STATE OF FLORIDA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Herschel T. Vinyard Jr., *Secretary*

LAND AND RECREATION
Robert G. Ballard, *Deputy Secretary*

FLORIDA GEOLOGICAL SURVEY
Jonathan D. Arthur, *State Geologist and Director*

A SEDIMENTOLOGICAL AND GRANULOMETRIC ATLAS OF THE BEACH SEDIMENTS OF FLORIDA'S NORTHWEST COAST AND BIG BEND

By

Daniel C. Phelps, Michelle M. L. Ladle, Adel A. Dabous and Eric P. Harrington

Submitted to the National Oceanic and Atmospheric Administration (NOAA)

This report was funded in part, through a grant agreement from the Florida Department of Environmental Protection, Florida Coastal Management Program, by a grant provided by the Office of Ocean and Coastal Resource Management under the Coastal Zone Management Act of 1972, as amended, National Oceanic and Atmospheric Administration Award No. *NA08NOS4190415.* The views, statements, findings, conclusions and recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the State of Florida, NOAA or any of their subagencies.

FLORIDA GEOLOGICAL SURVEY
Tallahassee, Florida
July 2011

TABLE OF CONTENTS

Abstract 1
Introduction 2
Previous work 3
Project description 4
Field procedures 4
Beach sample collection by county 5
Escambia County 5
Santa Rosa County 6
Okaloosa County 6
Walton County 6
Bay County 6
Gulf County 7
Franklin County 7
Wakulla County 7
Taylor County 7
Dixie County 8
Levy County 8
Citrus County 8
Hernando County 8
Pasco County 8
Pinellas County 8
Laboratory analysis 9
Sediment sample processing 9
Grain size distribution (GSD) curves 9
Sediment processing quality control 9
Beach reaches of the northwest coast of Florida 10
Perdido Key 10
Geographic setting 10
Beach history in brief 10
Data analysis 11
Santa Rosa/Okaloosa Island 11
Geographic setting 11
Beach history in brief 11
Data analysis 12
Choctawhatchee Bay to Philips Inlet 12
Geographic setting 12
Beach history in brief 12
Data analysis 13
Philips Inlet to St. Andrew Bay 13
Geographic setting 13
Beach history in brief 13
Data analysis 14
Shell Island/Crooked Island 14
Geographic setting 14
Beach history in brief 14
Data analysis 14
Mainland (Mexico Beach) 15
Geographic setting 15
Beach history in brief 15
Data analysis 15
St. Joseph Peninsula/Cape San Blas/Indian Peninsula 16
Geographic setting 16
Beach history in brief 16
Data analysis 16

St. Vincent Island..... 17
Geographic setting..... 17
Beach history in brief..... 17
Data analysis..... 17
Little St. George Island..... 18
Geographic setting..... 18
Beach history in brief..... 18
Data analysis..... 18
St. George Island 18
Geographic setting..... 18
Beach history in brief..... 19
Data analysis..... 19
Dog Island..... 19
Geographic setting..... 19
Beach history in brief..... 19
Data analysis..... 19
St. James Island/Alligator Point..... 20
Geographic setting..... 20
Beach history in brief..... 20
Data analysis 20
Beach reaches of the Big Bend coast of Florida..... 21
Wakulla County..... 21
Geographic setting..... 21
Beach history in brief..... 21
Data analysis..... 22
Dekle Beach and Keaton Beach, Taylor County..... 22
Geographic setting..... 22
Beach history in brief..... 22
Data analysis..... 22
Horseshoe Beach and Shired Island, Dixie County..... 23
Geographic setting..... 23
Beach history in brief..... 23
Data analysis..... 23
Cedar Keys, Levy County..... 23
Geographic setting..... 23
Beach history in brief..... 23
Data analysis..... 24
Fort Island Gulf Park, Citrus County..... 24
Geographic setting..... 24
Beach history in brief..... 24
Data analysis..... 24
Pine Island, Hernando County..... 25
Geographic setting..... 25
Beach history in brief..... 25
Data analysis..... 25
Onshore Pasco County..... 25
Geographic setting..... 25
Beach history in brief..... 25
Data analysis..... 25
Anclote Bar and Anclote Key, Pasco and Pinellas Counties..... 26
Geographic setting..... 26
Beach history in brief..... 26
Data analysis 26
Summary and conclusions..... 27
The beaches of Florida's northwest coast 27
The beaches of Florida's Big Bend..... 28

References Cited..... 29
Acknowledgements.....31

FIGURES

Figure 1. Northwest Florida coast and Big Bend beach sampling map
Figure 2. Sampling points along an ideal beach profile
Figure 3. Beach location with all sampling points present (Gulf County GF-25)
Figure 4. Beach location with berm but no mid-beach present (Walton County WL-07)
Figure 5. Beach location with mid-beach but no berm present (Bay County BY-05)
Figure 6. Beach location with only swash zone and back beach present (Franklin County FK-05)
Figure 7. Beach location with a single sample point present (Franklin County FK-08)
Figure 8. Sieve nest used in processing sediment samples
Figure 9. Mean grain size from the Alabama/Florida state line to Sabine Point
Figure 10. Mean grain size from Sabine Point to Choctawhatchee Bay
Figure 11. Mean grain from Choctawhatchee Bay to Philips Inlet
Figure 12. Mean grain size from Philips Inlet to St. Joseph Bay
Figure 13. Mean grain size from St. Joseph Point to Cape San Blas
Figure 14. Mean grain size from Cape San Blas to East Pass
Figure 15. Mean grain size from East Pass to Lighthouse Point (Alligator Point)
Figure 16. Pre-digestion grain size distribution comparisons of Apalachee Bay beaches
Figure 17. Pre-digestion grain size distribution comparisons of Taylor County and Dixie County beaches
Figure 18. Pre-digestion grain size distribution comparisons of Levy County beaches
Figure 19. Pre-digestion grain size distribution comparisons of southern Big Bend beaches
Figure 20. Mean grain size and carbonate percentage from Anclote Bar to Anna Maria Island
Figure 21. Mean grain size over the beaches of the northwest coast of Florida

TABLES

Table 1. Beach reaches related to beach sampling locations
Table 2. Latitude and longitude of beach sampling points
Table 3. Unit conversion factors (English to SI/SI to English)
Table 4. Beach monument survey points related to beach sampling locations
Table 5. Sizes of sieve sets used in grain size analysis
Table 6. Land designations related to beach sampling locations
Table 7. A summary of beach sediment descriptions
Table 8. A summary of the average carbonate percentages and mean grain sizes

APPENDICES

Appendix A. Beach sample catalogue
Appendix B. Sediment sample quality control analysis
Appendix C. Comparative grain size distribution curves across selected geographic features
Appendix D. Photomicrographs of selected samples
Appendix E. Power point presentation

ABSTRACT

This Florida Geological Survey (FGS) study was funded by the National Oceanic and Atmospheric Administration (NOAA). This study characterizes recently sampled sediments from the beaches of Escambia, Santa Rosa, Okaloosa, Walton, Bay, Gulf, Franklin, Wakulla, Taylor, Dixie, Citrus, Hernando, Levy, and Pasco Counties as well as the extreme northern beaches of Pinellas County. A total of 703 samples, 653 samples from 240 sites along the northwest coast of Florida and 50 samples from 39 sites in Florida's Big Bend, were collected, described and photographed. Selected samples from each location were granulometrically analyzed. Photographs, descriptions and the results of granulometric analyses are provided.

The study area on the northwest coast of Florida included the beaches of Escambia, Santa Rosa, Okaloosa, Walton, Bay, Gulf and Franklin Counties. The study area in Florida's Big Bend was comprised of the beaches of Wakulla, Taylor, Dixie, Citrus, Hernando, Levy, Pasco and northern Pinellas Counties. These study areas were broken down into 12 and 7 reaches, respectively. On the northwest coast of Florida, where the beaches are more continuous, the reaches are defined by geographic boundaries such as inlets and passes as well as the mouths of rivers, harbors, and bays. The data often showed a correlation between these boundaries and lateral changes in grain size. Progressing eastward along the northwest coast of Florida, approaching the low energy Big Bend, beaches are occasionally bounded by stretches of coastline where beaches are absent due to coastal erosion. Progressing into the Big Bend and southward through the region, beaches become uncommon. Those beaches that are present are bounded by tidal marshes. Moving further southward down the Big Bend, the barrier island complex of the southwest coast of Florida is reached and beaches again typify the coast.

The trend from west to east along the northwest coast of Florida shows a general eastward decline in mean grain size to Cape St. George. From Cape St. George eastward, there is an increase in mean grain size to the beginning of the Big Bend north of Ochlockonee Bay on the Franklin/Wakulla County line.

Changes in grain size define three regions along the northwest coast of Florida: (1) The first region is defined by the area bounded by sample locations ES-01 and BY-15. This region extends from Perdido Key to just west of the mouth of St. Andrew Bay. In this region, the mean grain size curve generally declines eastward. The curve peaks on Perdido Key, in western Escambia County, on Santa Rosa Island, in eastern Escambia County, and on the mainland beaches of western Bay County. (2) The second region is defined by the area bounded by sample locations BY-16 and FK-15. This region extends from just west of the mouth of St. Andrew Bay to Cape St. George on Little St. George Island. The mean grain size in this region averages lower than that in the regions to either side. (3) The third region is defined by the area bounded by sample locations FK-16, on the east side of Cape St. George, and FK-65, at the mouth of Ochlockonee Bay. Mean grain size generally increases eastward across this region. This region shows the largest variances of mean grain size among the three regions.

As the beaches of Florida's Big Bend are highly discontinuous, regions based on changes in mean grain size alone could not be defined. Three regions in Florida's Big Bend were identified within the study area: (1) the beaches of Wakulla County, (2) beaches in Levy and Dixie Counties, related to the ancestral Suwannee River and relict dunes and (3) the beaches of Pasco County and extreme northern Pinellas County that are more properly considered to be the northern most extension of the barrier island complex of the southwest coast of Florida. All of these beaches are more or less in a natural state. In contrast, the remaining beaches in the Big Bend, lying in Taylor, Dixie, Citrus, Hernando and mainland Pasco Counties, are geographically limited, narrow and frequently anthropogenic.

INTRODUCTION

This is the third of three studies comprising a comprehensive atlas of the beach sediments of Florida. This third study encompasses the Gulf of Mexico beaches of the northwest and central-west coast of Florida extending from the Alabama/Florida boundary on the border of Escambia County eastward and then southward through Florida's Big Bend to the northern border of Pinellas County. It includes samples from Anclote Bar and Anclote Key, offshore islands in southern Pasco County and extreme northern Pinellas County. No samples were collected from Jefferson County as that county has no sandy beaches. The study area is shown in Figure 1.

This report is a companion to Phelps *et al.* (2009) and (2010) which reported on the beach sediments of the east coast of Florida extending from the Florida/Georgia state line southward to Key Biscayne, and those of the southwest coast of Florida and the middle and lower portions of the Florida Keys, respectively. As was reported in those studies:

> *"Beach erosion is a constant concern in Florida and shore protection options, in substantial portions of the region, are limited by extensively urbanized coastal sectors which have significant commercial and residential development proximal to the beach. Such conditions make the option of asset relocation or abandonment generally unpalatable. The shore protection measure of choice is the periodic placement of sand along the beach."*

A review of available records suggests that the earliest recorded beach replenishment project conducted on the northwest coast of Florida was done in 1959 on Santa Rosa Island in Escambia County. (Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems Strategic Beach Management Plan for the Panhandle Gulf Coast Region (2008a), and Western Carolina University Program for the Study of Developed Shorelines (PSDS), 2011). Projects such as these, generally with increasing sand volumes and frequency, have continued to the present day. As has been reported previously in Phelps *et al.* (2009) and (2010) sediments to place on beaches must match to an acceptable extent those *in situ*. This study, together with work done in previous years, is intended to provide a base line analysis to facilitate sediment matching. While the primary parameter of concern is grain size, the issue of sediment color is of significant economic importance for western Panhandle beaches. The color of beach replenishment sediments, subsequent to their placement, thus must match, to an acceptable degree, the original *in situ* sediments or be even "whiter".

Regarding the issue of differentiating between the beaches of the northwest coast of Florida that have been replenished and those left to nature, no attempt was made to distinguish between the two. It was felt that, given the area's history of beach development, replenishment projects and inlet maintenance, to attempt to do so would be rather problematic.

It is assumed that the beaches of (1) Shell Island, Crooked Island, St. Vincent Island, Little St. George and Dog Island on the northwest coast of Florida, (2) most of the islands of the Cedar Keys, in the Big Bend, and (3) Anclote Bar and Anclote Key off the southwest coast of Florida, are in the most natural condition, i.e. the most minimally impacted by activities carried out on developed segments of beach and at inlets adjacent to them.

Sampling of beaches along the northwest coast of Florida and the Big Bend was done primarily on a county by county basis. Along the northwest coast of Florida inlets, passes, rivers and the mouths of bays and harbor frequently affect the natural near shore flow of sediments. They also occasionally represent political/economic boundaries which may limit the lateral extent of beach replenishment projects. It should be noted that these boundaries, in such cases, only define the limits of where sediments were, are and will be initially placed on a beach. In such cases, the forces of nature may modify the final distribution of such sediments in a manner not necessarily concordant with man's avowed intent.

Defined reaches, i.e. beach segments tied to sample site locations, are delineated in Table 1.

Grab sample sets of beach sediments collected at individual sampling points are referred to as "beach samples" or "samples". The individual sites selected for the collection of multiple beach samples are referred to as "beach sampling locations". The beach sampling locations are shown in Figure 1 and listed in Table 2. Individual sampling points within those locations utilized for the collection of beach samples are specified by their place on the beach profile. Photographs of individual beach samples can be found in Appendix A. Sediment analysis conducted to characterize a beach sample's grain size distribution is referred to as "granulometric analysis". This analysis is graphically displayed on grain size distribution (GSD) curves. These curves, created from selected beach samples at each location, can also be found in Appendix A. The sediment fraction referred to as "fines" is that material which will pass through a 4.00 phi, 0.0025 inch (63 micron) mesh opening (#230 sieve).

Maps included in this report use either the North American Datum of 1983, herein cited as "NAD83", or the World Geodetic System of 1984, herein cited as "WGS84". Global Positioning System (GPS) instrumentation used to collect geographic global positioning fixes and/or reference points is referred to as "GPS" instrumentation, fixes or points as applicable.

All "unit conversion factors", English to the International System of Units, i.e. Le Système International d'Unités, (SI) and SI to English, used in this report can be found listed in Table 3. These conversion factors are cited from Eshbach and Souders (1975) to four significant digits. Within the body of this report weight or volume quantifications are first expressed in English units followed, enclosed in brackets, by their expression in SI units.

PREVIOUS WORK

The earliest descriptions of the beaches of the Florida panhandle by the Florida Geological Survey can be found in the Survey's Twenty-first/Twenty-second Annual Report in a section by James H. C. Martens titled "Beaches of Florida" (Martens, 1931). He states that:

> *"On the Gulf coast of northwest Florida the sand is so nearly pure quartz and the grains are so clean that beaches and dunes are so dazzlingly white as fresh snow. An analysis of such sand from Pensacola gave 99.65 percent silica."*

He found the coarsest siliceous sand on the beaches of Florida to be lying on its northwest Gulf coast, "…especially Santa Rosa Island and the mainland to the east of it."

Davis (1997) divides the coast of the Florida panhandle into two parts: (1) the Apalachicola River delta area, a primary sediment source, and (2) "…the remaining, extensive, sand coast, which is a sediment sink." To the west of the Apalachicola River delta area the coastline is a combination of elongate, wave-dominated barrier islands, spits and mainland beaches.

The Big Bend of Florida, east of the Apalachicola River delta and extending southward to Anclote Key is characterized in Davis, (1997), as "The Marsh Coast of the Big Bend Area". Hine, *et al*., (2001), describes it as an "…open-marine, salt-marsh dominated (*Juncus roemerianus*) coast which exhibits…a lack of siliciclastic sand and mud." Hine *et al.* (1988), found sliciclastic sediments essentially absent on the coast from Citrus County southward to Anclote Key in Pasco County. Vernon (1951) observed that most of the keys of the Cedar Keys and those islands north to the Suwannee River are sand islands. He believed that the sand was sourced from deposition made by the river along its lower course. Wright, *et al.* (2005), in their analysis of the Suwannee River delta, found that where the islands of the Suwannee River delta intersect open marine shoreline, their western limbs have been reworked to form sandy beaches.

Anclote Bar and Anclote Key, lying the furthest south and east in this study area, mark the northern extent of the Florida southwest coast barrier island chain. As such, they are immediately adjacent to but

outside of what is generally geographically considered to be the Big Bend of Florida. Davis (1997) describes Anclote Key as "…an example of a wave-dominated barrier (island)."

PROJECT DESCRIPTION

The Bureau of Beaches and Coastal Systems (BBCS) of the Florida Department of Environmental Protection (FDEP) selected locations at approximately 1,000 foot (304.8 meters (m)) intervals for the purposes of beach monitoring and management which are an established reference feature in the study area. In this study, the beaches sampled were adjacent to every fifth BBCS location, where practicable. This resulted in a planned sample location spacing of approximately one mile (1.6 km). The planned sampling interval locally varied from this for points immediately adjacent to physically limiting geographic features such as inlets and the mouths of harbors and bays which limited sampling. The planned sampling interval also varied, on occasion, where it was determined from a review of online photo imagery and field observations that no beach existed at a proposed sampling location. Additionally, there were a few intended sampling locations where beach access could not be arranged. The beach sample locations used in this study are shown in Figure 1. Tables 2 and 4, respectively, tie latitude and longitude and beach monument location points to beach sampling locations.

FIELD PROCEDURES

Sample locations are shown on Figure 1. In planning the sample protocol, it was intended that at each sampling location samples would be collected from the swash zone, the beach berm, mid-beach and back beach. An idealized beach profile illustrating these locations is provided as Figure 2. Swash samples were collected just landward of the point waves reached at the time of sampling. Beach berm samples were collected if there was a distinct crest followed by a distinct fall in elevation landward of the swash zone sample point. Mid-beach samples were taken on wide beaches approximately midway between the swash zone sample point and the back beach sample point. Back beach samples were collected at the seaward base of the dune. If no dune was present, a sampling point was picked just short of where the beach was vegetated. Figure 3 is an example of a location where four points were sampled. Only occasionally were locations found where all four sample points were present. Swash zone, berm mid-beach and back beach samples were thus collected only at a few locations while at many others, swash zone, berm or mid-beach and back beach samples were obtained. Figure 4 is an example of a location where three points, including a berm, were sampled. Figure 5 is an example of a location where three points, swash zone, mid-beach and back beach were sampled. At some locations, where the beach was narrow, only samples from the swash zone and back beach were collected. Figure 6 is an example of a location where those two points were sampled. At other locations, where the beach was extremely narrow, samples from a single point on the beach were collected. Figure 7 is an example of such a location. Due to sampling protocol differences in place at the time of sampling in 2006, back beach samples were not collected at some sampling locations in Escambia, Santa Rosa and Okaloosa Counties. At a few locations, where no beach was present, no samples were taken. GPS locations were obtained for each of the sampling points within each location. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations, based on field observations, did not exceed five ft (1.5 m) above mean sea level (MSL).

Phelps *et al*. (2009) and (2010), discuss a simple alphanumeric scheme utilized to identify loose sediment samples. All beach samples discussed in this report are identified with a two letter code for the county, followed by consecutive beach location numbers, 01, 02, 03, 04, etc., and completed by a one or two letter designation indicating the sample's placement on the beach profile. Samples collected from the swash zone, beach berm, mid-beach and back beach are designated SS, B, MB and BB, respectively. For example, a sample collected at the first sample location in Escambia County in the swash zone would be delineated as ES-01-SS. The samples collected from locations on the northwest coast of Florida were numbered from west to east. Where the coast changes orientation they were numbered from north to south. The samples collected from locations in the Florida Big Bend were numbered from north to south. Two sampling locations on Anclote Key lie in Pinellas County. To prevent confusion with the

numbers already used for the Pinellas County sampling locations reported in Phelps *et al.* (2010), those two sampling locations were labeled from north to south, PI-49 and PI-50.

Access to the beach was primarily through the use of an all terrain utility vehicle (UTV) or by driving a truck on beach-adjacent roads as close to individual locations as possible and walking onto the beach. Island beaches not accessible by land were accessed by boat. However, in two of those circumstances, on St. Vincent and Little St. George Islands, all terrain vehicles were provided upon arrival. Other locations, Dog Island in Franklin County, several of the Cedar Keys in Levy County, Anclote Bar in Pasco County and Anclote Key in Pasco and Pinellas Counties, were accessed by nosing a boat onto the beach and wading in through the shallow surf.

With the exception of two locations on the eastern margin of Escambia County, ES-42 and ES-43, and all locations in Santa Rosa and Okaloosa Counties, upon arrival at a sampling location, the following procedure was adhered to:

- Sample points were typically marked using survey flags, caution triangles or "traffic cones".

- Photographs were taken illustrating the sample points as marked. Typically these photographs were shot from opposite directions down the length of the beach. Photos were also taken across the width of beach at most locations.

- GPS coordinates of all sampling points were recorded in the field book and the coordinates of the back beach sampling point, or in the case of sampling locations with a single sample point that individual sample point, were entered into the memory of a hand held, Garmin Etrex, GPS unit. The unit is typically accurate to approximately 15 ft (4.57 ms).

- Sampling holes were dug at each sample point and four individual bags of two ounce (56.7 gm) sample were collected from a depth of between 6 to 12 inches (15.2 cm to 30.4 cm) below land surface to eliminate the influence of aeolian winnowing of fines at the sediment surface.

- Sampling holes were then back filled.

A slightly different sampling procedure was used when collecting samples in 2006. For the two locations on the eastern edge of Escambia County, referenced above, and all locations in Santa Rosa and Okaloosa Counties, at each sampling point within an individual sampling location, three individual replicate samples, each totaling approximately 7-10 ounces (200-300 grams) of sediment, were obtained for granulometric analysis. Samples were collected by scooping sediments from the surface to an approximate depth of 1 inch (25.4 millimeters) below the beach surface at each sample point using an approximately 10 ounce (300 gram) scoop. Individual samples were split prior to granulometric analysis to avoid overloading the sieve stack.

BEACH SAMPLE COLLECTION BY COUNTY

Escambia County

Beach sediment samples for two locations from eastern Escambia County, referenced above, were collected on September 14, 2006. The remaining samples were collected from March 28 to 31, 2011. A total of 126 beach samples, from 42 sampling locations, were collected from Escambia County. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach. Due to the narrowness of the beach, this did not occur at most locations. As a result, only swash zone, beach berm and back beach samples were collected at some locations. At other locations, where a beach berm was not present, swash zone, mid-beach and back beach samples were collected. At a few locations, where the beach was narrower, only swash zone and back beach samples

were collected. At the two locations, ES-42 and ES-43, sampled in 2006, only swash zone and mid-beach samples were collected due to differences in the sampling procedure used at that time. No samples were collected at location ES-41. While the elevation of the sediment surface, relative to mean sea level, was not recorded these elevations did not exceed 5 feet (1.5 meters).

Santa Rosa County

Beach sediment samples in Santa Rosa County were collected on September 14, 2006. A total of ten beach samples, from four sampling locations, were collected from Santa Rosa County. It was intended that, at each sampling location, beach samples would be collected from the swash zone, beach berm, mid-beach and back beach. Due to the narrowness of the beach and differences in the sampling procedure use at that time, this did not occur. Samples were collected from the swash zone, mid-beach at one location, from the swash zone, berm and mid-beach at another, and from the swash zone and mid-beach at the remaining two. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (1.5 meters).

Okaloosa County

Beach sediment samples were collected from Okaloosa County on September 12 and 14, 2006. A total of 71 beach samples, from 27 sampling locations, were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach. Due to the narrowness of the beach and differences in the sampling procedure used at that time, this did not occur at most locations. Only swash zone, mid-beach and back beach samples were collected at some locations. At other locations, where the beach was extremely narrow, only swash zone and mid-beach samples were collected. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (1.5 meters).

Walton County

Beach sediment samples were collected from Walton County on February 15 and 16, 2011. A total of 76 beach samples, from 26 sampling locations, were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach. Due to the narrowness of the beach, this did not occur. At those sites where the beach was narrow, with one exception, only swash zone, berm and back beach samples were collected. At that location, where the beach was narrow and no berm was developed, only swash zone and back beach samples were collected. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (1.5 meters).

Bay County

Beach sediment samples were collected from Gulf County on January 11 and 31, 2010, and February 14, 15 and 17, 2011. A total of 134 beach samples, from 46 sampling locations, were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach; however, due to the narrowness of the beach, at only a few locations were samples collected from all four points. Only swash zone, berm and back beach samples were collected at many locations. At various other locations, where no berm was developed, swash zone, mid-beach and back beach samples were collected. At other locations, where the beach was narrower and no berm was developed, only swash zone and back beach samples were collected. At a few locations, where the beach was extremely narrow only swash zone samples were collected. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (1.5 meters).

Gulf County

Beach sediment samples were collected from Gulf County, for all but the four western most locations, on November 19 and December 10, 2010. Samples from the remaining four locations were collected on January 11, 2011. A total of 82 beach samples, from 30 sampling locations, were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach. Due to the narrowness of the beach, this did not occur at most locations. Only swash zone, mid-beach and back beach samples were collected at some locations. At other locations, only swash zone, berm and back beach samples were collected. At locations where the beach was extremely narrow, only swash zone and back beach or, on occasion, only swash zone samples were collected. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (1.5 meters).

Franklin County

Beach sediment samples were collected from Franklin County on September 1 and 3, October 11, November 2, and December 8, 2010. A total of 154 beach samples, from 65 sampling locations, were collected. While it was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach, this did not occur at most locations. Due to the narrowness of the beach, only swash zone, mid-beach and back beach samples were collected at some locations. At other locations, only swash zone, berm and back beach samples were collected. At locations where the beach was extremely narrow, only swash zone and back beach or, at one location, only swash zone samples were collected. Due to entry restrictions associated with bird nesting, only swash zone, berm and mid-beach samples were collected at one location. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (1.5 meters).

Wakulla County

Beach sediment samples were collected from Wakulla County on January 7, and 27, 2011. A total of 14 beach samples, from 12 sampling locations, were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach. Due to the narrowness of the beach, only swash zone and back beach or, more frequently, only swash zone samples were collected. Two locations, WK-04 and WK-11 were not sampled as either no beach was present or access could not be achieved. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (1.5 meters).

Taylor County

Beach sediment sampling was conducted in Taylor County on February 22, 2011. A total of two beach samples, from two out of the three intended sampling locations, were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach but, due to the narrowness of the beaches, only swash zone samples were collected. The location TY-02 was not sampled as access could not be achieved. While the elevation of the sediment surface relative to mean sea level was not recorded, the elevations of these samples did not exceed 5 feet (1.5 meters).

Dixie County

Beach sediment sampling was conducted in Dixie County on February 22, 2011. A total of two beach samples, from two out of the three intended sampling locations, were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach but, due to the narrowness of the beaches, only swash zone samples were collected. The location DX-02 was not sampled as no beach was present at those locations. While the elevation of the sediment surface relative to mean sea level was not recorded, the elevations of these samples did not exceed 5 feet (1.5 meters).

Levy County

Beach sediment sampling was conducted in Levy County on February 21, 2011. A total of ten beach samples, out of the 12 intended sampling locations, were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach but, due to the narrowness of the beaches, only swash zone samples were collected. The locations LV-06 and LV-12 were not sampled as no beach was present at those locations. While the elevation of the sediment surface relative to mean sea level was not recorded, the elevations of these samples did not exceed 5 feet (1.5 meters).

Citrus County

Beach sediment sampling was conducted in Citrus County on February 22, 2011. A single beach sample, from one sampling location, was collected. While the elevation of the sediment surface relative to mean sea level was not recorded, the elevation of this sample did not exceed 5 feet (1.5 meters).

Hernando County

Beach sediment sampling was conducted in Hernando County on February 22, 2011. A single beach sample, from one sampling location, was collected. While the elevation of the sediment surface relative to mean sea level was not recorded, the elevation of this sample did not exceed 5 feet (1.5 meters).

Pasco County

Beach sediment samples were collected from Pasco County on March 2, 2011. A total of 15 beach samples, from nine sampling locations, were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach. Due to the narrowness of the beach, this did not occur. Swash zone, berm and back beach samples were collected at only one location. At the remaining locations, where the beach was extremely narrow, only swash zone and back beach or, on occasion, only swash zone samples were collected. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (1.5 meters).

Pinellas County

Beach sediment samples were collected from Pinellas County on March 2, 2011. A total of five beach samples from two sampling locations on Anclote Key were collected. It was intended that at each sampling location beach samples would be collected from the swash zone, beach berm, mid-beach and back beach. Due to the narrowness of the beach, this did not occur. Swash zone, berm and back beach samples were collected at one of the two locations sampled. At the remaining location, where the beach

was extremely narrow, only swash zone and back beach samples were collected. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (1.5 meters).

Photographs of the beach locations visited and the samples collected are provided in Appendix A. Also included in Appendix A are sample descriptions as well as granulometric analyses and photo micrographs of selected samples.

LABORATORY ANALYSIS

Sediment sample processing

The sieve nest used in sample processing by the FGS is delineated in Table 5 and depicted in Figure 8. All grain size distribution analyses were conducted using general guidelines of the American Society for Testing and Materials (2000a, 2000b) and specific procedures advanced by the FGS sedimentology laboratory (Balsillie, 1995, 2002a, 2002b; Balsillie and Tanner, 1999; Balsillie, *et al.*, 1999; Balsillie *et al*. 2002a; Balsillie *et al.* 2002b; Balsillie and Dabous, 2003). Each sample was initially weighed after oven drying. The sample was then wet sieved through a #230 (0.63 millimeter (mm) or 4 phi) sieve, oven dried and reweighed with the weight loss being assigned to the fine fraction. The sample was then dry sieved with the portion of the pan fraction obtained during dry sieving also assigned to the fine fraction. The sample was then digested with a 4 Molar hydrochloric acid solution, rinsed with deionized water, oven dried and reweighed and the percentage of carbonate determined. If the percentage carbonate material was greater than 5 percent the sample was resieved.

The cumulative grain size distribution curves reflect the total grain size distribution (GSD) of the sample. The weight of the fine fraction (weight loss from wet sieving and weight of the pan fraction combined) was assigned to the less than 4 phi fraction. Grain size distribution curves are provided with analysis. A link is provided in the grain size analysis column in the index of beach samples.

A set of four individual samples was collected at every sampling point except for the two eastern most locations in Escambia and all locations in Santa Rosa and Okaloosa Counties where only three individual samples were collected. Sample #1 of a set was processed as described above. The results of their granulometric analyses are provided in Appendix A. Sample #2 of those sets, subsequent to being dried, was described and photographed. These data can also be accessed via Appendix A. Sample #3 of those sets was dried and 10 percent of those samples were processed, like sample #1, for the purpose of quality control. The results of these analyses are provided in Appendix B. If not processed, Sample #3 was retained as an archive sample. Sample #4 was held as a backup sample and, if not utilized, retained as an archive sample. Those sample sets not selected for processing were described, photographed and retained for processing in the future.

Grain size distribution (GSD) curves

GSD curves were made for each sample processed by the FGS. These curves can be found in Appendix A.

Sediment processing quality control

As a quality control check, 28 duplicate samples were processed separately for approximately ten percent of all beach samples initially processed. Graphical comparisons of initial and duplicate samples can be found in Appendix B. Using the Mann-Whitney Test (equivalent to the Wicoxon Test) to compare the distribution medians and Levene's Test, (Conover, 1999), to compare the variances, at a 95 percent

confidence level, there was no significant difference found between the distributions of the first and duplicate samples for either of the two tests with the exception of a single sample (FK-09-BB). For this sample, there was no significant difference between the compared variances; however, a significant difference was found between the compared medians of the pre-digestion analysis. This sample and its duplicate were found to have 1.29% and 0.55% carbonate material, respectively. Visual graphical inspection of the GSD curves shows a significant difference in the tails, which can be explained by the difference in the carbonate fraction.

BEACH REACHES OF THE NORTHWEST COAST OF FLORIDA

A list the beach reaches of the northwest Florida coast can be found in Table 1. Individual reaches are tied to their respective sets of sampling locations. Table 6 ties land designations to beach sampling locations and lists the boundaries of known metropolitan areas as well as federal, state, and county lands discussed in this report when they relate to sampling locations.

It should be noted that, due to storm events and/or the actions of man, many inlets and passes have, throughout history, periodically opened and closed. What was once one island might now be two or more and some islands may have become spits joined to the mainland. The separation of Little St. George from St. George Island in Franklin County is an example of the first situation. The Shell Island and Crooked Island barrier complex in Bay County is an example of the second situation.

Table 7 provides a summary of beach sediment descriptions. Table 8 is a summary of average carbonate percentages and mean grain sizes. It reveals that the sediments on these reaches of beaches average 3.5 percent or less carbonate. Figures 9 through 15, progressively from west to east, geographically tie grain size curves to long stretches of coastline. Shading across the displayed curve delineates where inlets occur and where the sampling interval exceeds one mile (1.6 km).

The Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems (2008a), Strategic Beach Management Plan for the Northwest Gulf Coast Region was extensively consulted and used to establish the timeline of recent beach replenishment and the construction of engineering structures on the beach reaches in this portion of the study area. Additionally, an historical database of beach replenishment projects, compiled by the Western Carolina University Program for the Study of Developed Shorelines (PSDS, 2009) was utilized for compiling the beach histories.

Perdido Key

Geographic setting

Perdido Key is an approximately 16 mile (25.7 km) long barrier island. On the north side of the key, from west to east, lie Old River, the Inland Waterway and Big Lagoon. On its south side lies the Gulf of Mexico. The key extends to the west approximately two miles (3.2 km) into Baldwin County, Alabama. To the east of the key lies Pensacola Pass, at the mouth of Pensacola Bay. This key is no more than a few hundred yards/meters wide in most places. It typically exhibits several rows of sand dunes with those fronting the Gulf stabilized by grasses.

Beach history in brief

Material from maintenance dredging of Pensacola Pass was placed on Perdido Key in 1985 and 1991. Beach and dune recovery operations were conducted after Hurricanes Opal, Georges, Ivan and Dennis. Subsequent to the 2004 hurricane season, emergency protective berms were constructed followed by a dune restoration project in 2005-2006. It is anticipated that a beach restoration project will be conducted on the western portions of the key in the near future.

Data Analysis

Within this reach of beach, 14 locations, ES-01 through ES-14, as delineated in Table 1 and shown in Figure 1, were sampled and 42 samples collected. Swash zone, berm, mid-beach and back beach samples were obtained from two locations, ES-01 and ES-03. Swash zone, berm and back beach samples were obtained from nine locations, ES-02, ES-05 through ES-09, ES-11, ES-12 and ES-14. Swash zone, mid-beach and back beach samples were obtained from one location ES-10. Swash zone and back beach samples were obtained from two locations, ES-04 and ES-13. No samples were collected from the portion of the Key that extends into Alabama.

Carbonate material averaged 0.5 percent of the sample sediments processed from the 14 locations within this reach of beach. The average mean grain size was 0.371 mm (1.431 phi). As shown in Figure 9, the sediments, with minor local excursions, trend coarser grained eastward to a peak at location ES-11 and then finer grained to Pensacola Pass. The sediments sampled on the east end of the island, immediately adjacent to Pensacola Pass, were the finest grained of those sampled on the island. They were also finer grained than those sampled on the west end of Santa Rosa Island.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of Pensacola Pass, between ES-14 and ES-15 can be found in Appendix C. A comparison of grain sizes for samples obtained immediately east and west of Pensacola Pass shows that the sediments west of the mouth are finer grained, with their curve peaking at approximately 1.9 phi, than those to the east whose curves peak at approximately 1.6 phi. A comparison of grain size for the samples obtained further from the inlet shows the sediments further west of the mouth are slightly coarser grained, with their curve peaking at approximately 1.4 phi, than those to the east.

Santa Rosa/Okaloosa Island

Geographic setting

Santa Rosa/Okaloosa Island is approximately 43.5 miles (70 km) long. On the north side of the island, from west to east, lie Pensacola Bay, Santa Rosa Sound and Choctawhatchee Bay, on the south side lies the Gulf of Mexico, to the west lies Pensacola Pass, at the mouth of Pensacola Bay, and to the east lies East Pass, at the mouth of Choctawhatchee Bay. Historically Santa Rosa Island has been impacted by numerous hurricanes with seven impacts occurring between 1959 and 2009 alone. A portion of the western part of the island is in the Gulf Islands National Seashore.

Beach history in brief

In 1959 dredge material, from maintenance dredging of Pensacola Pass, was placed on Santa Rosa Island. Initial construction of a restoration project on the west end of Santa Rosa Island at Pensacola Beach was completed in September 2003 using 4.2 million cubic yards (mcy) (3.2 million cubic meters (mcm)) of sand. Subsequent to the 2004 and 2005 hurricane seasons, 876,000 cubic yards (cy) (669,750 cubic meters (cm)) of sand was placed on the beach in 2006. A dune restoration project, which included additional sand, was completed as well. In 2006, further east at Navarre Beach, approximately 3.4 mcy (2.6 mcm) of sand was placed directly on the beach and as part of dune construction. In the vicinity of Fort Walton Beach, dunes were constructed over a period of years. In May 2006, approximately 50,000 cy (38,228 cm) of maintenance dredged beach quality material from East Pass was placed on Holiday Isle beach near the eastern end of the island. Operations to assist in the recovery of the beach and dune system at Henderson Beach State Park were conducted after Hurricanes Opal and Georges. In 2006, subsequent to Hurricane Ivan, emergency protective berms and dune restoration projects were constructed.

Data analysis

Within this reach of beach, 52 locations, ES-15 through ES-40, ES-42, ES-43, SR-01 through SR-04, and OA-01 through OA-20, as delineated in Table 1 and shown in Figure 1, were sampled and 156 samples collected. Twenty eight locations lie in Escambia County, four locations lie in Santa Rosa County and 20 locations lie in Okaloosa County. Swash zone, berm, mid-beach and back beach samples were obtained from seven locations in Escambia County, ES-15, ES-20, ES-22 through ES-24, ES-26 and ES-29. Swash zone, berm and back beach samples were obtained from ten locations in Escambia County, ES-17 through ES-19, ES-27, ES-33, ES-35, ES-36 and ES-38 through ES-40, as well as six locations, OA-15 through OA-20, in Okaloosa County. Swash zone, mid-beach and back beach samples were obtained from four locations in Escambia County, ES-21, ES-25, ES-30 and ES-32 and one location, SR-04, in Santa Rosa County. Swash zone and back beach samples were obtained from five locations in Escambia County, ES-16, ES-28, ES-31, ES-34 and ES-37. Due to differences in the sampling protocol used when samples were collected in 2006, only swash zone, berm and mid-beach samples were obtained from two locations in Escambia County, ES-42 and ES-43, one location in Santa Rosa County, SR-01 and 14 locations in Okaloosa County, OA-01 through OA-14. Additionally, only swash zone and mid-beach samples were collected at that time from two locations in Santa Rosa County, SA-02 and SA-03. No samples were collected from Escambia County location ES-41.

Carbonate material averaged 0.6 percent of the sample sediments processed from the 48 locations within this reach of beach. The average mean grain size was 0.375 mm (1.414 phi). Carbonate material averaged 0.7 percent of the 28 samples, from locations ES-15 through ES-43. The mean grain size was 0.379 mm (1.398 phi). Carbonate material averaged 0.1 percent in the 4 samples collected from locations SR-01 through SR-04 in Santa Rosa County. The average mean grain size was 0.409 mm (1.200 phi). Carbonate material averaged 0.6 percent of the 20 samples, from locations OA-01 through OA-20 in Okaloosa County. The mean grain size was 0.363 mm (1.464 phi). The sediments down the length of these beaches are coarser grained on average than the reaches on either side. As shown in Figures 9 and 10, the mean grain size curve exhibits a coarsening trend eastward that, with minor local excursions, peaks at sample location ES-40, in eastern Escambia County, and then trends finer grained to East Pass at the east end of the island.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of Pensacola Pass, between ES-14 and ES-15 and east and west of East Inlet, which forms the mouth of Choctawhatchee Bay, between OA-20 and OA-21 can be found in Appendix C. A comparison of grain sizes for samples obtained immediately east and west of Pensacola Pass shows that the sediments west of the mouth are finer grained, with their curve peaking at approximately 1.9 phi, than those to the east whose curves peak at approximately 1.6 phi. A comparison of grain size for the samples obtained further from the inlet shows the sediments west of the mouth are slightly coarser grained, with their curve peaking at approximately 1.4 phi, than those to the east. A comparison of grain sizes east and west of East Inlet shows that the sediments immediately west of the inlet are slightly finer grained, with their curves peaking at approximately 1.5 phi, than those to its east whose curves peak at approximately 1.2 phi.

Choctawhatchee Bay to Philips Inlet

Geographic setting

This expanse of coast forms, on its west end, a peninsula bounded on the north by Choctawhatchee Bay and on the south by the Gulf of Mexico. The beach is crossed by shallow, seasonal outflows from numerous coastal dune lakes which are common to the area.

Beach history in brief

After Hurricanes Opal and Georges, an assisted recovery of the beach and dune system in the Miramar Beach, Tang-O-Mar Beach, Gulf Pines, Sandestin, Four Mile Village, Beach Highlands, Dune

Allen Beach, Blue Mountain Beach, Gulf Trace, Seagrove Beach, Seacrest Beach and Inlet Beach areas in Walton County was conducted. In 2004, subsequent to Hurricane Ivan, emergency berms were constructed on Miramar Beach, Tang-O-Mar Beach, Gulf Pines, Sandestin, Four Mile Village, Beach Highlands, Dune Allen Beach, Blue Mountain Beach, Seacrest Beach and Inlet Beach. This was followed by a dune restoration project in 2005. The Destin-Western Walton Beach Restoration Project was completed in 2007. Approximately 950,000 cy (726,327 cm) and 1.9 mcy (1.5 mcm) of sand were placed in the Okaloosa and Walton County segments of the project, respectively.

Data analysis

Within this reach of beach, 33 locations (OA-21 through OA-27 and WL-01 through WL-26), as delineated in Table 1 and shown in Figure 1, were sampled and 101 samples collected. Seven locations lie in Okaloosa County and 26 locations lie in Walton County. Swash zone, berm, mid-beach and back beach samples were obtained from four locations, OA-21 through OA-24, in Okaloosa County. Swash zone, berm and back beach samples were obtained from 24 locations, WL-01 through WL-09, WL-11 through WL-13, and WL-15 through WL-26 in Walton County. Swash zone, mid-beach and back beach samples were obtained from three locations, OA-25, OA-26 and OA-27 in Okaloosa County. Swash zone and back beach samples were obtained from two locations in Walton County, WL-10 and WL-14.

Carbonate material averaged 0.6 percent of the sample sediments processed from the 33 locations within this reach of beach. The average mean grain size was 0.302 mm (1.727 phi). Carbonate material averaged 1.7 percent in the seven samples collected from locations OA-21 through OA-27. The average mean grain size was 0.361 mm (1.471 phi). Carbonate material averaged 0.4 percent of the 26 samples, from locations WL-01 through WL-26. The mean grain size was 0.286 mm (1.805 phi). As shown in Figure 11, the sediments down the length of these beaches exhibit an overall fining trend eastward.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of both East Inlet, which forms the mouth of Choctawhatchee Bay, between OA-20 and OA-21, and Philips Inlet, between WL-26 and BY-01, are shown in Appendix C. A comparison of grain sizes east and west of East Inlet shows that the sediments immediately west of the inlet are slightly finer grained, with their curves peaking at approximately 1.5 phi, than those to its east whose curves peak at approximately 1.2 phi. A comparison of grain sizes east and west of Philips Inlet shows that there is little difference in where the main peaks of their curves lie. The curves of the samples east of the inlet have secondary peaks at greater than -0.5 phi.

Philips Inlet to St. Andrew Bay

Geographic setting

This expanse of coast, which includes the Panama City Beaches and western portion of St. Andrew State Park, forms, on its east end, a peninsula bounded on the north by St. Andrew Bay and on the south by the Gulf of Mexico.

Beach history in brief

Dredged material was placed on the beach west of St. Andrew inlet in 1972, 1982, and has been for all maintenance events since 1984. In 1999, beach restoration was completed using 9.12 mcy (6.97 mcm) of sand obtained from multiple offshore borrow areas. As a result of the erosion caused by Hurricanes Ivan and Dennis, a project which involved placement of approximately 3.265 mcy (2.496 mcm) of sand from offshore borrow areas was completed in 2006. A dune restoration project involving the placement of approximately 17,000 cy (12,997 cm) of sand from an upland source was also completed in 2006.

Data analysis

Within this reach of beach, 20 locations in western to central Bay County (BY-01 through BY-20), as delineated in Table 1 and shown in Figure 1, were sampled and 57 samples collected. Swash zone, berm and back beach samples were obtained from 15 locations, BY-01, BY-02, BY-04 and BY-06 through BY-17. Swash zone, mid-beach and back beach samples were obtained from three locations, BY-05, BY-18 and BY-19. Swash zone and back beach samples were obtained from a single location, BY-03. A single point on the beach was sampled at location BY-20.

Carbonate material averaged 2.2 percent of the sample sediments processed from the 20 locations within this reach of beach. The average mean grain size was 0.339 mm (1.559 phi). The sediments down the length of these beaches are coarser grained on average than the reaches on either side and, as shown in Figure 12, exhibits, with localized coarsening and fining, a fining trend eastward.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of both Philips Inlet, between WL-26 and BY-01 and the mouth of St. Andrew Bay, between BY-20 and BY-21, are shown in Appendix C. A comparison of grain sizes east and west of Philips Inlet shows that there is little difference in where the main peaks of their curves lie. The curves of the samples east of the inlet have secondary peaks at greater than -0.5 phi. A comparison of grain sizes east and west of the mouth of St. Andrew Bay shows that the sediments immediately west of the bay mouth are finer grained, with its curve peaking at approximately 2.4 phi, than those to its east whose curves peak at approximately 1.8 ph.

Shell Island and Crooked Island

Geographic setting

The Shell Island and Crooked Island barrier complex form, at the present time, three peninsulas that are joined to the mainland and bounded to the southwest by the Gulf of Mexico. The western end of the reach is bounded by the mouth of St. Andrew Bay and the eastern end by Mexico Beach Inlet at Mexico Beach. St. Andrew Bay lies north of Shell Island. Northeast of Crooked Island lies St. Andrew Sound, which is distinct and separate from St. Andrew Bay. The entrance to St. Andrew Sound, Eloise Inlet, lies in the gap between the two peninsulas of Crooked Island. With the exception of the western end of Shell Island, which lies within St. Andrew State Park, and the eastern end of the eastern-most of the two Crooked Island peninsulas, these features all lie within Tyndale Air Force Base.

Beach history in brief

No historical information was found of any beach replenishment activities performed on these peninsulas. The area has a history of storm-formed inlets opening and closing such that portions of these peninsulas become islands and then are later rejoined to the mainland. The natural historic east entrance to St. Andrew Bay, East Pass, was dredged several times for navigation prior to 1935, when St. Andrew Inlet was cut through the peninsula as part of the federal navigation project. The old east entrance to St. Andrew Bay shoaled until it closed in 1998. It was dredged in 2001, but closed again in 2003. Hurricane Ivan reopened it in 2004, but it closed again in 2005. In 2005 hurricane Ivan, and later Dennis, caused severe beach and dune erosion with substantial sand over-wash along Shell Island and the Crooked Island portion of the barrier complex. Ivan also caused seven breaches in the Crooked Island portion but all but one breach had closed prior to Dennis in 2005.

Data analysis

Within this reach of beach, 23 locations in western to central Bay County, BY-21 through BY-43, as delineated in Table 1 and shown in Figure 1, were sampled and 69 samples collected. Swash zone, berm, mid-beach and back beach samples were obtained from seven locations, BY-23, BY-25, BY-29, BY-

30, BY-31, BY-36 and BY-37. Swash zone, berm and back beach samples were obtained from 12 locations, BY-21, BY-22, BY-26, through 28, BY-32, BY-33, BY-35, and BY-40 through BY-43. Swash zone and back beach samples were obtained from one location, BY-24. Samples from a single point on the beach were obtained from each of three locations, BY-34, BY-38 and BY-39.

Carbonate material averaged 0.6 percent of the sample sediments processed from the 20 locations within this reach of beach. The average mean grain size was 0.261 mm (1.940 phi). The sediments down the length of these beaches are both coarser grained on average than those on the reach to the west and finer grained on average than those on the reach to the east and, as shown in Figure 12, exhibit a slight fining trend from west to east to the middle of the reach.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of the mouth of St. Andrew Bay, between BY-20 and BY-21, and the cut at Mexico Beach, between BY-43 and BY-44, are shown in Appendix C. A comparison of grain sizes east and west of the mouth of St. Andrew Bay shows that the sediments immediately west of the bay mouth are finer grained, with its curve peaking at approximately 2.4 phi, than those to its east whose curves peak at approximately 1.8 ph. A comparison of grain sizes east and west of the cut at Mexico Beach are finer grained, with curves that peak at approximately 2.1 phi, than those further to its east whose curve peaks at approximately 1.5 phi.

Mainland (Mexico Beach)

Geographic setting

The town of Mexico Beach lies on the mainland coast between Mexico Beach Inlet and the tip of the St. Joseph Peninsula, which shelters the mainland coast and St. Joseph Bay behind it.

Beach history in brief

Subsequent to Hurricane Opal, a program of assisted recovery of the beach and dune system was conducted in Mexico Beach in 1995. Sand from upland borrow sites, was placed in alongshore berms. In 1998, Hurricane Earl caused further erosion that required a second phase of assisted recovery. Additional assisted recovery of the beach and dune system also followed the impacts of Hurricanes Ivan and Dennis.

Data analysis

Within this reach of beach, seven locations (BY-44 through BY-46 and GF-01 through GF-04), as delineated in Table 1 and shown in Figure 1, were sampled and 16 samples collected. Three of these seven locations lie in Bay County and four lie in Gulf County. Swash zone, berm and back beach samples were obtained from the three locations, BY-46 and GF-01 in Bay County and GF-03 in Gulf County. Swash zone and back beach samples were obtained from three of the locations, BY-44, GF-02 and GF-04, in Bay County. Only a single point on the beach was sampled at the remaining location, BY-45, in Bay County.

Carbonate material averaged 1.2 percent of the sample sediments processed from the seven locations within this reach of beach. The average mean grain size was 0.302 mm (1.725 phi). Carbonate material averaged 1.4 percent in the three samples collected from locations BY-44 through BY-46. The average mean grain size of those three samples was 0.316 mm (1.664 phi). Carbonate material averaged 1.1 percent of the four samples, from locations GF-01 through GF-04. The mean grain size was 0.293 mm (1.773 phi). The sediments down the length of these beaches are coarser grained, on average, than the reaches on either side and, as shown in Figures 12 and 13, exhibit a slight coarsening trend eastward.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of both the cut at Mexico Beach, between BY-43 and BY-44, and the mouth of St. Joseph Bay, between GF-04 and GF-05 are shown in Appendix C. A comparison of grain sizes east and west of the cut at Mexico Beach are finer grained, with curves that peak at approximately 2.1 phi, than those further to its east whose curve peaks at approximately 1.5 phi. A comparison of grain sizes east and west of the mouth of St. Joseph Bay shows little difference in where their curves peak. The curves for the samples collected west of the bay mouth have a greater coarse sediment fraction with approximately seven percent of the sample being 1.0 phi compared to approximately three percent for the two samples collected to the east of the bay mouth.

St. Joseph Peninsula/Cape San Blas/Indian Peninsula

Geographic setting

St. Joseph Peninsula is approximately 15 miles (24.1 km) long and 0.75 miles (1.2 km) wide at its widest point. It extends northward from Cape San Blas separating the Gulf of Mexico, on the west, from St. Joseph Bay, on the east. Its north end is comprised of the St. Joseph Peninsula State Park. Its south end connects to the mainland via Cape San Blas. Cape San Blas extends westward from the mainland and separates St. Joseph Bay on its north from the Gulf of Mexico on its south. Indian Peninsula extends eastward approximately three miles (4.8 km) from the mainland and separates Indian Lagoon on the north from the Gulf of Mexico on the south. The peninsula is approximately 0.5 miles (0.8 km) wide at its widest point. It is separated from St. Vincent Island to the east by Indian Pass.

Beach history in brief

In 1970, 1973 and 1986, dredged material from the St. Joseph Bay entrance channel was placed on the north end of the gulf shoreline of St. Joseph Peninsula. Assisted recovery of the beach and dune system on the St. Joseph Peninsula was conducted following Hurricanes Opal and Earl. Subsequent to the 2004 hurricane season, emergency protective berms were constructed on both the St. Joseph Peninsula and Cape San Blas. A dune restoration project for these areas was completed in 2005. In 2008, Gulf County initiated construction of the St. Joseph Peninsula Beach Restoration Project with 3.6 mcy (2.8 mcm) of sand from an offshore sand source. No work is reported to have been done on Indian Peninsula.

Data analysis

Within this reach of beach, 26 locations (GF-05 through GF-30), as delineated in Table 1 and shown in Figure 1, were sampled and 72 samples collected. Swash zone, berm, mid-beach and back beach samples were obtained from five locations, GF-12 and GF-25 through GF-28. Swash zone, berm and back beach samples were obtained from eight locations, GF-05, GF-11, GF-13, GF-15, GF-17, GF-20, GF-23, and GF-29. Swash zone, mid-beach and back beach samples were obtained from five locations, GF-08, GF-09, GF-16, GF-19, and GF-24. Swash zone and back beach samples were obtained from five locations, GF-06, GF-10, GF-14, GF-18, and GF-30. Single points on the beach were sampled at three locations, GF-07, GF-21, and GF-22.

Carbonate material averaged 1.7 percent of the sample sediments processed. The average mean grain size was 0.255 mm (1.970 phi). Carbonate material averaged 1.1 percent in the 17 samples collected from locations north of Cape San Blas (GF-05 through GF21). The average mean grain size was 0.262 mm (1.933 phi). Carbonate material averaged 2.8 percent of the nine samples, from locations east of Cape San Blas (GF-22 through GF-30). The mean grain size was 0.243 mm (2.043 phi). The sediments down the length of these beaches, as shown in Figures 13 and 14, exhibit a slight fining trend eastward along the St. Joseph Peninsula to the vicinity of Cape San Blas where they abruptly decrease in grain size. From Cape San Blas, they trend coarser in grain size eastward to Indian Pass.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of the mouth of St. Joseph Bay, between GF-04 and GF-05, as well as east and west of Cape San Blas, between GF-21 and GF-22, and Indian Pass, between GF-30 and FK01, are shown in Appendix C. A comparison of grain sizes east and west of the mouth of St. Joseph Bay shows little difference in where their curves peak. The curves for the samples collected west of the bay mouth have a greater coarse sediment fraction with approximately seven percent of the sample being 1.0 phi compared to approximately three percent for the two samples collected to the east of the bay mouth. A comparison of grain sizes east and west of Cape San Blas shows little difference. A comparison of grain sizes east and west of Indian Pass shows those sediments collected to the west to be approximately 0.5 phi coarser in grain size. The curves for the samples collected east of the pass have secondary peaks at grain sizes greater that 1.0 phi.

St. Vincent Island

Geographic setting

St. Vincent Island comprises the St. Vincent National Wildlife Refuge managed by the U.S. Fish and Wildlife Service. It is approximately nine miles (14.5 km) long and, at its widest, six miles (9.7 km) wide. The island is undeveloped and accessible only by boat or ferry. It is separated from the mainland to the north by St. Vincent Sound, from the Indian Peninsula to the west by Indian Pass and to the east from Little St. George Island by West Pass. It is bounded to the southwest by the Gulf of Mexico.

Beach history in brief

With the shoreline eroding into the maritime forest, portions of the beach on the island have been substantially narrowed. No beach restoration work has been reported on the island.

Data analysis

Within the reach of beach lying on St. Vincent Island, ten locations (FK-01 through FK-10), as delineated in Table 1 and shown in Figure 1, were sampled and 26 samples collected. Swash zone, berm, mid-beach and back beach samples were obtained from two locations, FK-03 and FK-04. Only swash zone, berm and mid-beach samples were obtained from location FK-07, as the back beach sample point was in a no-entry/restricted area. Swash zone, mid- beach and back beach samples were obtained from three locations, FK-02, FK-09 and FK-10. Swash zone and back beach samples were obtained from two locations, FK-01 and FK-05. Single points on the beach were sampled at two locations, FK-06 and FK-08.

Carbonate material averaged 1.3 percent of the sample sediments processed from the ten locations within this reach of beach. The average mean grain size was 0.249 mm (2.007 phi). As shown in Figure 14, the sediments down the length of these beaches trend slightly finer grained eastward. This trend is interrupted by a localized coarsening at the midpoint of this length of beach. Average grain size is coarser on St. Vincent Island than that on the reach to the west and finer grained than on Little St. George Island, the reach to the east.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of both Indian Pass, between GF-30 and FK-01, and West Pass, between FK-10 and FK-11, are shown in Appendix C. A comparison of grain sizes east and west of Indian Pass shows those sediments to the west to be approximately 0.5 phi coarser in grain size. The curves for the samples collected east of the pass have secondary peaks at grain sizes greater that 1.0 phi. A comparison of grain sizes east and west of West Pass shows little difference.

Little St. George Island

Geographic setting

Little St. George Island, also referred to as Cape St. George Island, is approximately ten miles (16.1 km) long and one mile (1.6 km) wide at its widest point. The island is undeveloped and accessible only by boat or ferry. It was formerly part of St. George Island, but was separated from St. George Island to the east in 1954 when Bob Sikes Cut, also known as Sikes or Government Cut, was established. It is separated from the mainland, to the north, by Apalachicola Bay and from St. Vincent Island, to the northwest, by West Pass. It is bounded on the south by the Gulf of Mexico.

Beach history in brief

Cape St. George, lying roughly at the middle point of the length of the island, is considered to be critically eroded. While no beach restoration is reported to have taken place on the island, material from maintenance dredging has been placed on the beach proximal to Bob Sikes Cut.

Data analysis

Within the reach of beach lying on Little St. George Island, 11 locations (FK-11 through FK-21), as delineated in Table 1 and shown in Figure 1, were sampled and 36 samples collected. Swash zone, berm, mid-beach and back beach samples were obtained from seven locations, FK-12 through FK-14 and FK-16 through FK-19. Swash zone and back beach samples were obtained from four locations, FK-11, FK-15, FK-20, and FK-21.

Carbonate material averaged 1.8 percent of the sample sediments processed from the 11 locations within this reach of beach. The average mean grain size was 0.281 mm (1.829 phi). As shown in Figure 14, the sediments trend progressively coarser grained eastward. Grain size is coarser on average than that on the reach to the west and finer grained on average than on St. George Island, the reach to the east.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of both West Pass, between FK-10 and FK-11, at Cape St. George, from FK-14 to FK-17, and Bob Sikes Cut, between FK-21 and FK-22, are shown in Appendix C. A comparison of grain sizes east and west of West Pass shows little difference. A comparison of the curves for the samples collected at Cape St. George shows little difference in their peaks but an increased percentage of coarse grained material in the samples collected east of the Cape. A comparison of grain sizes for samples obtained immediately east and west of Bob Sikes Cut shows that the sediments immediately west of the mouth, are slightly finer grained, with a curve peak at approximately 2.1 phi than those immediately to the east whose curve peaks at 1.4 phi. A comparison of grain size for the samples obtained further from the Cut shows the sediments to the west are slightly coarser grained, with its curve peaking at approximately 1.5 phi, than those farther to the east whose curve peaks at 1.6 phi.

St. George Island

Geographic setting

St. George Island is 28 miles (45.1 km) long and 2 miles (3.2 km) wide at its widest point. It is separated from the mainland, to the north, by Apalachicola Bay and St. George Sound. It is bounded on the southeast by the Gulf of Mexico. St. George Island State Park occupies the eastern nine miles (14.5 km) of the island.

Beach history in brief

In 2006, dune restoration was accomplished along a portion of the St. George Island State Park shoreline.

Data analysis

Within the reach of beach lying on St. George Island, 20 locations (FK-22 through FK-41), as delineated in Table 1 and shown in Figure 1, were sampled and 52 samples collected. Swash zone, berm, mid-beach and back beach samples were obtained from a single location, FK-22. Swash zone, berm and back beach samples were obtained from ten locations, FK-27 through FK-29, FK-31, FK-32, FK-35, FK-36, and FK-39 through FK-41. Swash zone and back beach samples were obtained from nine locations, FK-23 through FK-26, FK-30, FK-33, FK-34, FK-37, and FK-38.

Carbonate material averaged 1.7 percent of the sample sediments processed from the 20 locations within this reach of beach. The average mean grain size was 0.315 mm (1.665 phi). Compared to Little St. George Island to the west, grain size is finer on average on this reach of beach. Additionally, as shown in Figure 14, mean grain size on this reach, while locally variable, trends finer eastward.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of both Bob Sikes Cut, between FK-21 and FK-22, and East Pass, between FK-41 and FK-42, are shown in Appendix C. A comparison of grain sizes for samples obtained immediately east and west of Bob Sikes Cut shows that the sediments immediately west of the mouth, are slightly finer grained, with a curve peak at approximately 2.1 phi than those immediately to the east whose curve peaks at 1.4 phi. A comparison of grain size for the samples obtained further from the Cut shows the sediments to the west are slightly coarser grained, with its curve peaking at approximately 1.5 phi, than those farther to the east whose curve peaks at 1.6 phi. A comparison of grain size curves for samples east and west of East Pass shows that the peaks of the curves for sediments to the west are marginally coarser grained compared to those to the east with five percent of their sediments being 1.0 phi rather than the two or one percent seen to the east.

Dog Island

Geographic setting

Dog Island is separated from the mainland to the northwest by St. George Sound and from St. George Island to the east by East Pass. It is bounded on the southeast by the Gulf of Mexico. The island is approximately 6.8 miles (10.9 km) in length and is accessible only by boat, ferry or airplane. The Nature Conservancy owns much of the island with the remainder being private residential property.

Beach history in brief

No beach restoration activities have been reported on Dog Island.

Data analysis

Within the reach of beach lying on Dog Island, nine locations (FK-42 through FK-50), as delineated in Table 1 and shown in Figure 1, were sampled and 15 samples collected. Swash zone, berm and back beach samples were obtained from three locations, FK-42, FK-43 and FK-45. Swash zone, mid-beach and back beach samples were obtained from three locations, FK-44, FK-47 and FK-49. Swash zone and back beach samples were obtained from three locations, FK-46, FK-48 and FK-50.

Carbonate material averaged 0.1 percent of the sample sediments processed from the nine locations within this reach of beach. The average mean grain size was 0.319 mm (1.647 phi). Mean grain size is,

on average, finer grained than the reach to the east and, as shown in Figure 15, the sediments on this island's beaches, while locally variable, trend coarser grained eastward.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of both East Pass, between FK-41 and FK-42, and the east end of Dog Island and St. James Island, the mouth of St. George Sound in Apalachicola Bay, FK-50 and FK-51 are shown in Appendix C. A comparison of grain size curves for samples east and west of East Pass shows that the peaks of the curves for sediments to the west are marginally coarser grained compared to those to the east with five percent of their sediments being 1.0 phi rather than the two or one percent seen to the east. A comparison of grain sizes for samples obtained immediately east and west of the mouth of St. George Sound shows that the sediments west of the mouth are slightly finer grained, with their curve peaking at approximately 1.6 phi, than those immediately to the east whose curve peaks at approximately 1.4 phi. A comparison of grain size for the samples obtained further from the mouth to the east shows the sediments to the east are finer grained, with their curve peaking at approximately 2.1 phi, and broader in its range of grain sizes.

St. James Island/Alligator Point

Geographic setting

Alligator Point is an approximately seven mile (11.3 km) long peninsula extending westward from the mainland at Lighthouse Point. It is approximately 0.25 miles (0.32 km) wide, at its widest point, and separates Alligator Harbor from the Gulf of Mexico.

Beach history in brief

Extensive armoring has been constructed seaward of private properties and the county road on Alligator Point. This peninsula was severely impacted by Hurricanes Elena and Kate in 1985. Following these storms, revetments were constructed. Tropical Storm Beryl, in 1994, caused further damage, resulting in the necessity to construct emergency repairs and a revetment extension. In 1998 and 2005, both Hurricanes Earl and Dennis caused erosion and damage in this area.

Data analysis

Within this reach of beach, 15 locations (FK-51 through FK-65), as delineated in Table 1 and shown in Figure 1, were sampled and 21 samples collected. Swash zone, berm and back beach samples were obtained from two locations, FK-59, FK-61. Swash zone and back beach samples were obtained from two locations, FK-57 and FK-58. Single points on the beach were sampled at 11 locations, FK-51 through FK-56, FK-60 and FK-62 through FK-65.

Carbonate material averaged 0.6 percent of the sample sediments processed. The average mean grain size was 0.356 mm (1.489 phi). Carbonate material was below detectable limits in the four samples collected from locations on St. James Island (FK-51 through FK-54). The average mean grain size was 0.363 mm (1.460 phi). Carbonate material averaged 1.2 percent of the seven samples, from locations east of Lighthouse Point (FK-55 through FK-61). The mean grain size was 0.261 mm (1.940 phi). Carbonate material averaged 0.2 percent of the four samples, from locations north of Lighthouse Point (FK-62 through FK-65). The mean grain size was 0.517 mm (0.950 phi). Figure 15 displays mean grain size curves for the sediments on St. James Island, locations FK-51 through FK-54, and down the length of the beaches west of Lighthouse Point, locations FK-55 through FK-62. These sediments are coarser grained, on average, than the reach of beach north of Lighthouse Point extending to Bald Point, locations FK-63 through FK-65. Granulometric curves for those samples, along with curves for Wakulla County samples from locations WK-01 and WK-02, are displayed in the Ochlockonee Bay graph in Figure 16. A comparison of grain sizes immediately north and south of the mouth of Ochlockonee Bay, for locations WK-01 and FK-65 respectively, shows that the sediments to the south are both coarser grained and narrower in their range of grain sizes than those to the north.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size east and west of the east end of Dog Island and St. James Island, locations FK-50 and FK-51, the mouth of St. George Sound in Apalachicola Bay, north and south of the mouth of Alligator Harbor, locations FK-54 and FK-55, along Lighthouse Point, FK-60 to FK-63 and the mouth of Ochlockonee Bay, between locations FK-65 and WK-01 are shown in Appendix C. As discussed above, those for the mouth of Ochlockonee Bay are also shown in Figure 16. A comparison of grain sizes for samples obtained immediately east and west of the mouth of St. George Sound shows that the sediments west of the mouth are slightly finer grained, with their curve peaking at approximately 1.6 phi, than those immediately to the east whose curve peaks at approximately 1.4 phi. A comparison of grain size for the samples obtained further from the mouth to the east shows the sediments to the east are finer grained, with their curve peaking at approximately 2.1 phi, and broader in its range of grain sizes. A comparison of grain sizes for samples obtained north and south of the mouth of Alligator Harbor shows that sediments immediately to the north are bi-modal. Its curve's primary peak is at approximately -0.5 phi and shows that it is coarser grained than the sample immediately to the south whose primary peak is at approximately 1.3 phi. As noted above, a comparison of grain sizes north and south of the mouth of Ochlockonee Bay shows that the sediments to the south are both coarser grained, with their curves peaking at approximately 0.9 phi, and narrower in their range of grain sizes than those to the north whose curves peak at approximately 1.2 and 1.6 phi.

BEACH REACHES OF FLORIDA'S BIG BEND

Figures 16 through 20, progressively from north to south, illustrate grain size characteristics in the Big Bend. Figure 20 is an extension of Figure 7 from Phelps *et al.* (2010), into Pasco County. As is the case in Figures 9 through 15, shading across the displayed curves in Figure 20 delineate where inlets occur and where the sampling interval exceeds one mile (1.6 km).

The Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems (2008b), Strategic Beach Management Plan for the Big Bend Gulf Coast Region was extensively consulted and used to establish the timeline of recent beach replenishment and the construction of engineering structures on the beach reaches in this portion of the study area. Additionally, a historical database of beach replenishment projects, compiled by the Western Carolina University Program for the Study of Developed Shorelines (PSDS) (2009) was also consulted. Table 6 lists the boundaries of known metropolitan areas as well as federal, state, and county lands discussed in this report when they relate to sampling locations.

Wakulla County

Geographic setting

The short stretch of beach located adjacent to and to the north of the entrance to Ochlockonee Bay at Ochlockonee Point is in Mashes Sands County Park. Proceeding northeastward; Porter Island, Piney Island, Shell Point, Live Oak Island and Goose Creek Bay are found.

Beach history in brief

Hurricane Kate in 1985 severely damaged the beach at Shell Point. The beach at Mashes Sands County Park was severely eroded by Hurricane Dennis in 2005. As a result over time, extensive armoring, rock revetments and bulkheads have been constructed.

Data analysis

Only one sample point was utilized at each of the locations in Wakulla County. Locations WK-04 and WK-11 were not sampled as no beach was present. Carbonate material averaged 2.3 percent of the two samples collected on Mashes Sands, locations WK-01 and WK-02. The mean grain size was 0.425 mm (1.234 phi). Grain size curves for the samples collected from those locations are shown in Figure 16. That figure shows graphically a comparison of grain sizes north and south of the mouth of Ochlockonee Bay. The curves on that graph, for locations WK-01 and FK-65, show that the sediments to the south are both coarser grained than those to the north and narrower in their grain size distribution.

Porter Island was sampled at a single location, WK-03. The sample contained 0.7 percent carbonate and had a mean grain size of 0.400 mm (1.323 phi). Piney Island was sampled in three locations, WK-05 through WK-07. The samples collected on this short reach of beach were 1.7 percent carbonate. The mean grain size was 0.240 mm (2.059 phi). Figure 16 contains a graph depicting a comparison of the grain sizes on Porter and Piney Islands. That graph shows that the grain size distributions for samples from locations WK-03 and WK-05 are uni-modal and relatively narrow in their range of distribution. The graph also shows that the grain size distributions for samples from locations WK-06 and WK-07 are bi-modal and relatively broad in their range of distribution. A comparison of the curves from these two sets of samples shows that the sediments from locations WK-03 and WK-05 are coarser grained.

Shell Point was sampled at three locations, WK-08 through WK-10. The sediment sample taken from this short reach of beach contained 3.0 percent carbonate. The mean grain size was 0.346 mm (1.531 phi). Live Oak Island was sampled at two locations, WK-12 and WK-13. The sediment samples taken from this short reach of beach contained 0.7 percent carbonate. The mean grain size was 0.297 mm (1.752 phi). A single location inside Goose Creek Bay was sampled, WK-14. The sample, which contained 0.9 percent carbonate, had a mean grain size of 0.160 mm (2.645 phi). Figure 16 graphically shows a comparison of the grain sizes of sediments on Shell Point, Live Oak Island and inside Goose Creek Bay. The referenced graph on that figure shows that the grain size distributions for samples from locations WK-09 through WK-10 and WK-13, are bi-modal and relatively broad in their range of distribution while WK-12 and WK-14 are uni-modal, narrower in their distribution and fine grained.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A. Curves comparing grain size north and south of the mouth of Ochlockonee Bay, between FK-65 and WK-01, are shown in Appendix C and in Figure 16.

Dekle Beach and Keaton Beach, Taylor County

Geographic setting

These are short segments of mainland beaches which are proximal to residential development.

Beach history in brief

Erosion of the shoreline at Dekle Beach is threatening private development. No record of beach renourishment in the area was found.

Data analysis

Samples were collected from only one sample point at each of the two locations sampled in Taylor County. Location TY-02 was not sampled as no beach was present. Carbonate material comprised 1.9 percent of the sample collected on Dekle Beach, location TY-01. The mean grain size was 0.293 mm (1.771 phi). Keaton Beach was sampled at a single location, TY-03. The sample, which was 1.0 percent

carbonate, had a mean grain size of 0.325 mm (1.621 phi). Grain size curves for these samples are provided in Figure 17.

Photographs, as well as the granulometric analyses of the samples collected and processed, are provided in Appendix A.

Horseshoe Beach and Shired Island, Dixie County

Geographic setting

These are short stretches of beaches located in Dixie County. Horseshoe Beach is proximal to residential development while the beach at Shired Island is within a county park.

Beach history in brief

Horseshoe Beach is renourished on a four year cycle using sand from an upland source. Erosion on Shired Island reportedly threatens pre-Columbian shell middens and burial sites. No recorded beach restoration has occurred at Shired Island.

Data analysis

Only one sample point was utilized at each of the two locations sampled in Dixie County. Location DX-02 was not sampled as no beach was present. Carbonate material was 6.5 percent of the sample collected on Horseshoe Beach, DX-01. The mean grain size was 0.265 mm (1.916 phi). Shired Island was sampled at a single location, DX-03. The sample contained 6.5 percent carbonate. Its mean grain size was 0.269 mm (1.895 phi). Grain size curves for these samples are provided in Figure 17. The characteristics of the curve for the sample collected at Horseshoe Beach, DX-01, are different from those of the other samples collected, both to the south in Dixie County at Shired Island and to the north in Taylor County at Dekle Beach and Keaton Beach. Its curve is distinctly narrower. Additionally, the carbonate material was predominately shell fragments from mollusks. In the Dixie County samples processed, the carbonate material was predominately index foraminifera (*Lepidocyclina* sp. and *Amphistegina* sp. at DX-01 and *Nummulites* sp. and *Amphistegina* sp. at DX-03) which may signify eroded Ocala Limestone.

Photographs, as well as the granulometric analyses of the samples collected and processed, are shown in Appendix A.

The Cedar Keys, Levy County

Geographic setting

Five islands; North Key, Seahorse Key, Atsena Otie Key, Way Key and an unidentified key north and west of Way Key were sampled in the Cedar Keys. Most lie within the Cedar Keys National Wildlife Refuge. Seahorse Key rises to over 50 feet (15.24 meters) above mean sea level. It is believed to be a relic dune. All of the keys sampled, except for Way Key, are accessible only by boat. The town of Cedar Key lies on Way Key.

Beach history in brief

A short segment of critically eroded beach threatening public road and developed properties is located within the town of Cedar Key. Sand has been placed on this beach. Erosion on Atsena Otie Key is reported to be threatening archeological and historical sites. Field observations suggest that the same

may be occurring on Seahorse Key and the un-named key sampled at location LV-10. Except at the town of Cedar Key, no beach restoration has been reported to have been done on any of these keys.

Data analysis

Only one sample point was utilized at each of the ten locations sampled in Levy County. Locations LV-06 and LV-12 were not sampled as no beach was present. Carbonate material averaged 0.3 percent of the single sample collected on North Key, LV-01. The mean grain size was 0.289 mm (1.789 phi). Seahorse Key was sampled at four locations, LV-02 through LV-05. This key's beaches were 0.5 percent carbonate. Mean grain size was 0.244 mm (2.034 phi). Grain size curves for these samples are provided in Figure 18 on the graph labeled North Key/Seahorse Key.

Way Key was sampled in three locations, WK-07 through WK-09. While this short reach of beach averaged 5.2 percent carbonate, the carbonate percentage at LV-08 was significantly higher at 11.8 percent. In addition, *Nummulites* sp., *Amphistegina* sp. and *Sphaerogypsina globula* were found in the carbonate fraction of the samples from location LV-08 while *Nummulites* sp. and *Amphistegina* sp. were found at location LV-09. These foraminifera may indicate the presence of reworked Ocala Limestone in the samples. The mean grain size for this reach was 0.398 mm (1.330 phi). An unnamed key north and east of Way Key was sampled at a single location, LV-10. The sample contained 16.4 percent carbonate, consisting predominately of fragments of mollusks and barnacles. The mean grain size was 0.397 mm (1.332 phi). Atsena Otie Key was sampled at a single location, LV-11. The sample contained 1.0 percent carbonate. The mean grain size was 0.300 mm (1.736 phi). Grain size curves for these samples are provided in Figure 18 on the graph labeled Cedar Key/Atsena Otie Key. The characteristics of the curve for the sample collected at LV-09 are markedly different from those other samples collected in Levy County. It is both broader and its peak is shifted to the coarser grained end of the grain size spectrum. That location, on the beach at a city park, is known to have been replenished.

Photographs, as well as granulometric analysis, of samples collected and processed are provided in Appendix A.

Fort Gulf Island Gulf Park, Citrus County

Geographic setting

This is a short segment of beach proximal to the mouth of Crystal River.

Beach history in brief

This beach is renourished on a four year cycle using sand from an upland source.

Data analysis

Only one sample point was utilized at the single location sampled in Citrus County. Carbonate material averaged 0.7 percent of the single sample collected. The mean grain size was 0.354 mm (1.499 phi). Figure 19 depicts the grain size curve for this sample on a graph labeled Fort Island; Pine Island; Green Key; Mainland Pasco.

Photographs, as well as granulometric analysis, of samples collected and processed are provided in Appendix A.

Pine Island, Hernando County

Geographic setting

This is a short segment of beach on Pine Island at a county park variously known as Pine Island Park and Alfred Mckethan Park.

Beach history in brief

The sampling visit showed that concrete revetments were installed at this site at some point in the past. It is not known if any beach replenishment has been conducted.

Data analysis

Only one sample point was utilized at the single location sampled in Hernando County. Carbonate material averaged 1.6 percent of the single sample collected. The mean grain size was 0.609 mm (0.716 phi). Figure 19 shows the grain size curve for this sample on a graph labeled Fort Island; Pine Island; Green Key; Mainland Pasco. The characteristics of the curve for the sample collected at HR-01 are different from those of the sample collected in Citrus County to the north and on the mainland beaches of Pasco County to the south. It shows that the sample is both narrower in grain size distribution and on average coarser grained than the sample collected in Citrus County, CI-01. Additionally, the sample's curve lacks the coarse bi-modal tail of the curve for the sample taken at Green Bay, PI-08, to the south in Pasco County.

Photographs, as well as granulometric analysis, of samples collected and processed are provided in Appendix A.

Onshore Pasco County

Geographic setting

The three locations sampled all lie on the mainland. From north to south they are located on Green Key at Robert K. Rees Memorial Park, at Gulf Harbors and at Key Vista Nature Park. Two are north of the north end of Anclote Bar and the third lies due east of the midpoint of Anclote Key.

Beach history in brief

Information available from signage at Robert K. Rees Memorial Park indicates that the beach at Green Key was created when the key was modified for development. The other beaches appear to be natural.

Data analysis

Only one sample point was utilized at each of the three locations sampled. Proceeding from north to south, carbonate material averaged 43.5 percent of the single sample collected on Green Key, PS-07. The mean grain size was 0.472 mm (1.082 phi). Carbonate material averaged 4.9 percent of the single sample collected at Gulf Harbors, PS-08. The mean grain size was 0.206 mm (2.277 phi). Figure 19 shows the grain size curve for these samples on a graph labeled Fort Island; Pine Island; Green Key; Mainland Pasco. Carbonate material averaged 1.0 percent of the single sample collected at Key Vista Nature Park, PS-09. The mean grain size was 0.180 mm (2.472 phi).

Photographs, as well as granulometric analysis, of samples collected and processed are provided in Appendix A.

Anclote Bar and Anclote Key, Pasco and Pinellas Counties

Geographic setting

Anclote Bar and Anclote Key mark the northern extent of the Florida southwest coast barrier island chain. Both the bar and key are narrow and arcuate. Anclote Bar lies to the north of Anclote Key and is also known as North Anclote Bar. As seen on Figure 20, formerly there was a bar to the south of Anclote Key known as South Anclote Bar. It has since attached to Anclote Key. Anclote Bar and Anclote Key lie approximately three miles (4.8 km) off the coast and are accessible only by boat. Anclote Key spans the Pasco/Pinellas County border. Locations PI-49 and PI-50 lie in Pinellas County.

Beach history in brief

Anclote Key and Anclote Bar comprise both the Anclote Key State Preserve and Anclote National Wildlife Refuge. They are uninhabited and undeveloped. Much of the Gulf of Mexico side of Anclote Island has experienced some erosion in recent years.

Data analysis

Within the reach of beach lying on Anclote Bar, three locations (PS-01 through PS-03), as delineated in Table 1 and shown in Figure 1, were sampled and five samples collected. Swash zone and back beach samples were obtained from two locations, PS-01 and PS-02. Only a single sample point was utilized at PS-03. Within the reach of beach lying on Anclote Key, five locations (PS-04 through PS-09), as delineated in Table 1 and shown in Figure 1, were sampled and 12 samples collected. Swash zone, berm and back beach samples were obtained from two locations, PS-04 and PI-49. Swash zone and back beach samples were obtained from three locations, PS-05, PS-06 and PI-50.

Carbonate material averaged 1.8 percent of the sample sediments processed from the three locations lying on Anclote Bar. The average mean grain size was 0.185 mm (2.433 phi). Carbonate material averaged 1.0 percent of the sample sediments processed from the five locations lying on Anclote Key. The average mean grain size was 0.172 mm (2.542 phi). Carbonate material averaged 1.0 percent of the sample processed from the three locations on Anclote Bar, PS-04 through PS-06, lying in southern Pasco County. The average mean grain size for those samples was 0.171 mm (2.544 phi). Carbonate material averaged 1.0 percent of the sample processed from the two locations on Anclote Bar, PI-49 and PI-50, lying in northern Pinellas County. The average mean grain size for those samples was 0.172 mm (2.539 phi). The sediments on Anclote Bar contain more carbonate material and are coarser grained than those found on Anclote Key. When the samples collected on the north end of Anclote Key are compared with those from the south end, little difference is seen.

Comparisons of the grain size curves for locations PI-01 and PI-02 on Anclote Bar, and locations on the mainland, shown in Figure 19, reveal that grain size distribution is narrower on Anclote Bar than on the mainland. As shown in Figure 20, the sediments down the length of these island's beaches are almost entirely non-carbonate and fine grained. The sediments sampled on Anclote Bar were both slightly coarser grained and contained more carbonate material than those on Anclote Key.

Photographs, as well as granulometric analysis, of samples collected and processed are provided in Appendix A.

SUMMARY AND CONCLUSIONS

Appendix A provides photographs of beach conditions and descriptions and photographs of all samples as well as granulometric analysis of selected samples from each location. That appendix also provides analysis of their color via the use of Munsell Color Charts. Color, generally from an aesthetic view point, is considered a secondary parameter of importance. Historically however, the political/economic ramifications of beach replenishment sediment color mismatches with *in situ* sediments can be considerable. Appendix B provides sediment sample quality control analyses. Appendix C provides comparative grain size distribution curves across individual inlets, passes and river, bay and harbor mouths. Table 1 relates beach reaches to beach sampling locations, Table 2 provides the latitude and longitudes of the sample locations, Table 4 relates beach monument survey points to beach sampling locations, Table 6 relates land designations to beach sampling locations, Table 7 provides a summary of beach sediment descriptions and Table 8 provides a summary of the average carbonate percentages and mean grain size for the various reaches. Figures 9 through 15 graphically display changes in mean grain size from west to east for the northwest coast. Figures 16 through 19 graphically display grain size curves for samples collected from the beaches of Florida's Big Bend. Figure 20 displays changes in carbonate percentages and mean grain size for the reach of beach extending from Anclote Bar south to Ana Maria Key. Photomicrographs of 13 samples, illustrating variability in grain size and material, are provided in Appendix D. A Power Point presentation illustrating the study area and our findings is provided in Appendix E.

The beaches of Florida's northwest coast

Unlike the southwest coast and east coast of Florida, as seen in Phelps *et al.* (2009 and 2010), carbonate material on the beaches of Florida's northwest coast averages less than four percent of the sediments in the samples analyzed. It is a very small fraction of the total sediment volume. Based on analysis of the granulometric curves shown in Figure 21, the northwest coast of Florida can be divided into three regions.

Proceeding from west to east, the first region is defined by the area bounded by sample locations ES-01 and BY-15. This region includes the reaches of Perdido Key, Santa Rosa Island/Okaloosa Island and Choctawhatchee Bay to Philips Inlet as well as the major portion of the reach from Philips Inlet to St. Andrew Bay. It stops just west of the mouth of St. Andrew Bay. In this region, the mean grain size curve generally declines eastward. The curve peaks on Perdido Key, in western Escambia County, on Santa Rosa Island, in eastern Escambia County, and on the mainland beaches of western Bay County. Figures 9, 10 and 12, respectively, show the relationship of these peaks to geographic features.

The second region is defined by the area bounded by sample locations BY-16, approximately 4 miles (6.4 km.) west of the mouth of St. Andrews Bay, and FK-15, on the west side of Cape St. George. This region includes a small part of the reach from Philips Inlet to St. Andrew Bay and the reaches of the Shell Island/Crooked Island barrier complex, Mexico Beach, the St. Joseph Peninsula/Cape San Blas/Indian Peninsula barrier complex, St. Vincent Island and the western portion of Little St. George Island to Cape St. George. Figure 21 shows that the mean grain size in this region, on average, is finer grained than in the regions to either side.

The third region is defined by the area bounded by sample locations FK-16, on the east side of Cape St. George, and the beginning of Florida's Big Bend at FK-65. This region includes Little St. George Island east of Cape St. George and the reaches of St. George Island, Dog Island, and St. James Island/Alligator Point. It exhibits a large gap between FK-50, on the east end of Dog Island, and FK-51, where beaches start on the mainland. Mean grain size generally increases eastward across this region. Figure 15 shows that the mean grain size curve peaks both at the end of the Alligator Point spit and at Bald Point. Between those points, the curve shows a significant trough at the midpoint of the Alligator Point spit. This region shows the largest variances of mean grain size of any of the three regions.

The beaches of Florida's Big Bend

Several general observations can be made regarding the beaches of Florida's Big Bend. The majority of this area has very little in the way of sandy beaches due to a general paucity of natural sources of sand sized material. Mean grain size is quite variable across the Big Bend.

Beaches in Wakulla County and on Bald Point in Franklin County are highly variable in mean grain size. Progressing northward and eastward, from Franklin County into Wakulla County, mean grain size becomes quite variable from location to location and the grain size distribution curves go from uni-modal and coarser grained to bi-modal coarse and fine grained and then to uni-modal finer grained sediments predominating.

Of the beaches in Taylor County, those at Keaton Beach seem to have been anthropogenically altered. Both Keaton Beach and Dekle Beach have been substantially augmented and protected with engineered structures.

The natural beaches in Dixie and Levy Counties owe their existence to sediments supplied by the ancestral Suwannee River, relict dunes and likely reworking of the Ocala Limestone. While the mean grain size is variable, the sediments are finer grained than those on the beaches to the north in Franklin County at Bald Point and in Wakulla County. They are coarser grained than the beaches of Anclote Bar and Anclote Key further south.

The beaches sampled in Citrus and Hernando Counties have been modified with engineered structures. The beach at Fort Gulf Island Park in Citrus County is known to be anthropogenic.

Of the onshore beaches in southern Pasco County, the beach at Key Vista Nature Park appears to be natural while that at Robert K. Rees Memorial Park on Green Key is anthropogenic. The beach at Gulf Harbors is substantially augmented and protected with engineered structures.

Those beaches found on islands offshore of southern Pasco County and northern Pinellas County, Anclote Bar and Anclote Key, should more properly be identified as part of the southwest Florida barrier island system. They are the northern extension of the northern most of the regions described in Phelps *et al.* (2010). That region extends from the northern end of Anclote Bar to the middle of Clearwater Beach Island. It is typified by low carbonate percentages and mean grain sizes that are finer grained than those of the reach to its south and the natural beaches of the Cedar Keys well to the north.

REFERENCES CITED

American Society for Testing and Materials, 2000a, Standard test method for particle-size analysis of soils: West Conshohocken, Annual Book of ASTM Standards, American Society of Testing and Materials International, v. 4.08, p. 10-16.

American Society for Testing and Materials, 2000b, Standard guide for statistical procedures to use in developing and applying test methods: West Conshohocken, Annual Book of ASTM Standards, American Society of Testing and Materials International, v.14.02, p. 583-588.

Balsillie, J. H.,1995, William F. Tanner on environmental clastic granulometry: Florida Geological Survey Special Publication 40, 145 p.

Balsillie, J. H., 2002a, Analytic granulometry tools: http://www.dep.state.fl.us/geology/geologictopics/analytic_gran_tools/analytic_gran.htm, (February 2009).

Balsillie, J. H., 2002b, Red flags on the beach, part III: Journal of Coastal Research, v. 18, p. iii-vi.

Balsillie, J. H., and Dabous, A. A., 2003, A new type of sieve shaker; the Meinzer II, comparative study with Rotap technology: Florida Geological Survey Open File Report 87, 93 p.

Balsillie, J. H., and Tanner, W. F., 1999, Suite versus composite statistics: Sedimentary Geology, v. 125, p. 225-234.

Balsillie, J. H., Tanner, W. F., and Williams, H. K., 1999, Sticky grain occurrences in sieving: Florida Geological Survey Open File Report 79, 15 p.

Balsillie, J. H., Dabous, A. A., and Fischler, C. T., 2002a, Moment versus graphic measures in granulometry: Florida Geological Survey Open File Report 84 , 85 p.

Balsillie, J. H., Donoghue, J. F., Butler, K. M., and Koch, J. L., 2002b, Plotting equation for Gaussian percentiles and a spreadsheet program application for generating probability plots: Journal of Sedimentary Research, v. 72, p. 929-933.

Clark, R. R., 1993, Beach conditions in Florida: a statewide inventory and identification of the beach erosion problem areas in Florida: Florida Department of Environmental Protection, Beaches and Shores Technical and Design Memorandum 89-1, 202 p.

Conover, W.L., 1999 Practical nonparametric statistics, 3rd Edition: New York, John Wiley & Sons, 584 p.

Davis, R. A., 1994, Barriers island systems a geologic overview, *in* Davis, R. A., ed., Geology of Holocene Barrier Island Systems: Berlin, Springer-Verlag, p. 167-205.

Davis, R. A., 1997, Geology of the Florida Coast, *in* Randazzo, A.F. and Jones, D.S., eds. The Geology of Florida: Gainesville, University Press of Florida, p.155-168.

Eshbach, O.W., and Souders, M., eds., 1975, Handbook of Engineering Fundamentals, 3rd. Edition: New York, John Wiley & Sons, 1562 p.

Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems, 2008a, Strategic Beach Management Plan for the Panhandle Gulf Coast Region: http://www.dep.state.fl.us/beaches/publications/pdf/SBMP/Panhandle%20Gulf%20Coast%20Region.pdf (January 2011).

Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems, 2008b, Strategic Beach Management Plan for the Big Bend Gulf Coast Region: http://www.dep.state.fl.us/beaches/publications/pdf/SBMP/Big%20Bend%20Gulf%20Coast%20Region.pdf (May 2011).

Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems, 2008, Strategic Beach Management Plan for the Southwest Gulf Coast Region: http://www.dep.state.fl.us/beaches/publications/pdf/SBMP/Southwest%20Gulf%20Coast%20Region.pdf (May 2011).

Hine, A.C., Belknap, D.F., Hutton, J.G., Osking, E.B., and Evans, M.W., 1988. Recent geological history and modern sedimentary processes along an incipient, low-energy, epicontinental-sea coastline: Northwest Florida: Journal of Sedimentary Petrology v. 58 p. 567-79.

Hine, A.C., Brooks, G.R., Davis, R.A., Jr., Doyle, L.J., Gelfenbaum, G., Locker, S.D., Twichell, D.C., and Weisberg, R. H., 2001, A Summary of Findings of the West-Central Florida Coastal Studies Project: US Geological Survey Open File Report 01-303: http://pubs.usgs.gov/of/2001/of01-303/index.html, (June 2010)

Martens, J.H.C., 1931, Beaches of Florida, *in* Florida Geological Survey Twenty-First/Twenty-Second Annual Reports, p. 67-119.

Phelps, D.C., Ladle, M., and Dabous A. A., 2009, A sedimentological and granulometric atlas of the beach sediments of Florida's east coast, report to the National Oceanic and Atmospheric Administration: Florida Geological Survey unpublished report (on DVD).

Phelps, D.C., Ladle, M., and Dabous A. A., 2010, A sedimentological and granulometric atlas of the beach sediments of Florida's southwest coast and Keys, report to the National Oceanic and Atmospheric Administration: Florida Geological Survey unpublished report (on DVD).

Vernon, R.O., 1951, Geology of Citrus and Levy counties Florida: Florida Geological Survey Bulletin 33, p. 256

Western Carolina University Program for the Study of Developed Shorelines (PSDS), 2011, The U.S. Beach nourishment experience including New England, east coast barrier islands, Pacific coast, and Gulf of Mexico shorelines: http://www.wcu.edu/1038.asp (February 2010).

Wright, E.E., Hine, A.C., Goodbred, S.L. Jr. and Locker, S.D., 2005, The effects of sea-level and climate change on the development of a mixed siliciclastic-carbonate, deltaic coastline: Suwannee River, Florida, U.S.A: Journal of Sedimentary Research, v. 75, p 621-635.

ACKNOWLEDGMENTS

This report could not have been accomplished without the aid and assistance of numerous national wildlife refuge, national park, national defense, state park, county and city personnel who kindly provided access, through their jurisdictions, to the various beaches sampled. The authors are indebted to Brian Clark for his aid in the preparation of multiple figures within this report, to Cindy Fischler for taking the microphotographs, the Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems from whose reports we have in part extracted timelines of beach restoration and replenishment activities and to Guy (Harley) Means, Christopher Williams, Frank Rupert and Ronald Hoenstine for their efforts in the review and editing of the various drafts of this report. We would especially like to thank Julian (Wade) Stringer for his invaluable aid in sample collection and the care, operation and maintenance, in the field, of the utility vehicle and vessel utilized in sampling. Vessel operations in the surf zone and near shore are always difficult and occasionally hazardous. It was reassuring to have Mr. Stringer at the helm and Christopher Williams on the sampling team in those efforts.