GEOLOGICAL SURVEY OF ALABAMA

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GEOLOGIC INVESTIGATIONS PROGRAM

COMPREHENSIVE SHORELINE MAPPING, BALDWIN AND MOBILE COUNTIES, ALABAMA: PHASE II

OPEN FILE REPORT 1106

by

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CONTENTS

ILLUSTRATIONS

TABLES

COMPREHENSIVE SHORELINE MAPPING, BALDWIN AND MOBILE COUNTIES, ALABAMA: PHASE II

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INTRODUCTION

The purpose of this study is to classify shoreline protection and general shoreline type and to quantify shoreline change, where applicable, in Mobile and Baldwin Counties, Alabama. The overall project is divided into Phases I through III. Field work efforts for Phase I occurred between March 16, 2009, and November 6, 2009, during which the GSA mapped and documented about 210 miles of shoreline in Mobile Bay, Weeks Bay, Fish River, Magnolia River, Deer River system, and Fly Creek (Jones and others, 2009). The current or "Phase II" study areas include Bon Secour River, Oyster Bay, Little Lagoon, the Gulf Intracoastal Waterway (Alabama segment), Wolf Bay, the "Dog River System," and adjoining navigable tributaries as mapped between March 16, 2010 and October 29, 2010. This project is a cooperative effort between Alabama Department of Conservation and Natural Resources, Lands Division, Coastal Section (ADCNR) and the Geological Survey of Alabama (GSA) to accomplish the aforementioned tasks in Alabama's coastal zone.

Shoreline type and stabilization methods play an important role in the Alabama coastal area with both adverse and favorable impacts to shorelines. As a result of natural processes and anthropogenic influences, the intertidal area of coastal Alabama is constantly changing and change can occur extremely rapidly or subtly. Regardless of the rate of change, continuous development along coastal shoreline is inevitable and is a key factor in the observed change. Shoreline stabilization is the final overarching goal of erosion control projects and, because of persistence in coastal erosion, hard shoreline structures and non-structural shoreline protection types are found throughout coastal Alabama.

Although erosion is a natural process along a tidal shoreline, hard shoreline stabilization techniques can limit erosion and potential effects of sea level rise. The installation of hard shoreline structures can negatively impact nearshore and intertidal zones and upland habitat, alter established littoral patterns and shoreline dynamics, destroy existing marsh and curtail marsh development seaward of hard structures,

decrease the aesthetic value of property, as well as accelerate impacts of erosion on adjoining properties (Kana and others, 1995; Pennsylvania Department of Environmental Protection, 2001; LaRoche, 2007; National Park Service, 2009). Based on work by Stewart (2001), Johannessen and MacLennan (2006), LaRoche (2007), and the Louisiana Department of Natural Resources (2009), shoreline stabilization and type mapping can be used to:

- assist with shoreline planning, permitting coastal zone activities, Coastal Zone Management oversight, and further develop ordinances and regulatory guidelines;
- provide an effective tool for the assessment and forecasting of shoreline change and understanding cumulative and compounding effects of natural and anthropogenic influences through data acquisition;
- prioritize or evaluate protected shorelines for future conversion to a soft shoreline protective measure or alternative method and identify potential demonstration project areas for alternative methods;
- allow coastal managers access to up-to-date shoreline stabilization trends and characteristics through geospatial mapping;
- promote assessment of sediment management issues, coastal erosion, habitat protection, and flooding projects;
- promote new and improved methods for shoreline stabilization measures that have a positive impact on natural habitat, adjoining properties, and aesthetics; and
- promote governing and public education and awareness.

This report briefly describes shoreline protection and general type and shoreline change estimates within sections of the Alabama coastal zone in support of Section 309 of the Coastal Zone Management Act of 1972. Currently, no comprehensive inventory of geographic information system (GIS) thematic layers representing shoreline protection, shoreline type, and comprehensive compilation of public and private boat ramps for coastal Alabama exists. In addition, there is a need to further quantify areas of short-term erosion in coastal Alabama. The main objectives of this study, through the application of GIS, are to classify shoreline protection methods, classify general shoreline types, and quantify shoreline rates of change based on the available orthophotography.

ACKNOWLEDGMENTS

Funding for this project was provided by the ADCNR and, in part, by a grant from the National Oceanic and Atmospheric Administration (NOAA), Office of Ocean and Coastal Resource Management, Award No. 09NOS4190169. Thanks are extended to the Alabama Department of Conservation and Natural Resources, Lands Division, Coastal Section for assistance with initial planning and the use of boat and facilities. GSA also thanks the Mobile Bay National Estuary Program, the city of Mobile, the Mobile County Department of Revenue, Baldwin County Commission, the U.S. Geological Survey (USGS), and the U.S. Department of Agriculture for the acquisition and documentation of orthophotography sets.

PREVIOUS INVESTIGATIONS

Limited work has been done quantifying and mapping shoreline armoring and generalized type and shoreline change estimates within the tidal zones of Baldwin and Mobile Counties, Alabama. The work that has been done is outdated and was mainly determined through aerial photography. It has been recognized that both natural stressors and human activities play a role in hydrodynamics and shoreline change in coastal Alabama (Chermock, 1974; Hardin and others, 1976; Sapp and others, 1976; Alabama Coastal Area Board (ACAB), 1980; Smith, 1981; Douglass and Pickel, 1999a, 1999b). These natural and human factors include the construction of waterways, roads, and hard shoreline stabilization structures (for example jetties, groins, revetments, seawalls); the clearing or filling of shoreline-adjoining habitats such as pine savannah, maritime forest, beach and dune, and wetland; sediment supply; soil properties; and exposure to currents, waves, and storms. At the expense of natural shorelines, private property owners and governing entities have constructed shoreline structures to minimize shoreline erosion often leading to the erosion on adjoining shorelines and net loss in the intertidal zone (Sapp and others, 1976; Douglass and Pickel, 1999a).

SHORELINE CLASSIFICATION MAPPING

Until present, the amount of shoreline armoring has been determined through historical maps, aerial photography, and limited field data acquisition. Sapp and others (1976) determined that the filling of wetlands and the construction of jetties, groins, and seawalls were partly evident in the 1700s. Smith (1981) and ACAB (1980) also

determined the position of bulkheads, groins, jetties, and other forms of stabilization as related to shoreline loss and sediment retention. Formally considered the most reliable estimate to date, the work by Douglass and Pickel (1999a, 1999b) determined that 30 percent of the shoreline in Mobile Bay was armored by bulkheads and rubble by 1997; of the 153,400 feet of armored shoreline mapped, 71 percent, 21 percent, and 8 percent were bulkhead, rubble-mound revetment, and trash revetment, respectively. Their findings are tabulated in table 1.

Table 1.—Determined length of armored and natural shoreline in Mobile Bay, Alabama (modified from Douglass and Pickel, 1999a).

Year	Armored		Natural		Area of significant change in shoreline armoring
	Feet	Percent	Feet	Percent	
1955	39,900	8	475,600	92	Point Clear, Mullet Point
1974	72,000	14	443,500	86	Point Clear to Mullet Point, Morgan Peninsula, and part of western Mobile Bay
1985	132,000	26	383,500	74	western Mobile Bay, Mullet Point to Weeks Bay
1997	153,400	30	362,100	70	Fairhope to Weeks Bay, west Mobile Bay

Jones and others (2009) determined through the application of GIS technology during extensive field activities, the most predominant shoreline protection structures are bulkheads followed by rubble/riprap. About 721,776 feet of shoreline was mapped with 38.4 percent found to be armored. Phase I findings for Mobile Bay and additional areas are tabulated in table 2.

Table 2.—Results from Phase I activities as mapped and calculated using GIS for Baldwin and Mobile Counties, Alabama (modified from Jones and others, 2009).

Mapped area	Shoreline length (feet)	Hard armored shoreline/natural (percent)	Unretained shoreline (percent)
Mobile Bay	721,776	38.4	61.4
Weeks Bay	60,192	26.1	73.9
Fish River	158,928	24.3	75.7
Magnolia River	81,312	16.5	83.5
Deer River System	80,256	31.1	68.9
Fly Creek	15,312	52.8	47.2

SHORELINE CHANGE

Mobile Bay has been the focus of previous shoreline erosion studies (Hardin and others, 1976; ACAB, 1980; Smith, 1981). Hardin and others (1976) determined that about 56 percent of the coastal Alabama shoreline is eroding (from 0 – 5 feet per year (ft/yr) to more than 10 ft/yr), primarily along the western shore of Mobile Bay (average of 3.17 ft/yr; maximum at Cedar Point of 8.56 ft/yr), Dauphin Island, and the northern shoreline of Morgan Peninsula (average of about 3 ft/yr). Of the 504 miles of estuarine and gulf-fronting shoreline, the ACAB (1980) depicted 94 percent and 33 percent, respectively, of the gulf-fronting and estuarine shorelines receding. Areas common to the ACAB study included the eastern and western shore of Mobile Bay and the northern shore of Morgan Peninsula. The ACAB (1980) study determined the following:

- The western shore of Mobile Bay can be classified as a narrow sand or marsh shoreline with widespread erosion represented by bank undercutting and threatened residential structures and infrastructure with an estimated average receding rate of less than 5 ft/yr.
- The shorelines between Dog River Point and Fowl River Point and between Delchamps Bayou and Cedar Point represent areas of the highest erosion where Cedar Point was found to have receded about 488 feet between 1917 and 1974.
- Most of the eastern shoreline of Mobile Bay was estimated to be stable with periodic erosion north of Great Point Clear, Red Bluff, Seacliff, and areas along the lower part of the bay; north of Great Point Clear the average erosion was 5 ft/yr between 1917 and 1956.
- Erosion was common along the north Morgan Peninsula (Bon Secour River to Mobile Point) with rates estimated to be more than 10 ft/yr with shoreline loss determined between the years of 1917 and 1974 ranging between about 100 and 800 feet.

During Phase I, Jones and others (2009) determined shoreline change rates from orthophotography dating between 1996 and 2008, using the Digital Shoreline Analysis System (DSAS) (Thieler and others, 2009) for change analysis and statistics. In support of the findings by Hardin and others (1976) and ACAB (1980), areas of erosion were common on the western Mobile Bay and northern Morgan Peninsula shorelines. Jones and others (2009) quantified that western Mobile Bay exhibited high recession trends in the vicinity of Deer River and Point Judith. A mean shoreline change rate of -8.2 ± 4.5 feet per year is indicated near the mouth of Deer River. Moderate erosion is indicated at

other locations along western Mobile Bay such as Point Judith, Alabama Port, Delchamps Bayou, and Brookley. Significant erosion was quantified in Mobile Bay on Morgan Peninsula in the vicinity of St. Andrews Bay, Little Point Clear, and Three Rivers where rates of shoreline erosion range from -5.0 ± 1.3 to -29.3 ± 4.5 feet. The stretch of shoreline extending from Little Point Clear and east to Edith Hammock displayed an erosion trend with a mean shoreline change rate of -5.4 ± 2.3 feet per year. Similar to the findings by the ACAB (1980), eastern Mobile Bay exhibited slight erosion trends south of Ragged Point, with a mean shoreline change rate of -2.9 ± 2.0 feet per year. Locations along Bon Secour Bay showed similar trends. From Fish River Point to Seymour Bluff, valid transects were sparse yet those available retain a strong indication of recession with a mean shoreline change rate of -3.9 ± 2.7 feet per year.

STUDY AREA

Baldwin and Mobile Counties encompass over 2,800 square miles with the terrain area consisting mainly of mixed forest, evergreen forest, and agriculture-grassland cover types (U.S. Census Bureau, 2007; Keller and Bowman, 2006) and includes about 53 statute miles of Gulf of Mexico-fronting coastline and 607 statute miles of tidal shoreline (National Atlas of the United States, 2005). With the exception of developed areas, pine savannah, maritime forest, beach and dune, and marsh are the dominate land cover types in water-fronting land.

These counties lie within two physiographic districts: the Southern Pine Hills and the Coastal Lowlands (Sapp and Emplaincourt, 1975) (fig. 1). The Southern Pine Hills district is characterized by broad, rounded hills of low relief with segregated flat upland areas. As the number of incised channels increase with distance from the broad alluvium deposits, a dendritic drainage pattern is evident with well defined stream channels, narrow riparian buffers, and occasional steep stream banks. The Coastal Lowlands district is of very low relief and is characterized by abundant sand which allows for broad floodplains and wide riparian wetlands. The area is underlain by the Miocene series undifferentiated and the Citronelle Formation of Pliocene and Pleistocene age (fig. 1).

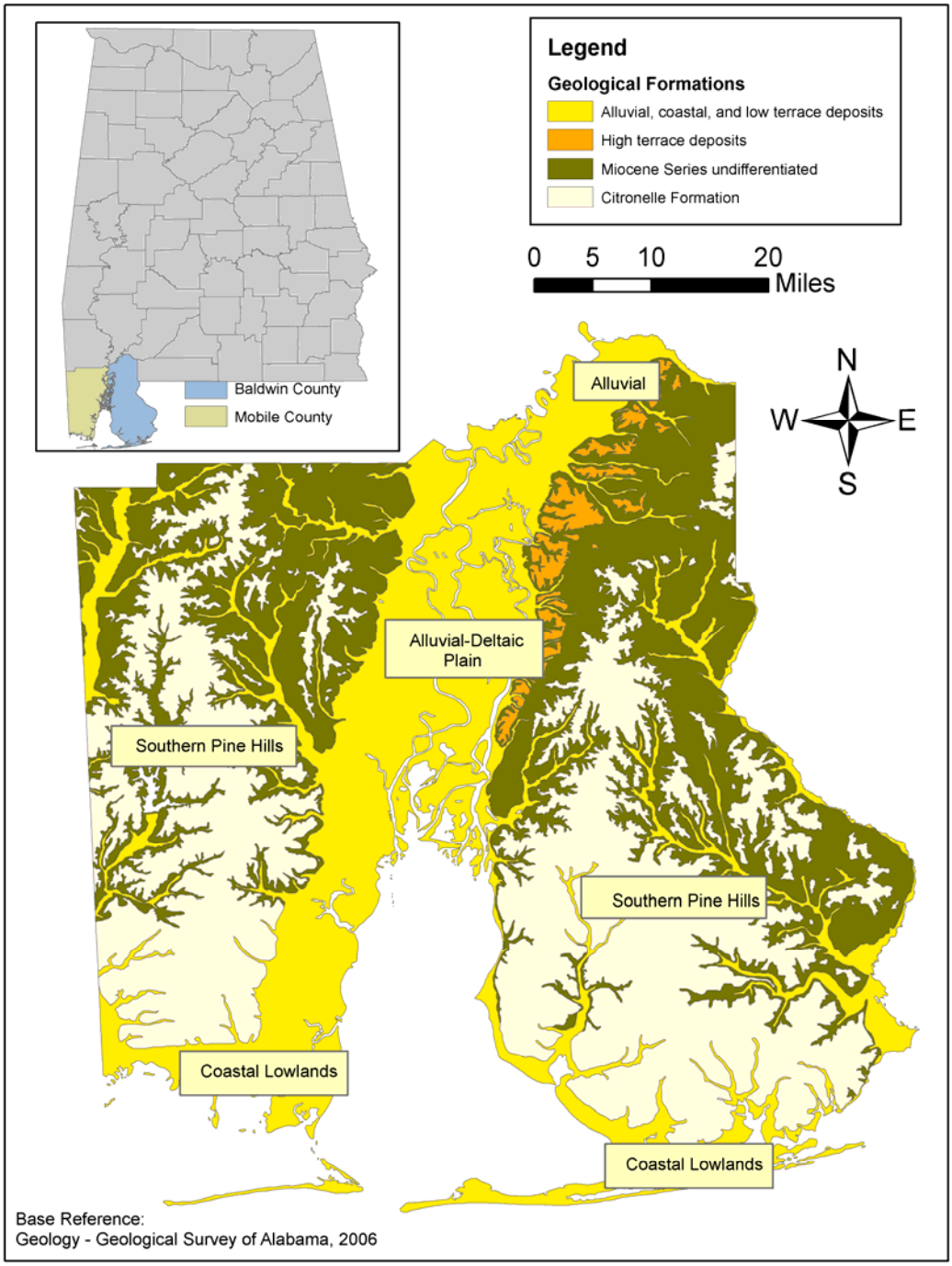

Figure 1.--Generalized geology and physiography in Baldwin and Mobile Counties, Alabama

The study areas for Phase II and described herein are Little Lagoon, the Alabama segment of the Gulf Intracoastal Waterway, Oyster Bay (includes Bear Creek), Wolf Bay, and Bon Secour River (including Boggy Branch and Brights Creek) in Baldwin County and Dog River and adjoining tributaries in Mobile County (fig. 2). For convenience, the “Dog River System” and its adjoining tributaries Alligator Bayou, Moore Creek, Robinsons Bayou, Perch Creek, Rabbit Creek, Rattlesnake Bayou, and Halls Mill Creek have been combined and are referred to hereafter as the Dog River System.

METHODOLOGY

This assessment was conducted based on developing shoreline protection and generalized type classification data using GIS during field reconnaissance and estimating shoreline rates of change by the GIS modeling of digitized historical shorelines from orthophotography developed into a shoreline vector modeling database.

Thematic development and modifications were performed using the Environmental Systems Research Institute, Inc. (ESRI®) ArcGIS® ArcInfo® 9.3 platform including ArcCatalog™ and ArcToolbox™. This software provided the necessary tools for data development, management, and portability. One update was needed to the GIS platform to facilitate data acquisition. The visual basic script for ArcGIS, “legend attribute”, was acquired and installed to attribute polyline and point shapefiles with unique classification entries (Hare, 2006). The script or extension promoted initial development of the classification attributes and allowed for further classification modifications during field collection (Gallant, 2009).

The base layer selected for the project is 0.5-meter pixel resolution (mission date: March 2006; horizontal position accuracy: 5 meters) color orthophotography collected and processed by Aerials Express, LLC, for the USGS to supply “best available” orthophotography to end users for urban coverage and pre- and post-hurricane planning in coastal areas (USGS, 2007). Although this image set does not include the middle waters of Mobile Bay or extreme northern Baldwin and Mobile Counties, its use is desirable because it minimizes file size, increases GIS performance and response, and eliminates coverage outside the project extent.

Figure 2.--Study area map.

0 4 8 12 Miles

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It should be noted that because GIS themes were developed, metadata documentation was processed through ArcCatalog and written to provide specific theme reference information such as abstract, purpose, lineage, data quality, time and scale of data, spatial reference, process step(s), attributes, disclaimers, and other information. Metadata was formally parsed using mp 2.7.33 developed by the USGS in October 2002. The function of the mp program is to identify errors within a metadata document that are inconsistent with the Content Standard for Digital Geospatial Metadata (CSDGM) (FGDC, 1998). Every effort was made to identify and correct discrepancies and warnings in compliance with CSDGM while retaining the metadata record as developed by the originator.

Shoreline mapping was conducted using a 20-foot Blue Wave® 200 V-Bay boat provided by ADCNR and a Fujitsu LifeBook® T5010 tablet personal computer preloaded with GIS software, project base layer orthophotography, and GIS themes. Field acquisition was expedited through real-time GPS tracking within the GIS and continuous editing of the shapefiles. Shoreline protection and general type were classified by visual field interpretation. The shoreline protection classification was conducted by evaluating material placed in one of three places: seaward of the shoreline, along the shoreline, or landward of the shoreline. The shoreline was used to classify shoreline type, but when prohibited by shoreline stabilization, type was evaluated landward behind the shoreface to determine the shoreline type. For Phase II, field work began on March 16, 2010 and was concluded on October 29, 2010.

SHORELINE CLASSIFICATION SCHEME

The shoreline protection and shoreline type categories were updated from last year to include areas where new shore protection types were encountered. Table 3 represents shoreline protection and type classifications. In addition to base layer data, the classification aspect consists of four geospatial thematic layers: shoreline protection polylines, shoreline type polylines, public and private boat ramp point locations, and photo point locations.

SHORE PROTECTION CLASSIFICATION

Sixteen categories were designated to describe shore protection where the bulkhead, rubble/riprap, and sill were subdivided with modifiers to better depict the types of hard shoreline protection (table 3). Jones and others (2009) detailed the types and

provided examples of each hard shore protection classification. It should be noted that the natural, unretained shoreline represents a shore "protected" within a natural setting by only vegetation or sediment with no apparent hard shoreline modification to protect the land behind it. The natural, unretained shoreline is commonly associated with wetland environments and undeveloped properties. It is likely that the rubble/riprap classification used in this study represents that identified by Douglass and Pickel (1999a) as "trash revetments" and "rubble-mound revetments."

Table 3.--Shoreline protection and type mapping classifications.

Shore Protection Classification (Shoreline Armoring)	Shoreline Type Classification (Natural Shoreline Characteristics)
1. Natural, unretained 2. Seawall (concrete, steel piles) 3. Bulkhead (concrete, rock) 4. Bulkhead (concrete, rock w/riprap) 5. Bulkhead (concrete, rock w/riprap and groin) 6. Bulkhead (steel, wood) 7. Bulkhead (w/groin) 8. Bulkhead (w/riprap) 9. Bulkhead (w/riprap and groin) 10. Bulkhead (w/retaining walls and riprap) 11. Bulkhead (w/retaining walls and groin) 12. Bulkhead (w/retaining walls) 13. Bulkhead (w/riprap and sill) 14. Bulkhead (w/riprap, sill and groin) 15. Bulkhead (w/sill) 16. Abutment 17. Revetment 18. Breakwater (headland, reef ball, wave fence) 19. Bioengineered (vegetated) 20. Groin 21. Jetty (steel pile, rock, concrete) 22. Sill (rock, shell) 23. Sill (wood) 24. Sill (wood w/riprap) 25. Beach Nourishment 26. Rubble/riprap 27. Rubble/riprap (w/groin) 28. Rubble/riprap (w/tires) 29. Boat ramp 30. Silt fence 31. Tires 32. Cement	1. Artificial 2. Vegetated bank shoreline a. Bluff b. High bank c. Low bank 3. Sediment bank shoreline a. Bluff b. High bank c. Low bank 4. Organic shorelines a. Open shoreline vegetated fringe b. Swamp forest c. Marsh 5. Sediment bank shoreline a. Bluff b. High bank c. Low bank 6. Inlet a. Ebb-tide delta b. Flood-tide delta 7. Pocket beach

SHORELINE TYPE CLASSIFICATION

Seven broad categories were designated to describe shoreline type (table 3). Jones and others (2009) detailed the types and provided examples of each shoreline type. Several subcategories were developed to better depict shoreline types and are mainly applied to vegetated bank, sediment bank, and organic categories. It should be noted that the growth of natural vegetation and hydrodynamic processes alter shorelines and, thus, delineating the artificial shoreline class can be problematic and is not always feasible.

SHORELINE RATE OF CHANGE

The GSA uses the Digital Shoreline Analysis System (DSAS) version 4.0 (Himmelstoss and others, 2009; Thieler and others, 2009) for shoreline change analysis. DSAS functionality and attributes are described in the user guide (Morton and others, 2004; Himmelstoss and others, 2009). The DSAS model is an extension that enhances the normal functionality of ArcGIS to model shoreline change rates and generate statistics from historical shoreline vector data. These data are provided in the GIS project and are attributed to the transect vectors. Incorporating the DSAS model into shoreline monitoring allows for repeatable, first approximation shoreline change analysis, creates an environment suitable for site specific analysis, facilitates updates as needed, and implements an existing modeling tool recognized across governmental agencies.

Imagery for the years of 1996, 1997, 2001, 2002, 2005, 2006, 2008, 2009 and 2010 were collected from sources such as the Baldwin County Commission, the Mobile County Department of Revenue, and the United States Geological Survey. These data were evaluated for spatial accuracy using ArcGIS®. Shoreline vectors were created for each year by digitizing the wet/dry line in ArcGIS. This process was conducted at a close scale to minimize spatial error. Continuous shoreline vectors are not possible due to various factors, including vegetated or canopied shorelines, bulkheads, or other manmade or natural features that obscured or prohibited change of the shoreline. As pointed out by Stewart (2001) and further modified during this study, limitations in the use of orthophotography for shoreline vector development and DSAS modeling is limited mainly by the resolution of source orthophotography, availability of historic

orthophotography for the study area, and shadows, glare, aquatic vegetation, and overhead obstructions disallowing the development of shoreline vectors. An estimate of error (table 4) has been calculated for each vector as described in Fletcher and others (2003), Morton and others (2004), and Jones and Patterson (2007).

Table 4.--Shoreline vectors and error estimates used in Digital Shoreline Analysis System (DSAS) modeling.

Measurement Errors	**1996, 50' (m)**	**1996, 100' (m)**	**1996, 200' (m)**	**1996, 400' (m)**	**1997 (m)**
Rectification Error (E_r)	0.381	0.762	1.524	3.048	1.524
Digitizing Error (E_d)	2	2	2	2	2
T-sheet Surveying Error (E_t)	0	0	0	0	0
Shoreline proxy offset (E_o)	0	0	0	0	0
Lidar position error (E_l)	0	0	0	0	0
Total Position Error (E_{sp})	2.04	2.14	2.51	3.65	2.51
	2001 (m)	**2002 (m)**	**2005 (m)**	**2006 (m)**	**2008 (m)**
Rectification Error (E_r)	0.762	1.524	0.762	1.524	3.34
Digitizing Error (E_d)	2	2	2	2	2
T-sheet Surveying Error (E_t)	0	0	0	0	0
Shoreline proxy offset (E_o)	0	0	0	0	0
Lidar position error (E_l)	0	0	0	0	0
Total Position Error (E_{sp})	2.14	2.51	2.14	2.51	3.89
	2009 (m)	**2010 (m)**			
Rectification Error (E_r)	0.762	2			
Digitizing Error (E_d)	1	1			
T-sheet Surveying Error (E_t)	0	0			
Shoreline proxy offset (E_o)	0	0			
Lidar position error (E_l)	0	0			
Total Position Error (E_{sp})	1.26	2.24			

A baseline was constructed seaward and parallel to the shoreline trend. Using DSAS modeling and a 10-meter spacing and perpendicular to the baseline, transects were cast at 50 and 600 meters, depending the baseline to shoreline distance. A confidence interval of 90% was applied. Fletcher and others (2003) reported vector error as random, uncorrelated, and unbiased, and therefore, it can be absorbed into the confidence interval calculated by the linear regression model.

To prevent inaccurate calculations, select transects were manually eliminated in areas represented by less than three historical shoreline vectors. Data validation included examining transect regression coefficients (R^2). Linear regression statistical techniques for expressing shoreline rates of change were applied because they have

been shown to be the most statistically robust quantitative methods when limited data are available (Crowell and others, 1997; Crowell and Leatherman, 1999). The DSAS model calculates the correlation coefficient (R^2) and standard error of estimate (LSE); therefore, these values were evaluated for accuracy. The standard error of estimate supports the accuracy of the rate prediction of shoreline change. Morton and others (2004) considered linear regression to be only adequate as a first approximation for shoreline change estimates because of inherent nonlinear behavior.

RESULTS

DOG RIVER SYSTEM

The seven individual tributaries adjoining Dog River are not discussed separately but rather combined into the Dog River System.

SHORE PROTECTION

The shore protection classification mapped in the Dog River System had twenty different types. Combined shore protection classes make up 669,399 feet (126.8 miles) of shoreline. Table 5 summarizes shore protection types, lengths, and percentages.

Figure 3 illustrates the distribution of shore protection in the Dog River System. About 457,451 feet (86.6 miles) or about 68.3 percent of the shoreline mapped is natural, unretained. About 40.2 miles or 31.7 percent was mapped with hard shore protection. Bulkhead shore protection makes up about 144,896 feet (27.4 miles) or about 21.6 percent of the total. Bulkhead (steel, wood) shore protection, the longest of the five subtypes mapped, makes up about 125,804 feet (23.8 miles) or about 18.8 percent of the total. Rubble/riprap, the second longest hard shoreline classification mapped, makes up about 44,682 feet (8.5 miles) or about 6.7 percent of the total shore protection. The remaining protection, about 41,462 feet, is mainly artificial, bulkhead, and sill (table 5). There were 178 private boat ramps and 6 public boat ramps encountered in the Dog River System making up about 3,315 feet or about 0.5 percent of the total shore protection in the Dog River System (fig. 4).

SHORELINE TYPES

There were eleven shoreline types identified in the Dog River System which were classified as follows: artificial, inlet, organic (marsh), organic (open, vegetated fringe), organic (swamp forest), pocket beach, sediment bank (high), sediment bank (low), vegetated bank (high) and vegetated bank (low) (table 6). These shoreline types make

up 668,979 feet or about 126.7 miles encountered in the Dog River System. Figure 5 illustrates the distribution of the shoreline types in the Dog River System.

Table 5.--Dog River System shore protection classification lengths and percentages.

Dog River System		
Shore protection classification	**Length (ft)**	**Percent (%)**
Abutment	1,874	0.28
Artificial	7,553	1.13
Boat Ramp	3,315	0.50
Breakwater (offshore)	288	0.04
Bulkhead (concrete, rock w/riprap)	825	0.12
Bulkhead (concrete, rock)	13,756	2.05
Bulkhead (steel, wood)	125,804	18.79
Bulkhead (w/retaining walls)	660	0.10
Bulkhead (w/riprap)	3,851	0.58
Cement	1,678	0.25
Groin	75	0.01
Jetty (steel pile, rock, concrete)	46	0.01
Natural, unretained	457,451	68.34
Revetment	668	0.10
Rubble/riprap	44,682	6.67
Sill (rock, shell)	771	0.12
Sill (wood w/riprap)	319	0.05
Sill (wood)	5,540	0.83
Silt fence	114	0.02
Weir	129	0.02
Total	669,399	100.00

Table 6.--Dog River System shoreline type classification lengths and percentages.

Dog River System		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	10,572	1.58
Inlet	2,921	0.44
Organic (marsh)	156,885	23.45
Organic (open, vegetated fringe)	66,636	9.96
Organic (swamp forest)	101,545	15.18
Pocket Beach	213	0.03
Sediment bank (high, 5 - 20 ft)	1,166	0.17
Sediment bank (low, 0 - 5 ft)	11,634	1.74
Vegetated bank (bluff, > 20 ft)	1,407	0.21
Vegetated bank (high, 5 - 20 ft)	31,561	4.72
Vegetated bank (low, 0 - 5 ft)	284,440	42.52
Total	668,979	100.00

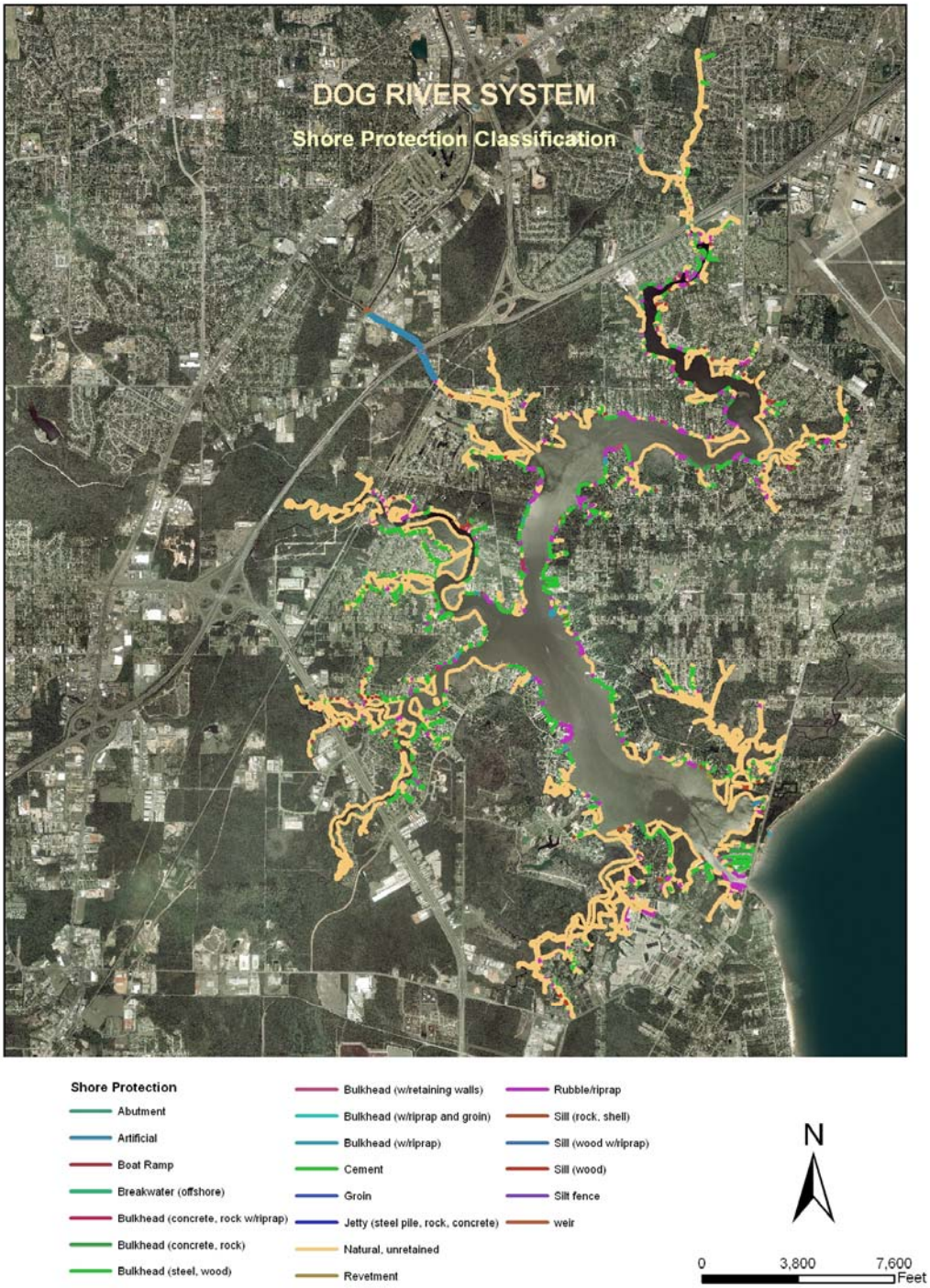

Figure 3.--Shore protection map of the Dog River System.

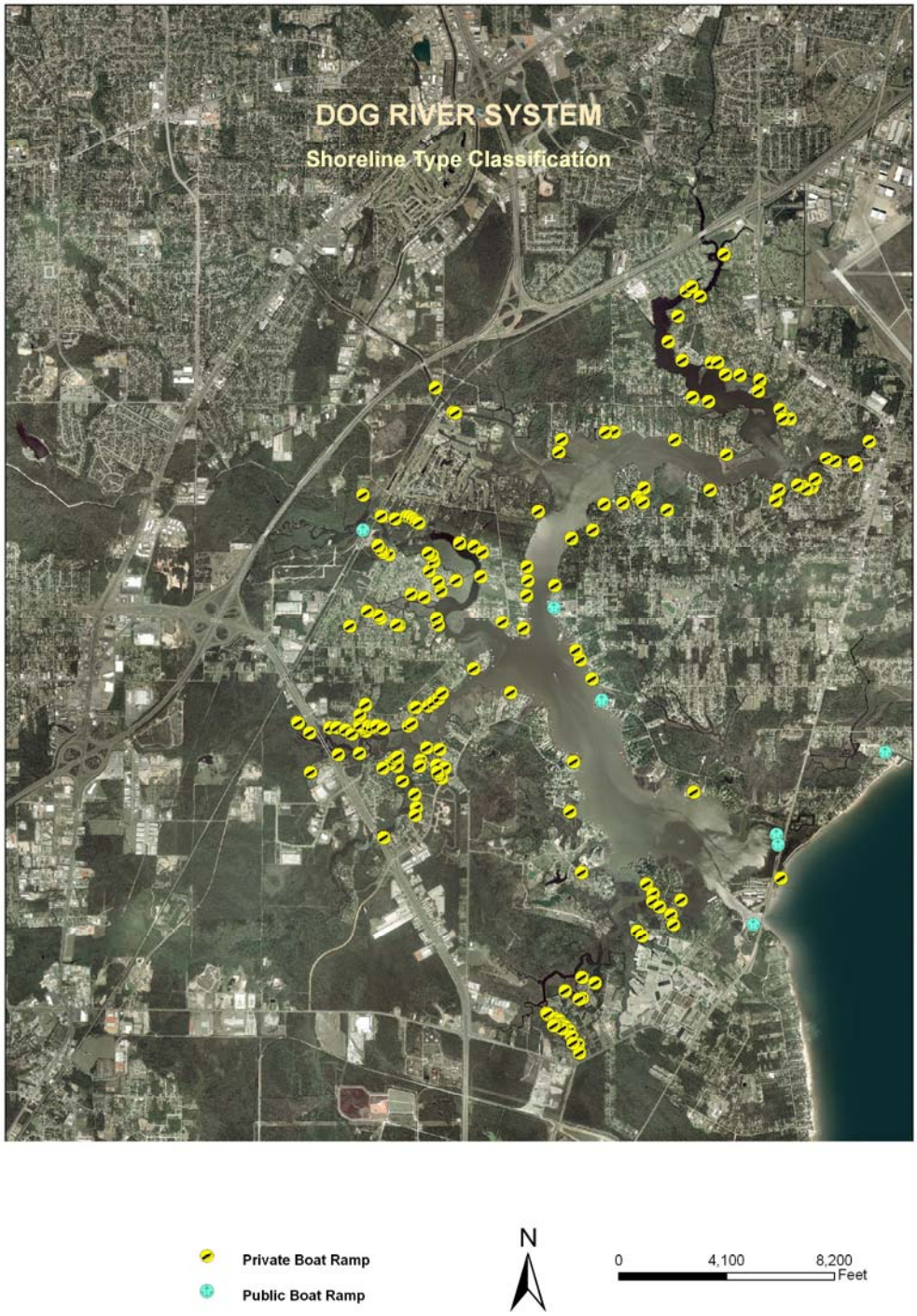

Figure 4.--Boat ramp locations in the Dog River System.

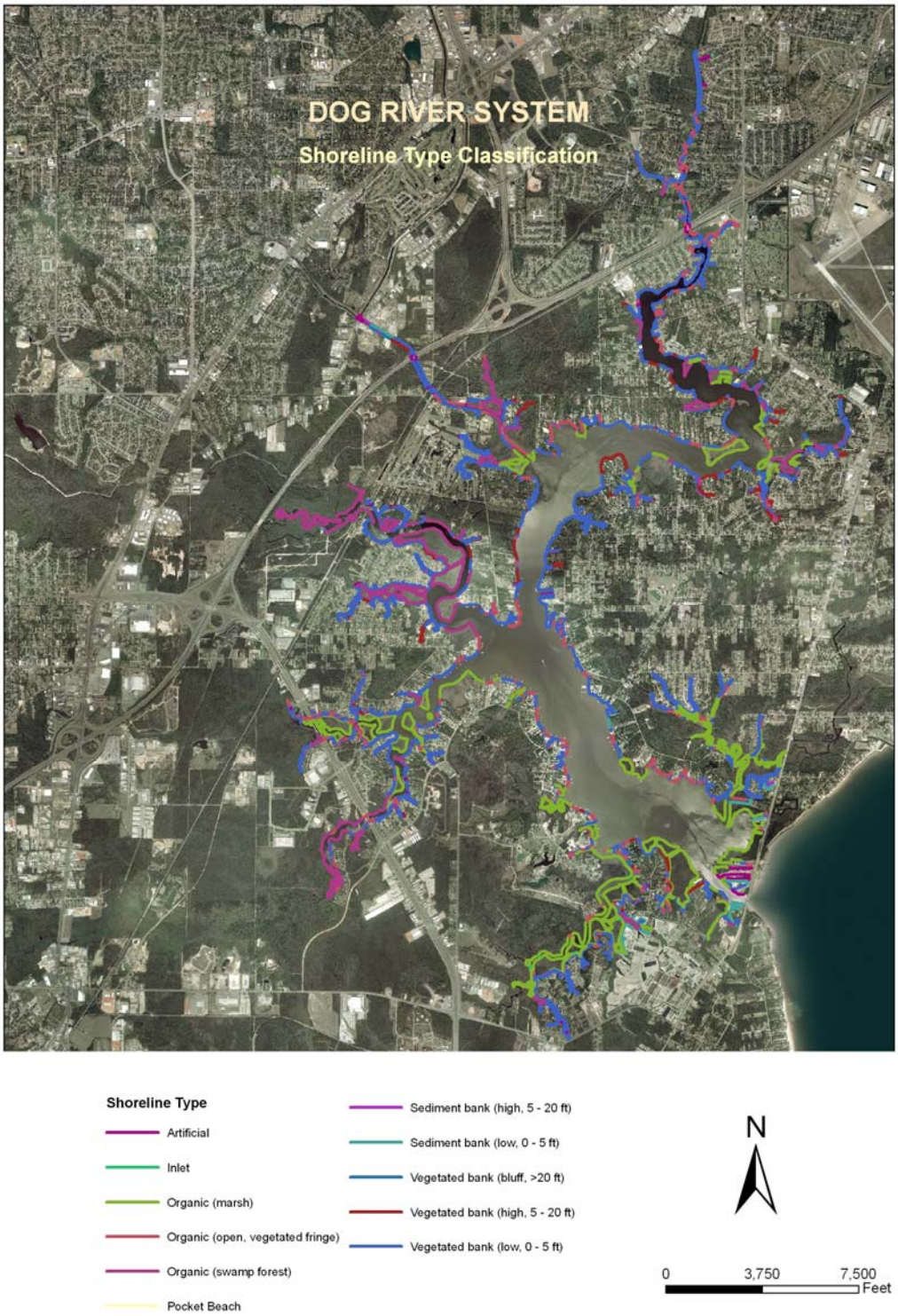

Figure 5.--Shoreline type map of the Dog River System.

Organic shoreline type makes up about 325,065 feet (61.6 miles) or about 48.6 percent of the total. Vegetated bank shoreline type makes up about 317,408 feet (53.9 miles) or about 47.4 percent of the total. Sediment bank shoreline type makes up about 12,800 feet (2.4 miles) or about 1.9 percent of the total in the Dog River System. Artificial and pocket beach shoreline types makes up about 10,572 feet (2.0 miles) or about 1.6 percent and about 213 feet or less than 0.1 percent of the total shoreline type in the Dog River System, respectively. There were 129 inlets identified.

BON SECOUR RIVER

SHORE PROTECTION

Fifteen different types of shore protection were mapped in the Bon Secour River which were classified as follows: boat ramp, bulkhead (concrete, rock), bulkhead (steel, wood), bulkhead (w/groin), bulkhead (w/riprap and groin), bulkhead (w/riprap and sill), bulkhead (w/riprap), bulkhead (w/sill), groin, natural, unretained, revetment, rubble/riprap, rubble/riprap (w/groin) and sill (wood). The detailed shore protection values for the Bon Secour River are listed in table 7. These shore protection types make up 184,841 feet or about 35 miles of shore protection that were mapped in the Bon Secour River (fig. 6). The Bon Secour River consists mainly of natural, unretained shoreline having about 131,570 feet (24.9 miles) or about 71.2 percent of the total with 28.8 percent armored. Bulkhead (steel, wood) shore protection, longest of the five bulkhead subtypes observed, makes up about 27,548 feet (5.2 miles) or about 14.9 percent of the total. Rubble/riprap shore protection makes up about 17,512 feet (3.3 miles) or about 9.5 percent of the total shore protection in the Bon Secour River. There were 54 private boat ramps and 4 public boat ramps encountered on Bon Secour River (fig. 7). The remaining 4.4 percent of the shoreline is armored through various methods listed above and tabulated in table 7.

SHORELINE TYPES

There were nine different general shoreline types adjoining the Bon Secour River (table 8) making up 187,355 feet or about 35.5 miles mapped. Figure 9 illustrates the distribution of the shoreline types in Bon Secour River. Organic shoreline type makes up about 89,592 feet (17 miles) or about 47.8 percent of the total shoreline type. Vegetated bank shoreline type makes up about 86,950 feet (16.5 miles) or about 46.4 percent.

Sediment bank shoreline type makes up about 6,378 feet (1.2 miles) or about 3.4 percent of the total shoreline type in Bon Secour River. Artificial and pocket beach makes up about 3,341 feet (1.8 percent) and about 252 feet (0.1 percent) of the total shoreline type mapped on the Bon Secour River, respectively. There were 34 inlets observed.

Table 7.--Bon Secour River shore protection classification lengths and percentages.

Bon Secour River		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat Ramp	1,045	0.57
Bulkhead (concrete, rock w/riprap and groin)	281	0.15
Bulkhead (concrete, rock)	904	0.49
Bulkhead (steel, wood)	27,548	14.90
Bulkhead (w/retaining walls)	79	0.04
Bulkhead (w/riprap)	852	0.46
Cement	23	0.01
Natural, unretained	131,570	71.18
Oyster Shells	3,630	1.96
Revetment	40	0.02
Rubble/riprap	17,474	9.45
Rubble/riprap (w/tires)	38	0.02
Sill (wood w/riprap)	357	0.19
Sill (wood)	900	0.49
Silt fence	99	0.05
Total	184,841	100.00

Table 8.--Bon Secour River shoreline type classification lengths and percentages.

Bon Secour River System		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	3,341	1.78
Inlet	842	0.45
Organic (marsh)	38,231	20.41
Organic (open, vegetated fringe)	43,855	23.41
Organic (swamp forest)	7,506	4.01
Pocket Beach	252	0.13
Sediment bank (low, 0 - 5 ft)	6,378	3.40
Vegetated bank (high, 5 - 20 ft)	3,814	2.04
Vegetated bank (low, 0 - 5 ft)	83,136	44.37
Total	187,355	100.00

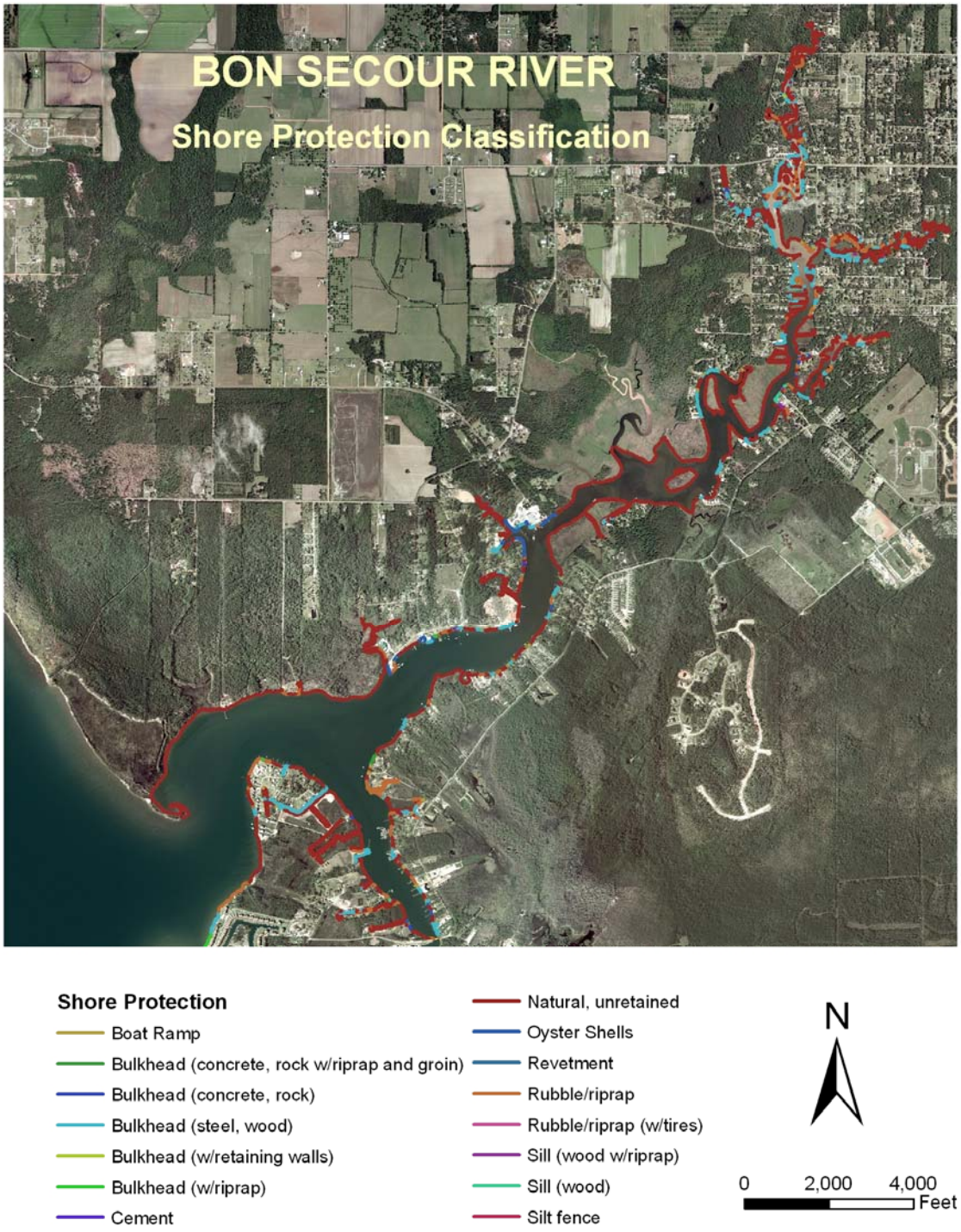

Figure 6.--Shore protection map of Bon Secour River.

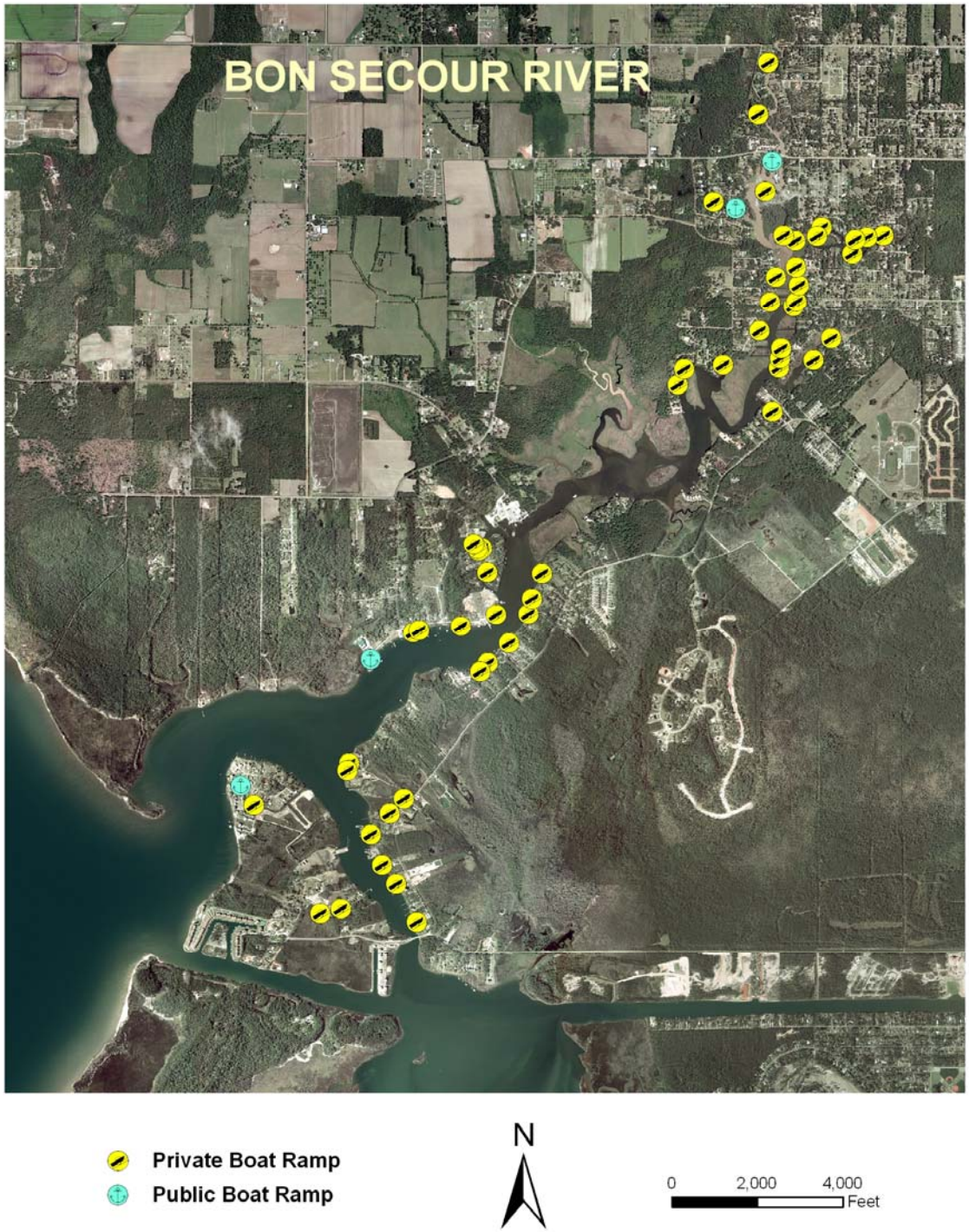

Figure 7.--Boat ramp locations on the Bon Secour River.

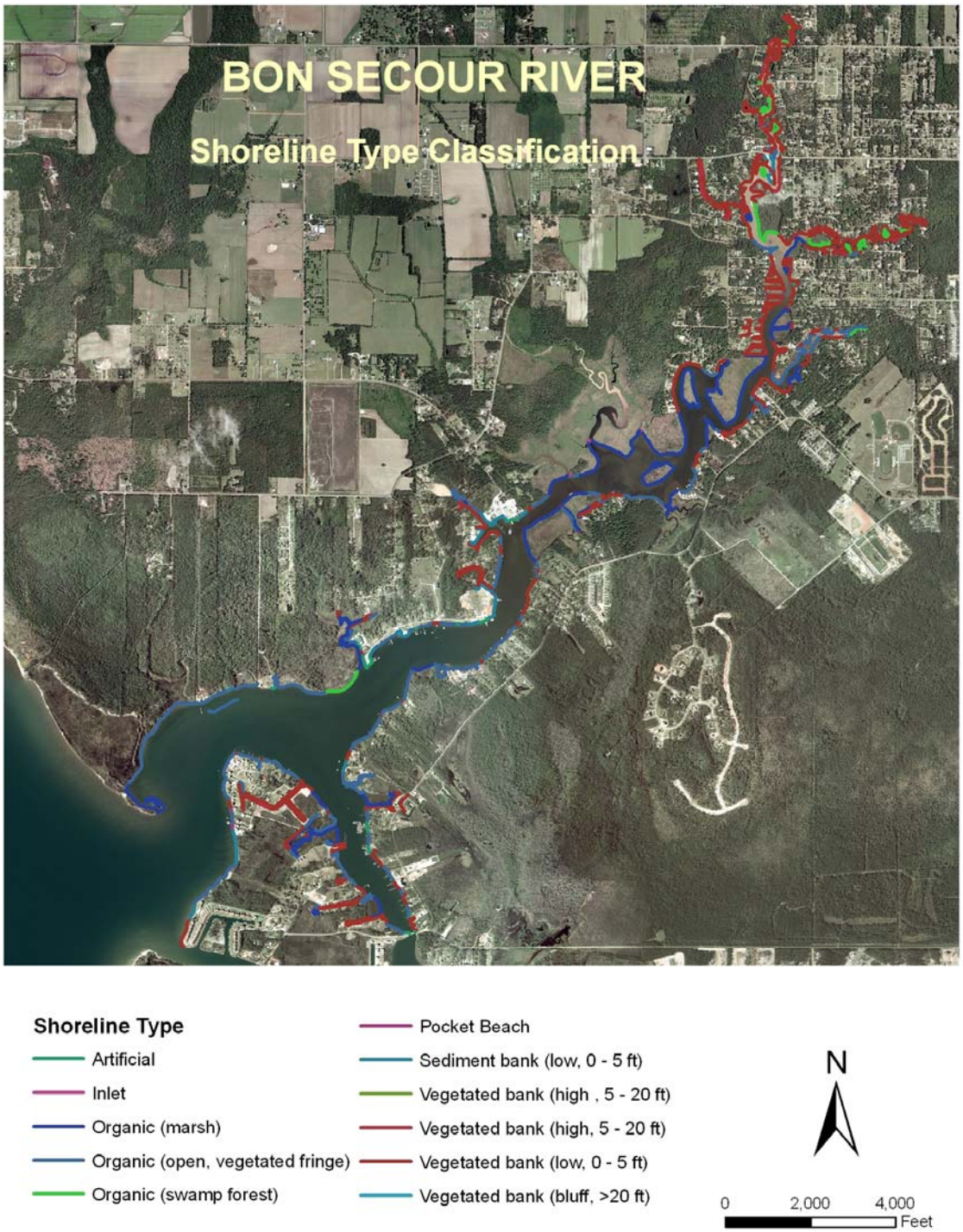

Figure 8.--Shoreline type map of Bon Secour River.

OYSTER BAY

SHORE PROTECTION

Field mapping of about 55,179 feet (10.5 miles) of shoreline in Oyster Bay for protection determined six different classifications as follows: boat ramp, bulkhead (steel, wood), jetty (steel pile, rock, concrete), rubble/riprap, natural, unretained, and sill (wood). Oyster Bay mainly adjoins undeveloped properties. The detailed shore protection values for Oyster Bay are provided in table 9. About 10.4 miles were mapped within Oyster Bay. Figure 9 illustrates the distribution of shore protection in and adjoining Oyster Bay.

The longest class of the Oyster Bay shoreline is natural, unretained having about 45,010 feet (8.5 miles) or about 81.6 percent of the total. Bulkhead (steel, wood) makes up about 6,124 feet (1.2 miles) or about 11.1 percent of the total 18.43 percent armored. Rubble/riprap makes up about 2,949 feet or about 5.3 percent of the total shore protection in Oyster Bay. There were two private boat ramps observed.

Table 9.--Oyster Bay shore protection classification lengths and percentages.

Oyster Bay		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat Ramp	46	0.08
Bulkhead (steel, wood)	6,124	11.10
Jetty (steel pile, rock, concrete)	900	1.63
Natural, unretained	45,010	81.57
Rubble/riprap	2,949	5.34
Sill (wood)	150	0.27
Total	55,179	100.00

SHORELINE TYPES

Illustrated on figure 10, there were eight general shoreline types identified in Oyster Bay which were classified as artificial, inlet, organic subtypes, sediment bank (low), vegetated bank (high) and vegetated bank (low) (table 10). Organic types make up about 37,168 feet (7.0 miles) or about 68.5 percent of the total. Vegetated bank shoreline types make up about 14,622 feet (2.8 miles) or about 26.9 percent. There were 22 inlets encountered in Oyster Bay.

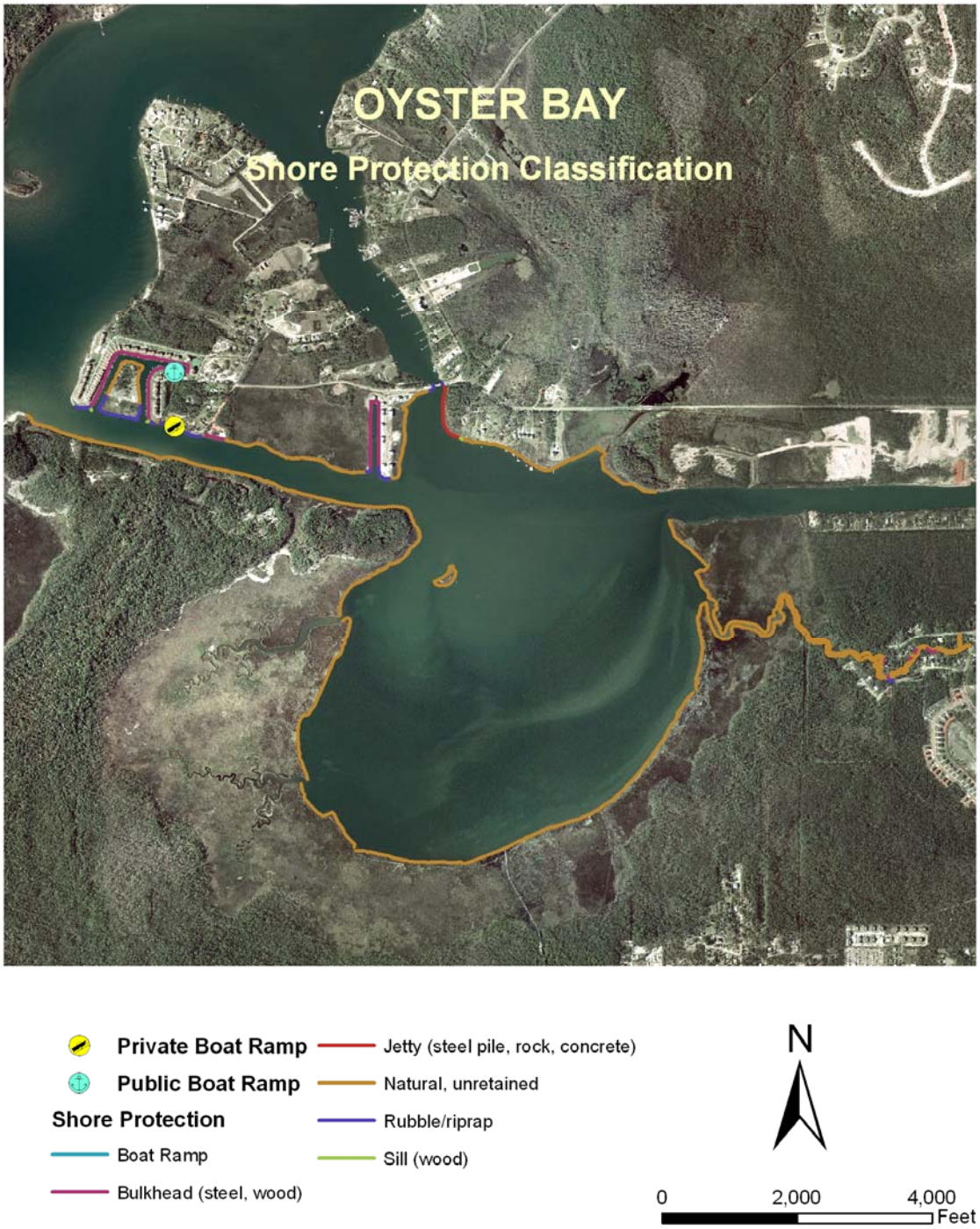

Figure 9.--Shore protection map of Oyster Bay.

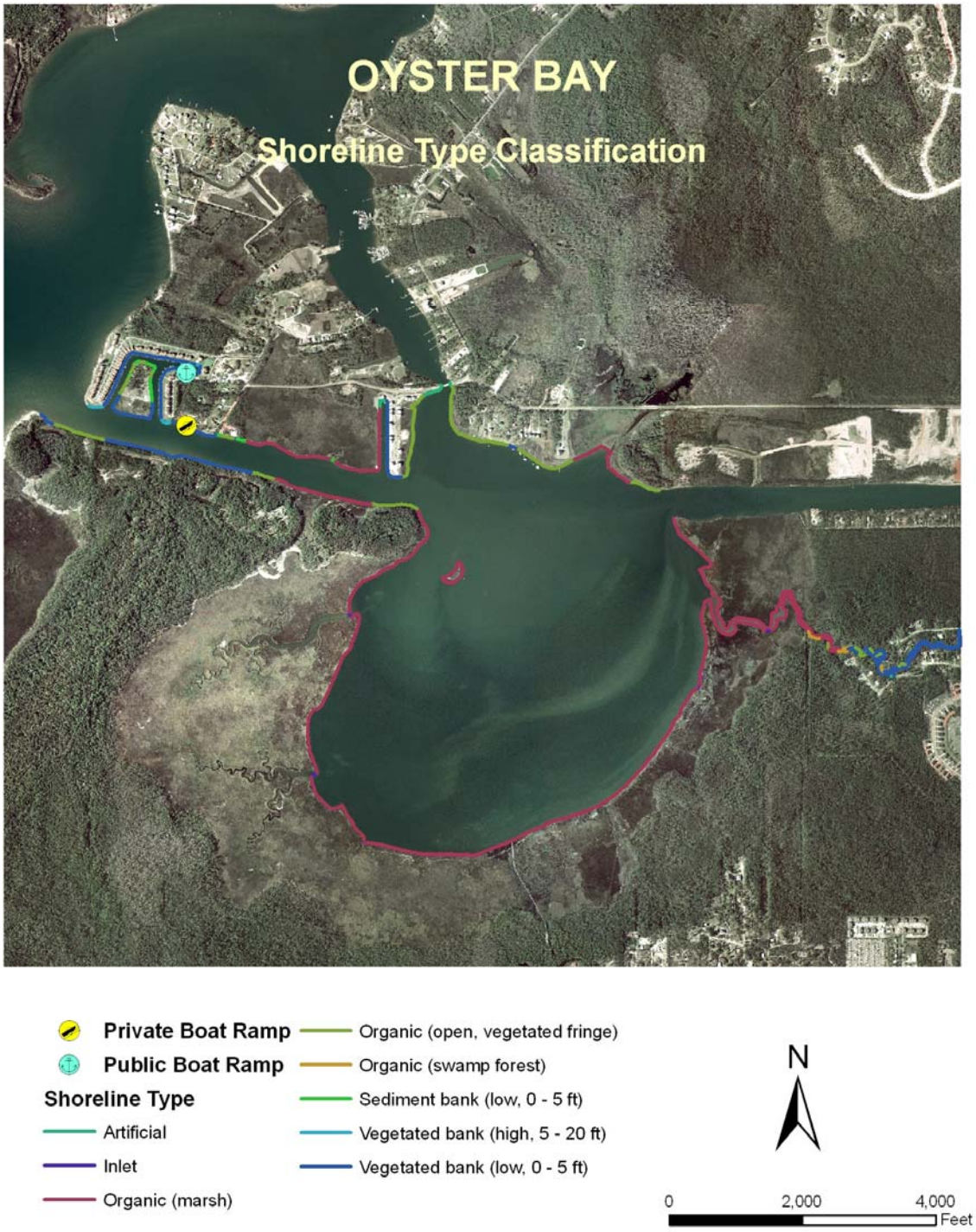

Figure 10.--Shoreline type map of Oyster Bay.

Table 10.--Oyster Bay shoreline type classification lengths and percentages.

Oyster Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	639	1.18
Inlet	828	1.53
Organic (marsh)	28,584	52.64
Organic (open, vegetated fringe)	7,897	14.54
Organic (swamp forest)	687	1.27
Sediment bank (low, 0 - 5 ft)	1,040	1.92
Vegetated bank (high, 5 - 20 ft)	527	0.97
Vegetated bank (low, 0 - 5 ft)	14,095	25.96
Total	54,298	100.00

LITTLE LAGOON

SHORE PROTECTION

Shore protection classifications in Little Lagoon are numerous. Fourteen different classification types were observed, including abutment, boat ramp, bulkhead subtypes, cement, groin, jetty (steel pile, rock, concrete), oyster shells, rubble/riprap, sill (wood w/riprap), and sill (wood). Detailed shore protection data for Little Lagoon are provided in table 11 where about 174,449 feet (33 miles) of shoreline were mapped. Figure 11 illustrates the distribution of shore protection as mapped in Little Lagoon.

Natural, unretained shoreline makes up about 119,207 feet (22.6 miles) and 68.3 percent of the total shore mapped under the shore protection classification. About 10.5 miles or 31.7 percent is hard, shoreline armored. Bulkhead shore protection is the longest mapped at 25.3 percent of the total; the bulkhead (steel, wood) subtype mapped had about 41,903 feet (7.9 miles) or 24 percent of the total. Rubble/riprap shore protection makes up about 7,589 feet (1.4 miles) or about 4.4 percent of the total shore protection in Little Lagoon. There were 135 private boat ramps and one public ramp (Lagoon Park) observed along the Little Lagoon shoreline (fig. 12). The remaining hard shore protection types noted above are about 13,339 feet (2.5 miles) and 7.7 percent.

Table 11.--Little Lagoon shore protection classification lengths and percentages.

Little Lagoon		
Shore protection classification	**Length (ft)**	**Percent (%)**
Abutment	221	0.13
Boat Ramp	2,182	1.25
Bulkhead (concrete, rock w/riprap)	163	0.09
Bulkhead (concrete, rock)	1,139	0.65
Bulkhead (steel, wood)	41,903	24.02
Bulkhead (w/riprap)	893	0.51
Cement	148	0.08
Groin	248	0.14
Jetty (steel pile, rock, concrete)	88	0.05
Natural, unretained	119,207	68.33
Oyster Shells	61	0.03
Rubble/riprap	7,589	4.35
Sill (wood w/riprap)	401	0.23
Sill (wood)	207	0.12
Total	174,449	100.00

SHORELINE TYPES

Ten basic shoreline types were mapped on Little Lagoon. These included artificial, inlet, organic (marsh), organic subtypes, pocket beach, sediment bank (high and low), and vegetated bank (high and low). Detailed shoreline type values for the Little Lagoon are listed in table 12 and their distribution is illustrated in figure 13.

Table 12.--Little Lagoon shoreline type classification lengths and percentages.

Little Lagoon		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	5,436	3.16
Inlet	220	0.13
Organic (marsh)	22,591	13.14
Organic (open, vegetated fringe)	35,872	20.87
Organic (swamp forest)	895	0.52
Pocket Beach	722	0.42
Sediment bank (high, 5 - 20 ft)	456	0.27
Sediment bank (low, 0 - 5 ft)	14,552	8.47
Vegetated bank (high, 5 - 20 ft)	1,726	1.00
Vegetated bank (low, 0 - 5 ft)	89,429	52.02
Total	171,896	100.00

Figure 11.--Shore protection map of Little Lagoon.

Figure 12.--Boat ramp distribution map of Little Lagoon.

Figure 13.--Shoreline type map of Little Lagoon.

The dominant shoreline type in Little Lagoon is vegetated bank making up about 91,155 feet (17.3 miles) or about 53 percent of the total which is predominantly vegetated low bank (52 percent). Organic shoreline type makes up about 59,358 feet (11.2 miles) or about 34.5 percent of the total. Although high subtype is minimal, the sediment bank shoreline types make up about 15,008 feet (2.8 miles) or about 8.7 percent. Lesser classifications with specifics are tabulated in table 12. There were ten inlets identified in Little Lagoon.

GULF INTRACOASTAL WATERWAY, ALABAMA SEGMENT

SHORE PROTECTION

Ten different shore protection classifications were mapped in the Gulf Intracoastal Waterway, Alabama segment (GIWW). These included boat ramp, breakwater (offshore), bulkhead subtypes, rubble/riprap, and sill subtypes. Shore protection estimates for the GIWW are listed in table 13 and figure 14 depicts the distribution.

Of the 88,644 feet mapped, hard shore protection accounted for 51.1 percent of the total. Natural, unretained shoreline makes up about 43,337 feet (8.2 miles) or about 48.9 percent of the total shore protection mapped in the GIWW. The most significant shore protection, rubble/riprap, makes up about 32,690 feet (6.2 miles) or about 36.9 percent of the total. Bulkhead (steel, wood), the longest of the three bulkheads classified, was mapped at 10,751 feet (2.0 miles) or 12.1 percent. Sill shore protection types makes up about 663 feet or 0.7 percent. There were six private and two public boat ramps observed (fig. 14).

Table 13.--Gulf Intracoastal Waterway, Alabama segment, shore protection classification lengths and percentages.

Gulf Intracoastal Waterway, Alabama segment		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat Ramp	205	0.23
Bulkhead (concrete, rock)	66	0.07
Bulkhead (steel, wood)	10,751	12.13
Bulkhead (w/riprap)	934	1.05
Natural, unretained	43,337	48.89
Rubble/riprap	32,690	36.88
Sill (rock, shell)	377	0.43
Sill (wood w/riprap)	91	0.10
Sill (wood)	195	0.22
Total	88,644	100.00

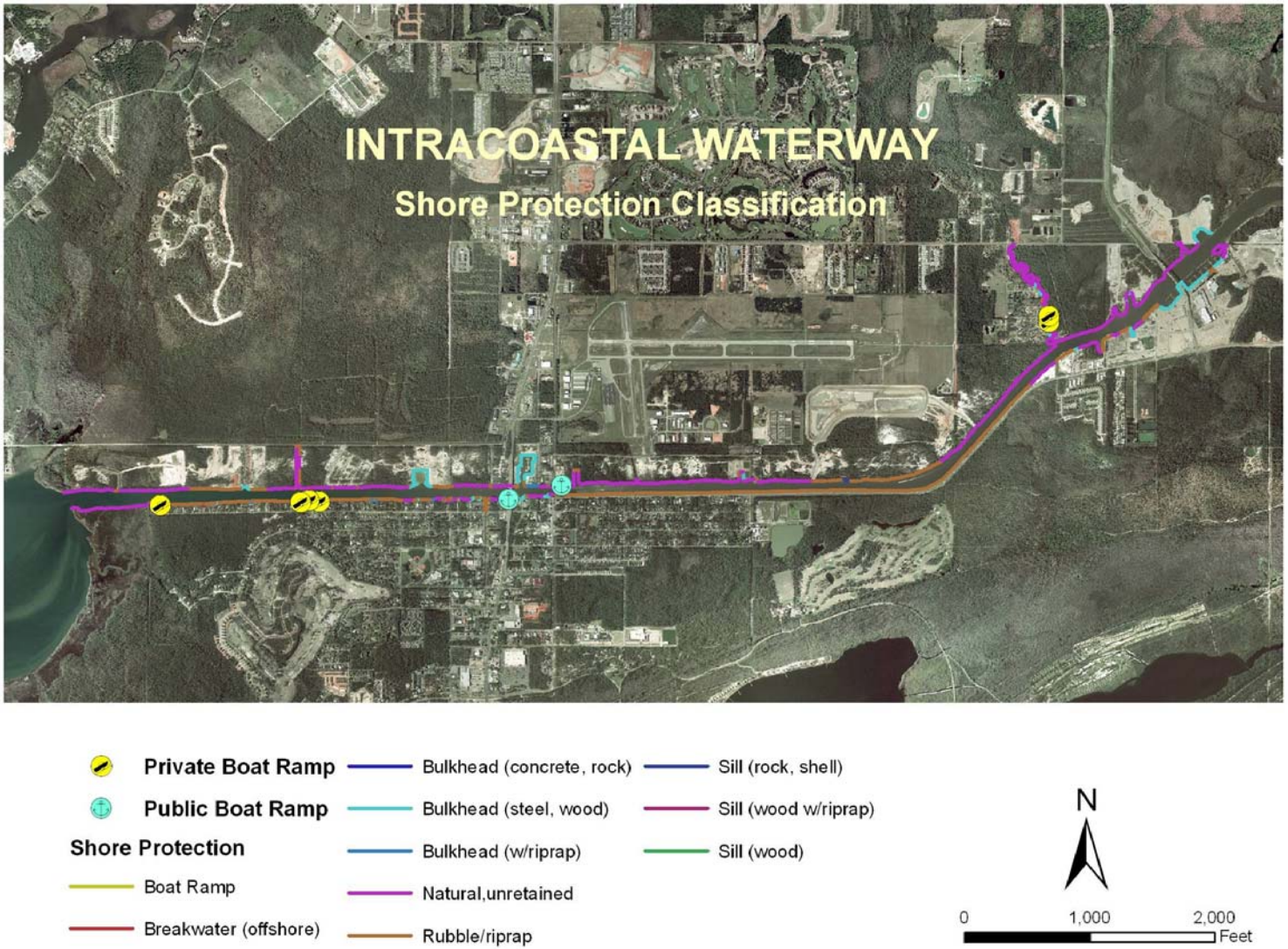

Figure 14.--Shore protection map of the Gulf Intracoastal Waterway, Alabama segment.

SHORELINE TYPES

Seven different fundamental shoreline type classifications were identified in the GIWW such as artificial, inlet, organic (marsh), organic (open, vegetated fringe), sediment bank (low), and vegetated bank (high and low). Specific shoreline type values are listed in table 14. Figure 15 illustrates the distribution of GIWW shoreline types.

The dominant shoreline type in the Intracoastal Waterway is vegetated bank making up about 56,361 feet (10.7 miles) or about 63.7 percent of the total in the GIWW with most classified in the low subtype. Artificial shoreline, the second longest mapped makes up about 21,239 feet (4 miles) or about 24 percent of the total. Organic shoreline type makes up about 7,159 feet (1.4 miles) or about 8.1 percent. There were twenty-three inlets identified which made up 948 feet or 1.1 percent.

Table 14.--Gulf Intracoastal Waterway, Alabama segment shoreline type classification lengths and percentages.

Gulf Intracoastal Waterway, Alabama Segment		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	21,239	24.00
Inlet	948	1.07
Organic (marsh)	2,618	2.96
Organic (open, vegetated fringe)	4,541	5.13
Sediment bank (low, 0 - 5 ft)	2,804	3.17
Vegetated bank (high, 5 - 20 ft)	5,400	6.10
Vegetated bank (low, 0 - 5 ft)	50,961	57.58
Total	88,510	100.00

WOLF BAY

SHORE PROTECTION

Natural, unretained shoreline was the only type of shore protection encountered along the western and eastern shorelines of Wolf Bay (fig. 16). Mapped were 35,187 feet (6.7 miles) of shoreline.

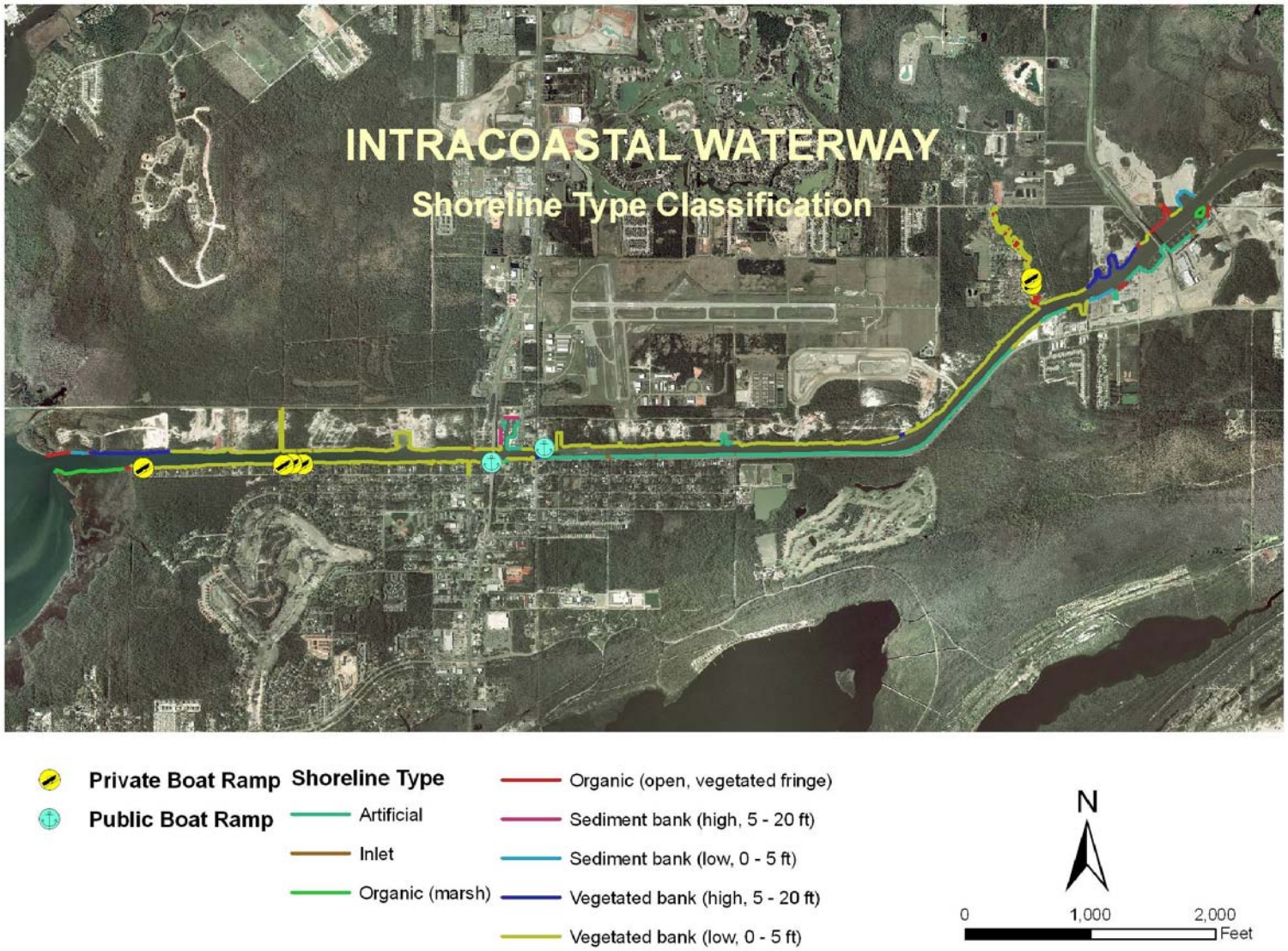

Figure 15.--Shoreline type map of the Gulf Intracoastal Waterway, Alabama segment.

Figure 16.--Shore protection map of Wolf Bay.

SHORELINE TYPES

There were five different types of shoreline identified in Wolf Bay along the 34,834 feet mapped which included inlet, organic (marsh and open, vegetated fringe), sediment bank (low), and vegetated bank (low) (table 15). Figure 17 illustrates the distribution of the shoreline types in Wolf Bay. Organic (marsh) and organic (open, vegetated fringe) shoreline type makes up about 11,077 feet (2.1 miles) or about 31.8 percent and 11,861 feet (2.2 miles) or about 34.1 percent of the total shoreline type in Wolf Bay, respectively. Low vegetated bank makes up about 6,275 feet (1.2 miles) or about 18 percent of the total. Low sediment bank shoreline type makes up about 5,363 feet (~1 mile) or about 15.4 percent. There were five inlets identified in Wolf Bay.

Table 15.--Wolf Bay shoreline type classification lengths and percentages.

Wolf Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Inlet	259	0.74
Organic (marsh)	11,077	31.80
Organic (open, vegetated fringe)	11,861	34.05
Sediment bank (low, 0 - 5 ft)	5,363	15.40
Vegetated bank (low, 0 - 5 ft)	6,275	18.01
Total	34,834	100.00

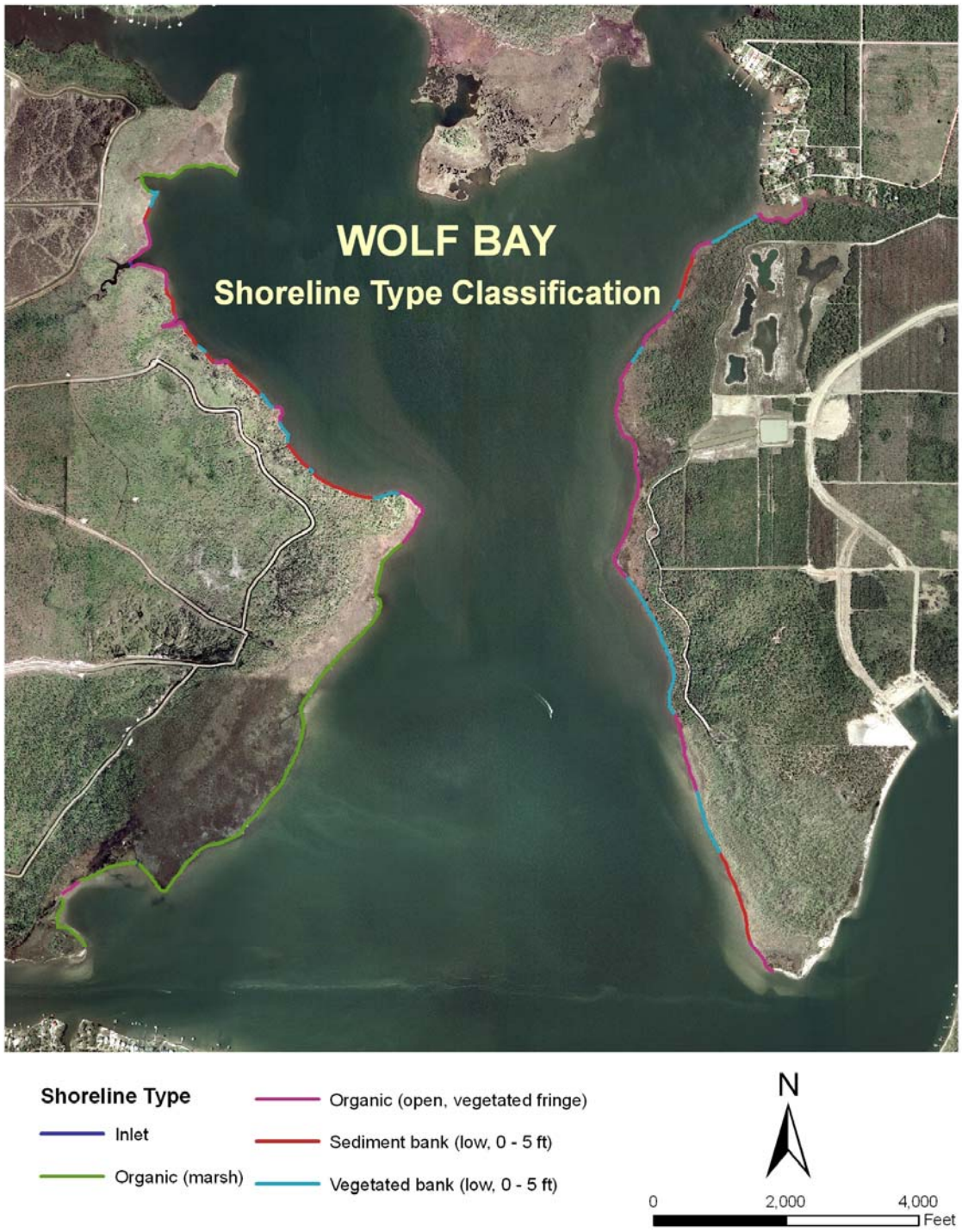

Figure 17.--Shoreline type map of Wolf Bay.

SHORELINE CHANGE ANALYSIS

A total of 2,902 transects were generated by DSAS and represent Wolf Bay, Little Lagoon, Cotton Bayou, and Terry Cove. Table 16 provides transect type and count, overall mean shoreline change, and percentages and rates for erosion and accretion for the shoreline areas. Error is based on a 90 percent confidence interval. Transect type "all" refers to the total number of transects generated for that area. Transect type "selected" refers to transects where calculated regression values (R^2) are less than 0.75 and transect casts with two or less shorelines were discarded. Based on all transects for combined areas, an estimated 91 percent and 8.5 percent indicated limited shoreline erosion and accretion, respectively. Below are findings based only on selected values.

Based on 423 selected transects for Wolf Bay (about 36 percent of all calculated and of the shoreline), a mean shoreline change rate of -1.69 ± 0.99 ft/yr was quantified. About 97 percent represented erosion with a maximum and mean of -6.36 ± 1.64 ft/yr and -1.79 ± 0.56 ft/yr, respectively. Erosion is most notable along the eastern shoreline, the western shoreline along and north of Mulberry Point, and the north shoreline (fig. 18). Areas of accretion were negligible.

Erosion and accretion for Little Lagoon was about 76 percent and 24 percent, respectively, which represented a mean of -0.22 ± 1.07 ft/yr quantified from 556 selected transects representing 45 percent of the shoreline. The distribution is depicted in figure 19. A maximum erosion rate of -7.15 ± 1.48 ft/yr and a mean erosion of -1.09 ± 0.61 ft/yr were intermittently distributed along the shoreline with some characteristically associated with areas of boat traffic (Gulf Shores) and dredging (Little Lagoon Pass). Although most accretion was quantified along the southern shoreline, a maximum rate of 10.30 ± 8.72 ft/yr and an average of 2.53 ± 2.52 ft/yr reflect the 24 percent quantified for Little Lagoon. Other receding areas were randomly distributed and mainly mixed with accretion areas along Bon Secour National Wildlife Refuge and Pine Beach in western Little Lagoon.

Selected rate of change data for Cotton Bayou and Terry Cove are illustrated on figure 20. Using 135 selected transects (38 percent of the total), about 99 percent of Cotton Bayou shoreline is receding. The maximum and mean erosion rates are -7.51 ± 2.98 ft/yr and -1.59 ± 0.83 ft/yr, respectively. A high percentage of selected Terry Cove transects (93 percent) was quantified as receding at a maximum rate of -3.97 ± 0.85 ft/yr with a mean of -1.79 ± 0.57 ft/yr. The 55 selected transects represent only about 37 percent of the shoreline. The highest erosion occurs around Boggy Point.

Shoreline Areas	Transects		Mean Shoreline Change Rate (ft/yr)	Erosion %	Erosion Rates (ft/yr)		Accreation %	Accretion Rates (ft/yr)		No Change
	Type	Number			Max	Mean		Max	Mean	
Wolf Bay	all	1180	-1.00 ± 0.99	89.32	-6.36 ± 1.64	-1.28 ± 0.88	10.09	7.22 ± 5.15	1.44 ± 1.96	0.59
	selected	423	-1.69 ± 0.60	97.64	-6.36 ± 1.64	-1.79 ± 0.56	2.36	6.33 ± 0.98	3.30 ± 2.49	0
Little Lagoon	all	1224	-0.07 ± 1.55	68.54	-7.87 ± 14.3	-0.78 ± 1.01	30.23	10.30 ± 8.72	1.54 ± 2.79	1.23
	selected	556	-0.22 ± 1.07	76.08	-7.15 ± 1.48	-1.09 ± 0.61	23.92	10.30 ± 8.72	2.53 ± 2.52	0
Cotton Bayou	all	351	-0.92 ± 1.15	84.05	-7.51 ± 2.98	-1.18 ± 1.13	14.24	3.74 ± 6.92	0.48 ± 1.31	1.71
	selected	135	-1.70 ± 0.96	99.26	-7.51 ± 2.98	-1.59 ± 0.83	0.74	1.18 ± 0.26	1.18 ± 0.26	0
Terry Cove	all	147	-0.89 ± 1.08	80.27	-5.84 ± 10.07	-1.22 ± 0.95	18.37	2.36 ± 5.08	0.51 ± 1.66	1.36
	selected	55	-1.60 ± 0.56	92.73	-3.97 ± 0.85	-1.79 ± 0.57	7.27	0.85 ± 1.02	0.67 ± 0.53	0

Table 16.--Tabulated results from Phase II Digital Shoreline Analysis System modeling.

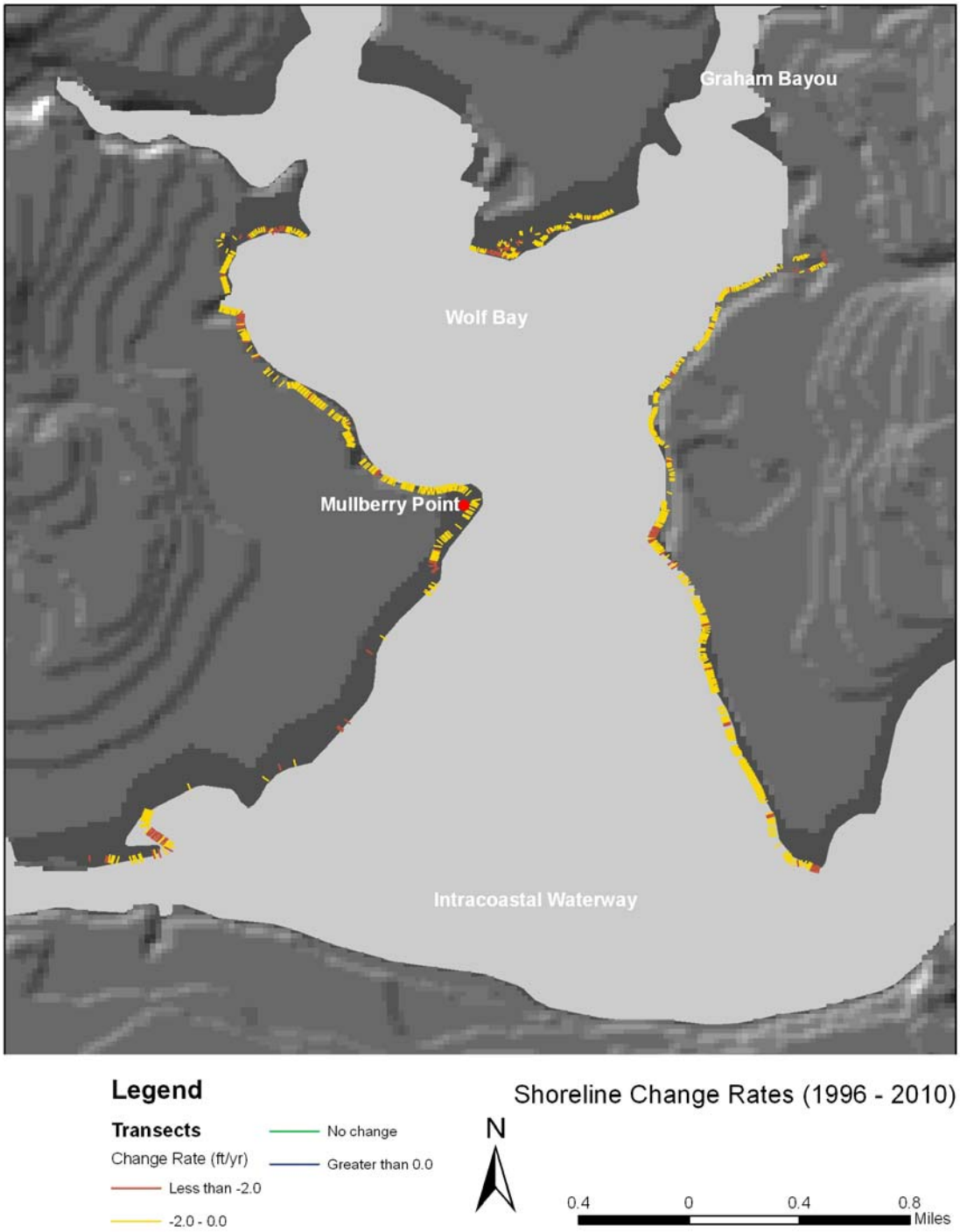

Figure 18.—Wolf Bay results from Digital Shoreline Analysis System (1996 through 2010).

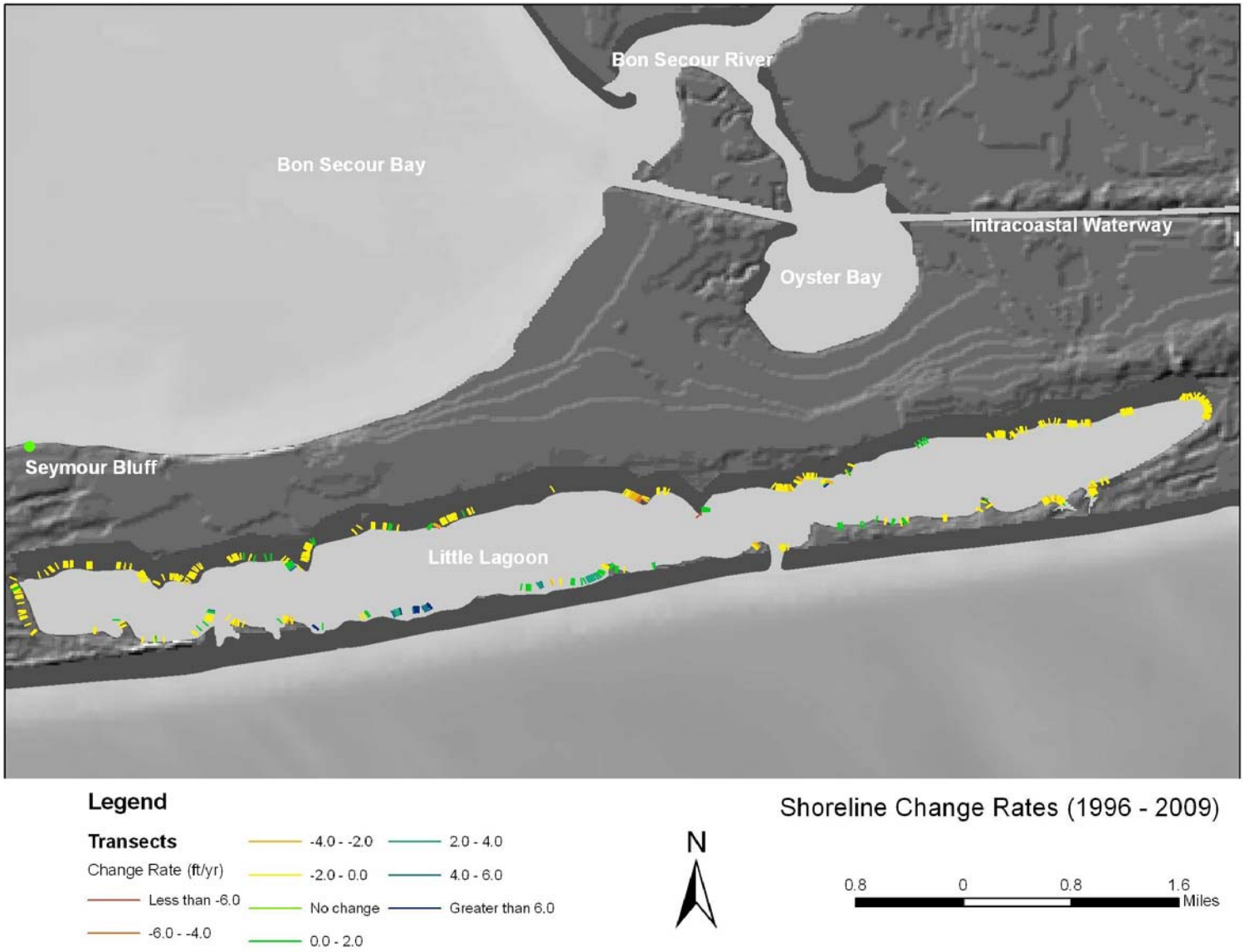

Figure 19.—Little Lagoon results from Digital Shoreline Analysis System (1996 through 2009).

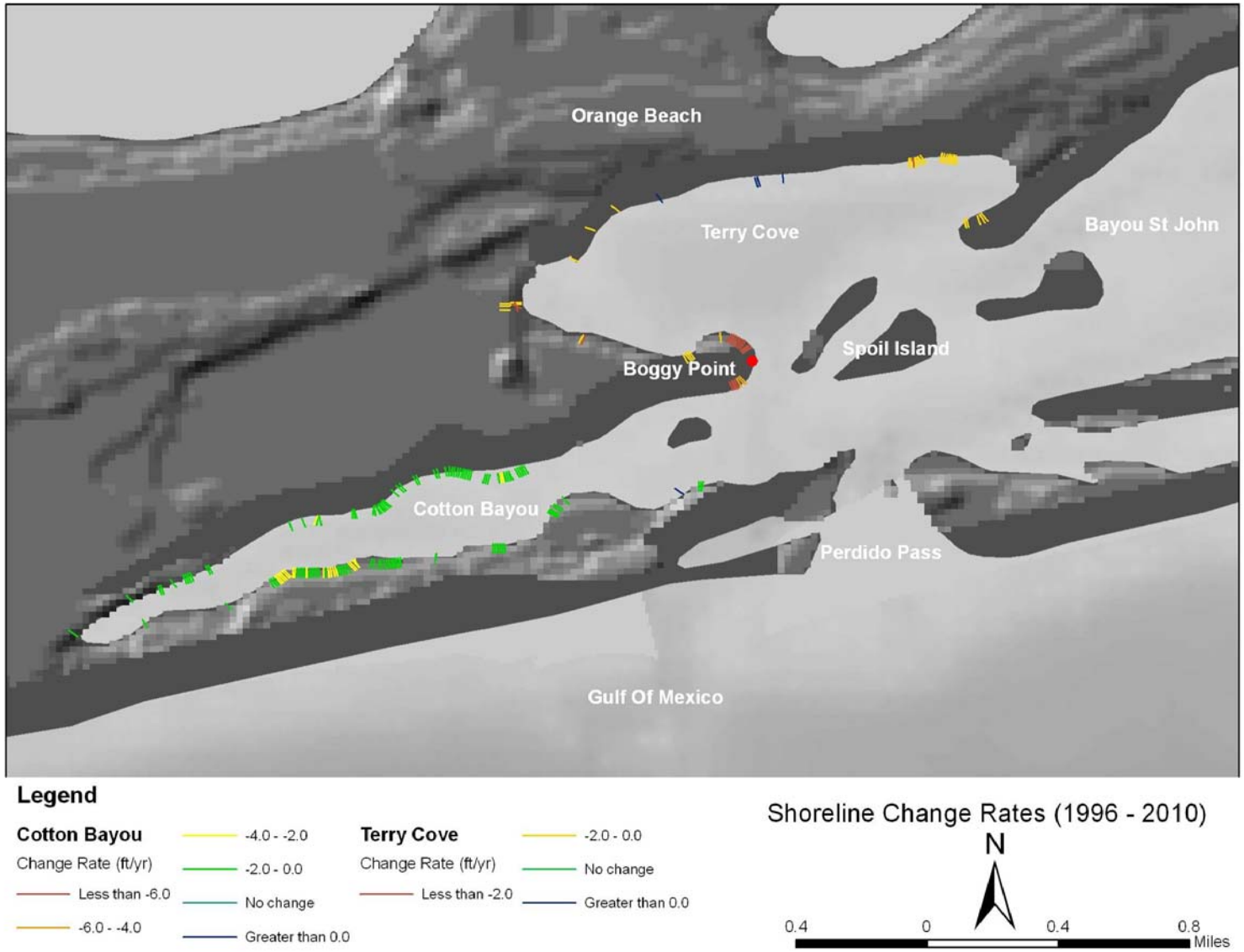

Figure 20.—Terry Cove and Cotton Bayou results from Digital Shoreline Analysis System (1996 through 2010).

CONCLUSIONS

In cooperation with the Alabama Department of Natural Resources, Lands Division, Coastal Section, funded in part by a grant from the National Oceanic and Atmospheric Administration (NOAA), Office of Ocean and Coastal Resource Management, Award No. 09NOS4190169, the Geological Survey of Alabama completed Phase II of a comprehensive shoreline mapping and shoreline change study in coastal Alabama. Shoreline protection and type and rates of change were quantified, where applicable, within the Dog River System, Bon Secour River, Oyster Bay, Gulf Intracoastal Waterway, and Wolf Bay.

An estimated 126.8 miles of shoreline were mapped in the Dog River System for shore protection, and about 31.7 percent was hard shore armored. Bulkhead makes up 27.4 miles (21.6 percent) and rubble/riprap makes up about 8.5 miles (6.7 percent) of the total. Organic shoreline type makes up 61.6 miles (48.6 percent) and vegetated bank is about 53.9 miles (47.4 percent) of the total. For the Dog River System, 178 and 6 private and public boat ramps were mapped, respectively.

Shore protection mapping for the Bon Secour River was about 35 miles in length with 28.8 percent armored; about 24.9 miles (71.2 percent) was natural, unretained. Bulkhead (steel, wood) and rubble/riprap make up about 5.2 miles (14.9 percent) and 3.3 miles (9.5 percent) of the total hard shore protection. Organic shoreline type was 17 miles or 47.8 percent; vegetated bank was about 16.5 miles or 46.4 percent of the total. There were a total of 58 boat ramps mapped.

Field mapping of about 10.5 miles of shoreline in Oyster Bay determined that 81.6 percent of the total was natural, unretained. Bulkhead (steel, wood) makes up about 1.2 miles (11.1 percent) of the total 18.43 percent armored. About 7 miles (68.5 percent) of shoreline type is organic; vegetated bank makes up about 2.8 miles (26.9 percent). Two boat ramps were observed.

An estimated 33 miles of shoreline protection were mapped in Little Lagoon. Approximately 22.6 miles (68.3 percent) is natural, unretained. About 10.5 miles or 31.7 percent is hard, shoreline armored. Bulkhead shore protection is the longest mapped shoreline protected type at 25.3 percent of the total. The dominant shoreline type in Little Lagoon is vegetated bank making up about 17.3 miles (53 percent); organic shoreline type makes up about 11.2 miles (34.5) percent of the total. There were 136 boat ramps mapped in Little Lagoon.

Of the 16.8 miles mapped on the Alabama segment of the Gulf Intracoastal Waterway, hard shore protection accounted for 51.1 percent of the total. Rubble/riprap and Bulkhead (steel, wood) were 36.9 percent and 12.1 percent, respectively. Natural, unretained shoreline makes up about 8.2 miles (48.9 percent). The dominant shoreline type is vegetated bank making up about 10.7 miles (63.7 percent). Artificial shoreline, the second longest shoreline protected type mapped, makes up about 24 percent of the total shoreline mapped. Only eight boat ramps were encountered.

Natural, unretained shoreline was the only type of shore protection encountered along the western and eastern shorelines of Wolf Bay (fig. 16). Mapped were 35,187 feet (6.7 miles) of shoreline. Organic (marsh) and organic (open, vegetated fringe) shoreline type makes up about 2.1 miles (31.8 percent) and 2.2 miles (34.1 percent) of the total shoreline type in Wolf Bay, respectively. Low vegetated bank makes up about 18 percent of the total and low sediment bank makes up about 15.4 percent.

For the determination of shoreline change along Wolf Bay, Little Lagoon, Cotton Bayou, and Terry Cove, a total of 2,902 transects were generated by DSAS. Error is based on a 90 percent confidence interval. Based on all transects for combined areas, an estimated 91 percent and 8.5 percent indicated limited shoreline erosion and accretion, respectively. To improve data validation, calculated regression values (R^2) less the 0.75 were discarded; therefore, results are based on these selected transects.

Based on 423 selected transects for Wolf Bay (36 percent of all calculated), a mean shoreline change rate of -1.69 ± 0.99 ft/yr was determined. About 97 percent represented erosion with a maximum and mean of -6.36 ± 1.64 ft/yr and -1.79 ± 0.56 ft/yr, respectively. Erosion is most notable along the eastern shoreline, the western shoreline along and north of Mulberry Point, and the north shoreline.

From 556 selected transects representing 45 percent of the Little Lagoon shoreline, erosion and accretion were about 76 percent and 24 percent, respectively. A maximum erosion rate of -7.15 ± 1.48 ft/yr and a mean erosion rate of -1.09 ± 0.61 ft/yr were distributed along the shoreline and appear a function of boating and maintenance. Although most of the accretion was quantified along the southern shoreline, a maximum rate of 10.30 ± 8.72 ft/yr reflects the 24 percent quantified in Little Lagoon. Other receding areas were randomly distributed and mainly mixed with accretion areas along Bon Secour National Wildlife Refuge and Pine Beach in west Little Lagoon.

Using 135 selected transects (38 percent of the total), about 99 percent of Cotton Bayou shoreline is receding. The maximum and mean erosion rates are -7.51 ± 2.98 ft/yr

and -1.59 ± 0.83 ft/yr, respectively. A high percentage of selected Terry Cove transects (93 percent) were quantified as receding at a maximum rate of -3.97 ± 0.85 ft/yr with a mean of -1.79 ± 0.57 ft/yr. The 55 selected transects represent only about 37 percent of the shoreline and is shared by both Cotton Bayou and Terry Cove. The highest erosion occurs around Boggy Point.

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