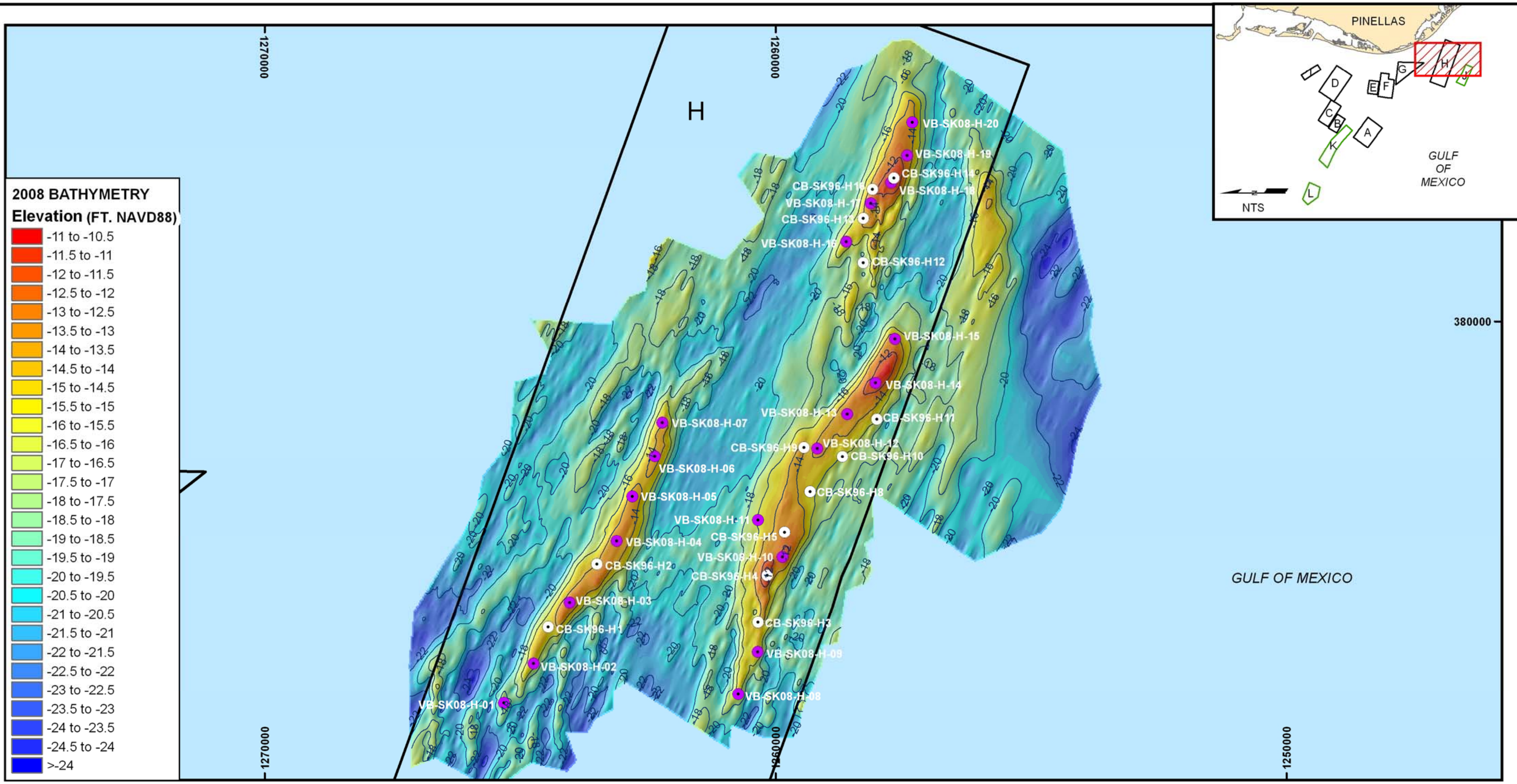
1 inch = 2,000 feet

TITLE:

FIGURE 16. BATHYMETRIC MAP OF USACE STUDY AREA F/G.

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 11/12/09	BY: BF	COMM NO: 1000030	FIGURE 16



NOTES

1) COORDINATES ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, WEST ZONE NORTH AMERICAN DATUM OF 1983 (NAD 83)
2) GRIDDED BATHYMETRIC DATA BASED ON GEOPHYSICAL DATA COLLECTED BY CPE IN 2008

LEGEND:

- 1996 ARDAMAN AND ASSOCIATES VIBRACORES
- 2008 CHALLENGE ENGINEERING & TESTING VIBRACORES
- BATHYMETRY (2FT NAVD88 CONTOUR INTERVAL)
- USACE STUDY AREAS

0 1,000 2,000 Feet

1 inch = 2,000 feet

TITLE:

FIGURE 17. BATHYMETRIC MAP OF STUDY AREA H.

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 11/12/09	BY: BF	COMM NO: 1000030	FIGURE 17

In 2008, vibracores were collected to target the crests of the sand ridges in areas D, G and H. Appendices 4 and 5 contain vibracore logs and photographs. The granularmetric reports and grain size curves/histograms of samples collected from these cores are presented in Appendices 6 and 7, respectively. Generally, the upper 4 ft. or so of sediment in Study Area D, the upper 3 ft. or so of sediment in Study Area G and the upper 6 ft. of sediment or so in Study Area H is fine-grained sand, with trace silt and varying amounts of shell. This material is typically classified as SP (poorly graded sand with little or no fines) or SW (well graded sand with little or no fines). Wet Munsell color is typically 5 or 6. The thickness of this potentially beach compatible material is dependent on ridge morphology. The ridges are oriented obliquely to the coastline (run roughly northwest-southeast). Generally, sediment is thickest towards the center of the ridges and thinnest at the margins of the ridges. The potentially beach-compatible material is underlain by marginal material (i.e. material containing a high content of shell and/or silt) and poor material (i.e. material containing a high content of silt, clay, shell or rock). The poor material is typically gravelly or clayey.

CPE reviewed the 2008 vibracore logs for sediment quality. The logs were color coded according to quality, where green is the highest quality, yellow and orange are marginal quality and red is poor quality. Blue and purple represent the presence of clay and rock respectively. Table 3 lists the criteria for color coding the vibracores.

Table 3. *Vibracore color code scheme showing the range of sediment differentiation.*

Color Code	**Description**
Green	High Quality Material- SP, SW
Yellow	Marginal Quality Material- SP-SM, SW-SM, SM
Orange	Shelly Material
Red	Poor Quality Material- high silt, shell and rock (GW, GM, GW-GM)
Blue	High clay and rock (GC, CL)
Purple	Individual Rocks

The seismic data that was collected in 2008 was processed and the color-coded vibracore logs were plotted directly onto the data using the SonarWiz.MAP +SBP software program. Each vibracore was plotted on the line that fell closest to its location (Figure 18). The seismic data was then interpreted and digitized based on the correlated vibracore data. Upon the completion of interpretation and digitization, all of the seismic data was then exported as a "Web" based project of HTML/JPEG files viewable in any standard web browser software package (Appendix 8). Not all of the seismic lines were annotated in this way. If a core was not collected near a particular seismic line, then it was not annotated because there was no control for digitization.

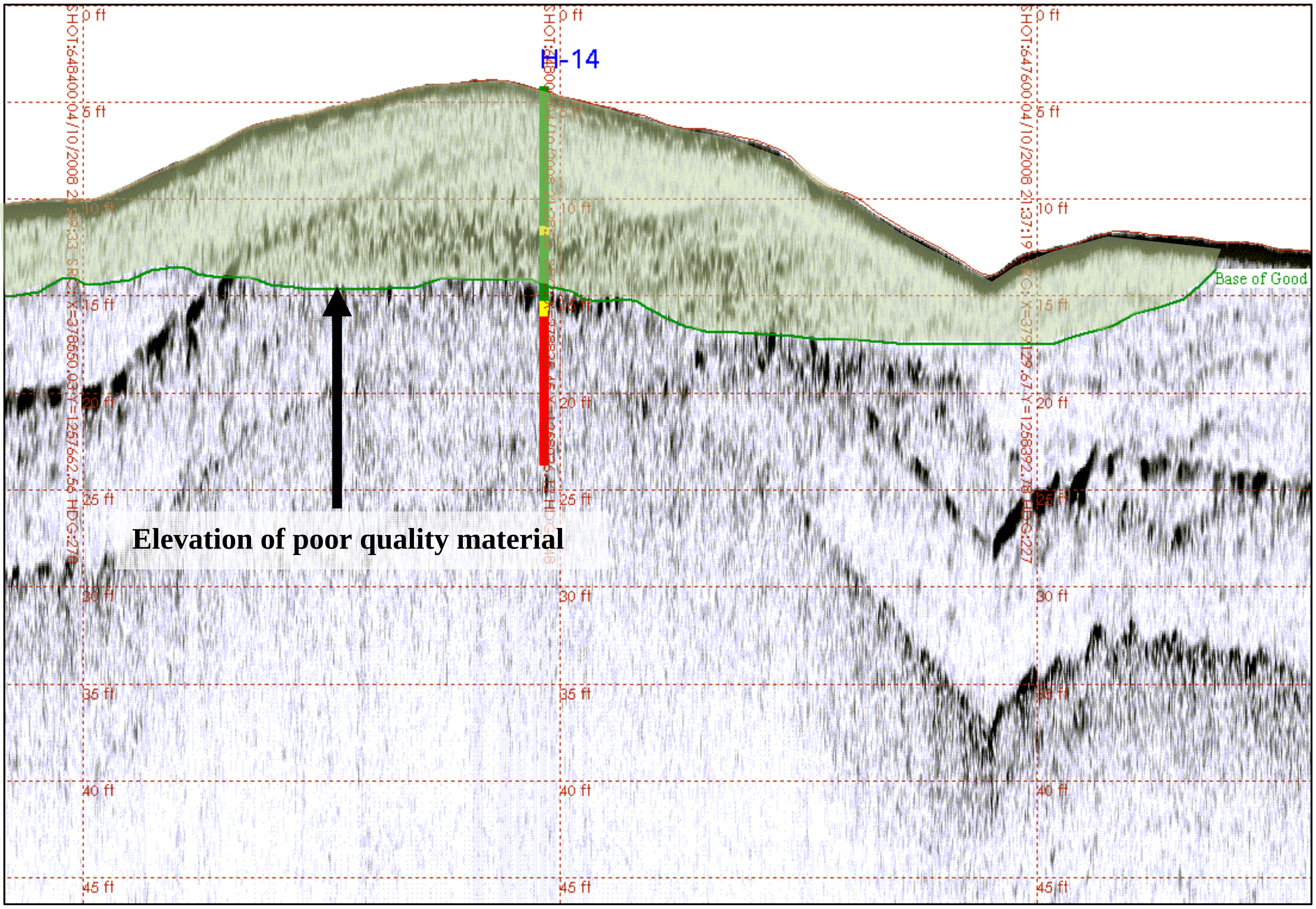
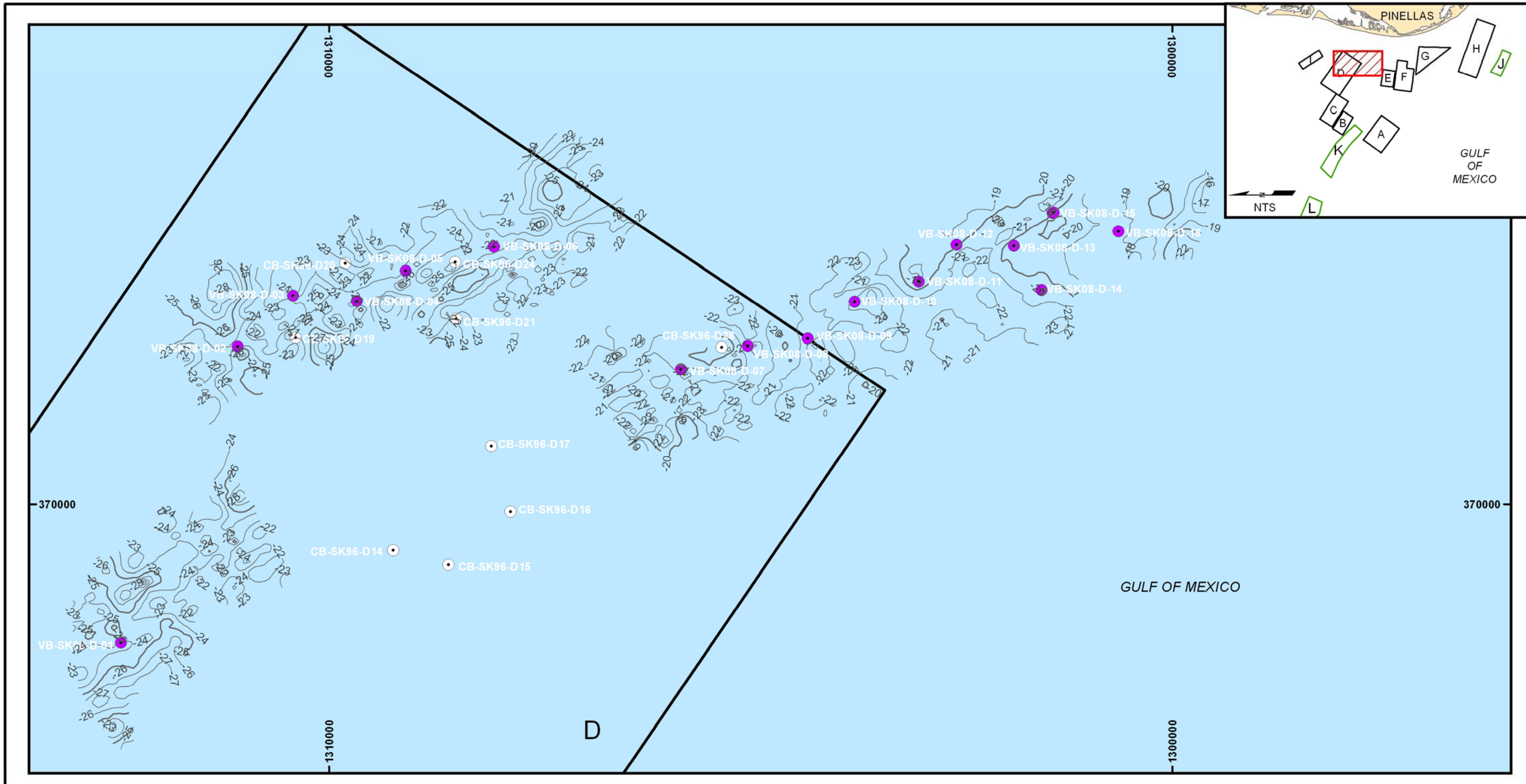


Figure 18. Correlation of geophysical and vibracore data to determine the thickness of sediments and to ascertain the presence of undesired rock and/or material unsuitable for dredging. Example shown is Line_189 from Area H.

Isopach maps were then created for Study Areas D, G and H (Figures 19, 20 and 21). These maps represent the thickness of potentially usable material above the poor material. Correlated seismic and vibracore data and resulting isopach maps, indicated that within Study Area D, sediment thickness ranges from approximately 3 ft. to 10 ft. and appears to be confined to the relatively narrow extent of the sand ridges. Within area G, sediment thickness is less than 5 ft. Within area H, sediment thickness ranges from less than 5 ft. to 10 ft., with the largest accumulation of sediment confined to the crests of the sand ridges.



NOTES

1) COORDINATES ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, WEST ZONE NORTH AMERICAN DATUM OF 1983 (NAD 83)

LEGEND:

FIRST REFLECTOR ELEVATION (FT NAVD88)

CONTOURS

INDEX CONTOURS

1997 ARDAMAN AND ASSOCIATES VIBRACORES

2008 CHALLENGE ENGINEERING & TESTING VIBRACORES

USACE STUDY AREAS

0 600 1,200 Feet

1 inch = 1,200 feet

N

TITLE:

FIGURE 19. ISOPACH MAP OF STUDY AREA D.

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 11/12/09 | BY: BF | COMM NO: 1000030 | FIGURE 19

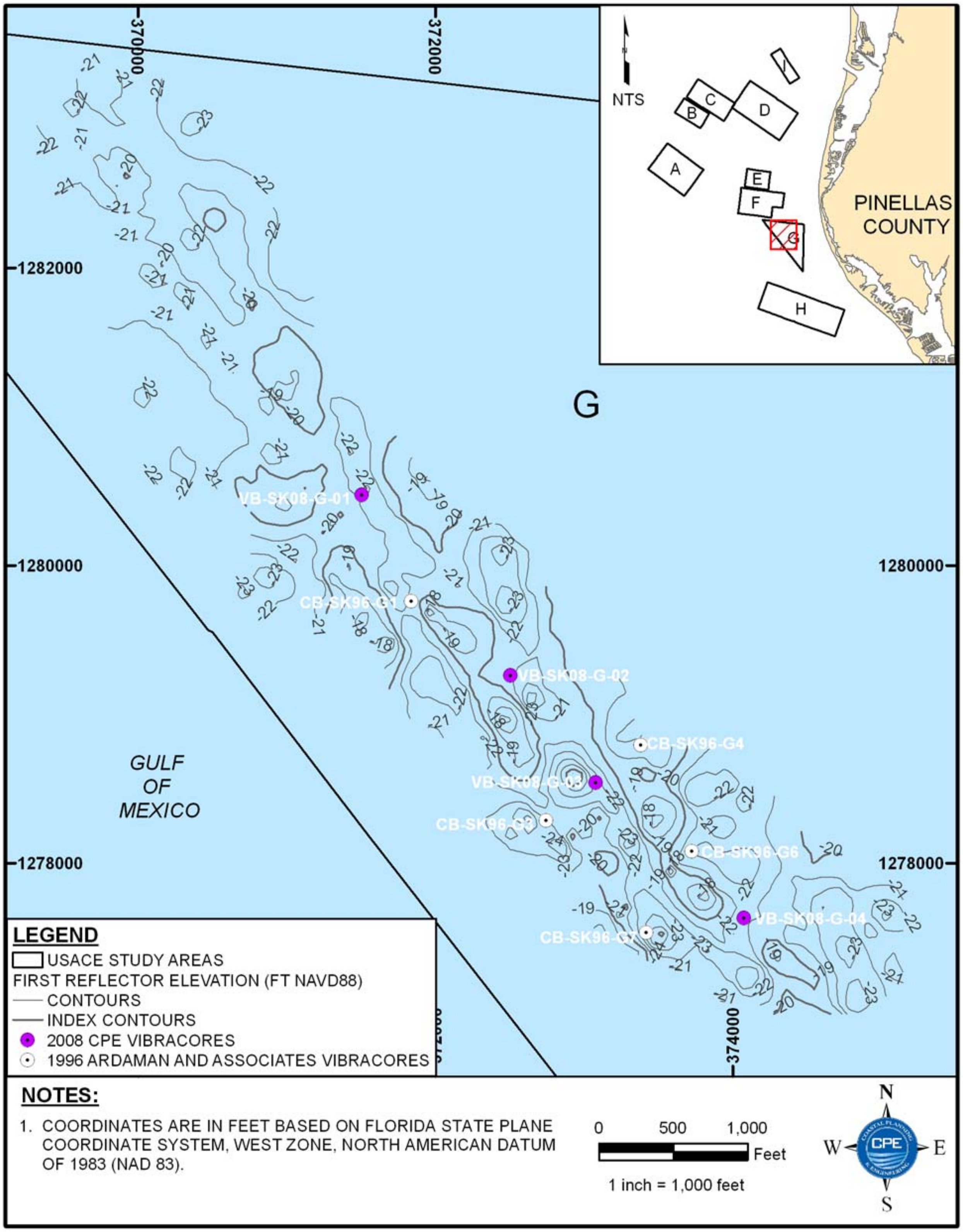


Figure 20. Isopach map developed for Study Area G.

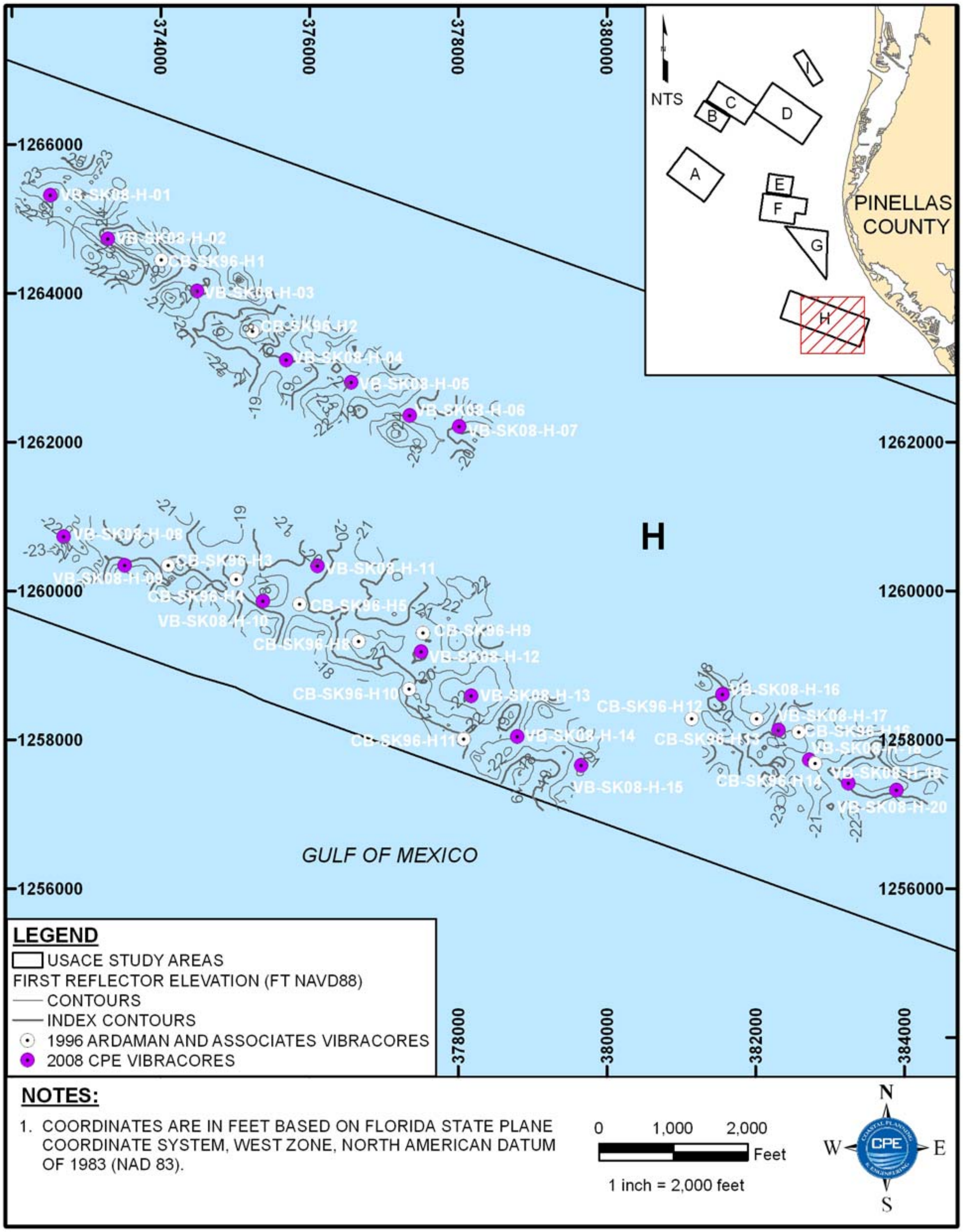


Figure 21. Isopach map developed for Study Area H.

The sidescan sonar data that was collected was analyzed to identify potential hardbottom. The sidescan sonar data was digitized (Appendix 9) based on the classification scheme listed in Table 2. The locations of the digitized bottom features are shown in Figures 22, 23 and 24. Hardbottom surrounds the sand ridges and limits the volume of sediment available. A series of transects and bounce dives were conducted to groundtruth any potential hardbottom falling within 600 ft. of the study areas. The results were presented and summarized in Craft and Ward (2009).

In addition to using the sidescan data to locate potential hardbottom, a potential shipwreck was identified at the southeastern edge of USACE Study Area F. Since this shipwreck was not charted during the previous cultural resource investigations conducted by the USACE, it is likely modern. No further activity is expected in the vicinity of this potential shipwreck because it falls within an area that did not prove to be a viable sand source.

This investigation confirmed that approximately 889,400 cy of potentially beach compatible material is located within areas D and H and that no significant volume of potentially beach compatible material is located within area G. This confirmed the results of the constructability analysis. The volume of potentially beach compatible material identified during this investigation was not sufficient for the next renourishment of Sand Key. This prompted new investigations to identify additional material.

In 2009, CPE conducted Phase II and III investigations to identify additional material. CPE was directed by Pinellas County to conduct a reconnaissance geophysical survey within Study Areas A, B and C, despite the low probability of identifying additional material. Due to the low probability of identifying additional material in these areas, several prominent sand ridges in the vicinity of the USACE Study Areas were also investigated. Upon review of the reconnaissance data, three (3) promising areas were identified (Areas J, K and L) (Figure 14). The FDEP BBCS and Pinellas County decided to focus subsequent investigation efforts on areas J and L. Additional remotely sensed data (*i.e.* seismic reflection profiles, sidescan sonar imagery and magnetometer surveys) and vibracores were collected during a Phase III investigation, which included a cultural resource investigation within areas J, L and the small area extending outside of USACE Study Area D.

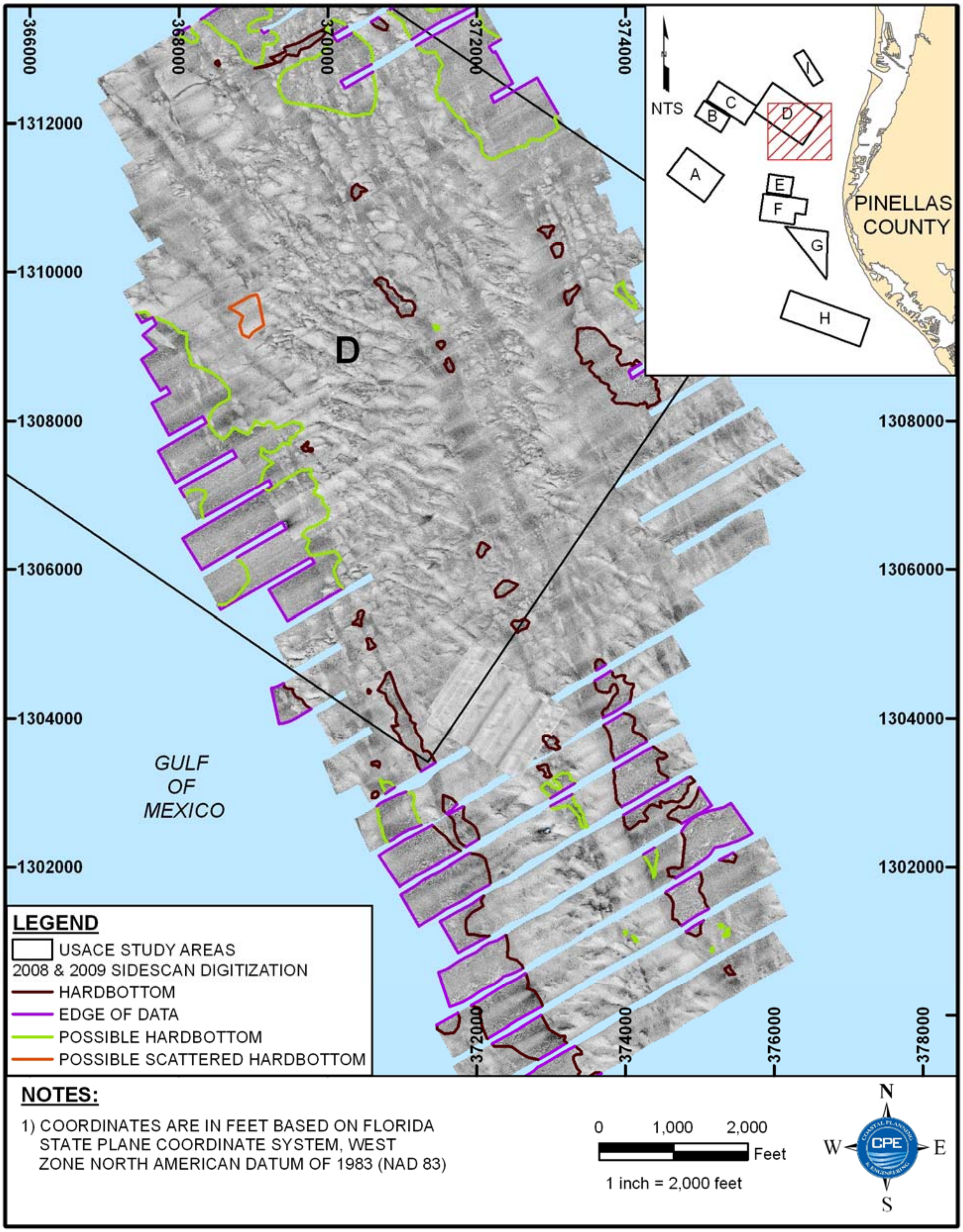


Figure 22. 2008 sidescan sonar mosaic and digitization for Study Area D.

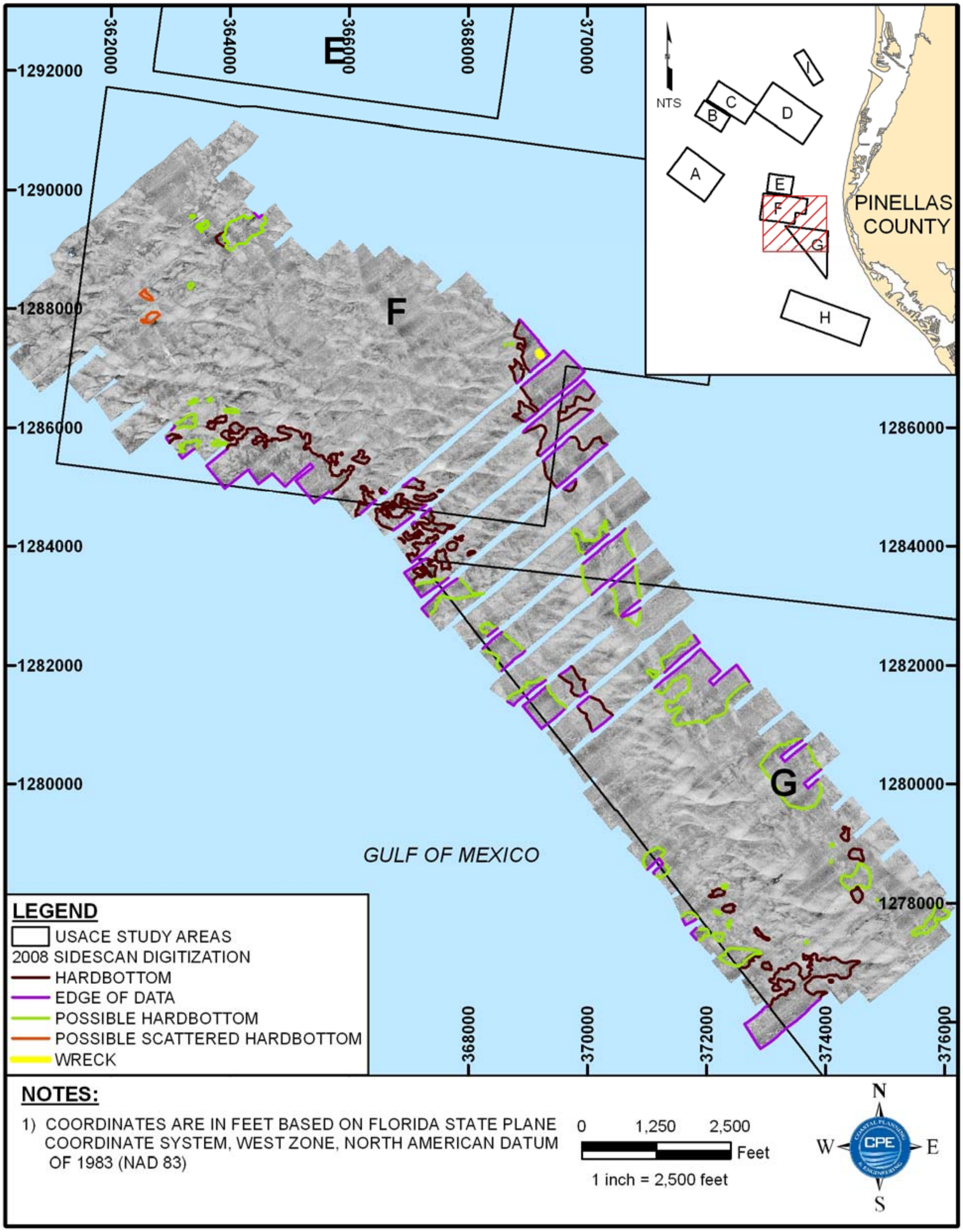


Figure 23. 2008 sidescan sonar mosaic and digitization for Study Areas F and G.

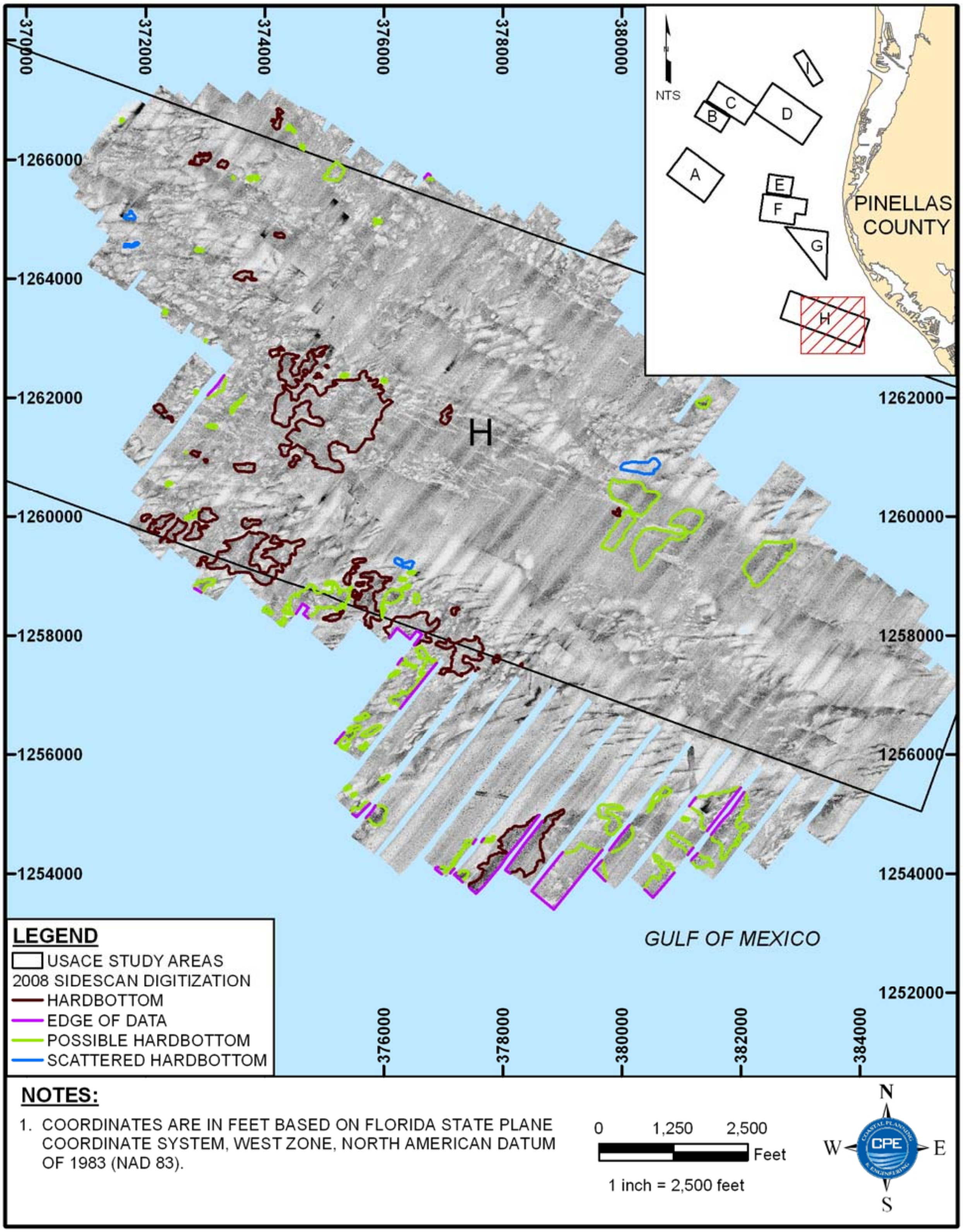


Figure 24. 2008 sidescan sonar mosaic and digitization for Study Area H.

Based on the geophysical data collected in 2009, bathymetric maps of USACE Study Areas J and L were created (Figures 25 and 26). These maps show the locations of the sand ridges as topographic highs on the seafloor.

Following the collection and analysis of the reconnaissance and design level geophysical (seismic reflection, bathymetry, sidescan sonar, magnetometer) data and the reconnaissance geotechnical data collected in 2009, a detailed plan to collect vibracores to target the most promising sand resources, while avoiding potential natural resources and magnetic anomalies, was developed. Appendices 4 and 5 contain vibracore logs and photographs. The granularmetric reports and grain size curves/histograms for the samples collected from the vibracores are presented in Appendices 6 and 7, respectively.

Vibracores collected within area J contained 4.6 to 7.2 ft. of fine-grained sand with trace silt, trace to some shell hash, trace whole shell and trace shell fragments. The wet Munsell color value of the sediment is ranges from 4 to 6 with a typical value of 5. The mean grain size ranges from 0.17 mm to 0.77 mm with the larger grain sizes being associated with sand layers with higher shell and/or shell hash contents. This sand is typically underlain by sand with rock fragments.

Vibracores collected within area L contained 4.5 to 10.8 ft of fine grained sand with trace silt, trace to little shell hash and trace shell fragments and whole shell. Generally the silt content increases with depth. The sand component is typically quartz, although three cores (PCVC-09-31, 33 and 36) contain carbonate as well as quartz from elevations of approximately -45 ft. to -53 ft NAVD88. Cores found in the eastern portion of the borrow area (PCVC-09-10, 23, 24, 25, 26, 27, 30 and 36) have shell hash layers varying from 0.3 ft thick to over 1 ft. thick at elevations ranging from -48.5 ft to -52.5 ft. NAVD88. Two cores (PCVC-09-23 and 32) have rock layers at their base at -52.1 ft and -52.8 ft. NAVD88. The remaining cores have isolated rock fragments at their bases at elevations of -52.4 ft to -54.2 ft. NAVD. Wet Munsell color values range from 3 to 8 with a typical value of 6. The darker values tend to be associated with clay rich or shell rich layers, often found towards the base of the cores. The mean grain size ranges from 0.14 mm to 1.17 mm, with the coarser grain sizes being associated with shell rich layers.

CPE reviewed the 2009 vibracore logs for sediment quality. The logs were color coded according to quality using the previously described criteria which are outlined in Table 3+. The seismic data that was collected was processed and the color-coded vibracore logs were then plotted directly onto the data (Figure 27). The seismic data was then interpreted and digitized based on the correlated vibracore data. Upon the completion of interpretation and digitization, all of the seismic data was then exported as a "Web" based project of HTML/JPEG files viewable in any standard web browser software package (Appendix 8). The geophysical data, coupled with analysis of the vibracores was used to determine the thickness of sediments and to identify the elevation of the basal rock unit.

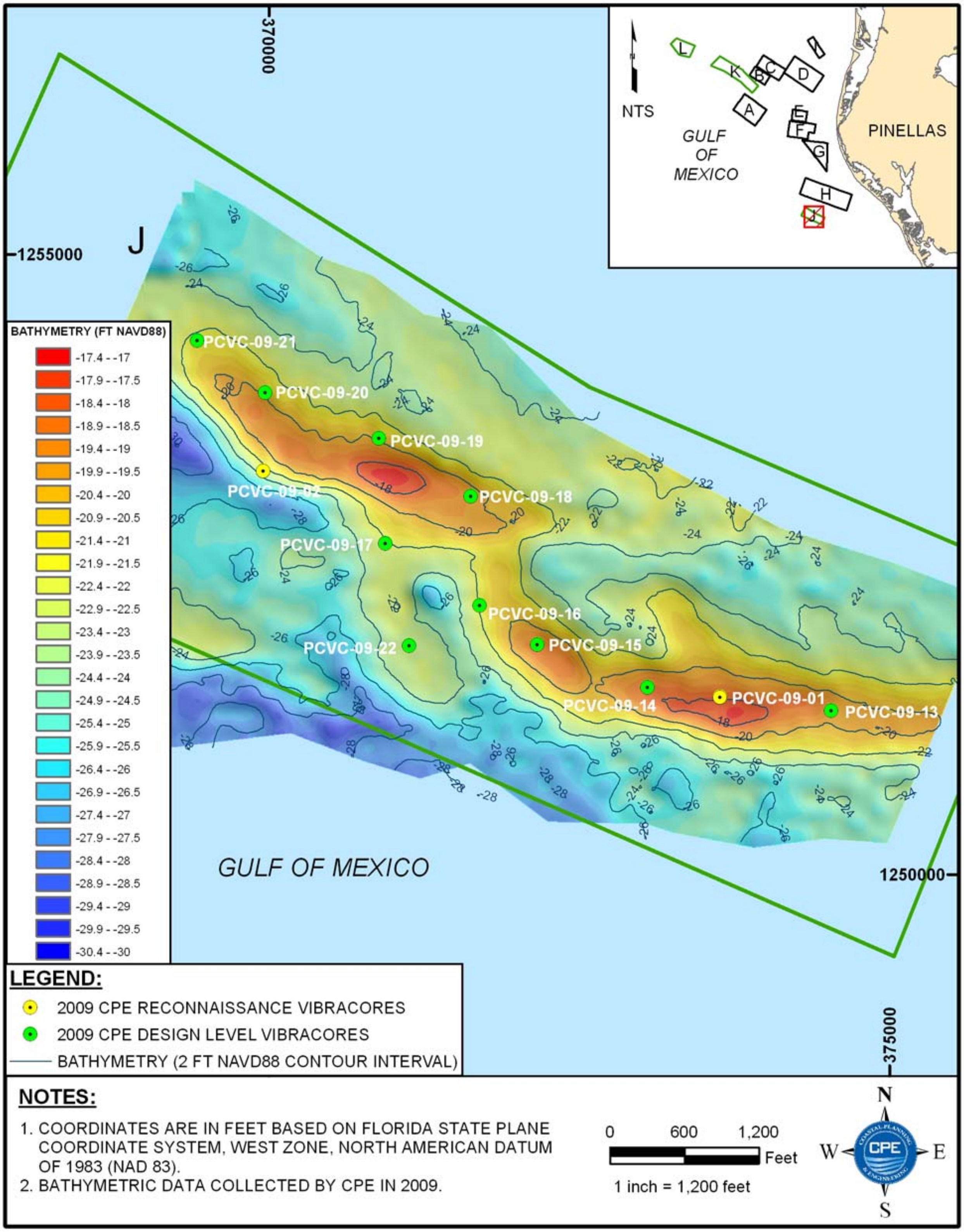


Figure 25. Bathymetric map created for Area J.

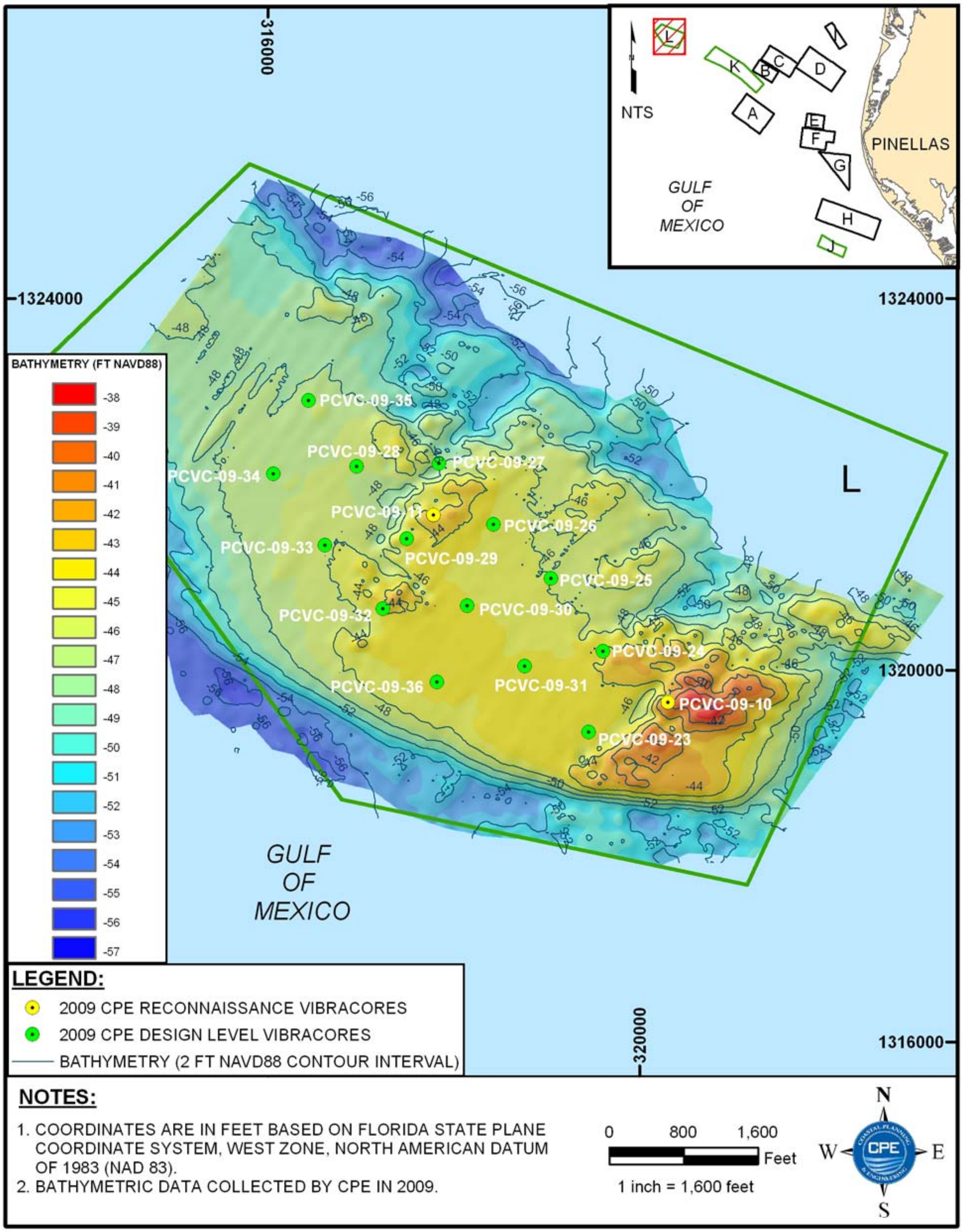


Figure 26. Bathymetric map created for Area L.

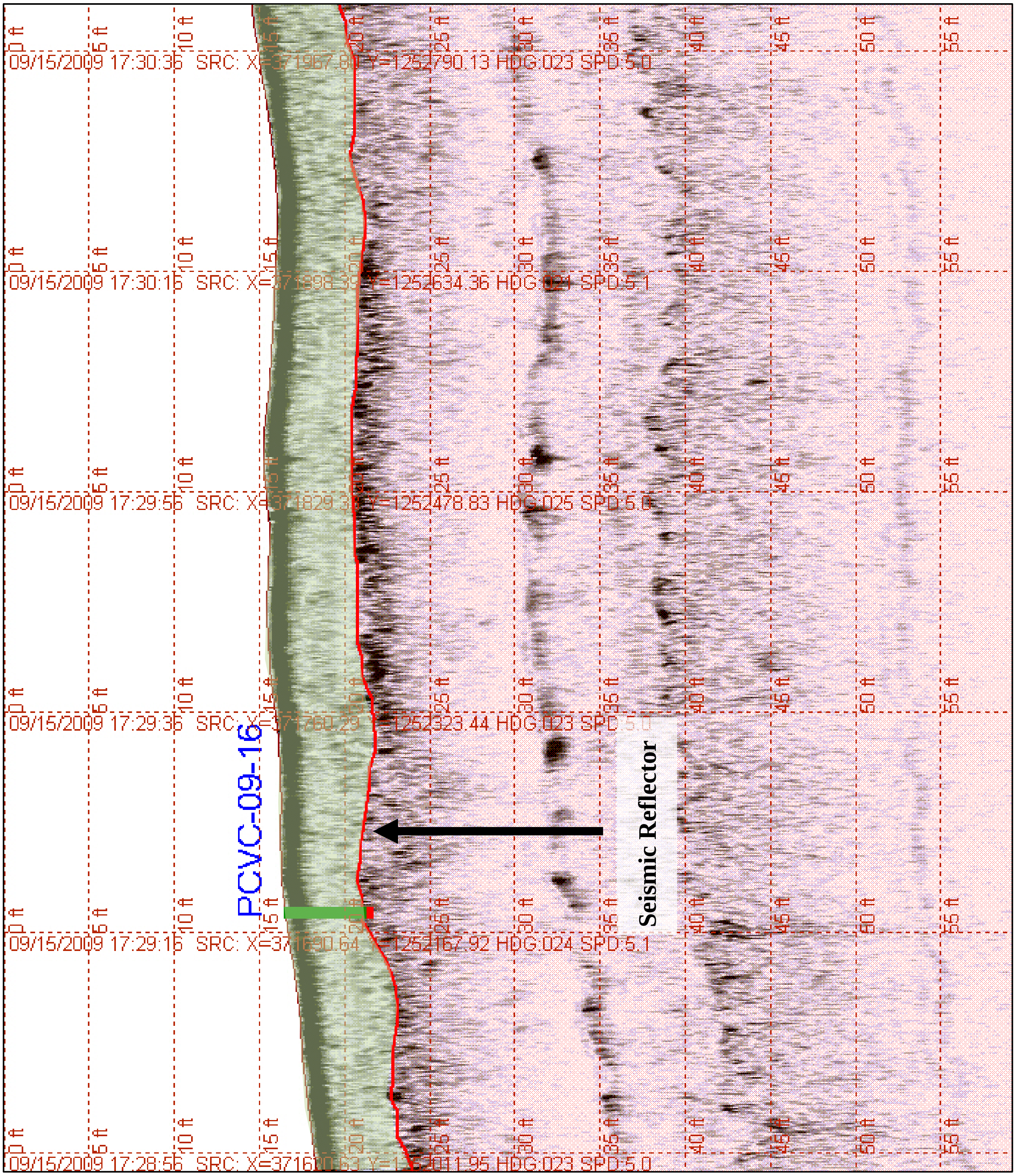


Figure 27. Correlation of geophysical and vibracore data to determine the thickness of sediments and to ascertain the presence of undesired rock and/or material unsuitable for dredging. The seismic reflector represents the elevation of marginal to poor quality material. Example shown is Line_036.

Based on analysis of the color coded vibracore logs and the seismic htmls, the top elevation of marginal to poor material (*i.e.* typically where the cores transition from a green to yellow or red color coding) was mapped for areas J and L. Contours indicating the top elevation of rock in the investigation areas are shown in Figures 28 and 29.

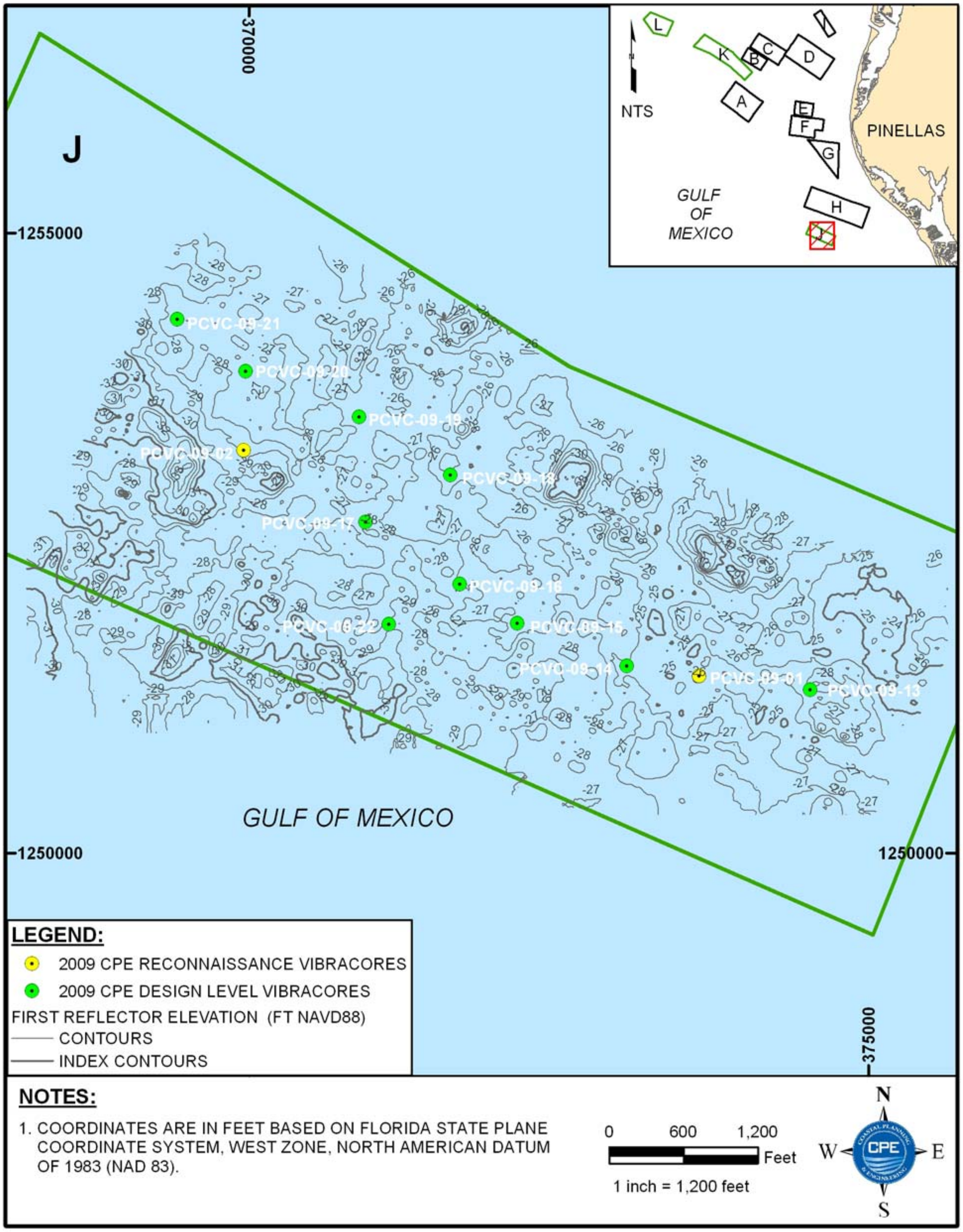


Figure 28. Area J showing the top elevation of marginal to poor quality material and vibracore locations.

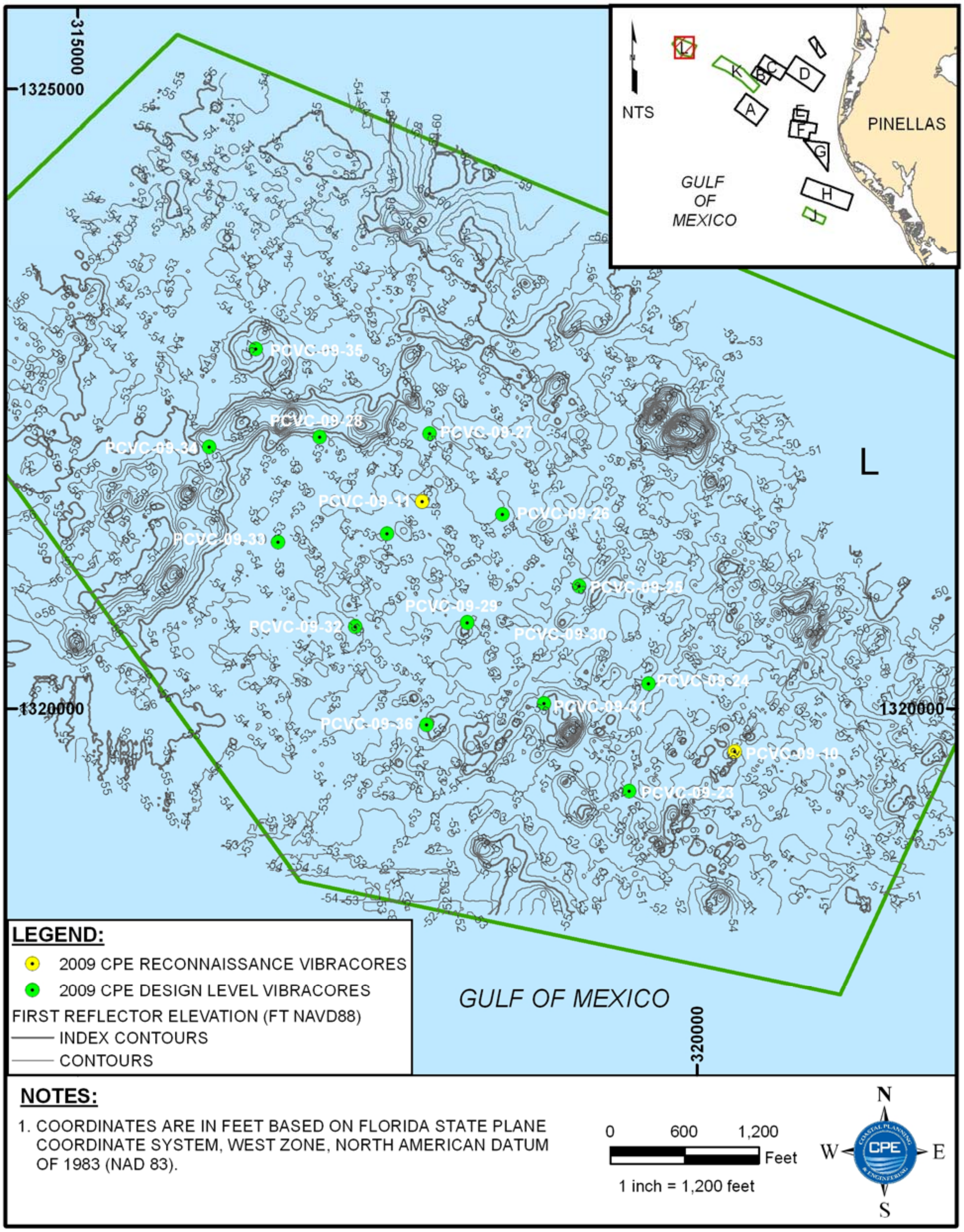


Figure 29. Area L showing the top elevation of marginal to poor quality material and vibracore locations.

The sidescan sonar data that was collected was reviewed and used to identify potential natural resources and potentially significant cultural resources. Based on the sidescan imagery, the locations of hardbottom, possible hardbottom, sand patches and sand waves were digitized. Areas labeled “Secondary Unknown Feature” were not clear enough to make a determination of the features they represent. These areas were avoided. The extent of the sidescan sonar coverage of areas J and L as well as the digitized features are shown in Figures 30 and 31, respectively. Mosaics showing greater detail are provided in Appendix 9.

To determine the projects affects on potentially significant submerged cultural resources, Tidewater Atlantic Research, Inc. (TAR) carried out a background literature review and supervised a cultural resource investigation of the proposed borrow areas (D, J, L). The cultural resource reports compiled by TAR are provided in Appendix 10.

TAR supervised the geophysical surveys conducted in areas D, J and L. Analysis of remote sensing data collected during this investigation, identified a total of twenty-seven (27) magnetic anomalies. No magnetic anomalies were found in area D. No culturally significant targets were detected in the acoustic record. In area J, twenty-five (25) magnetic anomalies were identified and no acoustic targets. Eleven (11) of the anomalies appear to be small single-source signatures associated with debris such as fish and crab traps, pipes, small diameter rods, cable, wire rope, chain or small boat anchors. Since these targets appear to be associated with small, single objects and are likely modern in nature, no additional investigation is recommended. The remaining anomalies form two (2) clusters. One cluster, designated J1, appears to be associated with a small diameter pipeline or armored cable. Avoidance is recommended by a 300 ft. radius buffer, although material generating the anomalies does not appear to be on the Minerals Management Services (MMS) database of Gulf of Mexico pipelines. The two (2) anomalies that form cluster J2 are suggestive of material such as a small vessel. Avoidance of these magnetic anomalies is recommended by the creation of a 100-ft radius buffer. In the event that avoidance is not possible, additional investigation is recommended to identify and assess the nature of the material generating the signatures. In area L, two (2) magnetic anomalies were found. One (1) anomaly exhibits signature characteristics suggestive of modern debris such as fish and crab traps, pipes, small diameter rods, cable, wire rope, chain or small boat anchors. The second anomaly exhibits signature characteristics suggestive of potentially significant cultural material such as a small vessel. Avoidance of this magnetic anomaly is recommended by the created of a 200 ft. radius buffer. If avoidance is not possible, additional investigation is recommended to identify and assess the nature of material generating the signature. No acoustic anomalies were found in area L. These results were provided to the Florida Division of Historical Resources (DHR) and MMS for review.

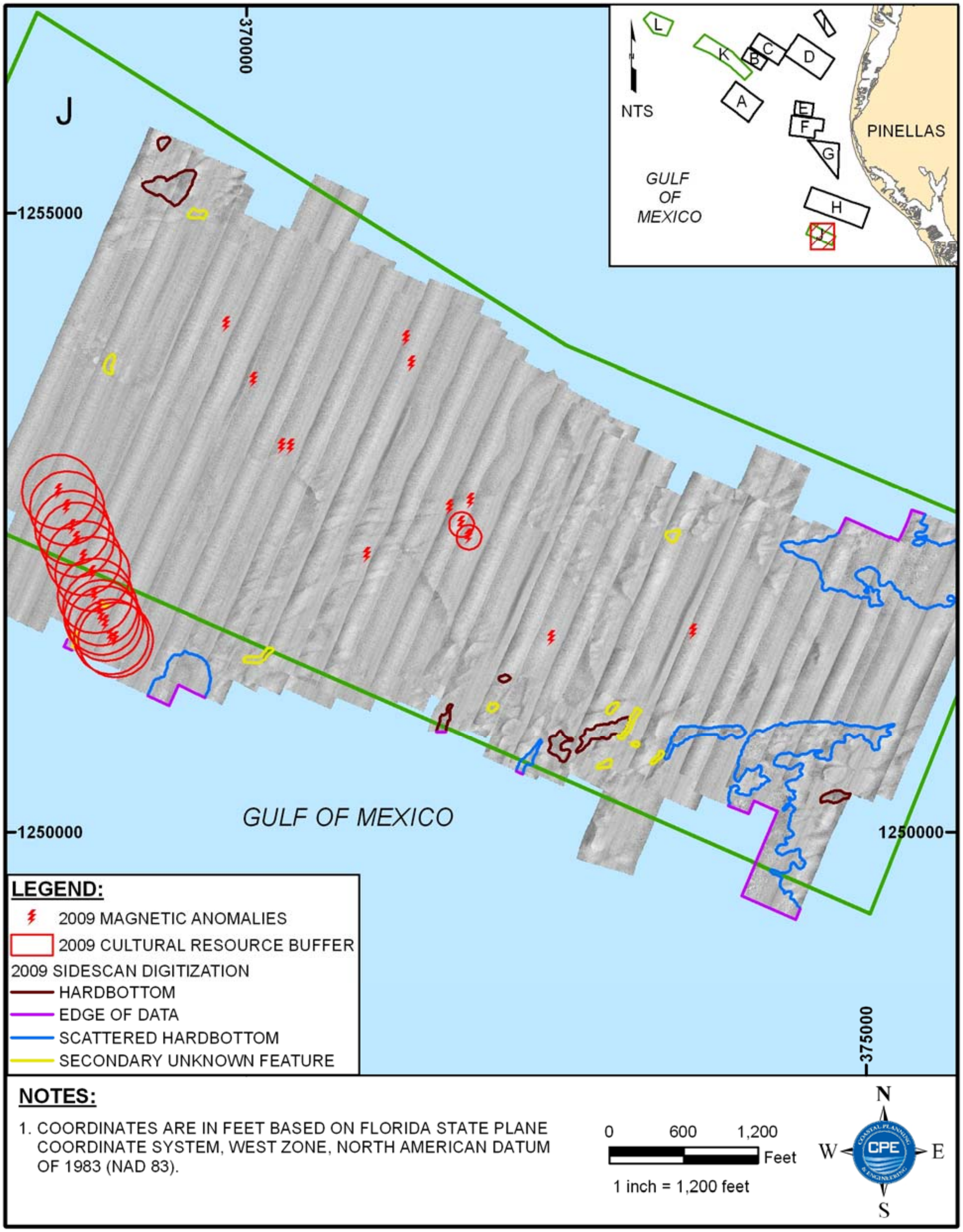


Figure 30. Sidescan sonar mosaic and digitization for Area J. A more detailed sidescan sonar mosaic is provided in Appendix 9.

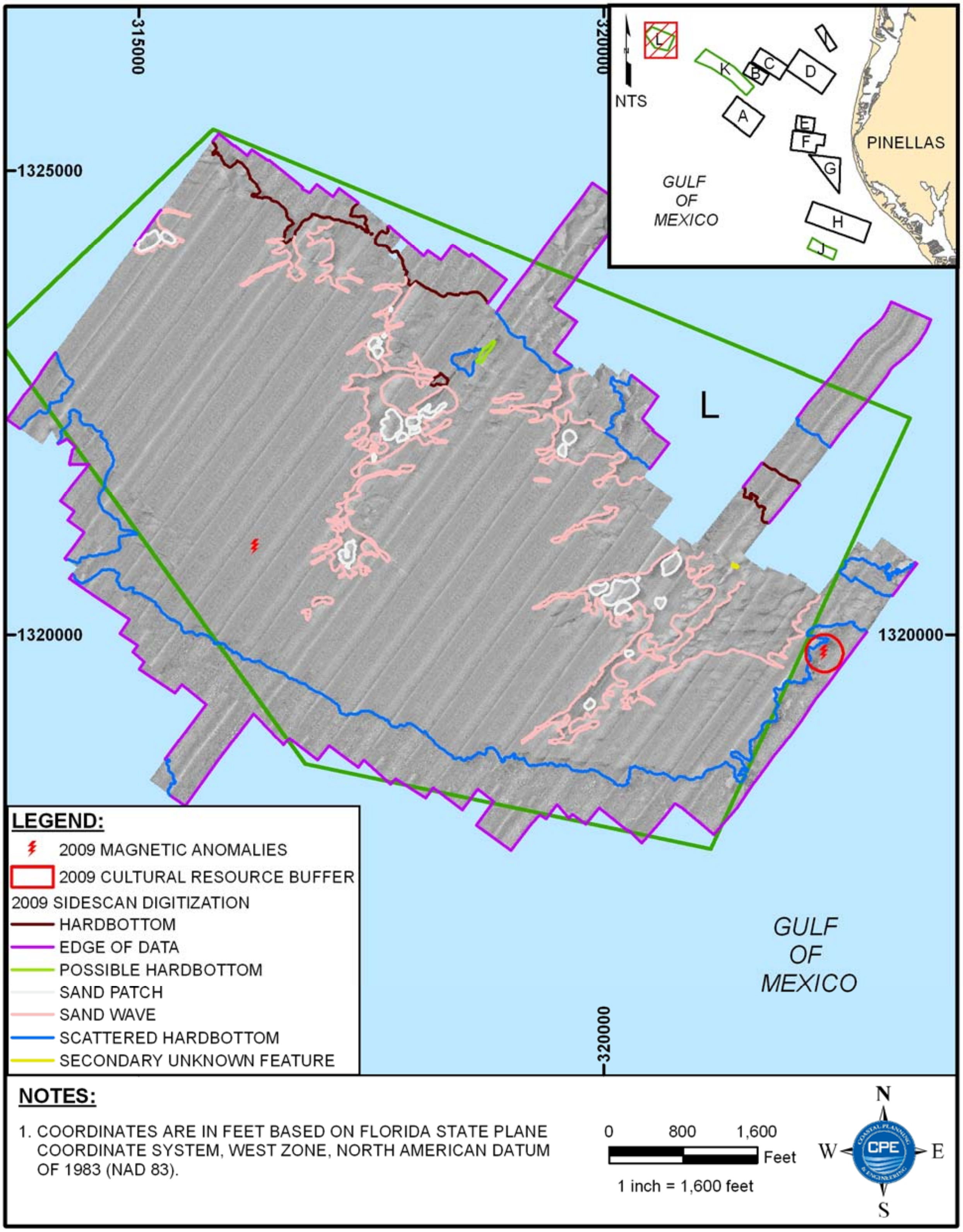


Figure 31. Sidescan sonar mosaic and digitization for Area L. A more detailed sidescan sonar mosaic is provided in Appendix 9.

BORROW AREA DESIGN

Based on the geophysical and geotechnical data collected in 2008 and 2009, potential borrow areas located within the USACE study areas and prominent ridges extending from the study areas were developed. Eight (8) borrow areas that contain potentially beach compatible material were designed in or around areas D, H, J and L (Figure 32). The design considerations used during borrow area development as well as the resulting volumes and sediment characteristics are detailed below.

Pinellas County did not have any requirements (i.e. color, carbonate content, shell content) that needed to be met beyond the required state and federal regulatory agency standards. Therefore, sands that appear to meet current state standards (Rule 62B-41.007(2)(j) F.A.C.) are considered potentially beach quality and were targeted during this sand search investigation. As color was not identified by Pinellas County as a requirement, it was not considered during borrow area design. However, color may indeed be an aesthetic issue of importance to local communities. Therefore it should be noted that Borrow Area L contains material having the lightest wet Munsell color and is aesthetically the closest to the existing beach material. Borrow areas identified in D, H and J contain material that is typically gray to dark gray when wet. Borrow Areas D1, D2 and D3 lighten considerably when dried, however they contain relatively low volumes of material. The primary source for these past Sand Key nourishment projects has been the Egmont Shoal Borrow Area, which has a mean grain size of 0.18 mm and is composed of primarily clean fine quartz sand (USACE, 2006). Based on the past use of this material, sand similar in nature to the Egmont Shoal Borrow Area should be considered to be compatible.

Excavation elevations were designed to incorporate a minimum two (2) ft. buffer over non-compatible material identified in the vibracores. Composite mean grain size, percent silt content and sorting were computed for each vibracore within Borrow Areas J and L by calculating the weighted average (sample weighted by representative lengths of the sampled layer within the core) and are included in Appendices 11, 12 and 13. The composite statistics for each borrow area were compiled by averaging the weighted results for all cores within the lateral and vertical limits of the borrow area (Table 4). The grain sizes of the fill materials are based on the geotechnical investigations for the borrow area.

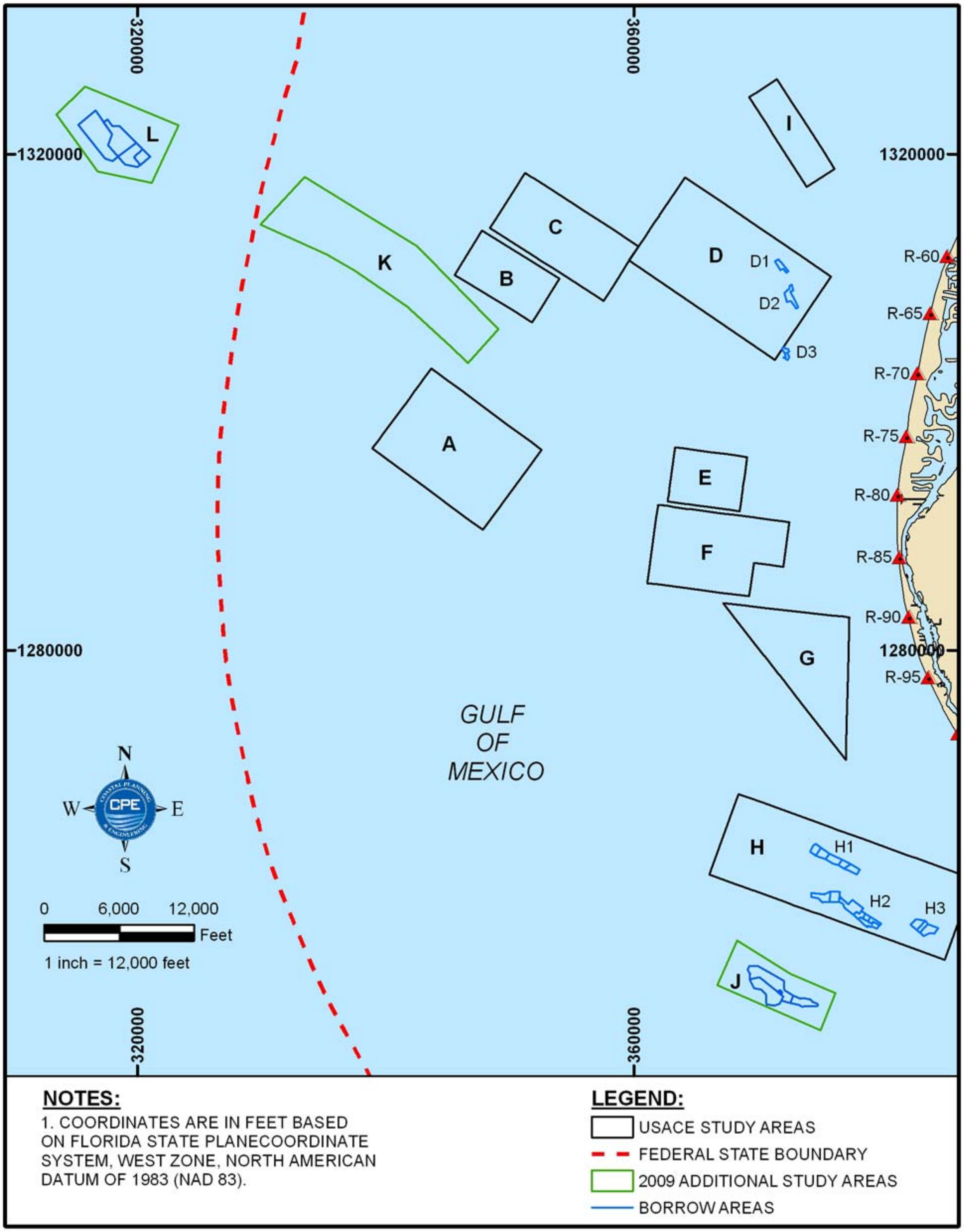


Figure 32. Borrow areas developed following the 2008 and 2009 geophysical and geotechnical investigations.

Table 4. *Borrow area characteristics.*

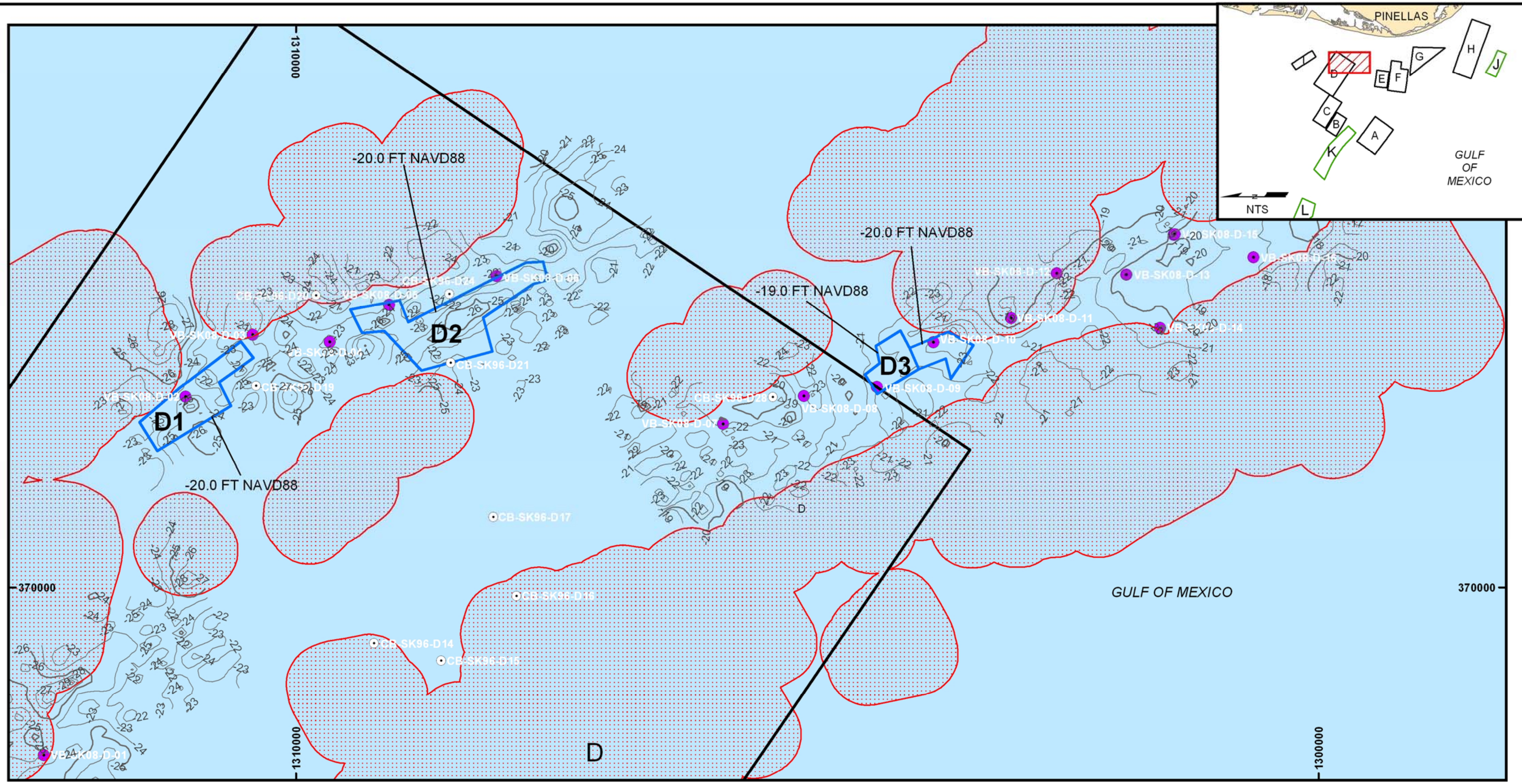
Location	Mean Grain Size[1] (mm)	(phi)	Sorting[1] (%)	Silt[2] (phi)	Volume (cy)
Borrow Area D1	0.19	2.37	0.77	1.79	12,800
Borrow Area D2	0.22	2.18	1.08	0.85	43,200
Borrow Area D3	0.17	2.55	0.58	0.87	16,000
Borrow Area H1	0.31	1.69	1.15	1.02	180,100
Borrow Area H2	0.30	1.73	1.12	0.64	466,100
Borrow Area H3	0.26	1.94	1.05	0.85	171,100
Borrow Area J	0.35	1.52	1.13	1.20	305,300
Borrow Area L	0.16	2.62	1.05	3.01	1,480,600

[1] Sieve analyses were conducted on all sediment samples in accordance with American Society for Testing and Materials Standard Materials Designation D422-63 for particle size analysis of soils. Grain size data was calculated by the moment method (Folk, 1974).
[2] Silt content is defined as the percentage of material finer than 0.0625 mm.

Borrow Areas D1, D2 and D3

Three (3) borrow areas were developed within Study Area D (Borrow Area D1, D2 and D3). The borrow areas developed within Study Area D are located approximately 2 miles offshore (Figure 32). The borrow areas were designed in water depths ranging from -14 to -23 ft. NAVD88. Areas D1 and D2 are entirely within USACE investigation area D, which was previously cleared for cultural resources. Borrow Area D3 is located outside of the USACE investigation area. Therefore, a cultural resource investigation of D3 was conducted in 2009. No potential cultural resources were identified in D3. All hardbottom, possible hardbottom and scattered possible hardbottom areas identified during 2008 and 2009 geophysical investigations were avoided by a 400 ft. buffer during borrow area design. Borrow Areas D1 and D2 have a single excavation elevation of -20.0 ft. NAVD88. Borrow Area D3 has excavation elevations of -19.0 ft. and -20.0 ft. NAVD88. The borrow areas developed in Study Area D are shown in Figure 33.

The borrow areas identified within Study Area D are characterized by eight (8) vibracores (VB-SK08-D-02, 03, 05, 06, 09 and 10; CB-SK96-21 and 24). These vibracores indicate that sediment within these borrow areas is typically fine-grained sand with trace silt, trace shell hash and trace shell fragments or whole shell. These areas have composite mean grain sizes that range from 0.17 to 0.22 mm, are moderately well to poorly sorted and contain between 0.85% and 1.79% silt. The average carbonate content is ranges from 55 to 86%. The sand in these areas has an average wet Munsell value ranging from 5.2 to 5.9. This area contains an estimated 72,000 cy of potentially beach compatible material.



NOTES

1) COORDINATES ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, WEST ZONE NORTH AMERICAN DATUM OF 1983 (NAD 83)

LEGEND:

- 1996 ARDAMAN AND ASSOCIATES VIBRACORES
- 2008 CHALLENGE ENGINEERING & TESTING VIBRACORES
- BORROW AREAS

FIRST REFLECTOR ELEVATIONS (FT NAVD88)

- CONTOURS
- INDEX CONTOURS
- 400 FT HARDBOTTOM BUFFER

0 500 1,000 Feet

1 inch = 1,000 feet

TITLE:

FIGURE 33. AREA D BORROW AREA DESIGN WITH FIRST SEISMIC REFLECTOR ELEVATIONS.

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 11/12/09	BY: BF	COMM NO: 1000030	FIGURE 33

Borrow Areas H1, H2 and H3

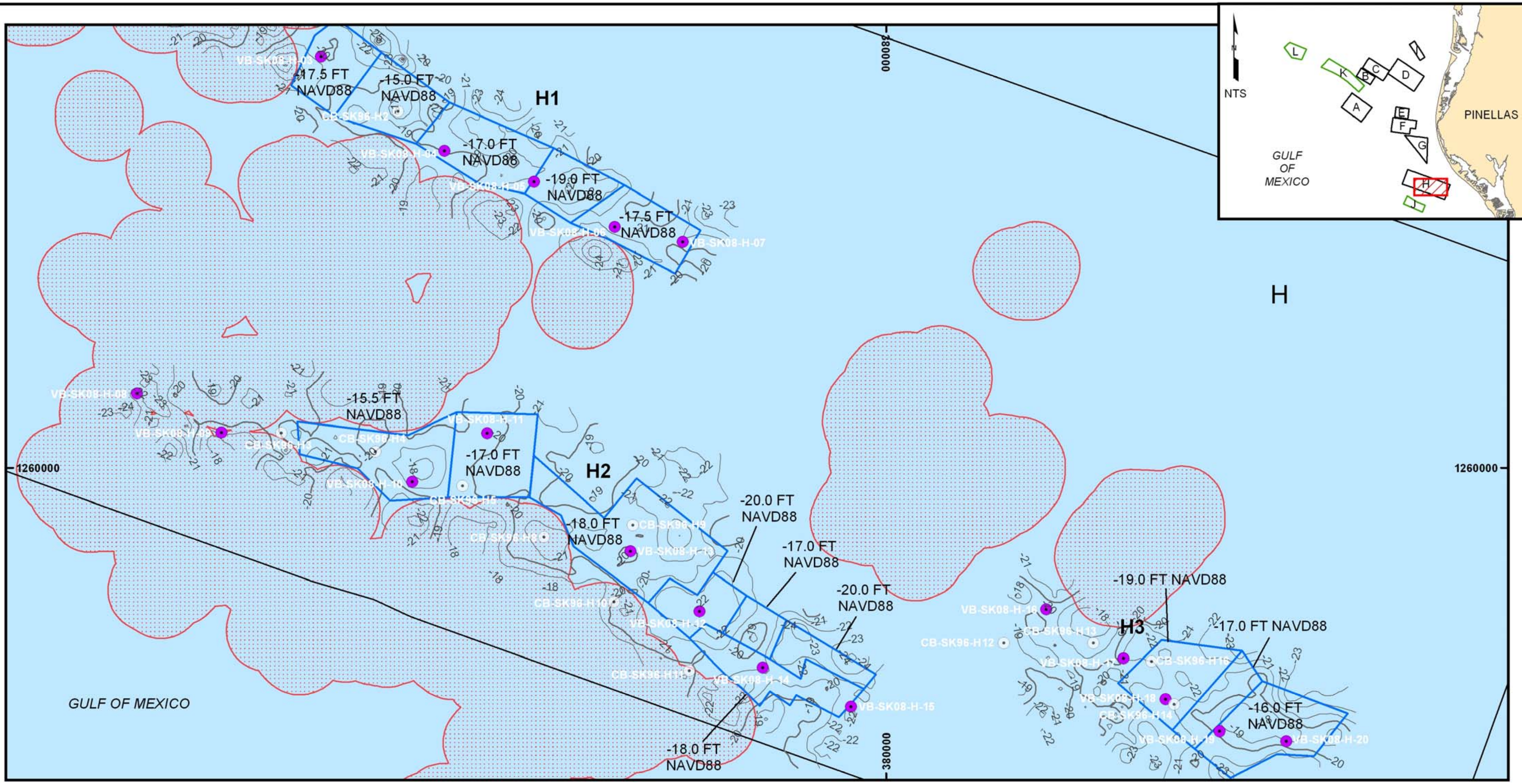
Three (3) borrow areas were developed within Study Area H (Borrow Areas H1, H2 and H3). The borrow areas are located approximately 3 miles offshore (Figure 32). The borrow areas were designed in water depths ranging from approximately -11 to -20 ft. NAVD88. Borrow Areas H1, H2 and H3 are entirely within USACE investigation area H, which was previously cleared for cultural resources. All hardbottom, possible hardbottom and scattered hardbottom areas identified during 2008 and 2009 geophysical investigations were avoided by a 400 ft. buffer during borrow area design. Borrow Area H1 is divided into five (5) cuts with elevations ranging from -15.0 ft. NAVD88 to -19.0 ft. NAVD88. Borrow Area H2 is divided into seven (7) cuts with elevations ranging from -15.5 ft. NAVD88 to -20.0 ft. NAVD88. Borrow Area H3 is divided into three (3) cuts with elevations ranging from -16.0 ft. NAVD88 to -19.0 ft. NAVD88. The borrow areas developed within Area H are shown in Figure 34.

Borrow Area H is characterized by twenty-five (25) vibracores (VB-SK08-H-03, 04, 05, 06, 07, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20 and CB-SK96-H-2, 3, 4, 5, 8, 9, 10, 11, 14 and 16). These vibracores indicate that sediment within Borrow Area H is typically fine-grained sand with trace silt, trace to some shell hash, trace shell fragments and whole shell. These areas have composite mean grain sizes that range from 0.26 to 0.31 mm, are poorly sorted and contain between 0.64% and 1.02% silt. The average carbonate content ranges from 49% to 60%. The sand in these areas has an average wet Munsell value ranging from 5.0 to 5.5. This area contains an estimated 817,300 cy of potentially beach compatible material.

Borrow Area J

A single borrow area was developed within Area J. The borrow area is located approximately 5 miles offshore (Figure 32). The borrow areas were designed in water depths ranging from approximately -17 to -28 ft. NAVD88. Two areas identified during the cultural resource investigation were buffered according to the report findings. One cluster that appears to be associated with a small diameter pipeline or armored cable lies a minimum of 1,000 ft. outside of the borrow area. The radius of the recommended buffer for this feature is 300 ft., therefore it is sufficiently far away from the borrow area to avoid potential impact. The second area is suggestive of a small vessel, and it was avoided by a 100 ft. radius buffer. All hardbottom, scattered hardbottom and secondary unknown feature areas identified during 2008 and 2009 geophysical investigations were avoided by a 400 ft. buffer during borrow area design. Borrow Area J is divided into three (3) cuts with elevations ranging from -22.0 ft. NAVD88 to -24.0 ft. NAVD88 (Figure 35).

Borrow Area J is characterized by twelve (12) vibracores (PCVC-09-01, 02, 13, 14, 15, 16, 17, 18, 19, 20, 21 and 22). These vibracores indicate that sediment within Borrow Area J is typically fine-grained sand with trace silt, little to some shell hash, trace shell fragments and trace whole shell. This area has a mean grain size of 0.35 mm, is poorly sorted and contains 1.20% silt. The average carbonate content is 46%. The sand has an average wet Munsell value of 4.9. This area contains an estimated 305,300 cy of potentially beach compatible material.



NOTES

1) COORDINATES ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, WEST ZONE NORTH AMERICAN DATUM OF 1983 (NAD 83)

LEGEND:

- 1996 ARDAMAN AND ASSOCIATES VIBRACORES
- 2008 CHALLENGE ENGINEERING & TESTING VIBRACORES
- BORROW AREAS

FIRST REFLECTOR ELEVATION (FT NAVD88)

- CONTOURS
- INDEX CONTOURS
- 400 FT HARDBOTTOM BUFFER

N

0 500 1,000 Feet

1 inch = 1,000 feet

TITLE:

FIGURE 34. BORROW AREAS DEVELOPED WITHIN STUDY AREA H AND SEISMIC FIRST REFLECTOR ELEVATIONS.

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 11/12/09	BY: BF	COMM NO: 1000030	FIGURE 34

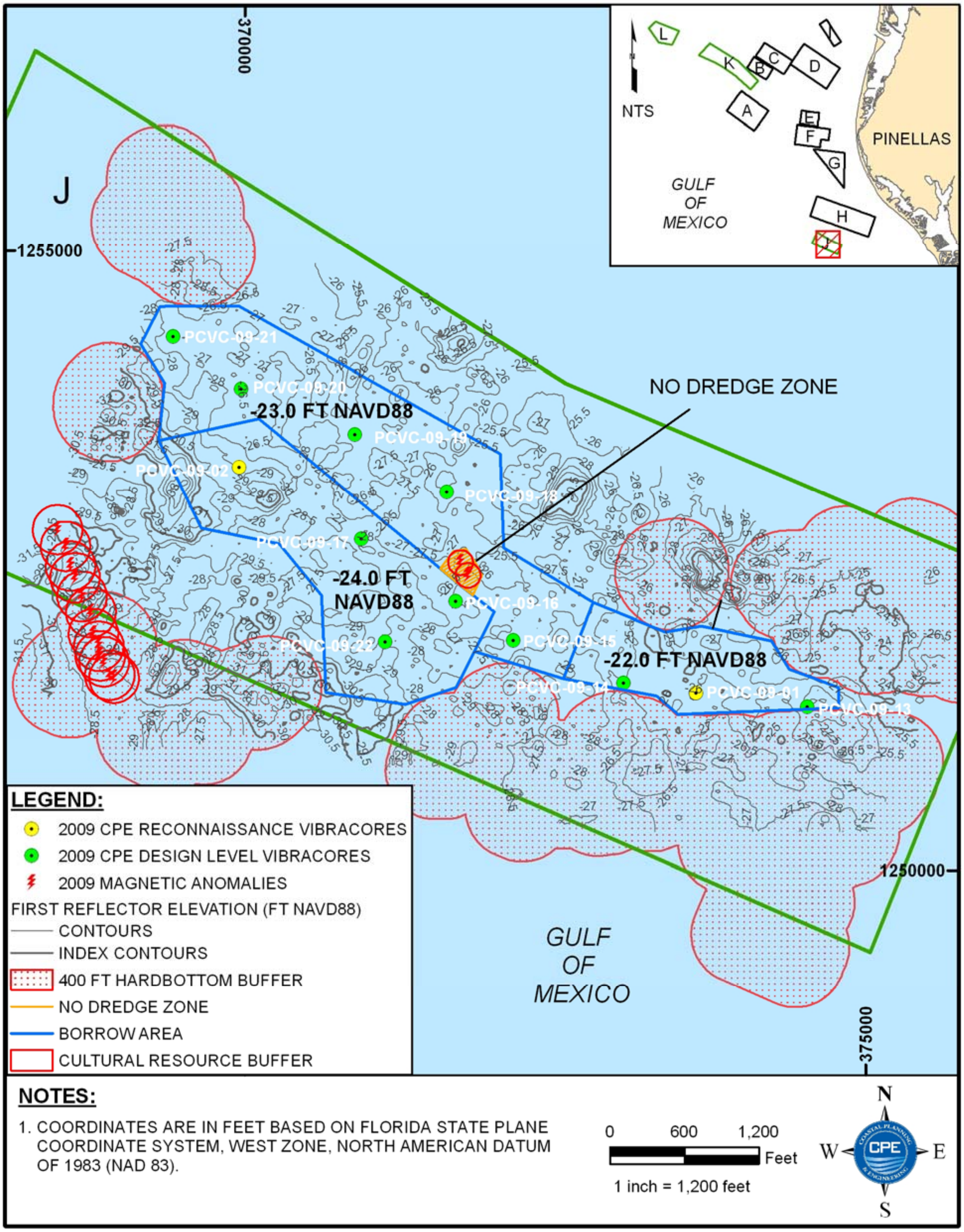


Figure 35. Borrow area developed within Area J with first seismic reflector elevations.

Borrow Area L

A single borrow area was developed within area L. The borrow area is located approximately 12 miles offshore in Federal waters (Figure 32). The borrow area was designed in water depths ranging from approximately -52 to -38 ft. NAVD88. One area was identified during the cultural resource investigation as having signature characteristics suggestive of modern debris. The cluster is located more than 1,000 ft. outside of the borrow area. The radius of the recommended buffer for this feature is 200 ft., therefore it is sufficiently far away from the borrow area to avoid potential impact. All hardbottom, possible hardbottom, scattered hardbottom and secondary unknown feature areas identified during 2008 and 2009 geophysical investigations were avoided by a 400 ft buffer during borrow area design. Borrow Area L is divided into four (4) cuts with elevations ranging from -45.5 ft. NAVD88 to -50.0 ft. NAVD88 (Figure 36).

Borrow Area L is characterized by sixteen (16) vibracores (PCVC-09-10, 11, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 and 36). These vibracores indicate that sediment within Borrow Area L is typically fine-grained sand with trace silt, trace shell hash, trace shell fragments and whole shell. This area has a mean grain size of 0.16 mm, is poorly sorted and contains 3.01% silt. The average carbonate content is 22%. The sand has an average wet Munsell value of 6.3. This area contains an estimated 1,480,600 cy of potentially beach compatible material.

Compatibility Analysis

As previously indicated, CPE strongly recommended conducting a compatibility analysis to determine compatibility between the beach and potential sand resources and to provide optimum project performance. However, Pinellas County did not wish to include a compatibility analysis in CPE’s sand search investigation, opting instead to utilize the University of South Florida (USF) and the USACE to perform compatibility analyses. Therefore unforeseen sand compatibility issues may result.

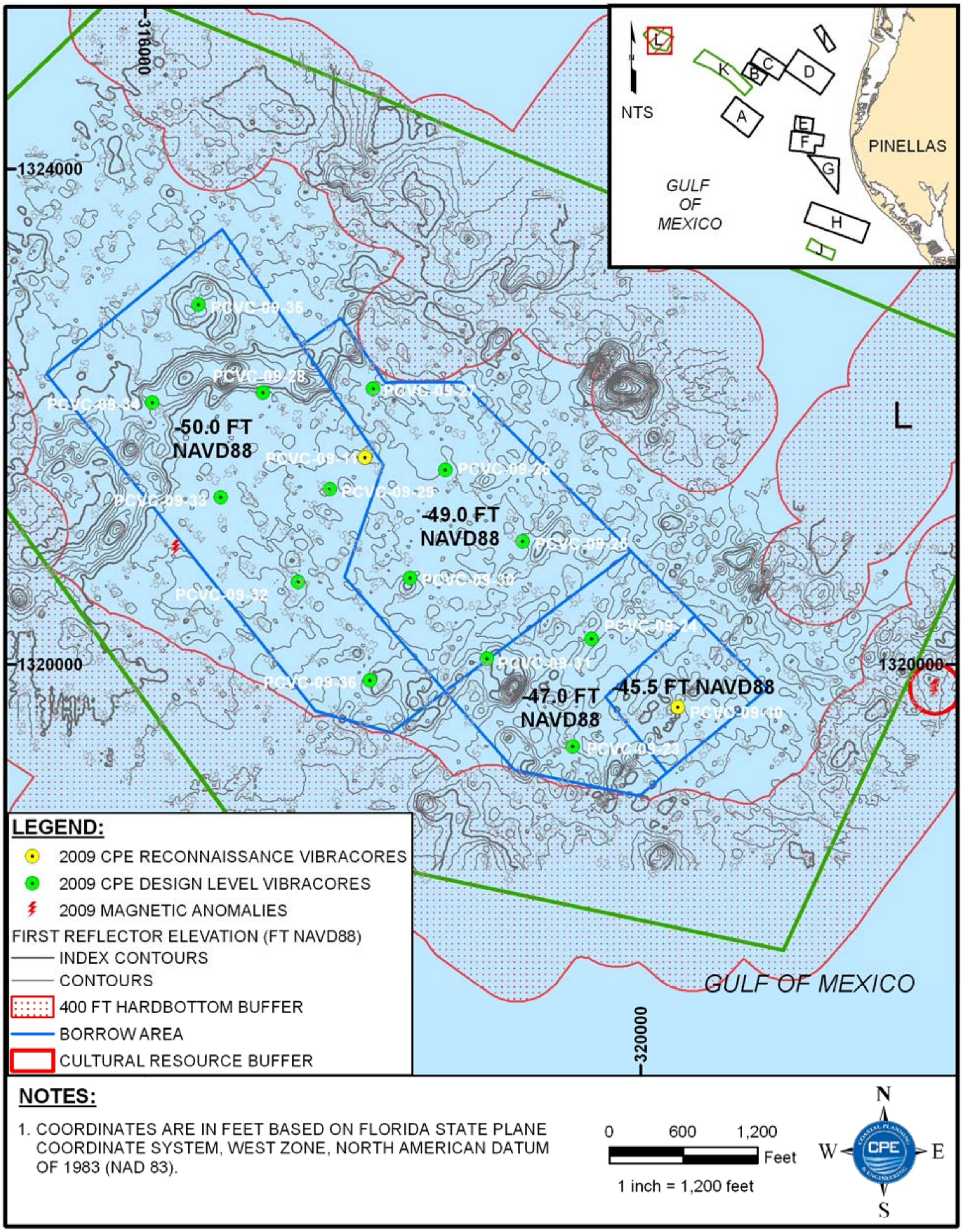


Figure 36. Borrow area developed within Area L with first seismic reflector elevations.

CONCLUSIONS/RECOMMENDATIONS

Eight (8) potential borrow areas were identified as a result of the 2008 and 2009 sand search investigations. The benefits and challenges associated with the different areas in terms of volume, sand quality and location relative to the project area are discussed below. Recommendations on potential use and additional investigations are also made.

Borrow Area L

Borrow Area L has the greatest potential for use in the next nourishment of Sand Key. This borrow area contains the largest volume of potentially beach compatible sand, having approximately 1,480,600 cy of material. This volume may also be increased if the vertical buffer above non-compatible material identified in the vibracores is reduced to 1 ft. instead of the preferred 2 ft. buffer currently recommended by the BBCS. A buffer reduction would need to be coordinated with the BBCS during the permitting process and would likely require additional vertical control on the dredge during excavation. Borrow Area L also has the lightest wet Munsell color value of the identified borrow areas at 6.3, which dries to 7.1. The color of the material identified in Borrow Area L is similar to the existing beach, which is white. The mean grain size of Borrow Area L is 0.16 mm, which is similar to the primary sand source used in past nourishments of Sand Key, the Egmont Shoal Borrow Area, which has a mean grain size of 0.18 mm (USACE, 2006). As this area has the smallest mean grain size, more material will be needed to obtain the same performance from this sand source in comparison to material identified in areas D, H and J. Borrow Area L is located approximately 12 miles offshore in Federal waters. A lease must be obtained from the MMS in order to use this resource.

Area D

Three borrow areas were identified in or around Study Area D. These areas are similar in quality to Borrow Area L. The material is relatively light in color. While the wet Munsell values range from 5.2 to 5.9, the sand dries to a Munsell value of 7.6 to 8.0. The mean grain size is also relatively small ranging from 0.17 to 0.22 mm. The total volume of material identified in this area is 72,000 cy. This volume may also be increased if the vertical buffer above non-compatible material identified in the vibracores is reduced to 1 ft. instead of the preferred 2 ft. buffer currently recommended by the BBCS. Because the volume of this material is small, these areas should be considered to supplement other sand sources. They are located approximately 2 miles offshore of the northern end of the project area. The proximity of these borrow sites to the project area could make their use cost effective, even though they contain a relatively small volume of sand.

Areas H and J

Three (3) borrow areas were developed in area H and one (1) borrow area was developed in area J. These areas contain relatively dark, coarse sand having grain sizes ranging from 0.26 to 0.35 mm. The grain size of the material found in areas H and J is coarser than the Egmont Shoal Borrow Area that was used for several previous nourishments. This sand is therefore likely to perform well and require the placement of less material to achieve the same results that would be accomplished using sand from areas L or D. The wet Munsell colors of these areas range from 4.9 to 5.5, and the sand dries to 5.9 to 7.2. While color was not identified as a requirement and was not considered during borrow area design, color may indeed be an aesthetic concern of importance to local communities as well as a marine turtle nesting issue. The color of this material is significantly darker than the existing beach. These areas are relatively close to the project area as they are located from 3 to 5 miles offshore, and therefore would likely be less costly to dredge than Borrow Area L, which is approximately 12 miles away.

Recommendations

CPE recommends that a compatibility analysis be performed between the identified borrow areas and the existing beach. If found compatible, CPE recommends the use of area L in the 2010 Sand Key Beach Renourishment project. This sand is close in color to the existing beach and would likely meet any potential aesthetic requirements of the local community. This area contains approximately 1,481,000 cy of sand. An additional 72,000 cy of material identified in Borrow Areas D1, D2 and D3 could be used to supplement the sand in Borrow Area L. The combined volume of these areas is 1,553,000 cy. The volume of material in these areas may be increased slightly by reducing the vertical buffer from 2 ft. to 1 ft. above non-compatible material identified in the vibracores. Although an additional 1,122,000 cy of sand was identified in areas H and J, the color of this material is significantly darker than the existing beach, and the sand may raise environmental and aesthetic concerns. The use of material from areas H and J is not recommended.

CPE recommends the design-level investigation of area K as well as reconnaissance level investigations of previously uninvestigated sand hills in order to identify beach compatible sand resources for future Sand Key (and other Pinellas County) shore protection projects. Based on reconnaissance level vibracores, area K contains material similar in quality to that identified in Borrow Area L, making it a promising target for future work. Similarly, several uninvestigated sand hills are present in Federal waters that have potential for containing beach compatible material. Material may also still exist in the Egmont Key Borrow Area and may be a viable option to complement sand sources identified in this project.

ACKNOWLEDGEMENTS

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