**FLORIDA NORTHEAST ATLANTIC SAND SEARCH (Phase III)**

**Investigation of Sand Resources on the Continental Shelf off the North Florida Atlantic Coast: Interpretation, Exploration and Significance to Beach Renourishment**

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**FLORIDA NORTHEAST ATLANTIC COAST SAND SEARCH (Phase III)**

**Executive Summary**

Mapping of reformatted reconnaissance-scale NOAA bathymetry enabled interpretation of seafloor features and development of a geologic model for sand searches on the continental shelf off the northeast Florida Atlantic coast. Classification of bathymetric features resulted in a typology for shelf landforms (on the shoreface, inner shelf floor, middle shelf floor, and outer shelf floor) that were related to sediment accumulation in the form of transverse bars, sand flats, sand ridges, sand waves, ebb-tidal deltas, and shoals. The total study area spanning five counties (Nassau, Duval, St. Johns, Flagler, and Volusia) from the shore to the 45 m isobath, covered 1,470,718 ha (about 14,707 km2). However, 409,860 ha were unmappable due to low resolution bathymetric data. Distinct sedimentary bodies with topographic expression, mapped as morphosedimentary features, contained about 78.5 billion m3 of sediment that has potential as a sand resource for beach renourishment. Containing large volumes of sediment, extended offshore county shelf areas offer the following potential sand resource base: Nassau County (6.2 billion m3)Duval County (13.5 billion m3), St. Johns County (28 billion m3), Flagler County (9 billion m3), and Volusia County (21.6 billion m3). About one-tenth of the potential offshore sand resources lie in state waters in an area of about 119,250 ha. More detailed bathymetric surveys are required to better estimate the sand resource potential. Target areas for future detailed study are recommended for transverse bars, ridge fields, sand waves, ebb-tidal deltas, and shoals.

**PURPOSE, GOAL AND PROJECT DESIGN**

The overall purpose of this reconnaissance-level project is to determine the sand resource potential on the continental shelf along the northeast Florida Atlantic coast. The results of this project will be incorporated into the ROSS (Reconnaissance Offshore Sand Search) database for the State of Florida, Bureau of Beaches and Coastal Systems (Tallahassee, Florida). Critical to this assessment of sand resource potential is the determination of areas previously investigated, areas actually exploited for sand as evidenced by borrow pits, areas that were investigated but not exploited, and areas that have not been investigated. In this way, a comprehensive overview of the status of sand resource investigations can be compiled and will provide guidance for future work. Development of a coastal geological framework is part of the scope of work because it facilitates comprehension of sediment distribution patterns, provides background for a better understanding of the types of sedimentary bodies that occur in the study area, and indicates geological and geomorphological constraints on the evolution and maintenance of sedimentary deposits on the shelf.

Key to this study was the availability of NOAA bathymetric data offshore Nassau, Duval, St. Johns, Flagler, and Volusia counties. Although limited by quality of the data, the NOAA bathymetry provided a convenient basis for mapping seafloor topography, determining geomorphological units, and establishing a submarine land topology that could be related to morphosedimentary bodies. Analyses of sandy seafloor areas could thus be conducted in a GIS environment, based on iterative queries to ascertain specific types of sedimentary bodies. By calculating sediment volume from maximum and minimum elevations of seafloor mapping units (morphosedimentary bodies) using computerized techniques, it was possible to estimate potential sediment volumes by mapping units and areas within each county. Results of the study indicate potential sand resources by types of deposits and their location on the continental shelf.

**INTRODUCTION**

The most prominent geological and geomorphological features along the northeast coast of Florida include sand flats and ebb-tidal deltas on the inner shelf; sand waves, shoals, and banks on the middle shelf; and large sand ridges on the outer shelf. Deepwater ridges occur along the seaward margin of the study area in water depths ranging from 28 to 45 m. Sand ridges are a pervasive morphological feature throughout the study area. Shoreface-attached sand sheets occur along the entire length of the study area and are surmounted inshore by ebb-tidal deltas, mostly in the northern part of the study area in Duval and St. Johns counties. Other minor sedimentary features include transverse bars alongshore Nassau County and ebb-tidal deltas on the inner shelf offshore Nassau, Duval, and St. Johns counties. Salient morphological properties of these seafloor features and their sand resource potential are summarized in this report. These morphosedimentary features are described in relation to their position on the continental shelf along with reference to the state-federal offshore boundary, water depth, and distance from shore (location of potential borrow sites for beach renourishment projects).

**Study Area and Coastal Geological Framework**

The study area is located off the northeast Florida Atlantic coast. It spans about 234 km of shoreline from the Florida-Georgia border to Brevard County. Taking in approximately 1,407,718 ha (14,077 km2), the mapping on the continental shelf extends about 85 km offshore along the northern boundary (Florida – Georgia state line) and about 40 km seaward along the offshore extension of the Volusia-Brevard county line. Figure 1a shows the area of study on the continental shelf in plan view. Although this bird’s eye view shows differentiation of bathymetry in terms of color-ramped data cells, the oblique image in Figure 1b (isometric diagram) better emphasizes differences in seafloor elevations, especially sand ridges and dissected margins of banks and sand waves. Figures 1a and 1b should be perused in conjunction with each other to best appreciate the variety of seafloor morphological units. These figures, produced by the conversion of bathymetric data points into digital terrain models of seafloor topography, should be visualized as a backdrop to historical descriptions of shelf morphology, sedimentary cover, and potential sand resources. Each morphological feature will be described in relation to its sand resource potential. It should be noted that these terrain models show the seafloor in a dynamic format that was not available to researchers making early observations of shelf morphology. New technologies and increased computer power allow researchers to significantly improve morphological interpretations.

The study area along the northeast coast of Florida (as shown in Figures 1a and 1b) occurs in the Atlantic and Gulf Coast Physiographic Province (Walker and Coleman, 1987). The seaward side of the study area contains a portion of the Atlantic continental shelf. The Atlantic margin continental shelf varies considerably in width, gradient, and morphologic complexity over the 3000 km it extends along the east coast of the United States. Almost all of it is covered by a surficial sand sheet, often with some gravel (Hollister, 1985). South of the former glaciated area, the shelf is characterized by fields of linear, northeast-trending shoals (Duane *et al*., 1972). These shoals form a small angle with the coast (usually less than 35°), display complex bathymetry, have up to 10 m of local relief, and have side slopes of a few degrees. As well-organized morphologic features, they extend from water depths of only a few meters out to depths of about 60 m. Even though they show large variation in size, complexity, and distribution along the eastern seaboard, they nevertheless can be grouped into arcuate (inlet and cape-associated) and linear shapes (Duane *et al*., 1972).

The shoals, composed of Holocene sands, rarely attain thicknesses greater than 10 m and generally rest on horizontal strata of marsh, lagoon, and estuarine deposits. Radiocarbon dating of the underlying material indicates that the shoals postdate the last transgression and are, therefore, less than 11,000 years old (Walker and Coleman, 1987). The shoal sands, which bear evidence of recent modification by current and wave activity, are generally well-sorted, medium-grained sands that are similar in lithology to present shoreline beaches. Although there are numerous theories concerning their origin, it is generally accepted that they were formed by nearshore processes (*e.g.* Duane *et al.,* 1972; Hollister, 1985; Walker and Coleman, 1987). Shoals that are now isolated on the shelf are judged to have been formerly shoreface-connected and subsequently detached during the coastal retreat that accompanied the last rise in sea level.

Carbonate sediments occur on most modern continental shelves (Ginsburg and James, 1974). The various skeletal and nonskeletal grains are not moved far from their environments of formation. Therefore, their distribution is a reliable tool for interpreting the history of Holocene deposition on continental shelves. Holocene shelf carbonates, summarized by Ginsburg and James (1974), are grouped into two intergrading categories: open shelves (*e.g.* eastern Gulf of Mexico) and rimmed shelves (*e.g*. south Florida). Rimmed shelves are those in which a continuous rim, or semicontinuous rim, or barrier lagoon on the shelf margin restricts circulation and wave action on the adjacent shelf lagoon. The rim along the southeast Florida coast is a barrier reef, which terminates just south of the Martin – Palm Beach County line.

The thin accumulation of surface sediments on open shelves is largely relict and formed in shallow water earlier in the Holocene. The deposits of rimmed shelves, especially the shallower ones, are often thick, young (<6000 years old) and continuous. Sand and granular-sized grains are the most frequent and widespread form of carbonate on modern shelves. Coral algal reefs and algal hardgrounds are characteristic of shelf margins in tropical seas. Lime muds and mixtures of lime mud and sands are limited to lagoons rimmed by shelf-margin barriers.

Surface sediments of the western North Atlantic shelf are relict and were deposited in shallow water earlier in the Holocene, as described by Emery (1968), Emery and Uchupi (1972), and Milliman, Pilkey and Ross (1972). From Cape Hatteras south to Miami, the percentage of carbonate increases progressively. Milliman, Pilkey and Ross (1972) mapped nine assemblages of carbonate sand grains on the southern shelf. North of Jacksonville, molluscan debris predominates over the interior shelf with zones of ooid-peloid and coralline algae near the margin. From Jacksonville to Miami, where the percentage of carbonate is higher, ooid-peloid sands are more extensive, barnacle fragments are a significant component, and the molluscan sand zone is narrower. According to Macintyre and Milliman (1970), the age of the ooid sand near the shelf margin off Florida ranges from 9000 to 14,000 years BP.

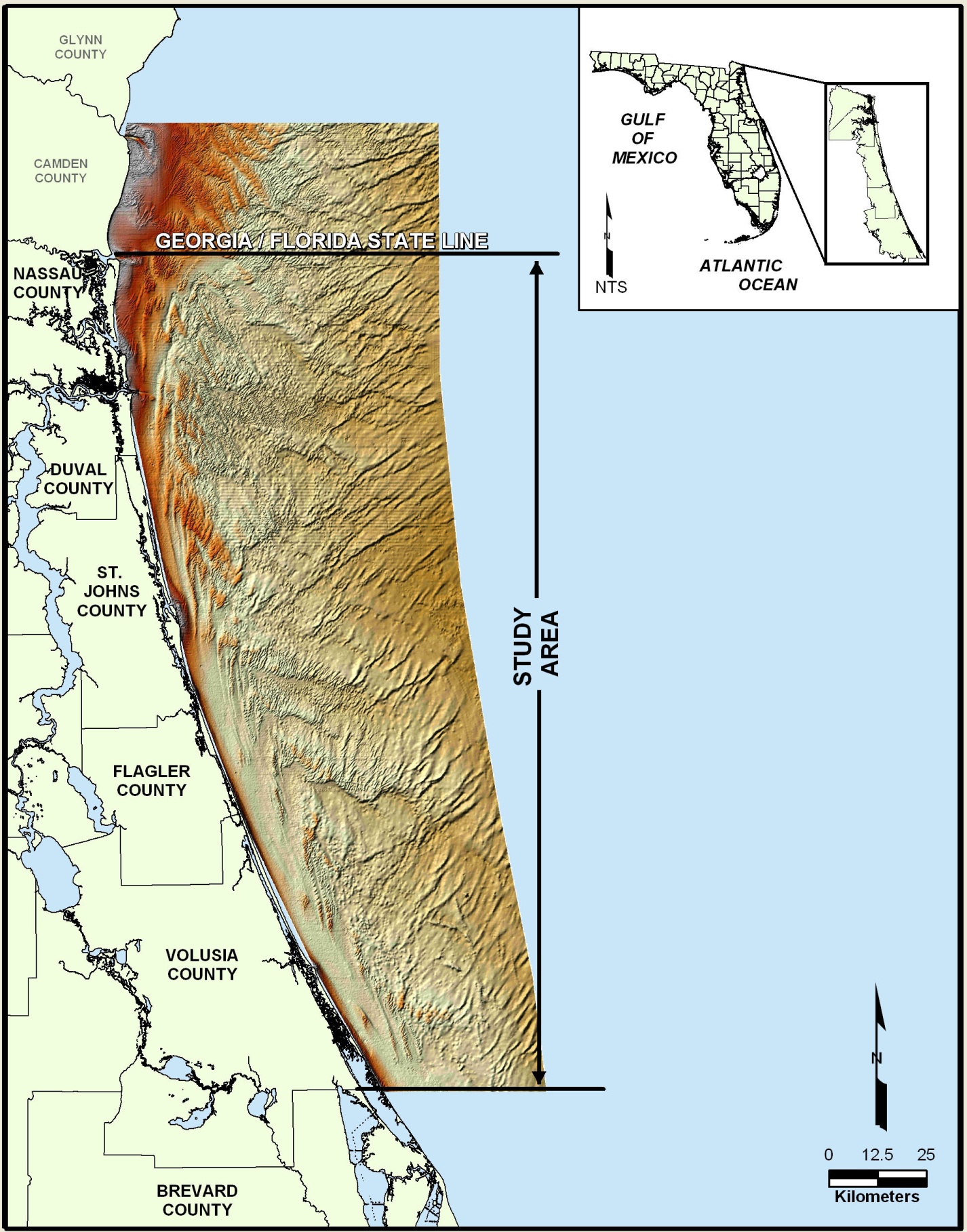


Figure 1a. Plan view of the study area along the northeast Florida Atlantic continental shelf, covering about 13,787 km2. The study area is defined by re-formatted NOAA bathymetry in state and federal waters along Nassau, Duval, St. Johns, Flagler, and Volusia counties. The study area extends from the shore to about the 45 m isobath, which extends up to 75 km offshore along the Florida-Georgia state line.

­ From Cape Hatteras to Cape Kennedy, the ridges of the shelf margin are interpreted as erosional remnants of Pleistocene limestone, capped by shallow-water calcarenite and coralline algal limestone. Milliman and Emery (1968) and Milliman, Pilkey and Ross (1968) radiocarbon dated samples of the algal limestone that ranged from about 12,000 to 27,000 years BP. From Cape Kennedy to Palm Beach the ridges are relict dunes or beach ridges capped with prolific growth of living branched corals (*Oculina* sp.) (Macintyre and Milliman, 1970). From Palm Beach to Miami the single ridge is an ‘inactive’ reef of hermatypic corals, octocorals, and sponges, with a narrow halo of carbonate sand rich in fragments of algae (Ginsburg and James, 1974).

**Geological Development of the Northeast Atlantic Coast of Florida**

The northern boundary of the basement structure supporting the Florida Platform was a linear structural basin located between the Peninsular Arch and the Paleozoic (4500 to 544 Ma) rocks of the southeastern United States. This structural zone was originally related to a suture zone and accreted continental terrane associated with the final closing of the Iapetus Ocean (proto-Atlantic Ocean). During the Jurrasic Period (when seafloor rifting and continental drift separated the Americas from Africa), the initial carbonate stratigraphic sequences onlapped from the south onto the Peninsular Arch basement rocks. As the Peninsular Arch became covered with shallow water carbonates (due to subsidence and sea-level rise) during the Early Cretaceous (146 to 65 Ma) to form the Suwannee Saddle (variously called the Suwannee Strait, Channel or Seaway; the Gulf Trough; or the Georgia Channel System) and the seaway that flooded it (Hine, 1997). This basin and seaway were paramount in maintaining the carbonate sediment producing environment to the south.

The continental shelf off the northeast coast of Florida is a wedge shaped platform with the apex pointed southward. The perspective shown in Figure 2 (a composite diagram that merges terrestrial satellite imagery with bathymetry) shows a wider shelf area in the northern part of the study area and narrow in the south, the seaward boundary of study being marked by the 45 m isobath. The shelf is about 120 km wide off Jacksonville but narrows to about 48 km wide off Cape Canaveral to the south. The shelf area is described here in terms of the geological framework, geomorphology, and sedimentology.

In terms of geological evolution, the shelf off northeastern Florida is relatively complicated with different hypotheses posited to account for some of the major features. Although the geological framework retains a complicated evolutionary history, some of the major developments are briefly mentioned here as a background to the description of major structures and processes that affect the geomorphology of the seafloor and surface sediments contained thereon.

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Figure 1b. Oblique terrain model of the study area showing in three-dimensional perspective the primary morphosedimentary features. Note in particular the numerous shore-parallel sand ridges alongshore and transverse sand ridges offshore. Shoal areas show up as reddish-colored tones in the northwest and southwest parts of the study area. Large sand waves are evident in the central part of the shelf area offshore St. Johns and Flager counties. This 3D image shows the wide range of forms that are developed along a sediment-rich shelf. The sediments making up the various deposits, interpreted as morphosedimentary units, are potential sand resources that require more detailed study.

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Figure 2. Composite diagram (not to scale) showing the study-area terrain model in relation to cadastral boundaries superimposed on satellite imagery. Near- and offshore sand ridges, bars, banks, shoals, and sand waves are clearly evident in the color-ramped bathymetry. Cape Canaveral is the large salient in Brevard County.

There are two fundamentally different views concerning the topographic complexity of the early basement structure underlying the Florida-Bahamas region. In one view, Mullins and Lynts (1977) postulate that the Bahamas Bank formed during the Jurassic on top of rift-generated horst-and-graben topography. This interpretation forms the basis for the so-called *graben hypothesis*. During long-term subsidence associated with the regional passive margin-setting, carbonate derived sedimentation on the megabank kept pace, forming thick (up to 14 km) shallow-water limestones. Sheridan *et al*. (1988) and Leg 101 Scientific Party (1988), on the other hand, envisioned a carbonate megabank that extended from the West Florida Escarpment (in the Gulf of Mexico) to the Blake-Bahamas Escarpment (east side of the Straits of Florida and western margin of the Blake Plateau-Bahama Bank). Because this megabank seemed to have formed by the Late Jurassic on a basement terrane not segmented into large horsts and grabens, it is referred to as the *megabank hypothesis*. Whether horst-and-graben or megabank, karst (subsurface and exposed sinkholes) developed in Paleocene, Eocene, and Oligocene limestones to produce subsurface local stratigraphic deformation in the form of folds and sags (Meisburger and Field, 1975; Popenoe *et al*., 1984). These folds have about 80 m of subsurface relief. Karstification (dissolution of limestone rocks) proceeded during the late Oligocene to early Miocene sea-level low stands. This surface karst topography and chemico-physical modification of the limestone structures probably control modern coastal morphology and shelf topography viz. Cape Canaveral, St. Lucie River estuary.

Geomorphological interpretation of the karstified terrain refers to several major physiographic features that resulted from geological structures (*e.g.* lineaments, folds, sags), subaerial weathering processes and subterranean dissolution, and sedimentation. The study area is located on the southern extension of the East Coast Shelf, which is defined by Uchupi (1968) as a gently seaward-sloping submarine plain bordering the Atlantic coast from Cape Cod to the Florida Keys. The East Coast Shelf is bounded by the 3-mile limit to the west (which marks the boundary between state and federal waters) and the Florida Hatteras Slope to the east. The north Florida Atlantic shelf area is part of the southeastern shelf. Following Price’s (1954) geomorphological terminology, Meisburger and Field (1975) subdivided the northeast Florida shelf into three main units: shoreface, shelf floor, and shelf edge. Exposed during glacio-eustatic sea-level lowstands during the Pleistocene, relict stream drainage patterns formed on the shelf (i.e. off Fernandina and St. Augustine) along with weathering profiles and Pleistocene soils.

From a sedimentological point of view, sediments occurring on the shelf are highly variable in terms of grain size characteristics, particle shape, and mineralogy (Meisburger and Field, 1975). Trends in sediment distribution appear to be related to both shelf and surface morphology and subbottom (geological) structure. Anomalous surface sediment patterns are related to the surface exposure of older underlying strata. In general, surficial sediments are detrital quartz sands that overlie older carbonate-rich quartz sand deposits. The overall distribution patterns of surface sediment on the shelf floor are largely the result of the thin and discontinuous nature of Pleistocene and Holocene sediments, but large volumes of quartz sand occur in spatially large but topographically subdued positive features. Adjoining patches of the shelf surface often contain sediments deposited at different times and under contrasting environmental conditions. Sediments as old as late Miocene and as young as Holocene are locally exposed in adjacent surface patches. Boundaries between these patches are sharp. They are not gradual as with facies changes in contemporaneous deposits. Thus, lithologic and faunal assemblages of the different patches may be strikingly different. In addition to the exposure of sediments of different age at the surface, there are lateral gradations within contemporaneous deposits and the disposition of surface sediments in detail is locally complex and irregular. However, there is a relatively uncomplicated dominant sediment distribution pattern – poorly sorted fine quartz sands that mantle the entire shoreface from Georgia to Cape Canaveral. The contact or boundary between shoreface facies and inner shelf facies commonly occurs at about the 3-mile limit, which occurs between the 30- and 50-foot isobath (see Figure 27 in Meisburger and Field, 1975) except just south of Flagler Beach where the shoreface narrows.

The thickness and spatial distribution of lithologic units on the shelf are organized by Meisburger and Field (1975) into three primary patterns: Georgia border to Jacksonville, Jacksonville to St. Augustine, and St. Augustine to Cape Canaveral. Most of the shelf region between Georgia and Jacksonville is covered by fine- to coarse-grained quartz sand deposits 0.3 to 1 m thick but ranging up to 2 m thick in places. Off Fernandina and Jacksonville, quartz sand is thicker (up to 2.5 m) and more uniform in lateral extent, probably due to the presence of the St. Johns and St. Mary’s Rivers. Late Tertiary dolomite silts and white foraminiferal sands occur several feet below the surface of the sea floor. Weathered materials representing the remains of Quaternary soils or groundwater profiles also occur below the surficial blanket sediments. Organic-rich muds and peats (radiocarbon-dated at 9625 YBP) also occur in the area at -18 m MLW.

In the Jacksonville to St. Augustine segment, the overall sediment character is similar to distribution patterns to the north. The relative distribution of the different sediment types changes significantly, however, both laterally and vertically. Fine- to medium-grained quartz sands are thicker and more laterally extensive. Pre-Pleistocene dolomite silts and foraminiferal sands are less abundant and more restricted in lateral extent. Reconnaissance vibracores from this area show relatively thick (>2.5 m) sequences of quartz sand. The Georgia region is a likely source for the north Florida shelf sands, based on the presence of (a) an unstable (they reflect derivation from Piedmont rocks without having passed through a sedimentary cycle of deposition, lithification, and subsequent erosion) heavy mineral assemblage similar to that of Georgia coastal sediments and reflecting a metamorphic-igneous provenance and (b) a fine-grained low carbonate nature suggesting modern fluvial derivation.

In the St. Augustine to Cape Canaveral segment, sediment character changes as the surface Quaternary sediments thicken and display facies changes that are quite marked. Clayey silt and muddy shell deposits, not present north of St. Augustine, occur near Daytona Beach. Silt and shell deposits may be related to shoreward migration of the Mosquito Lagoon barrier in response to rising sea level.

Sand resources on the shelf of northern Florida beyond the 3-mile limit are now relatively well known. Reconnaissance studies by Meisburger and Field (1975), for example, indicate the presence of quartz sand sheets up to 2 m thick and linear ridge-like shoals off Fort Pierce and Cape Canaveral and south of Daytona Beach. Bank shoals, flat-topped masses of irregular outline and low relief, occur throughout the area and contain several feet of quartz sand atop these topographic highs. Some show promise as sand sources, such as the shoal located 10 km offshore from Jacksonville and St. Augustine where the sand volume is estimated by Meisburger and Field (1997) to be on the order of 136 x 106 m3 (178 million cubic yards). Deposits off Ormond Beach and Marineland are estimated to contain about 46 x 106 m3 and 30 x 5.3 x 106 m3 (60 and 40 million cubic yards), respectively. A buried channel of the St. Johns River contains reasonably clean, medium- to coarse-grained quartz sand under a shallow overburden. Because some other channels are filled by silty sand and clay, detailed exploration is required to locate sand-filled channels. Linear shoals, such as those lying off Amelia Island, may contain thick sand accumulations. A sand ridge near St. Augustine, for example, is estimated to contain at least 5.3 x 106 m3 (7 million cubic yards) of sand in a layer 1.2 to 1.8 m thick.

**Morphosedimentary Features of the Continental Shelf**

The study area, occurs on the southern extension of the major physiographic unit identified by Uchupi (1968) as the East Coast Shelf. The Florida Hatteras Slope occurs seaward of the shelf break. The East Coast shelf is a gently seaward-sloping submarine plain bordering the Atlantic coast from near Cape Cod to the Florida Keys. The northeastern Florida Atlantic shelf area is part of the southeastern shelf. Following Price’s (1954) geomorphological terminology, Meisburger and Duane (1971) subdivided the central Florida shelf into three main units: shoreface (low water line to about -12 m), inner shelf plain (-12 to -23 m MLW), and outer shelf that is transitional from the ‘flat’ inner shelf to the top of the Florida-Hatteras Slope lying at -24 to -70 m MLW. The slope break generally falls between the 20 and 24-m depth contour. These shelf units were mapped by Finkl and Andrews (2007) from the Palm Beach County – Martin County line to the Brevard County – Volusia County line.

Meisburger and Field (1975) subsequently subdivided the northeast Florida continental shelf into two main physiographic units: shoreface and shelf floor (“ramp” of Price, 1954). In this report, the shelf floor is further divided into three subunits, following physiographic units on the central Florida shelf: inner shelf floor (-12 to -20 m MLW), mid shelf floor (-20 to 24 m MLW), and outer shelf floor (-24+ m MLW) (Figure 3). Because the continental shelf becomes wider with distance north, the upper slopes of the Florida-Hatteras Slope occur seaward of the mapping area beyond 45 m depth. The shoreface extends from the low water line to about -12 m. These units are shown in Figure 3 with major morphosedimentary boundaries superposed. The boundaries of morphosedimentary features are shown here in reference to physiographic subdivisions of the continental shelf in support of subsequent discussion. Future references to the geographic location of morphosedimentary features in relation to their positions within physiographic subdivisions of the continental shelf are keyed to Figure 3. These physiographic subdivisions of the continental shelf help to define coastal ocean process zones, as discussed for portions of the southeast Atlantic coast by Khalil (2000) and Finkl and Khalil (2000), that in turn can be related to contemporary and relict bedforms. Most of the larger morphosedimentary features on the seafloor are relict (Holocene in age) but contain clear evidence of subsequent reworking by more recent processes in the late Holocene since sea level reached it present position about 3000 to 5000 years ago. Downdrift extensions of shoreward margins of ridge fields and distal erosion of banks and sand waves are examples. Smaller bedforms occur nearshore but are mostly absent from the reformatted NOAA bathymetry due to scalar parameters of the acquired data.

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Figure 3. Physiographic subdivisions of the North Florida Atlantic Continental Shelf, showing the shoreface, inner shelf floor, middle shelf floor, and out shelf floor. Superimposed on top of these shelf units are boundaries of the morphosedimentary mapping units that are investigated for potential as sand sources for beach nourishment. →

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**METHODOLOGY**

The basic methodology of this reconnaissance assessment of offshore sand resources on the continental shelf off the northeast Florida Atlantic coast involved acquisition and manipulation of digital bathymetric data from NOAA (NOAA-GEODAS bathymetry), graphic display of the reformatted data points, and interpretation of the resulting spatial distribution patterns of bathymetric highs and lows in terms of seafloor physiographic units. Bathymetric patterns were interpreted as morphosedimentary bodies in terms of sand flats, ridge fields, sand waves, transverse bar systems, banks, and shoals. About twenty-nine mapping units were derived from the bathymetric data, including four ebb-tidal delta complexes at major inlets.

Historical (published and unpublished) data was perused to gather background information about the area and to assess sand resource potentials. Some historical data was general in scope while other data was point specific. Geotechnical (grab samples and vibracores) and geophysical data (seismic reflection profile surveys) were, for example, assessed from a variety of sources including the Florida Geological Survey and Minerals Management Service (Phelps *et al*., 2007). By combining seafloor mapping units, geotechnical, and geophysical data, it was possible to estimate sediment volumes by geomorphological mapping unit. The latter procedure was accomplished in a GIS platform where various criteria could be queried. Each methodology is briefly described as follows.

**Reformatting Hydrographic Survey Data and Creation of Data Reliability Diagram**

Bathymetric data (NOS Hydrographic Survey Data) were obtained from the NOAA Geophysical Data Center (NGDC at [www.ngdc.noaa.gov](http://www.ngdc.noaa.gov/)). The hydrographic data consists of historic survey information from 1924 to 1999. Original spacing of data varied from about 100 to 1500 feet, as shown in the reliability diagram inserted into Figures 3, 4 a, 4b, 9a, and 9b. The 500-foot grid (Zone C) was generally extended about 10 km offshore except seaward from the general latitude of southern St. Johns County to the offshore extension of the Flagler – Volusia county line. Most of the offshore area was mapped using a 1000-foot grid (Zone D). Approachways to the St. Johns River (Port of Jacksonville), where greater accuracy of depth information is required, were surveyed on 125-foot grids (Zone A). A small nearshore area off Jacksonville Beach was mapped using a 400-foot grid (Zone B). Zone G, in the nearshore off the St. Augustine Ebb-Tidal Delta, is based on a 400-foot grid. A small Zone H at the navigational entrance to Mayport was based on a 100-foot grid. Zone E designates a small area near the center of the offshore study area where no bathymetric information was available. Occurring far offshore is part of a broad scale survey area (Zone F) that is based on 1500-foot grid spacing. Locations of detailed bathymetric surveys, not used in these calculations, are shown in Figure 10a.

Perusal of the data reliability diagram shows that a range of spatial resolutions were used to compile the 3D bathymetric (terrain) model that forms the basis of this reconnaissance sand resource investigation. New 250-foot bathymetric grids, which used historical grid spacings indicated above by zone, were created using Surfer® to interpolate the original hydrographic data by equally spaced intervals so that resulting spatial distribution patterns would better resemble recognizable topography that could be color ramped. The result is a rasterized image that provides spatial continuity of point data in a format that represents a topographic surface. Differences in elevation can thus be shown as continuously varying spatial units that are amenable to color coding.

**Creation of Terrain Models of the Continental Shelf**

The basic mapping procedure was to group similar, spatially-related seafloor features into discrete mapping units. Recognition of seafloor features from the color-ramped bathymetry depends on the experience and knowledge of the interpreter. Variations in bottom topography are visualized using a color ramp that grades from reddish tones nearshore through yellowish tones on the middle shelf to brownish tones seaward in preference to bluish tones that are traditionally used to show water depth. The new color ramp was produced here to show submarine topography (morphosedimentary features), which is the subject of this report, not water depth. The map product thus produced is the result of mentation and deductive reasoning. The essential points of the mapping procedures are described, for example, by Benedet *et al*. (2004); Finkl and Warner (2004); Finkl (2005); Finkl, Benedet and Andrews (2005, 2006); and Finkl and Andrews (2007). The present work is an extension of the geological models for the continental shelf off the southern and central Atlantic coast of Florida, as prepared for the ROSS database project (Finkl, Andrews and Benedet, 2007; Finkl and Andrews, 2007).

**Determination of Sediment Volume in Morphosedimentary Features**

Sediment volume calculations were based on reformatted bathymetric data (NOS Hydrographic Survey Data) that were obtained from the NOAA Geophysical Data Center (NGDC at [www.ngdc.noaa.gov](http://www.ngdc.noaa.gov/)). These are the same data that were used to prepared the terrain models of seafloor units, based on hydrographic data consisting of historic survey information from 1924 to 1999 (see above). These data were provided as a \*.csv file of northing, easting and z points. The data were converted to a shapefile using the ArcGIS® 9.2 “XY Event Tool”. Using the ArcGIS 9.2 “Select by Location” function, individual polygon units were used to select the corresponding elevation point data. A 500-foot buffer was applied during the selection process to enable complete coverage of the unit during TIN (Triangulated Irregular Network) creation. A TIN is a data structure used to model surfaces such as elevation as a connected network of triangles. TINs are assembled from a series of data points with *X*, *Y*, and *Z* values that partition geographic space into contiguous, non-overlapping triangles (called faces). The nodes of each triangle are the elevation or surface points. To eliminate the overlap edges due to the triangulation creation process of the TIN unit, these individual TINs were edited by the three-dimensional individual unit polygon it was designed to represent. The resulting TIN was then imported into ArcScene®. Using the “Spatial Analysis” function within ArcScene, an estimated volume and area was obtained for each individual unit. This tool examines each of the individual triangles in the network and determines its contribution to the overall total area and volume. The baseline for estimated sediment volume is the lowest elevation within the morphosedimentary unit. All calculations were set to determine area and volume above this elevation. To determine potential sand volume, a three-dimensional rendering in ArcScene of each unit was visually analyzed, such as ridge fields, for percent ridge coverage. This visually determined percentage was used to calculate potential sand volume from the estimated total sand volume of each morphosedimentary unit. The percentage coverage of specified bathymetric features within morphological units is tabulated at appropriate locations in this report (see Tables 2 through 6). The computer program thus uses the difference between maximum and minimum elevations within the unit to calculate volume, but also takes into account other differences in elevation within the unit as determined by TINs.

**Characterization of Seafloor Mapping Units**

Morphological units comprised by combinations of depth, shape, and arrangement of soundings, and shadow patterns were drawn in the paper chart (at a scale of 1:40,00) by freehand and then digitized on screen. This dual procedure was followed because it is easier to identify and follow patterns on a large chart than by scrolling multiple computer screens. Screen resolution was better than print resolution and patterns marked on the reformatted NOAA bathymetric charts could be modified on screen when digitizing in ArcView (ArcGIS). The final digital product is thus compiled in a spatial context that facilitates analysis and computation of selected parameters such as areas for sand flats, sand waves, ridge fields, banks, and shoals (Figures 4a and 4b)*.*

Prior to embarking on the actual mapping process based on image interpretation, the color-ramped chart (3D model of the seafloor topography) was visually inspected and partially mapped in an effort to ascertain the range of features that could be identified in the study area, as described by Finkl, Benedet and Andrews (2004, 2005) and Finkl and Andrews (2007). A list of topographic features that occurred on the chart was compiled to a master list to make a comprehensive legend. Twenty-nine major landform features (Table 1) were found to occur in the survey area. These features are organized in terms of a geomorphological classification scheme. There are many possibilities for interpretation of features and the orientation depends on the purpose, which in this case was production of a geomorphological map for the purpose of assessing potential sand resources. The classification scheme is summarized in Table 1, where mapping units are organized by their primary mode of occurrence as transverse bars, sand flats, ridge fields, shoals, sand waves, banks, ebb-tidal deltas, and undifferentiated sea floor.

Because the development of a morphological classification scheme can be an endless task, it is necessary to focus on the purpose of the survey and to rationalize procedures for consistently recognizing morphological features that are identifiable at specific scales of observation. The nominal scale of observation for the northeast Atlantic coast of Florida was determined for ease of paper handling (at a scale of 1:40,000) and to match maps of submarine topography and potential sand resources along the central and southeastern Florida Atlantic coasts. In this way, a contiguous database is provided for the shelf area from about the latitude of Brevard County to the Florida-Georgia state line, an alongshore distance of about 602 km and an area of about 2,044,742 ha.

For large-scale reconnaissance mapping purposes, the printed map sheets provided sufficient detail for recognition of major features still showed general spatial trends. It was thus possible to identify a range of features while not becoming bogged down by too much detail, as might occur on dissected margins of sand banks and sand waves where there are complex patterns of ridge and valley topography. The other point to consider is the balance between what can be seen, what can be mapped, and what is useful or practical to delineate at a reconnaissance scale for estimating potential sand resources. The natural spatial heterogeneity of morphological units on the seafloor determines to a large extent what should be mapped. In a sense, then, most natural units are predetermined and they reflect the types of units that have been mapped and described by other researchers working elsewhere.

The main morphological features occurring in the study area are summarized in Table 1 in terms of sandy bottom types, sedimentary deposits arranged on the seafloor as long ridges, shoals, sand banks, sand waves, and related features. Mapping unit morphometrics, summarized in Table 1, are used to describe the various morphosedimentary features. From the point of view of area occupied, banks, sand waves, sand flats, and ridges are most extensive. The Farmton Sand Flat occupies about 202,000 ha and is followed by the Volusia Bank (about 167,000 ha), St. Johns Bank (about 137,000 ha), and the Duval Ridge Field (about 142,000 ha). Shoals, sand waves, ebb-tidal deltas, and transverse bars take in less territory but may contain important sand resources closer to shore.

Table 1*. Submarine physiographic units on the inner continental shelf (extending offshore to the 45-m isobath) along the northeast Florida Atlantic coast.*

|  |  |  |  |
| --- | --- | --- | --- |
| **Physiographic**  **Province** | **Morphometry1** | **Description** | **Comments/Source** |
| **Bars** | Based on examples of: Davis (1994), Brooks (1982), Dean & O’Brien (1987), Konicki & Holman (2000), FitzGerald (2005) | | |
| Talbot Transverse Bars | Bars 200 to 500 m wide, up to 3 km long, 55 to 80° azimuth, (5974 ha). | Bar field 16 km long by 5 km wide, wavelengths about 400 m, 6 to 10 m water depth, sand flat units interspersed between bars. | Defined in this work. Occurs on the shoreface updrift from the Tisonia – Nassau Sound delta. By-passing bars to the south. |
| **Ridge Fields** | Based on examples of: Stahl *et al.* (1974), Meisburger & Field (1975), Off (1976), Swift & Field (1981), Parker *et al*. (1982), Swift *et al.* (1984), McBride & Moslow (1991), Dyer & Huntley (1999), Snedden & Dalrymple (1999), Freedenberg *et al*. (2000), Finkl & Andrews (2007), Finkl, Benedet and Andrews (2007), Phelps *et al*. (2007) | | |
| Amelia | Ridge 1.75 km (south) to 4.60 km (north) wide, 23 km long, 90° azimuth, 4 to 6 km offshore, 2 to 4 m local relief (4,168 ha). | Main ridge field (5 km by 10 km) to north with one large downdrift extended finger, surrounded by sand flats. | Defined in this work. Occurs on the inner shelf floor. |
| Bunnel | Ridges 1 to 5 km wide, 25 km long, 90-100° azimuth, 8-10 km offshore, 2 to 5 m local relief (8438 ha) | Main ridge field (5 km by 10 km) to north with 3 main downdrift extended fingers, sand flats between ridges. | Defined in this work. Occurs on the middle inner shelf. |
| Crescent | Ridges 0.5 to 1 km wide, 13 km long, 90° to 100° azimuth, 7- 10 km offshore, 2 to 4 m local relief (9268 ha). | Broad ridge field (5 km by 5 km) to north with 5 main downdrift extended fingers, sand flats between ridges. | Defined in this work. Occurs on the inner shelf floor. |
| Duval | Ridges 0.5 to 2 km wide, up to 20 km long, 290° azimuth, 10 km offshore, 2-5 m local relief (141,796 ha). | Broad ridge field (25 km by 50 km) to north with 6 main downdrift extended fingers, sand flats between ridges. Ridge field 93 km long, from north to south. | Defined in this work. Occurs on the inner and middle shelf floors. |
| Edgewater | Ridges 0.5 to 1.2 km wide, 3 km long, wavelength about 0.5 km, 40° to 60° azimuth, 6-11 km offshore, x-x m local relief (15,979 ha). | Ridge field 40 km long with 3 main downdrift extended fingers, sand flats between ridges. | Defined in this work. Occurs on the inner shelf floor. |
| Fort Clinch | Ridges 200 to 500 m wide, up to 5 km long, wavelength about 200 to 500 m, 65° to 80° azimuths, 6 to 15 km offshore, 2-6 m local relief (6070 ha). | Broad ridge field (8 km by 8 km) to north with 2 main section separated by sand flats between ridges. | Defined in this work. Occurs on the inner shelf floor. |
| Espanda | Ridges 0.1 to 0.5 km wide, 2 km long, 15° to 20° azimuth, 10 km offshore, 2-4 m local relief (3434 ha). | General north-south ridge field 18 km long, ridges per se traverse NE-SW, wavelengths about 200-400 m. | Defined in this work. Occurs on the middle shelf floor. |
| Korona | Ridges 0.2 to 0.5 km wide, 1-4 km long, 30° to 40° azimuth, 8 to 12 km offshore, 2-4 m local relief (21,479 ha). | Broad ridge field (6 km by 14 km) to north with 2 main downdrift extended fingers 22 km long, sand flats between ridges, ridges transverse to the shore. | Defined in this work. Occurs on the inner and middle shelf floors. |
| **Sand Flats** | Based on examples of: Field & Duane (1974), Meisburger & Field (1975), Knebel (1981), Davis (1994), Warner (1999), Finkl & Khalil (2000), Finkl *et al*. (2003), Finkl & Warner (2004), Fenster (2005), Finkl, Benedet and Andrews (2007), Finkl & Andrews (2007) | | |
| Farmton | Sand flat main trunk about 10 km, ranges up to 20 km wide in south, about 225 km long, some low amplitude ridges 12 km long (201,528 ha). | Extensive shoreface-attached sand sheet from Georgia border in Brevard County. Encroached upon by sand ridges and surrounds shoals on inner shelf floor. Water depth range MLW to 20 m. | Defined in this work. Occurs on the shoreface, inner shelf floor, and shoreward part of the middle shelf floor. |
| **Sand Waves** | Based on examples of: Harvey (1966), McCave (1971), Terwindt (1971), Ludwick (1972), Boggs (1974), Fenster *et al*. (1990) | | |
| Flagler | Large shore-normal sand wave 36 km EW extent by 23 km NS extent, with long 5-15 km ridges (85° azimuth) superposed, southern margin of sand body and ridges dissected into smaller ridges, dissected zone about 5 km wide. Total area is 57,292 ha. | Broad E-W trending sand wave with superposed sand ridges and dissected distal margin. Local relief with-out ridges 2-4 m, with ridges 2-4 m, in dissection 2-4 m. Water depths range from 16 m to 26 m. | Defined in this work. Occurs mostly on middle shelf floor with northeastern segment on the inner part of the outer shelf floor. |
| Palm Coast | Large shore-normal sand wave 29 km EW extent by 10 km NS extent, with some long 2-5 km ridges (85° azimuth) superposed, southern margin of sand body and ridges dissected into smaller ridges, dissected zone 5-8 km wide. Total area is 25,434 ha. | Broad E-W trending sand wave with some super-posed sand ridges but mostly dissected surface. Local relief without ridges is 2 m, with ridges 2-4 m, in dissection 2-6 m. Water depths range from 16 m to 30 m. | Defined in this work. Occurs on middle shelf floor with northeastern segment on the inner part of the outer shelf floor. |
| Summer Haven | Large shore-normal sand wave 46 km EW extent by 10 km NS extent, with some long 2-5 km ridges (60°-75° azimuth) super-posed, dissected zone about 4 km wide. Total area is 55,722 ha. | Broad E-W trending sand wave with a few super-posed sand ridges and dissected distal margin. Local relief on wave surface 2-4 m, in dissection 2-6 m. Water depths range from 16 m to 28 m. | Defined in this work. Occurs on inner shelf floor, middle shelf floor, and seaward segment on the inner part of the outer shelf floor. |
| **Shoals** | Based on examples of: Purdy (1961), Palmer and Wilson (1978), Penland *et al*. (1989), McBride *et al*. (1999) | | |
| Allandale | Small shoal (2 km wide by 5 km long) oriented in NS direction, with small ridges (30° and 85° azimuths), 2 m local relief (675 ha). | Shoal area comprised by a series of small isolated sand ridges surrounded by the Farmton Sand Flat. Water depths range from 14 m to 16 m. | Defined in this work. Occurs on the inner shelf floor. |
| Beverly | Small shoal (3 km wide by 5 km long) oriented in NS direction, with five small ridges (about 350° azimuths), 2 m local relief (1248 ha). | Shoal area comprised by a series of small sand ridges, some of which are subdued extensions of longer ridges in the Farmton Sand Flat. Water depths range from16 m to18 m. | Defined in this work. Occurs on the inner shelf floor. |
| Oak Hill | Small shoal (1.5 to 2 km wide by 10 km long) oriented in NS direction, shoal centered on small ridges (45° and 50° azimuths), 6 m local relief (1813 ha). | Shoal area comprised by a series of small isolated sand ridges surrounded by the Farmton Sand Flat. Water depths range from 12 m to 18 m. | Defined in this work. Occurs on the inner shelf floor. |
| **Banks** | Based on examples of: Agassiz (1802), Illing (1954), Ginsburg and James (1974), Stride *et al*. (1982) | | |
| Nassau | Large NW-SE trending bank, 55 km long by 12-15 km wide, with very weak structurally controlled NW-SE trending ridge-and-valley sequences. | Generally subdued surface relief, except long dissected central region and southern margin. Water depths range from 16 m to 30 m. | Defined in this work. Occurs mostly on the shoreward parts of the outer shelf floor. |
| O’Neal | Moderate sized shore-parallel bank with 24 km E-W extent by 27 km N-S extent, traversed by low-relief sand ridges, NW part slightly dissected. 4 m local relief (31,039 ha). | Generally rolling surface but with some areas of ridges in northern part of unit, shoaler than adjoining Nassau Bank. Water depths range from 18 m to 28 m. | Defined in this work. Occurs partly on the seaward part of the inner shelf floor and shoreward part of the middle shelf floor. |
| Sawgrass | Large shore-normal bank with 63 km E-W extent by 29 km N-S extent, traversed by some ridges, some southern areas dissected, 5 m local relief (86,980 ha). | Generally flat surface but with some areas of hummocky terrain, some ridges, and dissected southern margins. Water depths range from 18 m to34 m. | Defined in this work. Occurs on the seaward margin of the inner shelf floor, across the middle shelf floor, and onto outer shelf floor. |
| St. Johns | Large shore-parallel bank about 70 km long by 14 km to 20 km wide, traversed by some widely spaced ridges (40° to 55° azimuth) up to 12 km long throughout, 4 m local relief (136,962 ha). | Generally flat surface but with some areas of hummocky terrain in the north. Water depths range from 22 m to 36 m. | Defined in this work. Occurs on the outer shelf floor. |
| Volusia | Large shore-parallel bank (10-14 km offshore) about 80 km long by 10 km to 25 km wide, traversed by some widely spaced ridges (50° to 85° azimuth) up to 12 km long throughout, 2-4 m local relief (166,917 ha). | Generally flat surface but with scattered areas of hummocky. Shoreward margin is dissected into the Edgewater Ridge Field. Water depths range from 16 m to 28 m. | Defined in this work. Occurs on the middle shelf floor and outer shelf floor. |
| **Ebb-Tidal Deltas** | Based on examples of: Dean & Walton (1975), Dean & O’Brien (1987), Finkl (1994), Davis (1997), Powell *et al*. (2006) | | |
| St. Augustine | The ebb-tidal delta extends 3 km offshore (updrift margin) and 25 km alongshore, overlaps the Farmton Sand Flat. 14 m local relief (5680 ha). | Deltaic sands with disrupted bypassing bars and transverse bars down-drift of the inlet. Water depths range from 0 m to 14 m. | Defined in this work. Occurs on the shoreface. |
| St. Johns | The ebb-tidal delta extends 2 km offshore (updrift margin) and 9 km alongshore, overlaps the Farmton Sand Flat, cut by navigation channel 5 km long by about 400 m wide. 22 m local relief (1840 ha). | Deltaic sands with deflected bypassing bars and transverse bars down-drift of the inlet. Water depths range from 0 m to 10 m. | Defined in this work. Occurs on the shoreface. |
| St. Mary’s Ebb-Tidal Delta | The ebb-tidal delta extends 5 km offshore and 13 km alongshore, overlaps the Farmton Sand Flat, cut by navigation channel 7 km long by about 230 m wide. 10 m local relief (4163 ha). | Deltaic sands with bypassing bars and transverse bars up-and downdrift of the inlet. Water depths range from 0 m to 6 m. | Defined in this work. Occurs on the shoreface. |
| Tisonia – Nassau Sound Ebb-Tidal Delta Complex | The ebb-tidal delta extends 2 km offshore and 7.5 km alongshore, overlaps the Farmton Sand Flat, well-defined transverse bars. 6 m local relief (1414 ha). | Deltaic sands with transverse bars (1°-10° azimuth). Water depths range from 0 m to 6 m. | Defined in this work. Occurs on the shoreface. |
| **Undifferentiated Seafloor** | Based on examples for ridges and banks by: Agassiz (1802), Illing (1954), Ginsburg and James (1974), Stahl *et al*. (1974), Meisburger & Field (1975), Off (1976), Swift & Field (1981), Parker *et al*. (1982), Stride *et al*. (1982), Swift *et al.* (1984), McBride & Moslow (1991), Dyer & Huntley (1999), Snedden & Dalrymple (1999), Freedenberg *et al*. (2000), Finkl & Andrews (2007), Phelps *et al*. (2007) | | |
| With Anastamosing Ridges | Complex deepwater seafloor region (40 km by 43 km) with ridges, up to 15 km long, that separate and reunite, includes small bank areas and undiffer-entiated topography. 6 m local relief (133,671 ha). | Complex shore-normal deepwater seafloor region (15 km by 65 km) with ridges, up to 15 km long, on the seaward part of the unit. 2-6 m local relief. | Defined in this work. Occurs on the outer shelf floor. |
| With Linear Sand Ridges | Complex shore-normal deepwater seafloor region (22 km by 140 km) with ridges, 10 km to 15 km long, throughout the unit. xx m local relief (174,749 ha). | Complex deepwater seafloor region with large rectilinear and broadly arcuate ridges, up to 4 m high. 4 m local relief. | Defined in this work. Occurs on the outer shelf floor. |
| With Transverse Ridges | Complex shore-normal deepwater seafloor region (15 km by 65 km) with ridges, up to 15 km long, on the seaward part of the unit. 6 m local relief (101,440 ha). | Contains numerous ridges with dominant 45° to 50° azimuth, dissected small bank areas in shoreward parts, and undifferentiated seafloor flats between ridges. Thicker sediment accumulation along shoreward margins. Water depths range from 18 m to 36 m. | Defined in this work. Occurs mostly on the outer shelf floor, but extends across the middle shelf floor onto the seaward-most segment of the outer shelf floor. |

1 Based on interpretation of reformatted NOAA bathymetry, but limited by scalar parameters determined in input of acquisition data that was of variable scales.

This classification of seafloor morphological types is open-ended and can be amended as required. These units, which are keyed to the reformatted NOAA color-ramped maps (Figures 4a and 4b), represent an initial attempt to characterize the nature of the continental shelf along the northeast Atlantic coast of Florida. Seafloor mapping units are described by the morphological group to which they belong as follows: bars, ridge fields, sand flats, sand waves, shoals, banks, ebb-tidal deltas, and undifferentiated seafloor.

**REGIONAL DISTRIBUTION OF SEAFLOOR MAPPING UNITS**

The study area shows a diverse range of morphological features that are comprised by extensive unconsolidated sedimentary deposits. Twenty-nine distinct types of submarine geomorphological units were identified and mapped. These units include subdivisions of sand ridges, shoals, banks, sand flats, sand waves, ebb-tidal deltas, transverse bars, and undifferentiated seafloor. The continental shelf area off each county is thus generally characterized by distinct submarine physiographic units (see Figure 3), not the least of which are sedimentary bodies that support exploitation of sand resources for beach nourishment.

The following brief description summarizes the overall geographic distribution of morphodynamic sedimentary units on the continental shelf in the study area. The purpose of this summary is to show regional (cross-county) continuity of mapping units and spatial interrelationships between units as they occur on different shelf floor environments (see Figures 3, 4a, and 4b). Ebb-tidal deltas are associated with major river inlets and occur on the shoreface. The four deltas recognized include the St. Augustine (centering on R120, St. Johns County), St. Johns (centering on R002, Duval County), St. Mary’s (centering on R010, Nassau County), and Tisonia – Nassau Sound (centering on R75, Duval County). The deltaic deposits merge with the continuous shoreface-attached sand sheet that makes up the Farmton Sand Flat mapping unit on the inner shelf floor, which extends northward from the Cape Canaveral cuspate foreland in the central Florida survey area (Finkl and Andrews, 2007). The Beverley (offshore R40, Flagler County), Allandale (offshore R90, Volusia County), and Oak Hill (offshore R210, Volusia County) shoals occur as enclaves within the Farmton Sand Flat and are transitional to the middle shelf floor. Banks, ridge fields, and sand waves on the middle and outer shelf floor occur seaward of shoreface-attached sand sheets and transitional shoals. Banks and sand waves tend to occur in deeper water seaward of the main ridge fields. The Duval Ridge Field mapping unit extends from the Georgia State line to about mid St. Johns County off R150 and is flanked shoreward by the Farmton Sand Flat and seaward by the Nassau Bank and Sawgrass Bank. Offshore sand waves (Summer Haven, Palm Coast, and Flagler) on middle and outer shelf floors are extensive off southern St. Johns County and Flagler County. These units merge seaward with the St. Johns Bank off St. Johns and Flagler counties. The Volusia Bank, occurring offshore Volusia County on middle and outer shelf segments, is abruptly terminated shoreward by the Korona and Edgewater ridge fields. Undifferentiated seafloor occurs along the seaward margins of the study area on the outer shelf floor. Although punctuated by large-scale bathymetric features, these areas of seafloor do not show detailed features at 1000 foot data spacing (Figures 4a and 4b, Data Reliability Zone Map, Zone ‘D’). Primary features in Zone D include pronounced sand ridges with distinctive patterns that are linear, anastamosing, or transverse. Undifferentiated outer shelf seafloor merges shoreward with banks and sand waves.

Salient morphometric properties of seafloor topographic units are described by county from north to south, starting with Nassau County and ending with Volusia County. Parts of the offshore continental shelf in all counties is designated as ‘Undifferentiated Seafloor’ due to low-resolution bathymetric data (see insert Data Reliability Zone Map, Figure 3). The mapping units described by county in the following discussion are shown in Figures 3, 4a, and 4b.

**SAND FLATS**

Sand flats are broad and often featureless (lacking clearly defined bedforms at the mapping scale) expanses of seafloor with an unconsolidated sediment cover that is mostly sandy, as defined by Warner (1999), Finkl and Warner (2004), Finkl *et al*. (2007), and Finkl and Andrews (2007) to characterize seafloor units along the southeast and central Florida Atlantic coasts. Sand flats are extensively mapped on the continental shelf along the southeast coast where they occur in inter-reefal positions between rock and coral-algal reefs (Finkl, Andrews and Benedet, 2007). They also occur extensively along the central Florida shelf where the barrier reefs of the Florida Reef Tract are missing. Here, the shoreface-attached sand flats are flanked seaward by ridge fields and banks, as described by Finkl and Andrews (2007). Only one sand flat occurs in the present study area, a northward extension of the Farmton Sand Flat of the central coast. The Farmton Sand Flat was previously defined by Finkl and Andrews (2007) in terms of summary morphometrics.

**Farmton Sand Flat**

The Farmton Sand Flat mapping unit (201,525 ha) (Table 1), defined by Finkl and Andrews (2007) along the central Florida Atlantic shelf, extends along the whole span of the study area from the Brevard County line to Georgia, a distance of about 225 km. This extensive shoreface-attached sand sheet extends offshore on the inner shelf floor. It is narrowest in St. Johns County offshore R050 (Figure 4a) and widest in Volusia County offshore from the coastal segment between Ariel and Shiloh (Figure 4b) where its seaward extent reaches 20 km offshore. Although continuous along the shore, offshore the Farmton Sand Flat interdigitates with sand ridges that encroach upon this sand sheet. Some of the sand ridges are continuous for 12 km. Encroaching ridges include the Amelia Sand Ridge, extending southwards from the Georgia border to about R020 in Duval County. Extended downdrift margins of the Duval Ridge Field in Nassau, Duval and St. Johns counties cross the federal-state boundary where they form large alternating finger ridges interspersed by broad sand flats. Similar extended downdrift ridge fingers are associated with the Cresent Ridge Field mapping unit in St. Johns County offshore R160 to R200. The second widest seaward extension of the Farmton Sand Flat is interrupted by the Bunnel Ridge Field and Korona Ridge Field off Flagler and Volusia counties (Figure 4b). Still more extended downdrift ridge fingers, dissecting the seaward margins of the Farmton Sand Flat, are associated with the Edgewater Ridge Field offshore Volusia County between R180 and R230.

In addition to seaward splintering of the sand flat by downdrift extensions of ridge fields, shoals (Allandale, Beverly, and Oak Hill) occur as enclaves within the Farmton Sand Flat mapping unit. Where not bounded by ridge field units, the sand flat merges seaward with sand waves, for example offshore R010 and R060 in Flagler County, or banks offshore R100 in Volusia County and southwards near the border with Brevard County (Figure 4b).

**TRANSVERSE BARS**

Transverse sand bars in the nearshore run obliquely to the longshore trend of the beach (Komar, 2005). They tend to occur in more or less rhythmic patterns as stand-alone features or welded to the shore. As described by Konicki and Holman (2000), these types of transverse sand bars may extend seaward from both the shoreline (trough transverse bars) and the shore-parallel sand bar (offshore transverse bars). Numerous origins have been suggested for the formation of these sand bars, but it is generally observed that when waves break at pronounced angles to the beach, the offshore bars that were originally parallel to the shore and segmented by evenly spaced rip currents, rotate to align themselves with the incoming wave crests (Komar, 1983). This may be the origin of the large sand bars that make up the Talbot mapping unit, as defined in this study (Table 1).

**Talbot Transverse Bar**

The Talbot Transverse Bar field occurs updrift from the Tisonia – Nassau Sound Ebb-Tidal Delta on the shoreface and inner shelf floor (Figure 4a) along the nearshore of Nassau County. Occupying about 6000 ha, the bar field extends about 15 km alongshore by about 5 km in width and merges with the Farmton Sand Flat mapping unit where sand flats occur interspersed between large bars. The unit eventually grades offshore into the Farmton Sand Flat. Some bars extend up to 4 km in length along 55° to 80° azimuths (Table 1). Individual larger bars range in width from 200 to 600 m.

**EBB-TIDAL DELTAS**

An ebb-tidal delta is an accumulation of sand that has been deposited by ebb-tidal currents. Modified by waves and tidal currents, these deltas exhibit a wide variety of forms that respond to energy levels in the region as well as geologic controls (Davis, 1994, 1997). Ebb-tidal deltas in the study area tend to exhibit asymmetric configurations with the swash platform (the broad shallow sand platform located on both sides of the main ebb-channel) deflected downdrift.

Measurement of delta size (area and thickness) shows spatiotemporal variability due to reports at different times by Dean and O’Brien (1987), Finkl (1994), and Powell, Thieke, and Mehta (2006). There are other complicating factors such as years when volume estimates were made and the parametrics applied, which are often complicated in complex deltaic areas where there is more than one discrete delta. The morphometrics applied in this study (Table 1) are based on the 3D terrain model derived from reformatted NOAA bathymetric data.

Four ebb-tidal deltas are defined in this study as the St. Augustine, St. Johns, St. Mary’s, and Tisonia - Nassau Sound. The first three names coincide with previous usage but the last designation refers to the complex delta at the entrance to Nassau Sound by the term Tisonia - Nassau Sound.

**St. Mary’s Ebb-Tidal Delta**

The St. Mary’s ebb-tidal delta (Figure 4a) occurs at the mouth of the St. Mary’s River in Nassau County along the northern most extent of the study area. Occupying an area of about 4163 ha (Table 1), the delta is about 13 km alongshore and extends 5 km seaward. The delta is cut by a major navigation channel that is about 7 km long. The deltaic sands are surmounted by transverse bars up- and downdrift of the inlet. Distal margins of the delta merge with the Farmton Sand Flat.

**St. Johns Ebb-Tidal Delta**

The St. Johns Ebb-Tidal Delta (Figure 4a) occurs at the mouth of the St. John River from about R020 to R050 in Duval County. Occupying area of about 1840 ha (Table 1), the delta stretches alongshore for a distance of about 9 km and extends offshore about 2 km from the updrift margin. Distal margins of the delta merge with the Farmton Sand Flat.

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Figure 4a. Seafloor Mapping Units Along the Northeast Florida Atlantic Coast, showing the spatial distribution of morphosedimentary features on the continental shelf off Nassau, Duval, and St. Johns counties. These morphologic seafloor features are based on subdivision of the seafloor in terms of bathymetric patterns, inferred processes of development, and compositional variation. →

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**St. Augustine Ebb-Tidal Delta**

The St. Augustine Ebb-Tidal Delta (Figure 4a) occurs at the mouth of the Guano Tolomato River and Matanzas River junction in St. Johns County. Occupying an area of about 8600 ha, the delta extends about 25 km alongshore from about R080 to R165. The updrift margin extends about 3 km offshore. Distal margins of the delta merge with the Farmton Sand Flat.

**Tisonia - Nassau Sound Ebb-Tidal Delta**

The Tisonia - Nassau Sound Ebb-Tidal Delta (Figure 4a) occurs at the mouth of Nassau Sound in Nassau and Duval counties. The delta, occupying are area of about 1400 ha (Table 1), stretches about 7.5 km along the shore from R060 in Nassau County to about R010 in Duval County. The delta reaches 2 km offshore at its widest extent. It overlies a small portion of the Farmton Sand Flat and is flanked by bypassing transverse bars on its updrift (northern) margin.

**SAND RIDGES**

Sand ridges are mounds of mostly sandy sediments that have been heaped up by currents to form linear mounds that have positive relief above the surrounding seafloor. These features have been described along continental shelves in numerous locations as prominent morphosedimentary features (*e.g*. Stahl, Koczan and Swift, 1974; Houbolt, 1976; Swift *et al*., 1978; Swift and Field, 1981; Swift, McKinney and Stahl, 1984; Parker, Lanfredi and Swift, 1986; Belderson, 1986; McBride and Moslow, 1991; Snedden, 1994; Dyer and Huntley, 1999; Snedden and Dalrymple, 1999; McBride, 2005). In general, sand ridges tend to be semi-permanent features that migrate slowly over time. These distinctive features have been found in many regions (see previous discussion) and they are no less prominent along the Florida Atlantic shelf, occurring from south of Miami (Meisburger and Duane, 1971; Duane *et al*., 1972; Field, 1974; Field and Duane, 1974; Finkl, Andrews and Benedet, 2007), along the central Florida Canaveral coast (Finkl and Andrews, 2007), to the Georgia State line. It is clear from the shoreward margins of these ridges that predominant southward-flowing currents have channeled seafloor sediments into extended downdrift ridge fingers that are parallel to the shore. Eight discrete sand ridge fields, as defined in this study (Table 1), are recognized as follows: Amelia, Bunnel, Crescent, Duval, Edgewater, Fort Clinch, Espanda, and Korona.

**Amelia Sand Ridge**

The Amelia Sand Ridge (Figure 4a) occurs in the northwestern part of the study area on the inner shelf offshore Nassau and Duval counties. The single large ridge is about 23 km long by 4.5 km wide (Table 1). It is surrounded by the Farmton Sand Flat and lies about 4 km to 6 km from shore. With a general azimuth of about 90 degrees, it is situated nearly parallel to the shore in state and federal waters. The ridge lies in water depths that range from 12 m to 18 m.

**Bunnel Ridge Field**

The Bunnel Ridge Field (Figure 4b), occupying about 8000 ha (Table 1), lies wholly in Flagler County on the seaward margin of the Farmton Sand Flat. It is flanked on it seaward margin by the Flagler Sand Wave. Lying on the Middle Shelf Floor, the ridge field occurs in water depths that range from 16 m to 22 m. The ridge field occurs about 8 km to 10 km offshore.

**Crescent Ridge Field**

The Crescent Ridge Field (Figure 2a), occupying about 9000 ha (Table 1), occurs offshore the southern part of St. Johns County. It is flanked shoreward by the Farmton Sand Flat and seaward by the Summer Haven Sand Wave and Espanda Ridge Field. Lying on the Inner Shelf Floor, the ridge field occurs in water depths that range from 16 m to 20 m. The ridge field occurs about 7 km to 10 km offshore.

**Duval Ridge Field**

The Duval Ridge Field (Figures 4a and 5), occupying about 142,000 ha (Table 1), is a very large mapping unit on the continental shelf that extends offshore from Nassau County, through Duval County, and into central St. Johns County. The unit is flanked on its shoreward margins by the Farmton Sand Flat. It seaward margins merge with the Nassau Bank, Sawgrass Bank, and Undifferentiated Seafloor with Transverse Ridges. This massive ridge field, approximately 20 km long by about 26 km wide, occurs in water depths that range from 12 m to 26 m mostly on the Inner Shelf Floor. Most sand ridges occur in federal waters but parts of some extended downcurrent fingers occur in state waters. As shown in Figure 5, the Duval Ridge Field is a large shore-parallel mapping unit that contains numerous sand ridges. The ridges, interspersed by valleys, form a ridge-and-valley topography that becomes shoaler with distance south. Shoreward margins of the ridge field are dissected into discrete downdrift-trending segments that surmount the Farmton Sand Flat.

**Edgewater Ridge Field**

The Edgewater Ridge Field (Figure 4b), occupying about 16,000 ha (Table 1), occurs offshore southern Volusia County. The ridge field, lying about 6 km to 10 km offshore, is flanked on shoreward margins by the Farmton Sand Flat and on seaward margins by the Volusia Bank. No part of the ridge field occurs in state waters.

**Fort Clinch Ridge Field**

The Fort Clinch Ridge Field (Figure 4a) is a small area of ridge sets that occupy about 6000 ha (Table 1). The ridge field occurs offshore southern Nassau County on inner shelf floor. Lying about 6 km offshore, the ridge field surmounts the Farmton Sand Flat, which surrounds this mapping unit. Ridges in the unit increase in size with distance north, becoming markedly pronounced north of the Florida-George state line.

The unit, which is bifurcated into a larger northern segment and a smaller southern segment is a discontinuous extension of Amelia Sand Ridge to the south, being separated from it by a narrow 1-km wide corridor of Farmton Sand Flat. One large sand ridge on the southwestern margin of the mapping unit extends across the Farmton Sand Flat into the Talbot Transverse Bar field.

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Figure 4b. Seafloor Mapping Units Along the Northeast Florida Atlantic Coast, showing the spatial distribution of morphosedimentary features on the continental shelf off Flagler and Volusia counties. These morphologic seafloor features are based on subdivision of the seafloor in terms of bathymetric patterns, inferred processes of development, and compositional variation. →

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**Espanda Ridge Field**

The Espanda Ridge Field (Figure 4a), occupying about 3400 ha (Table 1), occurs offshore southern St. Johns County and northern Flagler County on Middle Shelf Floor. Lying about 10 km offshore, the ridge field is flanked on its shoreward margins by the Farmton Sand Flat and Crescent Ridge Field. Seward margins merge with the Palm Coast Sand Wave. No part of the ridge field occurs in state waters.

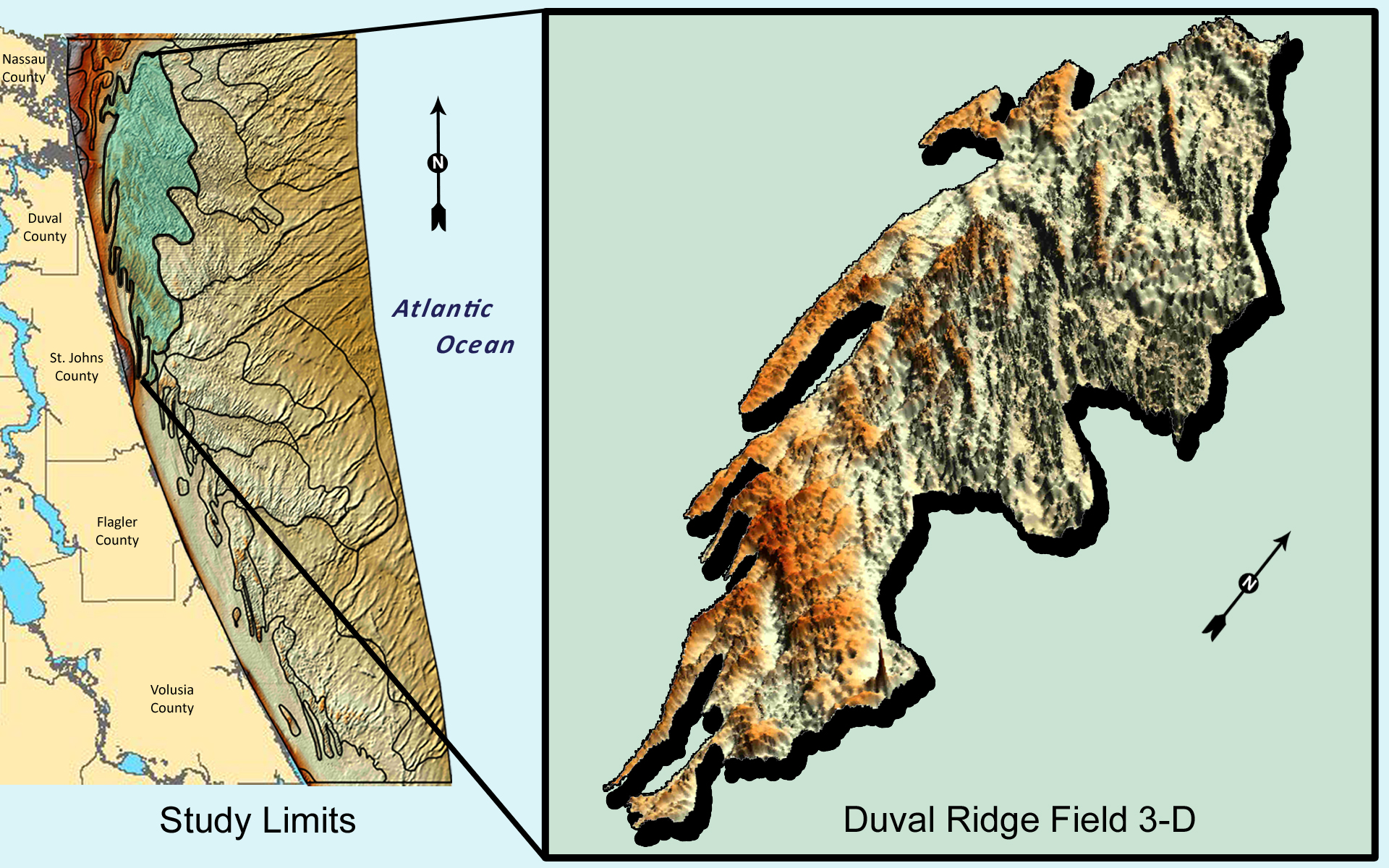


Figure 5. Three-dimensional terrain model (not to scale) of the Duval Ridge Field showing ridge sets making up the field and extended downdrift fingers on he shoreward margin of the field. The sand ridge field is flanked seaward by sand banks and shoreward by the Farmton Sand Flat. There is about 2-5 m of local relief in the ridge field that occupies about 142,000 ha and contains a potential sand volume of about 12 x 109 m3.

**Korona Ridge Field**

The Korona Ridge Field (Figure 4b), occupying about 21,000 ha (Table 1), occurs mostly on the Inner Shelf Floor offshore southern Flagler County and northern Volusia County. The unit is flanked on its seaward margin by the Volusia Bank and shoreward by the Farmton Sand Flat. Lying about 8 km to 12 km offshore, no part of the ridge field occurs in state waters.

**SHOALS**

A shoal is a shallow place in a body of water, more specifically a sandy elevation of the bottom of a body of water, constituting a hazard to navigation; a sandbank or sandbar. The term also includes a stretch of shallow water full of submerged reefs or sandbanks; "reefy shallows"; "shoaly waters" [synonyms: [reefy](http://dict.die.net/reefy/), [shelfy](http://dict.die.net/shelfy/), [shelvy](http://dict.die.net/shelvy/), [shoaly](http://dict.die.net/shoaly/)]. As applied in this study of bottom types and sand resources, the term shoal is used in a loose geomorphological sense to denote an area that lies at a shallower depth than the surrounding isobaths. In some cases, the shoals are comprised by broad singular sand ridges that are more or less equant in shape and isolated from other ridges. Three shoals are recognized in the study area: Allandale, Beverly, and Oak Hill.

**Allandale Shoal**

The Allandale Shoal (Figure 4b), occupying about 675 ha (Table 1), occurs on the Inner Shelf Floor off northern Volusia County in about 16 water depth. This small shoal, an enclave within the Farmton Sand Flat, lies mostly in federal waters but its shoreward extent occurs in state waters. Lying about 4 km offshore, the shoal represents a positive relief features on the otherwise normally topographically subdued surrounding sand flat.

**Beverly Shoal**

The Beverly Shoal (Figure 2b), occupying about 1200 ha (Table 1), occurs on the Inner Shelf Floor off central Flagler County. This small shoal, an enclave within the Farmton Sand Flat, lies mostly in federal waters but its shoreward extent occurs in state waters. Lying about 4 km offshore, the shoal represents a positive relief features on the otherwise normally topographically subdued surrounding sand flat.

**Oak Hill Shoal**

The Oak Hill Shoal (Figures 4a and 4b), occupying about 1800 ha (Table 1), occurs in the Inner Shelf Floor off Volusia County. This small shoal, an enclave within the Farmton Sand Flat, lies mostly in state waters but its seaward extent occurs in federal waters. Lying about 4 km offshore, the shoal represents a positive relief feature on the otherwise normally topographically subdued surrounding sand flat.

**BANKS**

The term ‘bank’ generally refers to extensive sandbanks that are covered by shallow water, but most usage tends to be somewhat vague. Although banks occur throughout all the oceans (*e.g*. Agassiz, 1802; Illing, 1954; Ginsburg and James, 1974; Stride *et al*., 1982), the definition is problematic. Most banks, however, are characterized as platforms that show a very large diversity of morphology and structures, from extremely wide carbonate systems (*e.g*. Great Bahamas Bank), to narrow oceanic reefs, (*e.g.* Les Glorieuses, France, Indian Ocean), and to atolls (*e.g*. Chinchorro Bank). Intuitively, banks should be almost entirely submerged when compared to atolls and other oceanic reefs. Reef formations were frequently named "banks" to refer principally to an area of shallow water. Lack of early clear geomorphological references and different administration likely explain the lack of consistency and homogenization. In any case, in this study, the term bank refers to sediment platforms that lie at relatively or comparatively shallower depths than the surrounding seafloor and which are generally characterized by low local relief and monotonous seafloor surface. Four banks are defined in this study: Nassau, Sawgrass, St. Johns, and Volusia banks.

**Nassau Bank**

The Nassau Bank (Figure 4a), occupying about 55,000 ha (Table 1), occurs on the Middle and Outer Shelf Floors off Nassau and Duval counties. The bank, more or less equant in shape, ranges up to 55 km in length by 15 km in width. Lying about 30 km offshore in water depths that range from 16 m to 30 m, the bank takes up a relatively large area of seafloor that is flanked shoreward by the Duval Ridge Field and seaward by Undifferentiated Seafloor with Anastomosing Ridges. Downdrift extended arms of the southeast-northwest trending bank interdigitate with the northeast-southwest trending Sawgrass Bank. Average water depths on the bank range from 20 m to 28 m.

**O’Neal Bank**

The O’Neal Bank (Figure 4a), occupying about 31,000 ha (Table 1), occurs on the Middle and Outer Shelf Floors off Nassau and Duval counties. The bank, more or less equant in shape, ranges up to 27 km in length by 24 km in width. Lying about 40 km offshore in water depths that range from 18 m to 28 m, the bank takes up a relatively large area of seafloor that is flanked shoreward by the Nassau Bank and seaward by Undifferentiated Seafloor with Anastomosing Ridges. Sand ridges surmount the general level of the rolling bank surface on its northern margin along the Florida - Georgia state line. Bank morphology in this mapping unit differs from that of the adjacent Nassau Bank in that it lacks surface expression of underlying structural control. Average water depths on the bank range from 20 m to 24 m.

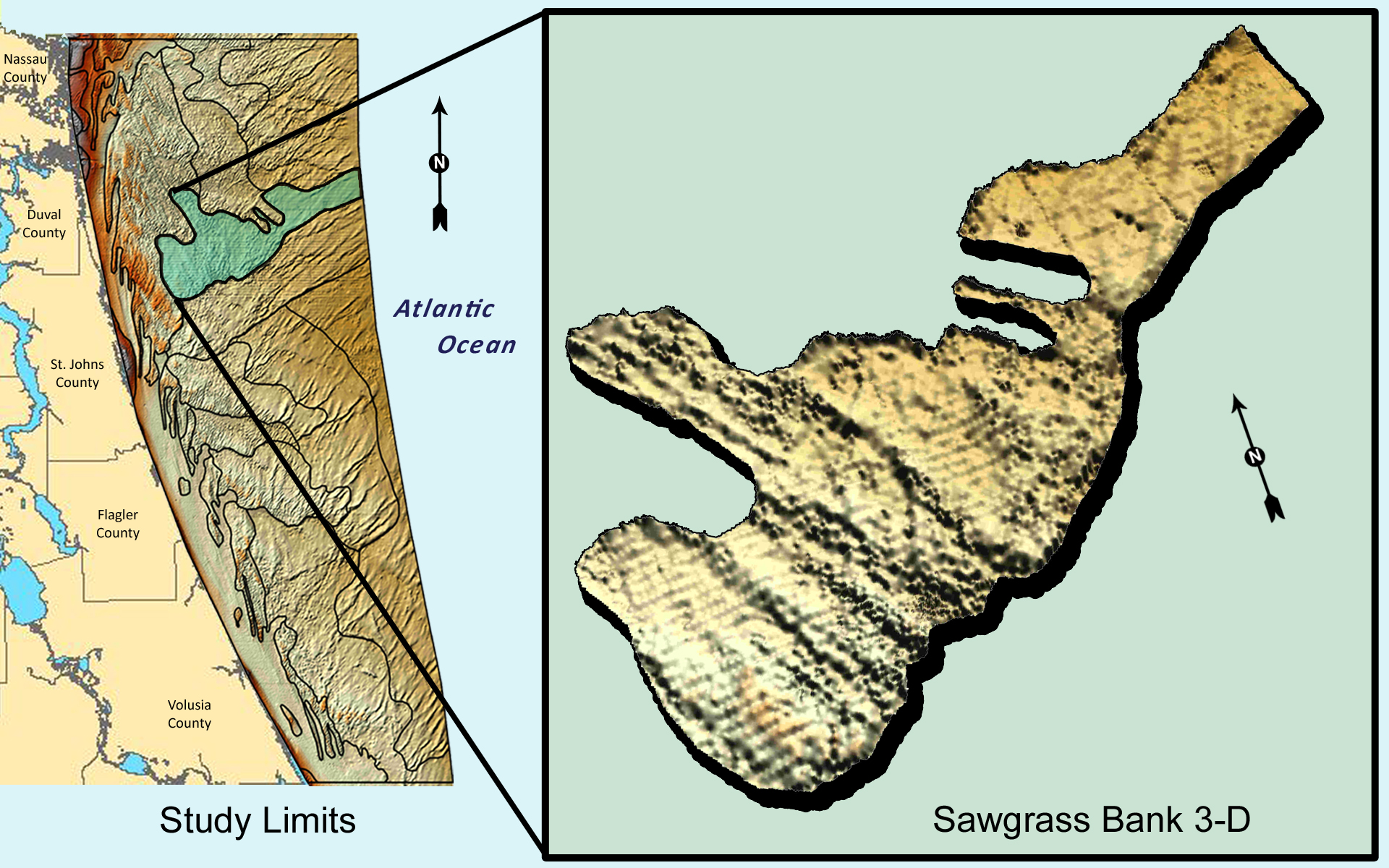


Figure 6. Three-dimensional terrain model (not to scale) of the Sawgrass Bank in the northern part of the study shelf area showing the general topography of the bank surface, including sand ridges that surmount the rolling topography of the seafloor. This large sand bank, which occurs mostly on middle and outer shelf floors, merges shoreward with the Farmton Sand Flat and merges north with the Nassau Bank but it otherwise flanked by undifferentiated seafloor mapping units with sand ridges. There is about 5 m of local relief on the bank that occupies about 87,000 ha and contains a potential sand volume of about 5 x 109 m3. The parallel lines running through the figure are artifacts for the reformatting process.

**Sawgrass Bank**

The Sawgrass Bank (Figure 4a), occupying about 87,000 ha (Table 1), is a northeast-southwest trending bank that extends from the Inner Shelf Floor to the Outer Shelf Floor. At its closest point, the bank is about 17 km offshore, but it extends up to 79 km offshore on its seaward margin. The bank is flanked shoreward by the Duval Ridge Field, to the north by Nassau Bank and Undifferentiated Seafloor with Anastamosing Ridges, and to the south by Undifferentiated Seafloor with Transverse Ridges. Water depths on the bank range from 18 m to 34 m. As depicted in Figure 6, the Sawgrass Bank is an area of extensive sandy bottom with smooth rolling topography that is punctuated by sand ridges that surmount the general level of the bank. Sand ridges are less prominent on the seaward extension of the bank.

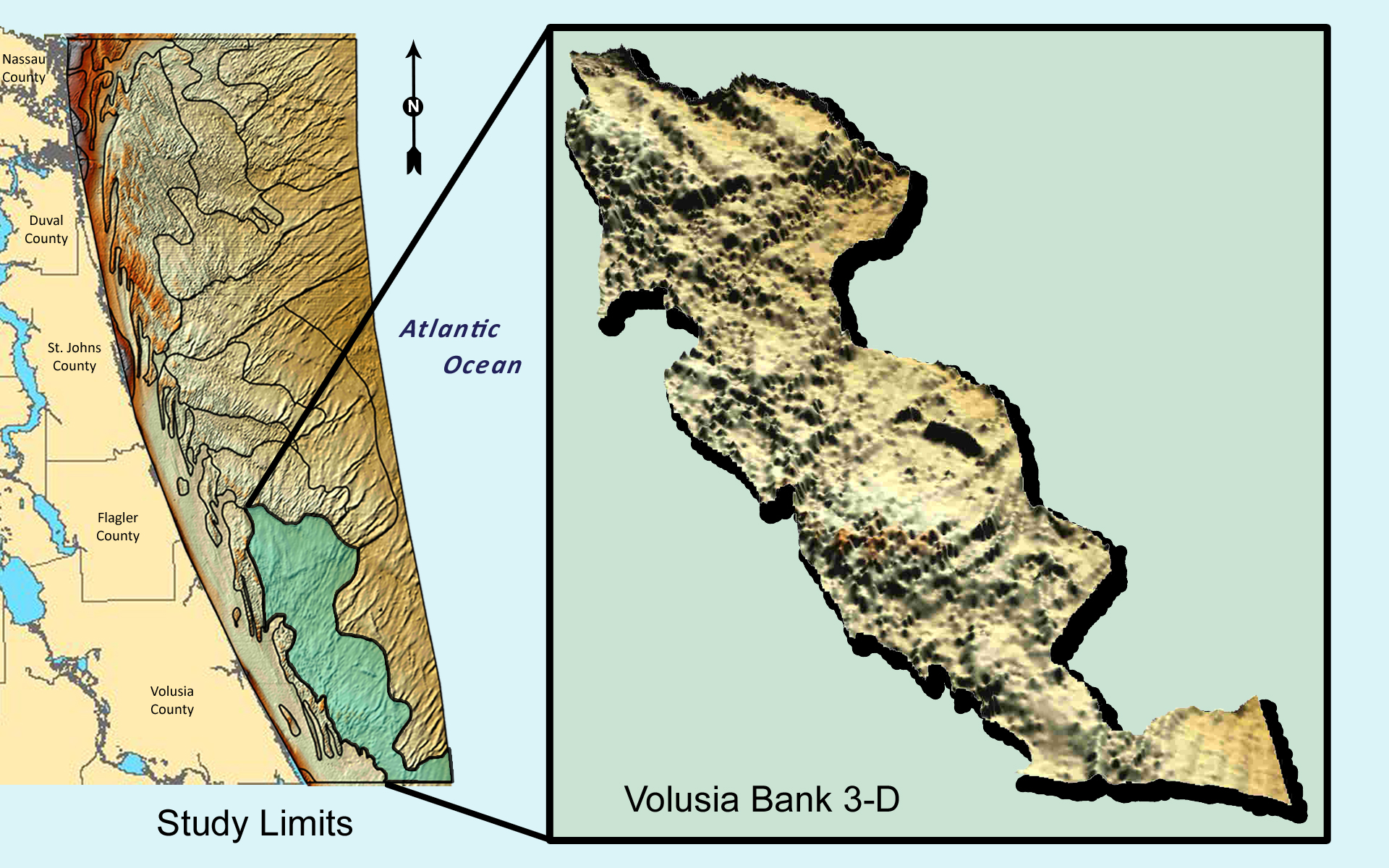


Figure 7. Three-dimensional terrain model (not to scale) of the very large Volusia Bank in the southern shelf study area showing the general topography of the bank surface, including sand ridges that surmount the rolling topography of the seafloor. This large sand bank, which occurs on mostly middle and outer shelf floors, merges shoreward with ridge fields but is otherwise flanked by undifferentiated seafloor mapping units with sand ridges. There is about 2-4 m of local relief on the bank that occupies about 167,000 ha and contains a potential sand volume of about 16 x 109 m3.

**St. Johns Bank**

The St. Johns Bank (Figures 4a and 4b) is a large offshore mapping unit that occupies about 137,000 ha (Table 1). The bank occurs about 30-50 km offshore and is about 20 km wide by 70 km long. On its seaward margin, it merges with Undifferentiated Seafloor with Sand Ridges. To the north is it cut off by Undifferentiated Seafloor with Transverse Ridges and to the south by the Edgewater Ridge Field and Volusia Bank. On its shoreward flanks, the bank merges with the Summer Haven Sand Wave, Palm Coast Sand Wave, and the Flager Sand Wave. Water depths on the bank range from 24 m to 32 m.

**Volusia Bank**

The Volusia Bank (Figure 4b) occupies about 167,000 ha on the Middle and Outer Shelf Floor from southern Flagler County through offshore Volusia County. The bank occurs about 10 km to 14 km offshore and is about 25 km wide by 80 km long. On its seaward margin, it merges with Undifferentiated Seafloor with Sand Ridges. To the north is it cut off by the Flagler Sand Wave. Shoreward, the mapping unit is flanked by the Farmton Sand Flat, except where intervened by the Korona Ridge Field and Edgewater Ridge Field. Water depths on the bank range from 16 m to 32 m. As depicted in Figure 7, the Volusia Bank is a large shore-parallel bank that is surmounted by widely-spaced transverse sand ridges. Shoal areas occur in the southern part of the bank offshore from R200 to R230.

**SAND WAVES**

Sand waves are types of sand structures that are commonly observed on an offshore seabed. From a geological point of view, a submarine sand wave is a large ridge-like primary structure resembling a water wave on the upper surface of a sedimentary bed that is formed by high-velocity air or water currents (*e.g.* Van Veen, 1935; Harvey, 1966; McCave, 1971; Terwindt, 1971; Ludwick, 1972; Caston and Stride, 1973; Boggs, 1974; Bokuniewicz, Gordon and Kastens, 1977; Allen, 1980; Field et al., 1981; Fenster et al., 1990). In a kumatological sense, sand waves were recognized in early research as processially related to the formation of sand banks (Cornish, 1899; 1901a,b) and part of the larger study of waves and wave-structures. Sand waves are in general characterized by downcurrent migration, as described by Hennings *et al*. (2004) for typical occurrences in the North Sea, where they observed complex configuration of different bedforms in four-dimensional in space and time using radar and optical mapping methods. The sand waves occurring offshore the Florida northeast Atlantic coast are mega-sand waves in the sense they form large-scale features that are many kilometers across. A fair impression of the waveform, depicted in the location diagrams (Figures 1a, 1b, and 2) offshore St. Johns and Flagler counties, is emphasized by large volumes of sand being moved southwards by currents. Three large sand waves, representing major submarine geomorphological features, are defined in this study as the Flagler, Palm Coast, and Summer Haven sand waves.

**Flagler Sand Wave**

The Flagler Sand Wave (Figure 4b) contains east-west extending morphosedimentary features that occupies about 57,000 ha. Occurring about 17-42 km offshore, the sand wave is about 36 km wide (E-W extent) by 23 km long (N-S extent). It is bounded seaward by the St. Johns Bank, to the north by the Palm Coast Sand Wave, and to the south by the Edgewater Ridge Field and Korona Ridge Field. Shoreward, the bank is truncated by the Bunnel Ridge Field. Water depths on the sand wave range from 16 m to 26 m.

**Palm Coast Sand Wave**

The Palm Coast Sand Wave (Figures 4a and 4b) is an east-west extending morphosedimentary features that occupies about 25,000 ha. Occurring about 12-16 km offshore, the sand wave is about 29 km wide (E-W extent) by 10 km long (N-S extent). It is bounded seaward by the St. Johns Bank, to the north by the Summer Haven Sand Bank, and to the south by the Flagler Sand Wave. It is bounded shoreward by the Espanda Ridge Field. Water depths on the sand wave range from 18 m to 28 m.

**Summer Haven Sand Wave**

The Summer Haven Sand Wave (Figure 4a) an east-west extending morphosedimentary features that occupies about 56,000 ha. Occurring about 11-15 km offshore, the sand wave is about 46 km wide (E-W extent) by 10-20 km long (N-S extent). It is bounded seaward by the St. Johns Bank, to the north by Undifferentiated Seafloor with Transverse Ridges, and to the south by the Palm Coast Sand Wave. It is bounded shoreward by the Crescent Ridge Field. Water depths on the sand wave range from 16m to 28 m. As shown in Figure 8, the Summer Haven Sand Wave is a shore-perpendicular sand wave with a strongly dissected distal southern margin. This clip of the overall terrain model shows the geographic position of the sand wave on the shelf in relation to surrounding morphological units. Although the bank surface contains some widely spaced sand ridges, its main character can be summarized in terms of a large shoal area along its proximal northern half and eroded southern segment. As with many other morphosedimentary units in the study area, the Summer Haven Sand Wave is surmounted by large sand ridges.

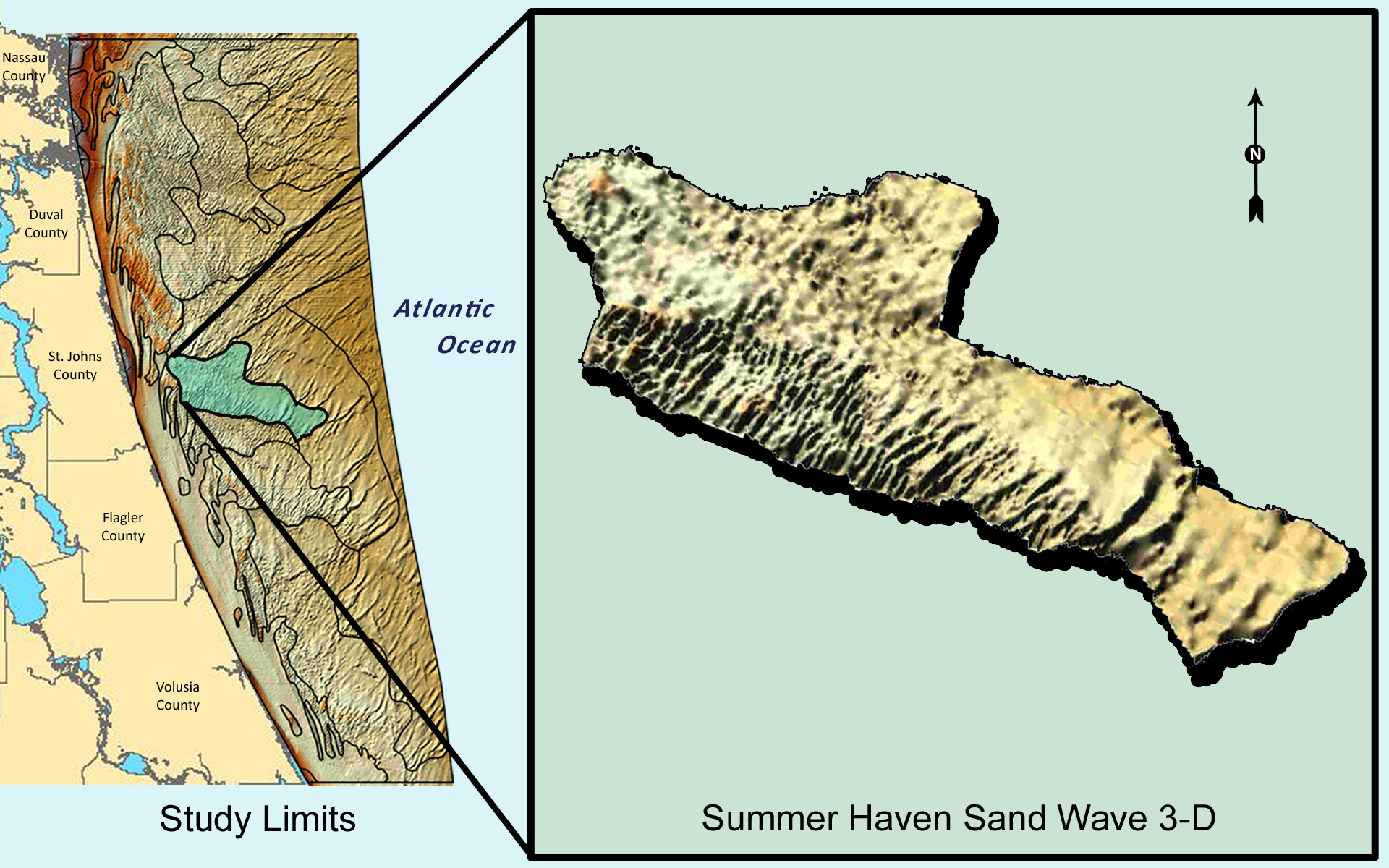


Figure 8. Three-dimensional terrain model (not to scale) of the Summer Haven Sand Wave showing the general topography of the sand wave surface, including isolated sand ridges that surmount the undulating topography of the seafloor. This large sand bank, which occurs in a mid-study area location on inner, middle, and outer shelf positions, is flanked shoreward by the Crescent Ridge Field and merges north with undifferentiated seafloor with transverse sand ridges. The Summer Haven Sand Wave is sharply differentiated from the Palm Coast Sand Wave to the south by its strongly dissected southern margin. There is about 206 m of local relief on the bank that occupies about 56,000 ha and contains a potential sand volume of about 3 x 109 m3.

These large ridges or more or less pervasive throughout the shelf area and do not change the overall character of the recognized mapping unit. In the example seen here, it is clear that most mapping units are complex intergrades that retain vestiges of prior development earlier in the Holocene when sea level was lower and the shoreline was farther seaward. Rising sea levels throughout the Holocene brought changing environmental conditions that modified the surface of the sand wave in the form of more recent sand ridges transgressing relict forms. The sequence of events is shown in Figure 8.

**UNDIFFERENTIATED SEAFLOOR**

Part of the study area could not be adequately depicted in the three-dimensional terrain model. These locations mostly include seaward portions of Zones D and F (Figure 2, Data Reliability Zone Map) where bathymetric data spacing was on the order of 1000 to 1500 feet. Only large-scale features with dimensions on the order of several thousands of feet can be differentiated when analyzing the low spatial resolution data. Unless there was a salient or pronounced bathymetric feature such as a large sediment ridge, broad expanses of seafloor were thus shown as more or less homogenous spatial entities that could not be differentiated on the basis of bathymetric inequalities that could be interpreted in terms of discrete (individual) landforms or landform assemblages.

Sediment ridges in Zones D and F attained sufficient local relief to be distinguished from surrounding seafloor. Local relief was generally in the range 2 to 4 m to show up at nominal mapping scales. Three distinct spatial patterns of sediment ridges occur in these offshore areas: ridges that run transverse to the shore, more or less parallel to the shore, and ridges that divide and re-intersect (anastamosing configuration). Large areas of seafloor are unremarkable, except for the distinct ridge patterns that are so evident in the bathymetric model (*e.g*. Figure 2).

**Undifferentiated Seafloor with Transverse Ridges**

This complex shore-normal deepwater seafloor region (up to 65 km in length, extending in a NE-SW direction) retains ridges that are up to 15 km in length (Figure 4a). The dominant directions of ridge crests range from 45° to 50° azimuth (Table 1). This seafloor zone also contains numerous dissected small bank areas on the shoreward part of the outer shelf floor and on the middle shelf floor. Relatively flat expanses of seafloor (as mapped at this scale) occur between ridges in water depths ranging from 20 m to 28 m. Local relief of the ridges ranges up to 6 m. The mapping unit is bounded along its northern boundary by the Sawgrass Bank and to the south by St. Johns Bank and the Summer Haven Sand Wave.

**Undifferentiated Seafloor with Linear Sand Ridges**

This mapping unit is a complex shore-normal deepwater seafloor region with sediment ridges (Figures 4a and 4b), up to 15 km in length, that show dominant 45° to 50° azimuths (Table 1). Most ridges are rectilinear, but some are slightly curvilinear in planform, especially in the southern part of the unit. The offshore zone, about 15 km wide by about 65 km long, occurs along the seaward margins of the study area from central St. Johns County to southern Volusia County in water depths that range from 24 m to 40 m. Extensive low local-relief seafloor intervenes between ridges. Shoreward margins of the mapping unit merge with the St. Johns Bank and Volusia Bank. To the north, the unit is terminated by transverse ridges on undifferentiated seafloor offshore central St. Johns County.

**Undifferentiated Seafloor with Anastomosing Ridges**

Anastomosing sediment ridges occur in the northeast part of the offshore study area off Nassau and Duval counties (Figure 4a). This mapping unit occupies an offshore area of about 40 km by 43 km and contains sediment ridges that range up to about 15 km in length (Table 1). This complex deepwater seafloor region, which contains numerous ridges that separate and re-unite, also features small bank areas and undifferentiated low-relief topography. The ridges stand about 4 m above the surrounding seafloor. Occurring in deep water ranging from 20 m to 34 m, the mapping unit is flanked along its shoreward margin by the Nassau Bank and on its southern boundary by the Sawgrass Bank. Relatively flat expanses of seafloor (as mapped at this scale) occur between ridges in water depths ranging from 28 m to 32 m. Local relief of the ridges ranges from 2 m up to 6 m.

**MORPHOMETRIC PROPERTIES OF SEAFLOOR MAPPING UNITS AND**

**SAND RESOURCE POTENTIALS IN NASSAU COUNTY**

The continental shelf survey area in Nassau County, the northernmost county on the northeast Florida Atlantic coast, occupies approximately 177,279 ha and extends from the Georgia State line southwards to Duval County. Shoreline length is about 50 km, but the survey area extends about 85 km offshore. The largest mapping units in the Nassau County offshore area include all of the O’Neal Bank (about 29,000 ha), most of the Duval Ridge Field (about 23,000 ha), northernmost segment of the Farmton Sand Flat (about 21,000 ha), and the bulk of the Nassau Bank (about 16,000 ha) (Table 2). Smaller units include the Amelia Sand Ridge, Fort Clinch Ridge Field, St. Mary’s Ebb-Tidal Delta, Talbot Transverse Bar, and the Tisonia - Nassau Sound Ebb-Tidal Delta.

Potential sand resources in the mapped area of the continental shelf off Nassau County amount to something on the order of 6 x 109 m3 (6,229,352,628 m3) of sediment. This sediment volume estimate is based on the thickness of morphosedimentary units such as banks, sand flats, sand ridges, deltas, and transverse bars. Parameters used in the calculations of volume estimates are summarized in Table 2 where the range in meters from the height plane is shown for each mapping unit. The percent of area used in the volume calculations is based on a visual estimate of areal coverage in plan view. The largest sediment volume is associated with the O’Neal Bank (2.2 x 109 m3), followed by the Farmton Sand Flat (1.3 x 109 m3) and Duval Ridge Field (8.85 x 106 m3) (Table 2, Figure 9a). The O’Neal Bank takes up about 16% of the shelf area whereas the Farmton Sand Flat occupies about 12% and the Duval Ridge Field about 13%. Although taking up only 2% of the shelf area, the Amelia Sand Ridge is an obvious single sediment source. Even though undifferentiated seafloor mapping units, which make up 40% of the shelf area off Nassau County, are not included in calculations of potential sand resources, they should not be ignored because sand ridges occur in these large offshore areas.

**Amelia Sand Ridge**

The northern segment of the Amelia Sand Ridge morphosedimentary unit, as defined here, lies in federal waters offshore Nassau County in water depths ranging from 12 m to 14 m. Lying about 7 km offshore, the unit occurs as an enclave within the Farmton Sand Flat. Although the planform of the ridge field runs parallel to the shore, individual ridges making up the field tend to strike normal to the shore at an angle of about 15° along the primary axis of the field. A small ridge set making up the hook on the northern margin of the ridge field, about 11 km offshore, lies at about a 60° angle from horizontal. This smaller ridge set, comprised by two main ridges, is about 3 km in length. A topographically subdued extension of this smaller ridge set connects with the southern margin of the Fort Clinch Ridge Field to the north. The ridge field occurs in water depths that range from 12 m to 14 m.

Table 2.*Sand resource potential in Nassau County by morphosedimentary units where volume calculations are based on percent areal coverage in the mapping unit, which may be less**than unity in**ridge fields, banks, and ebb-tidal deltas.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Morpho-sedimentary Features** | **Shelf Area (ha)1** | **% of County Continental Shelf Area2** | **Height of Plane (m)** | **Elevation Range**3  **(Max to Min Depth)**  **(m)** | **% Area Used in Volume Calculations4** | **Sediment Volume**  **(m3)** |
| Amelia Sand Ridge | 3,128 | 2 | -16.46 | -16.46 to -9.10 | 75 | 72,044,360 |
| Duval Ridge Field | 22,765 | 13 | -25.20 | -25.2 to -12.80 | 60 | 885,420,661 |
| Farmton Sand  Flat A | 2 | 0<1 | -17.91 | -17.91 to -15.25 | 100 | 44,045 |
| Farmton Sand  Flat B | 59 | 0<1 | -15.88 | -15.88 to -14.80 | 50 | 95,817 |
| Farmton Sand  Flat C | 20,814 | 12 | -21.90 | -21.9 to 0.10 | 90 | 1,267,646,990 |
| Fort Clinch Ridge Field A | 5,999 | 3 | -16.80 | -16.8 to -7.90 | 85 | 176,541,502 |
| Fort Clinch Ridge Field B | 71 | 0<1 | -16.87 | -16.87 to -13.60 | 75 | 827,182 |
| Nassau Bank | 15,733 | 9 | -26.93 | -26.93 to -15.60 | 85 | 819,865,998 |
| O’Neal Bank | 29,162 | 16 | -30.00 | -30.00 to -14.40 | 90 | 2,228,086,362 |
| St Mary’s Ebb-tidal Delta | 4,163 | 2 | -19.60 | -19.60 to 0.90 | 100 | 598,661,552 |
| Talbot Transverse Bar | 4,886 | 3 | -13.62 | -13.62 to 0.10 | 80 | 177,024,179 |
| Tisonia-Nassau Sound Ebb-Tidal Delta | 139 | 0<1 | -5.20 | -5.2 to -0.24 | 80 | 3,093,981 |
| **Total** | **106,921** | **60** |  |  |  | **6,229,352,628** |

1 For conversion of hectares (ha) to square kilometers (100 ha = 1 km2), move decimal point two digits to the left.

2 Refers to continental shelf area offshore from county lines for ease of reference. State waters lie shoreward of the

3-mile and federal waters are seaward.

3 Based on measurement of local relief from the reformatted NOAA bathymetry. These measurements are limited by

the grid scale of the NOAA bathymetric data. Sediment volume was calculated from a TIN data structure

using the maximum and minimum elevations within the mapping unit.

4 Some mapping units embrace larger areas than sand ridges *per se*, for example, to simplify mapping. Areas thus

designated as ridge fields contains sand ridges plus intervening swales and sand plain units.

Potential sand resources in the Amelia Sand Ridge are estimated to range on the order of 72 x 106 m3 (72,044,360 m3) (Table 2, Figure 9a). Calculations of sediment volume were based on an estimated 75% ridge coverage in the mapping unit where ridges averaged about <1 km in width. Thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-16.46 m) and shallowest isobath (-9.10 m) for the unit (Table 2). Variations in thickness throughout the mapping unit were as a basis for volume estimates.

**Duval Ridge Field**

The northernmost extension of the Duval Ridge Field (Figure 4a), as defined here, occurs mainly on the inner shelf in federal waters off Nassau County. The ridge field occupies about 22,765 ha (13% of the shelf area) and is flanked along its seaward boundary by the Nassau Bank and shoreward by the Farmton Sand Flat. The ridge field is about 20 km long and extends up to 30 km offshore. Individual ridges trend 290° azimuth, are 3 km in width by up to 10 km long, and display wavelengths of about 1 km to 2 km. Local relief ranges from 2 to 4 m in water depths ranging from 16 m to 24 m. The ridge and valley topography of the mapping unit seems to be structurally controlled by fractures in underlying bedrock sequences. These planes of weakness along faults and fractures appear to be propagated upwards through the surficial sedimentary cover that makes up the seafloor deposits. The ridge field occurs in water depths that range from 16 m to 24 m.

Potential sand resources in the Duval Ridge Field are estimated to range on the order of 885 x 106 m3 (885,420,661 m3) (Table 2, Figure 9a). Calculations were based on an estimated 60% ridge coverage (13,659 ha) in the mapping unit with a maximum thickness of about 12 m. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-25.2 m) and shallowest isobath (-12.8 m) for the unit (Table 2). Variations in thickness throughout the mapping unit, as shown in Figure 5, were used as a basis for volume estimates.

**Farmton Sand Flat**

The northern extension of the Farmton Sand Flat (Figure 4a), originally defined by Finkl and Andrews (2007) on the central Florida Atlantic coast, extends along the shoreface and shoreward portions of the inner continental shelf floor (Figure 3). The Farmton Sand Flat occupies about 20,875 ha in Nassau County. At its furthest seaward extent, the sand flat lies about 25 km offshore Nassau County. The sand flat is dissection alongshore by the St. Marys Ebb-Tidal Delta and Talbot Transverse Bar field. Offshore, this morphosedimentary unit is flanked by the Duval Ridge Field. The sand sheet shows about 2 m of local relief and occurs in water depths that range from 12 m to 16 m.

Potential sand resources in the Farmton Sand Flat are estimated to be on the order of 1.3 x 106 m3 (1,267,786,852 m3) (Table 2, Figure 9a). This calculation was based on 100% of the ‘A’ mapping unit being comprised by sand flats but with 50% of the ‘B’ mapping unit and 90% of the ‘C’ containing sand flats. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-21.9 m) and shallowest isobath (-0.1 m) for the unit (Table 2). Variations in thickness throughout the mapping units (A, B, and C) form a basis for volume estimates.

**Fort Clinch Ridge Field**

The Fort Clinch Ridge Field (Figure 4a) occurs as an enclave within the Farmton Sand Flat on the northern margin of Nassau County (6070 ha, 3% of shelf area). Lying about 6 km offshore at its closest point to the shore, the ridge field extends up to 16 km offshore. The ridge field, about 8 km wide by 8 km long, contains two ridge fields that are separated by a medial valley about 1 km wide. The smaller ridge set is about 2 km wide by about 5.5 km in length. Ridge crests in the smaller shoreward ridge set average about 50° azimuth where those in the larger seaward set average about 60° to 65° azimuth. The seaward ridges show a wavelength of about 200 m to 500 m with individual ridges ranging between 100 m and 400 m in width. Shoreward ridges in the southwestern part of the mapping unit tend to be somewhat wider with 300 m to 450 m widths, but with lower local relief (2 m compared to 4 m in the seaward extended ridge sets). The ridge field occurs in water depths that range from 10 m to 16 m.

Potential sand resources in the Fort Clinch Field are estimated to range on the order of 177 x 106 m3 (177,368,684 m3; 176,541,502 m3 in mapping unit ‘A’ and 827,182 m3 in mapping unit ‘B’) (Table 2, Figure 9a). Calculations were based on an estimated 75% and 85% ridge coverage in the ‘A’ (5,999 ha) and ‘B’ (71 ha) mapping units, respectively. Sediment thickness in the ‘A’ mapping unit was calculated from differences in elevation computed between the depth of the deepest isobath (-16.8 m) and shallowest isobath (-7.90 m) (Table 2). The same calculations were made for the ‘B’ mapping unit using the depth range -16.87 to -13.60 m. Variations in thickness throughout the mapping were used as a basis for volume estimates.

**Nassau Bank**

The northern extension of the Nassau Bank (Figure 4a) lies offshore Nassau County (9% of the shelf area), about 25 km from shore at its closest point just south of the Georgia border. The bank, about 8 km wide by 15 km long, is flanked seaward by the O’Neal Bank and shoreward by the Duval Ridge Field. The bank contain a topographically subdued medial ridge field that is about 8 km long; individual ridges range from 20° to 60° azimuth with local relief averaging about 2 m. Ridges in the northeastern part of the bank, taking in about 2 km2, and each about 1 km in width and about 3 km in length, exhibit average local relief of about 2 m. The bank occurs in water depths that range from 16 m to 24 m.

Potential sand resources in the Nassau Bank are estimated to range on the order of 819 x 106 m3 (819,865,998 m3) (Table 2, Figure 9a). Calculations of sediment volume were based on an estimated 85% bank coverage in the mapping unit where valleys between bank ridges averaged were excluded. Thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-26.93 m) and shallowest isobath (-15.60 m) for the unit (Table 2). Variations in thickness throughout the mapping unit were used as a basis for these volume estimates.

**O’Neal Bank**

The southern extension of the O’Neal Bank (Figure 4a) from across the state line in Georgia, occupies about 29,162 ha offshore Nassau County (16% of the shelf area). The bank, about 28 km long by 20 km wide, lies about 30 km offshore and is strongly dissected along the Florida-Georgia border and southwards into the central part of the bank. The bank is flanked seaward by undifferentiated seafloor with anastomosing ridges and shoreward by the Nassau Bank. Sand ridges surmounting the general level of the bank strike about 50° to 55° azimuth. These ridges, which average about 200 to 400 m in width, range up to 3 km in length.

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Figure 9a. Potential Sand Resources Along the Northeast Florida Atlantic Coast, showing the spatial distribution of morphosedimentary features on the continental shelf off Nassau, Duval, and St. Johns counties. Sediment volumes are shown as choropleths by morphosedimentary unit by county. Extensions of morphosedimentary features in different offshore county areas my thus show different sediment volume ranges. The morphosedimentary volume units are shown as transparent colors so that seafloor topography (*e.g*. bars, ridges, ebb-tidal deltas) is visible. Undifferentiated seafloor is not included in the sediment volume calculations. →

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Local relief on the dissection northern margin of the bank averages about 4 m whereas on the southern margin it is about 6 m. The bank occurs in water depths that range from 18 m to 28 m.

Potential sand resources in the O’Neal Bank are estimated on the order of 2 x 109 m3 (2,228,086,362 m3) (Table 2, Figure 9a). Calculations of sediment volume were based on an estimated 90% bank coverage in the mapping unit where valleys between bank ridges along dissected margins were excluded. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-30.00 m) and shallowest isobath (-14.40 m) for the unit (Table 2). Variations in thickness throughout the mapping unit were used as a basis for these volume estimates.

**St. Mary’s Ebb-Tidal Delta**

The southern or downdrift part of the St. Marys Ebb-Tidal Delta mapping unit occurs in Nassau County (Figure 4a). Occupying about 4163 ha (2% of the offshore area, Table 2), the delta extends up to 5.5 km offshore where bypassing bars migrate around the inlet. The delta extends 8.6 km downcoast from the Florida-Georgia border and maintains a relatively constant width of about 3 km, terminating in about 10 m water depth where the delta overlies the Farmton Sand Flat. Small transverse bars occur alongshore.

Potential sand resources in the St. Marys Ebb-Tidal Delta are estimated to range on the order of 598 x 106 m3 (598,661,552 m3) (Table 2, Figure 9a). Calculations of sediment volume were based on an estimated 100% delta coverage in the mapping unit. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-19.60 m) and shallowest isobath (-0.90 m) for the unit (Table 2). Variations in thickness throughout the mapping unit were used as a basis for these volume estimates. Variation in ebb-tidal delta volume is illustrated by Powell *et al*. (2006) who report 2.5 x 108 m3, the difference probably being related to assumptions of sand thickness versus the computerized method employed in our calculations.

**Talbot Transverse Bar**

The Talbot Transverse Bar field (Figure 4a) occurs downdrift of the St. Mary’s Ebb-Tidal Delta and updrift from the Tisonia - Nassau Sound Ebb-Tidal Delta. The bar field, occupying about 4886 ha (3% of the shelf area) along 16 km of shore, extends up to 5 km offshore onto the Farmton Sand Flat. Some of the longer bars extend up to 2 or 3 km in length, striking along 55° to 80° azimuths. Individual bar widths range between 200 and 500 m. Although wavelengths are about 400 m, there are large sand flat areas (up to 1 km2) interspersed between bar sets.

Potential sand resources in the Talbot Transverse Bar field are estimated on the order of 177 x 106 m3 (177,024,179 m3) (Table 2, Figure 9a). Calculations of sediment volume were based on an estimated 80% ridge set coverage in the mapping unit. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-13.62 m) and shallowest isobath (-0.10 m) for the unit (Table 2). Variations in thickness throughout the mapping unit were used as a basis for these volume estimates.

**Tisonia - Nassau Sound Ebb-Tidal Delta**

The northernmost extension of the Tisonia - Nassau Sound Ebb-Tidal Delta (Figure 4a) occurs in the nearshore zone of southern Nassau County. This small updrift segment of the delta (139 ha, Table 2) extends about 1 km offshore and is about 2 km long. Some transverse bars, up to 500 m in length, from the Talbot Transverse Bar field extend onto deltaic sands and into the mouth of the estuary. The delta merges seaward with the Talbot Transverse Bar system and extends into the main ebb-tidal sand sequence southward in Duval County. The delta occurs in water depths of about 0-8 m.

Potential sand resources in the Tisonia - Nassau Sound Ebb-Tidal Delta are estimated on the order of 3 x 106 m3 (3,093,981 m3) (Table 2, Figure 9a). Calculations of sediment volume were based on an estimated 80% delta coverage in the mapping unit. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-5.2 m) and shallowest isobath (-0.24 m) for the unit (Table 2). Variations in thickness throughout the mapping unit were used as a basis for these volume estimates. Variation in ebb-tidal delta volume is illustrated by Powell *et al*. (2006) who report 4.1 x 107 m3, the difference probably being related to assumptions of sand thickness versus the computerized method employed in our calculations.

**MORPHOMETRIC PROPERTIES OF SEAFLOOR MAPPING UNITS AND**

**SAND RESOURCE POTENTIALS IN DUVAL COUNTY**

The survey area in Duval County occupies approximately 233,677 ha and extends from the Nassau County line to the St. Johns County line, an along-coast distance of about 29.5 km. Extending 80 km offshore, the shelf area is quite diverse being comprised by nearshore bar fields, sand flats, ridge fields, banks, and ebb-tidal deltas.

The main morphological features on the continental shelf include the following mapping units (Figure 4a), from the shore seaward: the Tisonia - Nassau Sound Ebb-Tidal Delta, St. Johns Ebb-Tidal Delta, Farmton Sand Flat, Amelia Sand Ridge, Duval Ridge Field, Nassau Bank, and undifferentiated seafloor with anastamosing ridges. A small portion of the Sawgrass Bank occurs on the Duval – St. Johns county line.

Potential sand resources in the mapped area of the continental shelf in Duval County (166,102 ha) amount to something on the order of 13.5 x 109 m3 (13,539,702,214 m3) of sediment (Table 3). This sediment volume estimate is based on assumptions for average thickness of morphosedimentary units such as bars, ebb-tidal deltas, sand flats, ridge fields, and banks. Parameters used in calculations of volume estimates are summarized in Table 3. The Duval Ridge Field has the largest sediment volume, but the Amelia Sand Ridge Field may offer greater ease of dredging access as the deposits lie closer to shore in state waters. The sand resource potential of each mapping unit is discussed in relation to geographic occurrence, spatial distribution patterns, and morphosedimentary properties, as summarized in Figure 9a and Tables 1 and 3.

Table 3. *Sand resource potential in Duval County by morphosedimentary units where volume calculations are based on percent areal coverage in the mapping unit, which is less than unity for bars and ridge fields.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Morpho-sedimentary Features** | **Shelf Area (ha)1** | **% of County Continental Shelf Area2** | **Height of Plane (m)** | **Elevation Range3**  **(Max to Min Depth)**  **(m)** | **% Area Used in Volume Calculations4** | **Sediment Volume**  **(m3)** |
| Amelia Sand Ridge | 1,039 | 0<1 | -14.94 | -14.94 to -10.30 | 75 | 14,503,233 |
| Duval Ridge Field A | 65,666 | 28 | -30.90 | -30.90 to -9.90 | 80 | 6,310,497,260 |
| Duval Ridge Field B | 34 | 0<1 | -16.06 | -16.06 to -13.77 | 95 | 482,412 |
| Duval Ridge Field C | 200 | 0<1 | -16.00 | -16.00 to -14.10 | 70 | 1,050,680 |
| Farmton Sand Flat A | 1,876 | 1 | -20.10 | -20.10 to -14.80 | 100 | 57,901,147 |
| Farmton Sand Flat B | 16,558 | 7 | -25.10 | -25.10 to -0.43 | 100 | 1,906,134,113 |
| Nassau Bank | 46,321 | 20 | -32.20 | -32.20 to-17.80 | 95 | 3,382,559,254 |
| O'neal Bank | 1,876 | 1 | -29.08 | -29.08 to -20.39 | 60 | 65,099,683 |
| Sawgrass Bank A | 425 | 0<1 | -30.70 | -30.70 to -25.83 | 40 | 3,310,420 |
| Sawgrass Bank B | 6,171 | 3 | -29.80 | -29.80 to -19.40 | 75 | 267,634,629 |
| Sawgrass Bank C | 21,730 | 9 | -37.10 | -37.10 to -12.40 | 100 | 1,184,980,647 |
| St. Johns Ebb-tidal Delta | 1,840 | 1 | -23.90 | -23.90 to 0.30 | 65 | 223,953,578 |
| Talbot Transverse Bar | 1,089 | 0<1 | -14.23 | -14.23 to -2.90 | 50 | 27,558,352 |
| Tisonia – Nassau Sound Ebb-Tidal Delta Complex | 1,275 | 1 | -10.70 | -10.70 to 0.90 | 85 | 94,036,806 |
| **Total** | **166,102** | **71** |  |  |  | 13,539,702,214 |

1 For conversion of hectares (ha) to square kilometers (100 ha = 1 km2), move decimal point two digits to the left.

2 Refers to continental shelf area offshore from county lines for ease of reference. State waters lie shoreward of the

3-mile and federal waters are seaward.

3 Based on measurement of local relief from the reformatted NOAA bathymetry. These measurements are limited by

the grid scale of the NOAA bathymetric data. Sediment volume was calculated from a TIN data structure

using the maximum and minimum elevations within the mapping unit.

4 Some mapping units embrace larger areas than sand ridges *per se*, for example, to simplify mapping. Areas thus

designated as ridge fields contains sand ridges plus intervening swales and sand plain units.

**Amelia Sand Ridge**

The southern segment of the Amelia Sand Ridge morphosedimentary unit (Figure 4a), as defined here, lies mostly in state waters offshore Duval County in water depths ranging from 12 m to 14 m. Lying about 4 km offshore, the 10-km long unit occurs as an enclave within the Farmton Sand Flat. Although the planform of the ridge field runs parallel to the shore, individual ridges making up the field tend to strike normal to the shore at an angle of about 15° along the primary axis of the field. The ridge field occurs in water depths that range from 12 m to 14 m.

Potential sand resources in the Amelia Sand Ridge are estimated to range on the order of 14 x 106 m3 (14,503,233 m3) (Table 3, Figure 9a). Calculations were based on an estimated 75% ridge coverage (1039 ha) in the mapping unit with a maximum thickness of about 5.5 m. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-14.94 m) and shallowest isobath (-10.30 m) for the unit (Table 3). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Duval Ridge Field**

The northern extension of the Duval Ridge Field (Figure 4a), as defined here, occurs mainly on the inner shelf in federal waters off Nassau County but extends onto the middle shelf near is seaward margin. The ridge field occupies about 65,900 ha (28% of the shelf area) and is flanked along its seaward boundary by the Nassau Bank and shoreward by the Farmton Sand Flat. Because the ridge field is dissected by offshore extension of county boundaries, the unit is divided into three segments (Table 3): (A) bulk of the unit (65,666 ha), (B) a small sliver on the Nassau-Duval county line, and (C) a small part of the ridge field recurving southward into Duval County from Nassau County. The main ridge field segment is about 28 km long by 20 km wide and extends up to 30 km offshore. Individual ridges trend 290 degrees azimuth, are 3 km in width by up to 15 km long, and display wavelengths of about 1 to 2 km. Local relief ranges from 2 to 4 m in water depths ranging from 14 m to 24 m. The ridge and valley topography of the mapping unit seems to be structurally controlled by fractures in underlying bedrock sequences. These planes of weakness along faults and fractures appear to be propagated upwards through the surficial sedimentary cover that makes up the seafloor deposits. The ridge field occurs in water depths that range from 14 m to 24 m.

Potential sand resources in the Duval Ridge Field segments (A, B, and C) are estimated to range on the order of 6.3 x 109 m3 (6,312,030,352 m3) (Table 3, Figure 9a). Calculations were based on an estimated 80%, 95%, and 70% ridge coverages (65,900 ha) in A, B, and C segments, respectively, with a maximum thickness of about 20 m occurring in segment A. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-30.90 m) and shallowest isobath (-9.90 m) for the unit, but varied by spatial unit (Segments A, B, and C in Table 3). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Farmton Sand Flat**

The northern extension of the Farmton Sand Flat (Figure 4a), originally defined by Finkl and Andrews (2007) on the central Florida Atlantic coast, extends along the shoreface and shoreward portions of the inner continental shelf floor (Figure 3) in Duval County. The Farmton Sand Flat occupies about 18,434 ha in Duval County. At its furthest seaward extent, the sand flat lies about 12 km offshore. The sand flat is overlapped alongshore by the Tisonia - Nassau Sound and St. Johns ebb-tidal deltas and Talbot Transverse Bar field. Offshore, this morphosedimentary unit is flanked by the Duval Ridge Field. The sand sheet shows about 8 m of local relief and occurs in water depths that range from 8 m to 16 m.

Potential sand resources in the Farmton Sand Flat are estimated to be on the order of 1.96 x 109 m3 (1,964,035,260 m3) (Table 3, Figure 9a). This calculation was based on 100% of the ‘A’ and ‘B’ mapping units being comprised by sand flats. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-25.1 m) and shallowest isobath (-0.43 m) for the unit (Table 3). Variations in thickness throughout the mapping units (A and B) were used as a basis for volume estimates.

**Nassau Bank**

The bulk of the Nassau Bank, defined here, occurs in Duval County (Figure 4a). Lying about 30 km offshore, the bank is 28 km long by 14 wide. It is flanked seaward by undifferentiated seafloor with anastamosing ridges, to the south by the Sawgrass Bank and shoreward by the Duval Ridge Field. Occupying about 20% (46,321 ha) of the offshore area, the mapping unit makes up a significant block of landform assemblages. Most of the unit contains low-relief seafloor units, except in area “A” of the data reliability map (Figure 4a) where more detailed bathymetry was acquired along the approachway to the St. Johns River system. The detailed bathymetry here shows dissected seafloor units with about 4 m of local relief whereas bathymetric variance on the northern and southern margins of the bank average about 2 m.

Potential sand resources in the Nassau Bank are estimated to range on the order of 3 x 109 m3 (3,382,559,254 m3) (Table 3, Figure 9a). Calculations of sediment volume were based on an estimated 95% bank coverage in the mapping unit where valleys between bank ridges along dissected margins were excluded. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-32.20 m) and shallowest isobath (-17.80 m) for the unit (Table 3). Variations in thickness throughout the mapping unit were used as a basis for these volume estimates.

**O’Neal Bank**

A small segment of the southernmost extension of the O’Neal Bank, as defined here, (Figure 4a) extends across the northern offshore border of Duval County. This segment, occupying about 1876 ha (1% of offshore county shelf area), lies about 45 km offshore from the mouth of the St. Johns River estuary. The bank contains a few small sand ridges between 1 and 3 km in length and ranging from 300 m to 600 m in width. The bank is flanked shoreward by the Nassau Bank and seaward by undifferentiated seafloor with anastamosing ridges. The bank occurs in water depths that range from 18 m to 28 m.

Potential sand resources in the O’Neal Bank are estimated to range on the order of 65 x 106 m3 (65,099,683 m3) (Table 3, Figure 9a). Calculations of sediment volume were based on an estimated 60% bank coverage in the mapping unit where valleys between bank ridges along dissected margins were excluded. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-20.39 m) and shallowest isobath (-29.08 m) for the unit (Table 3). Variations in thickness throughout the mapping unit were used as a basis for these volume estimates.

**Sawgrass Bank**

Extensions of the Sawgrass Bank (Figure 4a), as defined here, occur along the southern offshore boundary of Duval County about 25 km (Segment B), 48 km (Segment A), and 56 km (Segment C) (Table 3) from shore. These segments of the bank, all lying on the outer shelf floor, respectively occupy 425 ha, 6171 ha, and 21,730 ha of the shelf. These units are bounded seaward by the Nassau Bank and shoreward by the Duval Ridge Field. Topographic relief of the bank stands in marked contrast to the structurally controlled ridges of the Duval Ridge Field and sedimentary plateaus of the Nassau Bank. Prominent sand ridges are associated with Segment A whereas segments B and C generally lack ridges. Local relief in all three segments averages about 3 m. The bank occurs in water depths that range from 22 m to 36 m.

Potential sand resources in the Sawgrass Bank are estimated on the order of 1.2 x 109 m3 (1,184,980,647 m3) in Segment C, about 2.67 x 106 m3 (267,634,629 m3) in Segment B and 3.3 x 106 m3 (3,310,420 m3) in Segment A (Table 3, Figure 3). Calculations of sediment volume were based on an estimated 40% bank coverage in Segment A, 75% bank coverage in Segment B, and 100% bank coverage in Segment C. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-37.10 m) in Segment C and shallowest isobath (-19.4 m) in Segment B (Table 3). Variations in thickness throughout the mapping units, as shown in Figure 6, were used as a basis for these volume estimates.

**St. Johns Ebb-Tidal Delta**

The St. Johns Ebb-Tidal Delta, occurring on the shoreface, lies wholly in Duval County and its physical description, therefore, matches that given previously (see page 20).

Occupying about 1840 ha (1% of the shelf area), the delta sediment volume amounts to something on the order of 2.23 x 106 m3 (223,953,578 m3) (Table 3, Figure 9a). Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-23.90 m) and shallowest isobath (-0.30 m) (Table 3). Variations in thickness throughout the mapping units were used as a basis for these volume estimates. Powell *et al*. (2006) combined the St. John and Ft. George ebb-tidal deltas to get an estimated volume of about 1.3 x 108 m3. The larger volume obtained by Powell *et al.* (2006), compared to that derived in this report, may be due to perceived differences in sediment thickness.

**Talbot Transverse Bar**

The southern extension of the Talbot Transverse Bar field (Figure 4a), as defined here, occurs on the northwestern boundary of the shelf area on the shoreface. Here, the bar field is about 4.8 km in length by about 2.6 km in width at it widest point. The bar field, superposed on top of the Farmton Sand Flat, merges shoreward with the Tisonia - Nassau Sound Ebb-Tidal Delta. Bars nearly 3 km long lie at a high angle to the coast (75° to 80° azimuth) but bend shoreward near the outer boundary of the delta to merge with shore-normal bars on the delta platform.

Potential sand resources in the Talbot Transverse Bar field are estimated on the order of 27 x 106 m3 (27,558,352 m3) (Table 3, Figure 9a). Calculations of sediment volume were based on an estimated 50% bar coverage in the mapping unit. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-14.23 m) and shallowest isobath (-2.90 m) for the unit (Table 3). Variations in thickness throughout the mapping unit were used as a basis for these volume estimates.

**Tisonia - Nassau Sound Ebb-Tidal Delta**

Most of the Tisonia - Nassau Sound Ebb-Tidal Delta (Figure 4a), as defined here, occurs in the Duval County shelf area. The delta extends alongshore for about 6 km and extends offshore for a distance of about 2.5 km. The delta is built out over the Farmton Sand Flat on the shoreface and merges seaward with the Talbot Transverse Bar field. Occurring in about 6 m water depth, local relief averages about 4 m.

Occupying an area of about 1275 ha (1% of the shelf area), the delta is estimated to contain about 94 x 106 m3 (94,036,806 m3) of sand (Table 3, Figure 9a). Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-10.70 m) and shallowest isobath (-0.9 m) for the unit (Table 3). Variations in thickness throughout the mapping unit were used as a basis for these volume estimates. Powell *et al*. (2006) estimate volume at 4.1 x 107 m3.

**MORPHOMETRIC PROPERTIES OF SEAFLOOR MAPPING UNITS AND**

**SAND RESOURCE POTENTIALS IN ST. JOHNS COUNTY**

The survey area in St. Johns County, the largest offshore county shelf area from Brevard County to the Georgia state line, occupies approximately 484,542 ha and extends from the Duval County line to the Flagler County line, an along-coast distance of about 67 km. Extending 75 km offshore, the shelf area is quite diverse being comprised by sand flats, ridge fields, banks, sand waves, and ebb-tidal deltas. These seafloor features account for about 69% of the total shelf area (Table 4), the remained being taken up by undifferentiated seafloor with transverse ridges.

The main morphological seafloor features on the continental shelf include the following mapping units (Figure 2a), from the shore seaward: the St. Augustine Ebb-Tidal Delta, St. Johns Ebb-Tidal Delta, Farmton Sand Flat, Duval Ridge Field, Espanda Ridge Field, Sawgrass Bank, Summerhaven Sand Wave, St. Johns Bank, and undifferentiated seafloor with transverse ridges. A small portion of the Nassau Bank occurs on the Duval – St. Johns county line.

Potential sand resources in the mapped area of the continental shelf in St. Johns County (332,253 ha) amount to something on the order of 28.1 x 109 m3 (28,074,693,160 m3) of sediment (Table 4). This estimate of sediment volume is based on assumptions for average thickness of morphosedimentary units such as ebb-tidal deltas, sand flats, ridge fields, sand waves, and banks. Parameters used in calculations of volume estimates are summarized in Table 4. The Farmton Sand Flat has the largest potential sediment volume, followed by the Duval Ridge Field, Palm Coast Sand Wave, Sawgrass Bank, St. Johns Bank, and the Summer Haven Sand Wave. The sand resource potential of each mapping unit is discussed in relation to geographic occurrence, spatial distribution patterns, and morphosedimentary properties, as summarized in Figures 4a and 9a and Table 4.

Table 4. *Sand resource potential in St. Johns County by morphosedimentary units where volume calculations are based on percent areal coverage in the mapping unit, which is less than unity for bars and ridge fields.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Morphosedimentary Features** | **Shelf Area (ha)1** | **% of County Continental Shelf Area2** | **Height of Plane (m)** | **Elevation Range3**  **(Max to Min Depth)**  **(m)** | **% Area Used in Volume Calculations4** | **Sediment Volume**  **(m3)** |
| Cresent Ridge Field | 9,268 | 2 | -21.90 | -21.90 to -13.00 | 80 | 272,961,435 |
| Duval Ridge Field A | 586 | 0<1 | -16.05 | -16.05 to -12.70 | 90 | 10,081,184 |
| Duval Ridge Field B | 52,545 | 11 | -25.10 | -25.10 to -1.50 | 85 | 3,737,889,865 |
| Espanda Ridge Field | 2,109 | 0<1 | -21.90 | -21.90 to -15.60 | 75 | 48,492,776 |
| Farmton Sand Flat | 44,424 | 9 | -42.80 | -42.80 to -1.27 | 100 | 11,008,406,697 |
| Flagler Sand Wave | 82 | 0<1 | -28.80 | -28.80 to -25.43 | 60 | 664,062 |
| Nassau Bank A | 856 | 0<1 | -30.40 | -30.40 to -24.70 | 85 | 27,358,142 |
| Nassau Bank B | 1,707 | 0<1 | -30.50 | -30.50 to -22.70 | 65 | 43,202,847 |
| Palm Coast Sand Wave | 19,656 | 4 | -30.60 | -30.60 to -15.50 | 90 | 1,356,261,482 |
| Sawgrass Bank | 58,653 | 12 | -32.00 | -32.00 to -15.20 | 75 | 3,703,423,583 |
| St Augustine Eeb-tidal Delta | 7,680 | 2 | -15.76 | -15.76 to 0.60 | 70 | 278,911,261 |
| St Johns Bank | 83,966 | 17 | -38.37 | -38.37 to -18.50 | 65 | 4,443,225,825 |
| Summer Haven Sand Wave | 55,722 | 11 | -30.58 | -30.58 to -14.80 | 70 | 3,143,814,001 |
| **Total** | **332,253** | **69** |  |  |  | 28,074,693,160 |

1 For conversion of hectares (ha) to square kilometers (100 ha = 1 km2), move decimal point two digits to the left.

2 Refers to continental shelf area offshore from county lines for ease of reference. State waters lie shoreward of the

3-mile and federal waters are seaward.

3 Based on measurement of local relief from the reformatted NOAA bathymetry. These measurements are limited by

the grid scale of the NOAA bathymetric data. Sediment volume was calculated from a TIN data structure

using the maximum and minimum elevations within the mapping unit.

4 Some mapping units embrace larger areas than sand ridges *per se*, for example, to simplify mapping. Areas thus

designated as ridge fields contains sand ridges plus intervening swales and sand plain units.

**Crescent Ridge Field**

Occupying about 9268 ha (2% of the mapped shelf area), the Cresent Ridge Field (Figure 4a), as defined here, occurs on the inner shelf floor in the southwestern part of the offshore shelf area. Shoreward the ridge field overlaps the Farmton Sand Flat mapping unit and is flanked on its seaward margin by the Summer Haven Sand Wave and Palm Coast Sand Wave. The ridge field is about 5 km wide at its widest extent in the north where it merges with the Summer Haven Sand Wave. About 6 km south of its northern apex, the ridge field trifurcates into three southward extending fingers, the longest set of which is about 14 km in length. The sand ridges sets average about 0.5 to 1 km in width and the extended fingers respectively range up to 11, 14 and 15 km in length in the shoreward, middle, and seaward arms. Occurring 7 to 10 km offshore, the ridges trend along 90° to 100° azimuths. Greatest local relief (about 4 m) occurs at the northern end of the middle extended ridge set. The ridges occur in water depths that range from 16 m to 20 m.

Potential sand resources in the Crescent Ridge Field are estimated to range on the order of 272 x 106 m3 (272,961,435 m3) (Table 4, Figure 9a). Calculations were based on an estimated 80% ridge coverage with a maximum thickness of about 9 m. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-21.90 m) and shallowest isobath (-13.0 m) for the unit. Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Duval Ridge Field**

The Duval Ridge Field (Figure 4a), as defined here, extends through the central part of the inner shelf floor from Duval County to the south-central part of the continental shelf off St. Johns County. Due to shoreward downdrift extending fingers of the ridge field, a small section of the shoreward-most finger (Segment A) extends from Duval County into St. Johns County. The main body of the ridge field is denoted as Segment B for computational purposes when calculating areas and potential sediment volumes. Taking in the larger area, Segment B occupies about 52,545 ha (11% of the county continental shelf area) (Table 4). The much smaller Segment A occupies about 586 ha.

The ridge field shoreward overlaps the Farmton Sand Flat and is bordered on its seaward margins by the Sawgrass Bank and undifferentiated seafloor with transverse ridges. Some of the downdrift extending fingers show subdued continuation of low-relief ridges onto the Farmton Sand Flat, for example, the shoreward-most sediment tail being 20 km in length and merging with the St. Augustine Ebb-Tidal Delta. Structural control of the ridge field is evident in the northern part of the shelf area but becomes less clear with distance south. Local relief (about 2-4 m) is most pronounced where the ridge field begins to fragment into downdrift fingers along a 32-km long diagonal extending from Segment A to a point about 16 km offshore. The ridges occur in water depths that range from 12 m to 24 m.

Potential sand resources in the Duval Ridge Field are estimated to range on the order of 3.7 x 109 m3 (3,737,889,865 m3) in Segment B and about 10 x 106 m3 (10,081,184 m3) in Segment A (Table 4, Figure 9a). Calculations were based on an estimated 90% ridge coverage in Segment A with a maximum thickness of about 3.4 m and an estimated 85% ridge coverage in Segment B with a maximum thickness range of about 24 m. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-25.10 m) and shallowest isobath (-1.50 m) for both units combined. Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Espanda Ridge Field**

The northern extension of the Espanda Ridge Field, as defined here, occurs along the border with Flagler County about 10 km offshore from R190. The ridge field extends northwards about 10 km on the middle shelf floor into the southern part of the offshore St. Johns County continental shelf. The ridge field is flanked on its shoreward margin by the Crescent Ridge Field and on its seaward margin by the Palm Coast Sand Wave. The ridge field terminates northward on the dissected southern boundary of the Summer Haven Sand Wave. Individual ridges average about 0.5 km to 1 km in width and range up to 2 km in length, trending on azimuths of about 15° to 20° (Table 1). The ridges occur in water depths that range from 18 m to 20 m.

Potential sand resources in the Espanda Ridge Field are estimated to range on the order of 48 x 106 m3 (48,492,776 m3) (Table 4, Figure 9a). Calculations were based on an estimated 75% ridge coverage with a maximum thickness range of about 6.3 m. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-21.90 m) and shallowest isobath (-15.60 m) for both units combined. Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Farmton Sand Flat**

The Farmton Sand Flat (Figure 4a), as defined by Finkl and Andrews (2006), occurs all along the inner shelf floor in St. Johns County, a distance of about 65 km. The sand flats are flanked on seaward margins by the Duval and Crescent ridge fields. These sand flats extend up to 12 km offshore but are partly surmounted by sand ridges that come within 2 km of shore. This shoreface attached sand sheet displays a generally subdued relief that is only broken by low sand ridges extending downdrift from shoreward-aligning fingers of the Duval Ridge Field. The sand sheet is also overlain by the St. Augustine Ebb-Tidal Delta from R080 to R170. The sand flats occur in water depths that range from 2 m to 20 m.

Potential sand resources in the Farmton Sand Flat are estimated to be on the order of 11 x 109 m3 (11,008,406,697 m3) (Table 4, Figure 9a). This calculation was based on 100% of the mapping unit being comprised by sand flats as including subdued sand ridge extensions from the Duval Ridge Field. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-42.80 m) and shallowest isobath (-1.27 m) for the unit (Table 4). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Flagler Sand Wave**

A small sliver of the Flagler Sand Wave (an area of about 82 ha) (Figure 4a), occurs on the border with Flagler County about 36 km offshore from R200. This small unit is flanked to the north by the dissected margin of the Palm Coast Sand Wave. Sand accumulating on the northern margin of the Flager Sand wave present a strikingly smooth seafloor compared to the dissection that occurs on the southern downdrift margins of the updrift sand wave. The sand wave occurs in water depths that range from 26 m to 28 m.

Potential sand resources in the Flagler Sand Wave are estimated to be on the order of 6.64 x 105 m3 (664,062 m3) (Table 4, Figure 9a). This calculation was based on 60% of the mapping unit being comprised by sand wave units. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-28.80 m) and shallowest isobath (-25.43 m) for the unit (Table 4). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Nassau Bank**

Two small southern-most extensions of the Nassau Bank (Figure 4a), as defined here, occur on the shelf offshore St. Johns County. Segments A and B respectively lie about 46 km and 51 km offshore R070. These southern extensions of the Nassau Bank protrude into the mapping unit identified as Undifferentiated Seafloor with Transverse Ridges. Segment A takes in 856 ha and Segment B occupies 1707 ha. The southwestern flanks of the banks are marginally dissected. Local relief on these segments averages about 3 m. The sand bank occurs in water depths that range from 24 m to 30 m.

Potential sand resources in these small extensions of the Nassau Bank are estimated to be on the order of 27 x 106 m3 (27,358,142 m3) in Segment A and about 43 x 106 m3 (43,202,847 m3) in Segment B (Table 4, Figure 9a). This calculation was based on 85% of Segment A being comprised by sand wave units and 65% of Segment B containing sand wave units. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-30.50 m) and shallowest isobath (-22.70 m) between both units (Table 4). Variations in thickness throughout the mapping unit were used as a basis for volume estimates. The sand bank occurs in water depths that range from 24 m to 30 m.

**Palm Coast Sand Wave**

Comprising 19,656 ha (4% of the shelf area), the bulk of the Palm Coast Sand Wave (Figure 4a), as defined here, occurs in St. Johns County. The sand wave occurs mostly on the middle shelf floor but extends 45 km seaward onto the outer shelf floor. The northern flank of the sand wave is bordered by the dissected southern downdrift margin of the Summer Haven Sand Wave, which also wraps around the seaward end of the sand wave. The Espanda Ridge Field marks the dissected shoreward margin. The southern downdrift margin of the sand bank is characterized by a 2-km to 5-km wide dissected zone with numerous ridges. Local relief in the dissected zone is about x m compared to about x m on the surface of the bank. The sand wave occurs in water depths that range from 24 m to 34 m.

Potential sand resources in the Palm Coast Wave are estimated to be on the order of 1.4 x 109 m3 (1,356,261,482 m3) (Table 4, Figure 9a). This calculation was based on 90% of the mapping unit being comprised by sand wave units. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-30.60 m) and shallowest isobath (-15.50 m) for a maximum sediment thickness range of 15 m in the unit (Table 4). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Sawgrass Bank**

The large segment (58,653 ha, 12% of the shelf area) of the Sawgrass Bank (Figure 4a) occurring in St. Johns County lies along the northern border with Duval County. Here, the bank lies about 16 km offshore on the middle shelf floor but extends seaward onto the outer shelf floor. The bank is flanked on its shoreward margin by the Duval Ridge Field and seaward by undifferentiated seafloor with transverse ridges. Local relief on the bank averages about 5 m (Table 1), except along the southern dissected margin that lies about 30 km from shore. Some sand ridges surmount the bank surface, especially on the middle shelf floor on shoreward margins of the outer shelf floor. The sand bank occurs in water depths that range from 16 m to 28 m.

Potential sand resources in the Sawgrass Bank are estimated to be on the order of 3.7 x 109 m3 (3,703,423,583 m3) (Table 4, Figure 9a). This calculation was based on 75% of the mapping unit being comprised by sand wave units, except along dissected margins. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-32.00 m) and shallowest isobath (-15.20 m) for a maximum sediment thickness range of 16.8 m in the unit (Table 4). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**St. Augustine Ebb-Tidal Delta**

The St. Augustine Ebb-Tidal Delta (Figure 4a) occurs mostly on the shoreface but its distal surface surmounts the inner shelf floor. Sediment is contributed to the delta from sand ridges that extend southwards from depositional fingers of the Duval Ridge Field. Some of these sand ridges originate about 20 km to the north, eventually merging with the delta with feeder sand. One large sand ridge lies about 800 m offshore the deltafront. Local relief averages about 10 m on the delta swash platform. The sand bank occurs in water depths that range from 0 m to 10 m.

Potential sand resources in the St. Augustine Ebb-Tidal Delta are estimated to be on the order of 278 x 106 m3 (278,911,261 m3) (Table 4, Figure 9a). This calculation was based on 70% of the mapping unit being comprised by deltaic sand units. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-15.76 m) and shallowest isobath (-0.60 m) for a maximum sediment thickness range of about 15 m in the unit (Table 4). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**St. Johns Bank**

The St. Johns Bank (Figure 4a) is a large sand bank that occupies about 83,966 ha (about 17% of the county continental shelf area) (Table 4) about 35 km offshore on the outer shelf floor. This sand bank extends about 65 km offshore in the central and southern parts of the survey area. It merges seaward with undifferentiated seafloor with sand ridges and is bounded shoreward by the Summer Haven and Palm Coast sand waves. Some areas of hummocky terrain occur near the central part of the sand bank about 40 offshore from R150 to R170. Some large sand ridges surmount the general level of the bank and extend in a general northeast-southwest direction (40° to 55° azimuth) for about 10 to 12 km. Local relief on the bank surface average about 4 m, except in the vicinity of sand ridges. The sand bank occurs in water depths that range from 24 m to 34 m.

Potential sand resources in the St. Johns Bank are estimated to be on the order of 4.4 x 109 m3 (4,443,225,825 m3) (Table 4, Figure 9a). This calculation was based on 65% of the mapping unit being comprised by sand wave units, except along dissected margins. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-38.37 m) and shallowest isobath (-18.50 m) for a maximum sediment thickness range of 19.9 m in the unit, valley to ridge crest (Table 4). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Summer Haven Sand Wave**

The Summer Haven Sand Wave (Figure 4a) occupies about 55,722 ha (11% of the county continental shelf area) (Table 4) and lies about 12 km offshore on the middle shelf floor. The mapping unit extends another 40 km seaward to where it imperceptibly merges with the St. Johns Bank on the outer shelf floor. The sand wave is bounded to the north by the St. Johns Bank and undifferentiated seafloor with transverse ridges. The shoreward margin on the inner shelf floor breaks down into the Crescent Ridge Field, which represents degradation of the sand wave into large downdrift ridge segments. The southern 2-4 km wide dissected margin of the sand wave terminates at the updrift margin of the Palm Coast Sand Wave. Some large sand ridges, 2-5 km long (60°-75° azimuth) (Table 1), surmount the general level of the sand wave surface. The sand wave occurs in water depths that range from 16 m to 28 m.

Potential sand resources in the Summer Haven Sand Wave are estimated to be on the order of 3 x 109 m3 (3,143,814,001 m3) (Table 4, Figure 9a). This calculation was based on 70% of the mapping unit being comprised by sand wave units, except along dissected margins. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-30.58 m) and shallowest isobath (-14.80 m) for a maximum sediment thickness range of 15.8 m in the unit (Table 4), valley in dissected margin to ridge crest on top of sand wave surface. Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**MORPHOMETRIC PROPERTIES OF SEAFLOOR MAPPING UNITS AND**

**SAND RESOURCE POTENTIALS IN FLAGLER COUNTY**

The survey area in Flagler County, the second smallest offshore county shelf area (185,321 ha) after Nassau County, extends from St. Johns County to Volusia County for an along-coast distance of about 28 km. Extending about 70 km offshore, the shelf area is quite diverse being comprised by sand flats, ridge fields, sand waves, and banks. These seafloor features account for about 94% of the total mapped shelf area (Table 5), the small remainder being taken up by undifferentiated seafloor with transverse ridges.

The main morphological seafloor features on the continental shelf include the following mapping units (Figure 4b), from the shore seaward: the Farmton Sand Flat, Beverly Shoal, Bunnel Ridge Field, Korona Ridge Field, Espanda Ridge Field, Flagler Sand Wave, and the St. Johns Bank. Mapping units taking up the most area include the Flagler Sand Wave, St. Johns Bank, and Farmton Sand Flat.

Potential sand resources in the mapped area of the continental shelf in Flagler County (174,911 ha) amount to 9.53 x 109 m3 (9,003,473,109 m3) of sediment. This sediment volume estimate is based on assumptions for average thickness of morphosedimentary units such as, sand flats, ridge fields, sand waves, shoals, and banks. Parameters used in calculations of volume estimates are summarized in Table 5. The Flagler Sand Wave has the largest potential sediment volume, followed by the St. Johns Sand Bank and the Farmton Sand Flat. The sand resource potential of each mapping unit is discussed in relation to geographic occurrence, spatial distribution patterns, and morphosedimentary properties, as summarized in Figure 9b and Table 5.

Table 5. *Sand resource potential in Flagler County by morphosedimentary units where volume calculations are based on percent areal coverage in the mapping unit, which is less than unity for bars and ridge fields.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Morphosedimentary Features** | **Shelf Area (ha)1** | **% of County Continental Shelf Area2** | **Height of Plane (m)** | **Elevation Range**  **(Max to Min Depth)**  **(m)** | **% Area Used in Volume Calculations3** | **Sediment Volume**  **(m3)** |
| Beverly Shoal | 1,248 | 1 | -19.60 | -19.60 to -15.07 | 85 | 20,805,031 |
| Bunnel Ridge Field | 7,858 | 4 | -23.30 | -23.30 to -13.50 | 45 | 120,438,990 |
| Espanda Ridge Field | 1,325 | 1 | -21.31 | -21.31 to -15.80 | 95 | 31,579,280 |
| Farmton Sand Flat A | 4,163 | 2 | -24.07 | -24.07 to -16.30 | 100 | 104,760,654 |
| Farmton Sand Flat B | 28,764 | 16 | -22.90 | -22.90 to -2.62 | 100 | 1,339,104,804 |
| Flagler Sand Wave | 57,210 | 31 | -30.04 | -30.04 to -13.40 | 95 | 4,629,812,289 |
| Korona Ridge Field | 6,381 | 3 | -24.70 | -24.70 to -16.52 | 80 | 217,017,988 |
| Palm Coast Sand Wave A | 477 | 0<1 | -30.40 | -30.40 to -25.83 | 75 | 8,623,525 |
| Palm Coast Sand Wave B | 5,305 | 3 | -27.57 | -27.57 to -15.10 | 95 | 393,105,653 |
| St Johns Bank | 50,006 | 27 | -34.00 | -34.00 to -17.60 | 50 | 1,680,485,857 |
| Volusia Bank | 12,172 | 7 | -31.60 | -31.60 to -19.25 | 65 | 457,739,038 |
| **Total** | **174,911** | **94** |  |  |  | **9,003,473,109** |

1 For conversion of hectares (ha) to square kilometers (100 ha = 1 km2), move decimal point two digits to the left.

2 Refers to continental shelf area offshore from county lines for ease of reference. State waters lie shoreward of the

3-mile and federal waters are seaward.

3 Based on measurement of local relief from the reformatted NOAA bathymetry. These measurements are limited by

the grid scale of the NOAA bathymetric data. Sediment volume was calculated from a TIN data structure

using the maximum and minimum elevations within the mapping unit.

4 Some mapping units embrace larger areas than sand ridges *per se*, for example, to simplify mapping. Areas thus

designated as ridge fields contains sand ridges plus intervening swales and sand plain units.

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Figure 9b. Potential Sand Resources Along the Northeast Florida Atlantic Coast, showing the spatial distribution of morphosedimentary features on the continental shelf off Flagler and Volusia counties. Sediment volumes are shown as choropleths by morphosedimentary unit by county. Extensions of morphosedimentary features in different offshore county areas my thus show different sediment volume ranges. The morphosedimentary volume units are shown as transparent colors so that seafloor topography (*e.g*. bars, ridges, ebb-tidal deltas) is visible. Undifferentiated seafloor is not included in the sediment volume calculations. →

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**Beverly Shoal**

Lying about 4.5 km offshore R040, the Beverly Shoal (Figure 4b) occurs as an enclave within the Farmton Sand Flat. The shoal is about 2.8 km wide by 4.5 km long, taking in about 1248 ha (1% of the county continental shelf area) (Table 5). It contains the distal margins of subdued shoals (350° azimuths) extending downdrift (southwards) from the Crescent Ridge Field, about 11 km updrift (northwards). Smaller subdued ridge extensions from the Espanda Ridge Field mark the seaward flank of the shoal.

Potential sand resources in the Beverly Shoal are estimated to be on the order of 20 x 106 m3 (20,805,031 m3) (Table 5, Figure 9b). This calculation was based on 85% of the mapping unit being comprised by sand ridge units that make up the shoal area. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-19.60 m) and shallowest isobath (-15.07 m) for a maximum sediment thickness range of 4.5 m in the unit (Table 5). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Bunnel Ridge Field**

The Bunnel Ridge Field (Figure 4b) encompasses about 7858 ha (4% of county continental shelf area) (Table 5). The shoreward margins of the Bunnel Ridge Filed lie about 10 km offshore R020 to R100. The ridge field, lying on the middle shelf floor, is about 25 km long by 5 km wide at it widest point offshore R030. The seaward margin of the main ridge field is flanked by the Flagler Sand Wave whereas the downdrift southern extended fingers are surrounded by Farmton Sand Flats. Surmounting the Farmton Sand Flat, the ridge field extends southwards into Volusia County. Individual ridges range from 1 to 5 km in width and strike about 90° to 100° azimuths. Ridges in downdrift-extending fingers of the main ridge field are narrower (300 m to 800 m) and shorter (3 km to 6 km). The ridges occur in water depths that range from 16 m to 22 m.

Potential sand resources in the Bunnel Ridge Field (Figure 4b) are estimated to range on the order of 120 x 106 m3 (120,438,990 m3) (Table 5, Figure 9b). Calculations were based on an estimated 45% ridge coverage (the remainder of the mapping unit being dissected ridge margins and slopes to sand flats) with a maximum thickness range of about 10.8 m. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-23.30 m) and shallowest isobath (-13.50 m) (Table 5). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Espanda Ridge Field**

The southern part of the Espanda Ridge Field (Figure 4b), lying about 10 km offshore on the middle shelf floor, extends about 9.5 km into Flagler County from St. Johns County. This southern extension of the ridge field (1325 ha, 1% of the county continental shelf area) (Table 5), which is about 3 km wide along the southern border of St. John County and which narrows to less than 1 km in width at its distal point, is surrounded by Farmton Sand Flats. Individual ridges that make up the ridge field average about 100 to 500 m in width, are about 2 km long, and lie on 15° to 20° azimuths (Table 1). Subdued ridges extend downdrift from the ridge field onto the Farmton Sand Flat.

Potential sand resources in the Espanda Ridge Field are estimated to range on the order of 31 x 106 m3 (31,579,280 m3) (Table 5, Figure 9b). Calculations were based on an estimated 95% ridge coverage with a maximum thickness range of about 5.5 m. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-21.31 m) and shallowest isobath (-15.80 m) (Table 5). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Farmton Sand Flat**

The Farmton Sand Flat (Figure 4b) is a shoreface-connected sand sheet that generally extends about 10 km offshore on the inner shelf floor and shoreward part of the middle shelf floor, but extensio sand ridges may extend up to 20 km offshore. For computational purposes, the sand flats have been divided into two segments, A and B. Segment A lies seaward, being cut off from the main body of sand flats by the Bunnel Ridge Field. Segment A, the smaller of the two parts, takes in about 4163 ha (2% of the county continental shelf area) (Table 5). Segment B, the larger of the two parts, lies alongshore and takes in about 28,764 ha (16% of the county continental shelf area) (Table 5). These extensive sand sheets show low local relief (about 2-4 m) and occur in water depths of about 2 m to 22 m.

Potential sand resources in the Farmton Sand Flat are estimated to be on the order of 100 x 106 m3 (104,760,654 m3) in Segment A and about 1.4 x 109 m3 (1,339,104,804 m3) in Segment B (Table 5, Figure 9b). This calculation was based on 100% of the ‘A’ and ‘B’ mapping units being comprised by sand flats. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-24.07 m) (Segment B) and shallowest isobath (-2.62 m) (Segment A) for both units (Table 5). Variations in thickness throughout the mapping units (A and B) were used as a basis for volume estimates.

**Flagler Sand Wave**

The Flagler Sand Wave (Figure 4b) lies wholly in Flagler County, except for a small sliver in St. Johns County. The mapping unit takes in 57,210 ha (31% of the county continental shelf area) (Table 5). The unit is the southernmost sand wave in the Summer Haven – Palm Coast – Flagler sand-wave triumvirate. The Bunnel Ridge Field represents the dissected shoreward margin of the sand wave where sediments are transported downdrift in long fingers. The mapping unit is bounded seaward by the St. Johns Bank. The Volusia Bank occurs to the south where the dissected southern margin of the Flagler Sand Wave dissipates into a smoothly flowing bathymetry. Lying 16 km to 50 km offshore, this large shore-normal sand wave is about 36 km wide in east-west extent by about 23 km long in a north-south extent, with long 5-15 km ridges (85° azimuth) superimposed (Table 1). The northern undissected zones range up to 12 km in north-south extent before breaking up into the 5-km wide southern dissected zone.

Potential sand resources in the Flagler Sand Wave are estimated to be on the order of 4.6 x 109 m3 (4,629,812,289 m3) (Table 5, Figure 9b). This calculation was based on 95% of the mapping unit being comprised by northern sand wave surface and ridge units, as occur along the southern dissected margin. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-30.04 m) and shallowest isobath (-13.40 m) for a maximum sediment thickness range of 16.6 m in the unit, valley in dissected margin to ridge crest on top of sand wave surface (Table 5). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Korona Ridge Field**

The northern extension of the Korona Ridge Field (Figure 4b), lying about 13 km offshore on the inner and middle shelf floor, extends about 9.5 km into Flagler County from Volusia County. This northern extension of the ridge field (6381 ha, 3% of the county continental shelf area) (Table 5), which is about 6.5 km wide along the northern border of Volusia County, is flanked shoreward by the Farmton Sand Flat. The seaward margin of the ridge field is flanked by the Volusia Bank. Individual ridges making the ridge field average about 200 to 500 m wide by 1 km to 4 km long along 30° to 40° azimuths (Table 1). Compared to the southern part of the Korona Ridge Field in Volusia County, the northern extension show weaker ridge development and stronger expression of broad merged ridges.

Potential sand resources in the Korona Ridge Field are estimated to range on the order of 271 x 106 m3 (271,017,988 m3) (Table 5, Figure 9b). Calculations were based on an estimated 80% ridge coverage with a maximum thickness range of about 8 m. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-24.70 m) and shallowest isobath (-16.52 m) (Table 5). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Palm Coast Sand Wave**

The southern dissected margins of the Palm Coast Sand Wave (Figure 4b) lie partly in Flagler County, extending 3 km to 5 km across the seaward extended border from St. Johns County into Flagler County. The mapping unit is divided into two part for computation purposes, A and B. Part A is the smaller shoreward part of the sand wave that takes in 477 ha and part B, the larger seaward part, takes in 5305 ha (3% of the county continental shelf area) (Table 5). These two segments are the middle sand wave in the Summer Haven – Palm Coast – Flagler sand-wave triumvirate. The mapping unit is bounded seaward by the Summer Haven Sand Wave and St. Johns Bank. This dissected southern flank of the Palm Coast Bank dissipates into a smoothly flowing bathymetry on the Flagler Sand Wave. Lying 12 km to 30 km offshore, this part of the large shore-normal sand wave is about 20 km wide in east-west extent by about 3 km long in a north-south extent, with some ridges (85° azimuth) superposed (Table 1). The sand wave has a local relief of about 2-4 m and occurs in water depths that range from 18 m to 22m.

Potential sand resources in the Palm Coast Sand Wave are estimated to be on the order of 8 x 106 m3 (8,623,525 m3) (Table 5, Figure 9b). This calculation was based on 75% of the mapping unit being comprised by sand wave surface and ridge units, as occur along the southern dissected margin. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-30.40 m) and shallowest isobath (-25.83 m) for a maximum sediment thickness range of 4.6 m in the unit, from the valleys in the dissected margin to ridge crests on top of sand wave surface (Table 5). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**St. Johns Bank**

Occurring 42 km to 62 km offshore, the St. Johns Bank (Figure 4b) takes up about 50,000 ha (Table 5) on the outer shelf floor from the offshore extension of the St. Johns County line to the Volusia County line, a distance of about 27 km. The bank grades shoreward into the Flagler Sand Wave and the Volusia Bank. It is bounded seaward by undifferentiated seafloor with transverse ridges. Although the bank displays a generally flat surface with some areas of hummocky terrain in the north, it is surmounted by some widely spaced (2 km to 5 km apart) sand ridges (40° to 55° azimuths) up to 12 km long throughout the mapping unit. This large shore-parallel bank extends up to 65 km offshore into water depths that average about 27 m. Local relief on the bank surface *per se* is about 2 m but is greater (up to 6 m) in the vicinity of surmounted sand ridges.

Potential sand resources in the St. Johns Bank are estimated to be on the order of 1.7 x 109 m3 (1,680,485,857 m3) (Table 5, Figure 9b). This calculation was based on 50% of the mapping unit being comprised by sand bank units (smooth seafloor mapped from reformatted NOAA data in Zone D), except along dissected margins. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-34.00 m) and shallowest isobath (-17.60 m) for a maximum sediment thickness range of 16.4 m in the unit, from valley to ridge crest (Table 5). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Volusia Bank**

The northern extension of the Volusia Bank (Figure 4b) occurs on the offshore extension of the Flagler-Volusia county line. Here, the bank lies about 20 km to 43 km offshore and is bounded seaward by the St. Johns Bank and shoreward by the northern part of the Korona Ridge Field. The bank is separated from the dissected margin of the Flagler Sand Wave to the north. This distinct boundary is characterized by a rapid change from dissected terrain on the southern flanks of the sand wave to generally flat seafloor of the bank that is occasionally punctuated by low-relief (4 m) sand ridges. The bank has a local relief of about 2-4 m and occurs in water depths that range from 24 m to 30 m.

Potential sand resources in the Volusia Bank are estimated to be on the order of 457 x 106 m3 (457,739,038 m3) (Table 5, Figure 9b). This calculation was based on 65% of the mapping unit being comprised by sand bank units (smooth seafloor mapped from reformatted NOAA data in Zone D), except along dissected margins. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-31.60 m) and shallowest isobath (-19.25 m) for a maximum sediment thickness range of 12.4 m in the unit, valley to ridge crest (Table 5). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**MORPHOMETRIC PROPERTIES OF SEAFLOOR MAPPING UNITS AND**

**SAND RESOURCE POTENTIALS IN VOLUSIA COUNTY**

The survey area in Volusia County, the second largest offshore county shelf area (389,900 ha) after St. Johns County, extends from Flagler County to Brevard County for an along-coast distance of about 79 km. Extending about 65 km offshore, the shelf area is quite diverse being comprised by sand flats, ridge fields, shoals, bars, and banks. These seafloor features account for about 72% of the total mapped shelf area (Table 6), the remainder being taken up by undifferentiated seafloor with transverse ridges.

The main morphological seafloor features on the continental shelf include the following mapping units (Figure 4b), from the shore seaward: the Farmton Sand Flat, Allandale Shoal, Oak Hill Shoal, Korona Ridge Field, Edgewater Ridge Field, and the Volusia Bank. Mapping units taking up the most area include the Farmton Sand Flat, Volusia Bank, Korona Ridge Field, and the Edgewater Ridge Field.

Potential sand resources in the mapped area of the continental shelf in Volusia County (154,745 ha) amount to something on the order of 21.6 x 109 m3 (21,663,274,180 m3) of sediment. This sediment volume estimate is based on assumptions for average thickness of morphosedimentary units such as sand flats, bars, ridge fields, shoals, and banks. Parameters used in calculations of volume estimates are summarized in Table 6. The Volusia Bank has the largest potential sediment volume, followed by the Farmton Sand Flat and the Korona Ridge Field. The sand resource potential of each mapping unit is discussed in relation to geographic occurrence, spatial distribution patterns, and morphosedimentary properties, as summarized in Figure 9b and Table 6.

Table 6. *Sand resource potential in Volusia County by morphosedimentary units where volume calculations are based on percent areal coverage in the mapping unit, which is less than unity for bars and ridge fields.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Morphosedimentary Features** | **Shelf Area (ha)1** | **% of County Continental Shelf Area2** | **Height of Plane (m)** | **Elevation Range3**  **(Max to Min Depth)**  **(m)** | **% Area Used in Volume Calculations4** | **Sediment Volume**  **(m3)** |
| Allandale Shoal | 675 | 0<1 | -18.06 | -18.06 to -12.70 | 75 | 9,526,333 |
| Bunnel Ridge Field | 580 | 0<1 | -20.45 | -20.45 to -14.80 | 30 | 3,616,347 |
| Canaveral Transverse Bar | 929 | 0<1 | -15.76 | -15.76 to -2.51 | 35 | 13,743,891 |
| Edgewater Ridge Field | 15,979 | 4 | -23.20 | -23.20 to -12.60 | 95 | 721,072,271 |
| Farmton Sand Flat | 87,864 | 23 | -23.83 | -23.83 to 0 | 100 | 4,883,172,022 |
| Korona Ridge Field | 15,098 | 4 | -2.63 | -22.63 to -10.90 | 100 | 696,182,204 |
| Oak Hill Shoal | 1,813 | 0<1 | -20.17 | -20.17 to -10.00 | 60 | 36,616,288 |
| St. Johns Bank | 2,990 | 1 | -34.49 | -34.49 to -22.10 | 95 | 163,233,003 |
| Volusia Bank | 154,745 | 40 | -35.30 | -35.30 to -14.60 | 80 | 15,136,111,820 |
| **Total** | **280,671** | **72** |  |  |  | 21,663,274,180 |

1 For conversion of hectares (ha) to square kilometers (100 ha = 1 km2), move decimal point two digits to the left.

2 Refers to continental shelf area offshore from county lines for ease of reference. State waters lie shoreward of the

3-mile and federal waters are seaward.

3 Based on measurement of local relief from the reformatted NOAA bathymetry. These measurements are limited by

the grid scale of the NOAA bathymetric data. Sediment volume was calculated from a TIN data structure

using the maximum and minimum elevations within the mapping unit.

4 Some mapping units embrace larger areas than sand ridges *per se*, for example, to simplify mapping. Areas thus

designated as ridge fields contains sand ridges plus intervening swales and sand plain units.

**Allandale Shoal**

The Allandale Shoal (Figure 4b) lies about 5 km offshore R100 in about 16 m water depth. The shoal is an enclave within the Farmton Sand Flat mapping unit. The small shoal takes up about 675 ha and is comprised by sand ridges (30° and 85° azimuths) with updrift linkages to the Bunnel Ridge Field. The shoal, 2 km wide by 5 km long, is oriented in NS direction, lies about 1.5 km shoreward of the Korona Ridge Field. The shoal occurs in water depths that range from 16 m to 18 m.

Potential sand resources in the Allandale Shoal are estimated to be on the order of 9 x 106 m3 (9,526,333 m3) (Table 6, Figure 9b). This calculation was based on 75% of the mapping unit being comprised by sand ridge units that make up the shoal area. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-18.06 m) and shallowest isobath (-12.70 m) for a maximum sediment thickness range of about 6 m in the unit (Table 6). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Canaveral Transverse Bar**

The northern extension of the Canaveral Transverse Bar field (Figure 4b), previously described by Finkl and Andrews (2007), occurs alongshore on the shoreface and inner shelf floor on the Volusia-Brevard county line. Here, the ridge field extends about 4 km alongshore and about 2.5 km offshore. The bar field occupies about 929 ha with individual bars 200 to 500 m wide, striking along 55 to 80° azimuths. The bar field, which tapers off seaward to the Farmton Sand Flat, has a local relief of about 4 m and occurs in water depths of about 20 m.

Potential sand resources in the Canaveral Transverse Bar field are estimated to be on the order of 13 x 106 m3 (13,743,891 m3) (Table 6, Figure 9b). This calculation was based on 35% of the mapping unit being comprised by transverse bars (bar and trough seafloor mapped from reformatted NOAA data in Zone C). Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-15.76 m) and shallowest isobath (-2.51 m) for a maximum sediment thickness range of 13 m in the unit, deepest trough to highest bar crest (Table 6). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Edgewater Ridge Field**

The Edgewater Ridge Field (Figure 4b) only occurs in Volusia County, about 6 km to 11 km offshore on the middle shelf floor. The ridge field marks the seaward extent of the Farmton Sand Flat and is characterized by an abrupt transition from flat seafloor to ridge and valley topography. The mapping unit represents the shoreward dissected margin of the Volusia Bank. Individual ridges making up the ridge field are about 0.5 to 1.2 km wide and about 3 km long (along 40° to 60° azimuths) with wavelengths about 500 m (Table 1). There are three large downdrift extended fingers of the ridge field that average about 8 km to 12 km in length. The ridge field shows a local relief of about 6 m and occurs in water depths that range from 14 m to 20 m.

Potential sand resources in the Edgewater Ridge Field are estimated to be on the order of 721 x 106 m3 (721,072,271 m3) (Table 6, Figure 9b). This calculation was based on 95% of the mapping unit being comprised by sand ridges (ridge and valley topography mapped from reformatted NOAA data in Zones C and D). Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-23.20 m) and shallowest isobath (-12.60 m) for a maximum sediment thickness range of 10.5 m in the unit, from the deepest trough to the highest ridge crest (Table 6). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Farmton Sand Flat**

The largest single mapping unit in offshore Volusia County, the Farmton Sand Flat (Figure 4b) occupies 87,864 ha on the shoreface, inner shelf floor, and shoreward-most margin of the middle shelf floor. The sand flats are bounded seaward by the Korona Ridge Field, Edgewater Ridge Field, and the Volusia Bank. The morphological transition from sand flat to seaward morphosedimentary units is abrupt, except in the southern part of the county offshore zone where the sand flats merge with the Volusia Bank. The Allandale and Oak Hill shoals occur within the Farmton Sand Flat as enclaves. The sand flats show a local relief of about 2-4 m and occurs in water depths that range from 2 m to 20 m.

Potential sand resources in the Farmton Sand Flat are estimated to be on the order of 4.9 x 109 m3 (4,883,172,022 m3) (Table 6, Figure 9b). This calculation was based on 100% of the mapping unit being comprised by sand flats. Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-23.83 m) and shallowest isobath (-0 m) (Table 6). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Korona Ridge Field**

The southern extension of the Korona Ridge Field (Figure 4b) occurs south of the Flagler-Volusia county border, extending about 30 km southward into the offshore region of Volusia County. Lying 8 km to 12 km offshore, the ridge field abruptly terminates shoreward at the Farmton Sand Flat. The mapping unit represents 4-km wide dissected shoreward margin of the Volusia Bank. Individual ridges, about 200 to 500 km wide by 1-4 km long, strike along 30° to 40° azimuths (Table 1). This broad ridge field (5 km wide) has two main downdrift extended fingers that are about 22 km long with sand flats between the ridges. Individual subridges lie transverse to the shore. The ridge field shows a local relief of about 4 m and occurs in water depths that range from 14 m to 22 m.

Potential sand resources in the Korona Ridge Field are estimated to be on the order of 7 x 106 m3 (696,182,204 m3) (Table 6, Figure 9b). This calculation was based on 100% of the mapping unit being comprised by sand ridges (ridge and valley topography mapped from reformatted NOAA data in Zones C and D). Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-22.63 m) and shallowest isobath (-10.90 m) for a maximum sediment thickness range of 10.5 m in the unit, deepest trough to highest ridge crest (Table 6). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Oak Hill Shoal**

Located about 3 km offshore on the inner shelf floor, the small Oak Hill Shoal (Figure 4b) occurs as an enclave within the Farmton Sand Flat. The shoal, about 1.5 to 2 km wide by 10 km long, is oriented in a north-south direction and centers on small transverse ridges that strike along 45° and 50° azimuths (Table 1). Topographically subdued sand ridges extending 21 km downdrift from the Korona Ridge Field feed into the Oak Hill Shoal. The shoal shows a local relief of about 4 m and occurs in water depths that range from 14 m to 18 m.

Potential sand resources in the Oak Ridge Shoal are estimated to be on the order of 36 x 106 m3 (36,616,288 m3) (Table 6, Figure 9b). This calculation was based on 60% of the mapping unit being comprised by sand ridges (ridge and valley topography mapped from reformatted NOAA data in Zone C). Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-20.17 m) and shallowest isobath (-10.00 m) for a maximum sediment thickness range of about 10 m in the unit, deepest trough to highest ridge crest (Table 6). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**St. Johns Bank**

A small segment of the southernmost extension of the St. Johns Bank (Figure 4b) occurs along the Flagler-Volusia county line. The bank is about 12.5 km wide along the county line and extends 3.8 km into Volusia County. The bank is adjacent shoreward with the Volusia Bank and seawards with undifferentiated seafloor with transverse ridges. Distal portions of some sand ridges occur within the mapping unit. The shoal shows a local relief of about 6 m and occurs in water depths that range from 24 m to 30 m.

Potential sand resources in the St. Johns Bank are estimated to be on the order of 163 x 106 m3 (163,233,003 m3) (Table 6, Figure 9b). This calculation was based on 95% of the mapping unit being comprised by bank surfaces some sand ridges (ridge and valley topography mapped from reformatted NOAA data in Zone D). Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-34.49 m) and shallowest isobath (-22.10 m) for a maximum sediment thickness range of about 12.5 m in the unit, from the deepest trough to the highest ridge crest (Table 6). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**Volusia Bank**

The Volusia Bank (Figure 4b) is a large shore-parallel offshore bank that is about 76 km long by about 11 km to 30 km wide. The bank occurs on the middle and outer shelf floors. Dissected shoreward margins of the bank are identified as the Korona and Edgewater ridge fields. The bank is flanked seaward by undifferentiated seafloor with transverse ridges. The bank surface is characterized by scattered pockets of hummocky terrain amid a generally flat seafloor surface that is surmounted by widely spaced ridges, up to 12 km long, that strike along 50° to 85° azimuths. These sand ridges continue onto the bank from farther offshore, but are less prominent and topographically subdued compared to their deepwater occurrence.

Potential sand resources in the Volusia Bank are estimated to be on the order of 15 x 109 m3 (15,136,111,820 m3) (Table 6, Figure 9b). This calculation was based on 80% of the mapping unit being comprised by bank surfaces and some sand ridges (ridge and valley topography mapped from reformatted NOAA data in Zone D). Sediment thickness was calculated from differences in elevation computed between the depth of the deepest isobath (-35.30 m) and shallowest isobath (-14.60 m) for a maximum sediment thickness range of about 20.7 m in the unit, deepest trough to highest ridge crest (Table 6). Variations in thickness throughout the mapping unit were used as a basis for volume estimates.

**SUMMARY OF POTENTIAL SAND RESOURCES ALONG THE**

**NORTHEAST FLORIDA ATLANTIC COAST**

The preceding analysis reported on the kind and sequence of seabed topography in relation to sedimentary bodies. This information was communicated by county, but this summary reports total occurrence of morphosedimentary features for the whole study area on the continental shelf off the northeast Florida Atlantic coast (Table 7). Based on this reconnaissance survey, the total estimated volume of potential sand resources on the continental shelf amounts to something on the order of 78.5 x 109 m3 (102 billion cubic yards). This estimate is based on areal distribution patterns and conservative deposit thicknesses that were derived from local relief on sand ridges, sand flats, transverse bars, sand waves, banks, shoals, and ebb-tidal deltas.

This section of the western North Atlantic Shelf along the northeast Florida shore contains abundant sediments that have accumulated in a range of deposits. These unconsolidated surficial seafloor materials are prominent on the shoreface, inner shelf floor, middle shelf floor and outer shelf floor. The largest potential sand resources occur in St. Johns County (28 x 109 m3), followed by Volusia County (21.6 x 109 m3), which together take in about 612,924 ha of seafloor. Significant potential sand resources are also associated with Duval County (13.5 x 109 m3), Flagler County (9 x 109 m3), andNassau County (6.2 x 109 m3) (see Tables 2 through 6).

Of primary interest to the State of Florida is the volume of potential sand resources that occur in state waters, that is, shoreward of the so-called 3-mile offshore limit. One way to assess the sand resource potential in state waters is to determine the areas of specific morphosedimentary features that occur shoreward of the 3-mile limit, as shown in Table 7. With such a wide shelf area extending to the 45 m isobath, only a small percentage of the mapped morphosedimentary units occurs within state jurisdiction. Conversely, on broad shallow shelf areas such as occur offshore the northeast coast of Florida, most of the sand resources fall under the jurisdiction of the federal government. The largest potential sand resource area in state waters is associated with the Farmton Sand Flat (93,759 ha). The Talbot Transverse Bar field occupies about 5972 ha, followed by the St. Augustine Ebb-Tidal Delta that takes in 5680 ha and the St. Johns and Tisonia – Nassau Sound ebb-tidal deltas that respectively include about 1840 ha and 1414 ha. The part of the Duval Ridge Field occurring in state waters includes about 2519 ha. Along with lesser areas of ridges and shoals, state waters include 119,250 ha overall (Table 7). Ebb-tidal deltas have been a traditional sand source and consequently areas associated with ridges, bars, and shoals constitute new locations with potential as sand resource areas.

Table 7. *Explanation of mapping units occurring in state and federal waters, based on the 3-mile jurisdictional limit, and showing the breakdown of hectares and percentages by zone of occurrence and by unit.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Morphosedimentary Feature** | **State Shelf Area (ha)** | **Federal Shelf Area (ha)** | **Total Shelf Area (ha)** | **State Area (%)** | **Federal Area (%)** | **State % by Unit** | **Federal % by Unit** |
| Allandale Shoal | 183 | 492 | 675 | 0.15 | 0.04 | 27.10 | 72.90 |
| Amelia Sand Ridge | 895 | 3,273 | 4,168 | 0.75 | 0.24 | 21.47 | 78.53 |
| Beverly Shoal | 321 | 927 | 1,248 | 0.27 | 0.07 | 25.72 | 74.28 |
| Bunnel Ridge Field | 0 | 8,438 | 8,438 | 0.00 | 0.62 | 0.00 | 100.00 |
| Canaveral Transverse Bar | 929 | 0 | 929 | 0.78 | 0.00 | 100.00 | 0.00 |
| Crescent Ridge Field | 0 | 9,268 | 9,268 | 0.00 | 0.69 | 0.00 | 100.00 |
| Duval Ridge Field | 2,519 | 139,278 | 141,796 | 2.11 | 10.31 | 1.78 | 98.22 |
| Edgewater Ridge Field | 0 | 15,979 | 15,979 | 0.00 | 1.18 | 0.00 | 100.00 |
| Espanda Ridge Field | 0 | 3,434 | 3,434 | 0.00 | 0.25 | 0.00 | 100.00 |
| Farmton Sand Flat | 93,759 | 107,750 | 201,509 | 78.62 | 7.97 | 46.53 | 53.47 |
| Flagler Sand Wave | 0 | 57,292 | 57,292 | 0.00 | 4.24 | 0.00 | 100.00 |
| Fort Clinch Ridge Field | 244 | 5,827 | 6,071 | 0.20 | 0.43 | 0.00 | 100.00 |
| Korona Ridge Field | 0 | 21,479 | 21,479 | 0.00 | 1.59 | 0.00 | 100.00 |
| Nassau Bank | 0 | 64,617 | 64,617 | 0.00 | 4.78 | 0.00 | 100.00 |
| Oak Hill Shoal | 1,331 | 481 | 1,813 | 1.12 | 0.04 | 73.44 | 26.56 |
| O'Neal Bank | 0 | 31,039 | 31,039 | 0.00 | 2.30 | 0.00 | 100.00 |
| Palm Coast Sand Wave | 0 | 25,438 | 25,438 | 0.00 | 1.88 | 0.00 | 100.00 |
| Sawgrass Bank | 0 | 86,980 | 86,980 | 0.00 | 6.44 | 0.00 | 100.00 |
| St. Augustine Ebb-Tidal Delta | 5,680 | 0 | 5,680 | 4.76 | 0.00 | 100.00 | 0.00 |
| St. Johns Bank | 0 | 136,962 | 136,962 | 0.00 | 10.13 | 0.00 | 100.00 |
| St. Johns Ebb-Tidal Delta | 1,840 | 0 | 1,840 | 1.54 | 0.00 | 100.00 | 0.00 |
| St. Mary's Ebb-Tidal Delta | 4,163 | 0 | 4,163 | 3.49 | 0.00 | 100.00 | 0.00 |
| Summer Haven Sand Wave | 0 | 55,722 | 55,722 | 0.00 | 4.12 | 0.00 | 100.00 |
| Talbot Transverse Bar | 5,972 | 2 | 5,974 | 5.01 | 0.00 | 99.97 | 0.03 |
| Tisonia – Nassau Sound Ebb-Tidal Delta Complex | 1,414 | 0 | 1,414 | 1.19 | 0.00 | 100.00 | 0.00 |
| Undifferentiated Seafloor with Anastomosing Ridges | 0 | 133,671 | 133,671 | 0.00 | 9.89 | 0.00 | 100.00 |
| Undifferentiated Seafloor with Linear Sand Ridges | 0 | 174,749 | 174,749 | 0.00 | 12.93 | 0.00 | 100.00 |
| Undifferentiated Seafloor with Transverse Ridges | 0 | 101,440 | 101,440 | 0.00 | 7.51 | 0.00 | 100.00 |
| Volusia Bank | 0 | 166,907 | 166,907 | 0.00 | 12.35 | 0.00 | 100.00 |
| **Total** | **119,250** | **1,351,444** | **1,470,693** | **100.00** | **100.00** | **8.11** | **91.89** |

1 Percentage of total study area under State of Florida jurisdiction, *i.e*. landward of 3-mile limit.

2 Percentage of total study area under federal jurisdiction, *i.e*. seaward of 3-mile limit.

3 Percentage of state-controlled continental shelf area comprised by mapping unit, *i.e.* landward of 3-mile limit.

4  Percentage of federally-controlled continental shelf area comprised by mapping unit, *i.e*. seaward of 3-mile limit.

5 Percentage of mapping unit under state jurisdiction*, i.e.* landward of 3-mile limit.

6 Percentage of mapping unit under federal jurisdiction, *i.e*. seaward of 3-mile limit.

The Farmton Sand Flat is a significant potential sand resource for the state because it makes up about 79% of the seafloor area under state jurisdiction with nearly half (47%) of the morphosedimentary units occurring shoreward of the 3-mile limit (Table 7). The Talbot Transverse Bar field makes up about 5% of the area under state control, as does the St. Augustine Ebb-Tidal Delta followed by about 3.5% for the St. Mary’s Ebb-Tidal Delta. Areas of all other morphosedimentary features within the 3-mile limit make minor (<3%) contribution to state-controlled seafloor. Another way to look at the sand resource base is to consider the area percent of the morphosedimentary units under state jurisdiction. In the case of the Farmton Sand Flat, for example, about 47% of this morphosedimentary unit falls under state jurisdiction. For state percent by area by morphosedimentary unit, total amount to about 27% and 26% percent respectively for the Allandale and Beverly shoals; about three-quarters (73%) of the Oak Hill Shoal area comes under state hegemony (Table 7). What all this means is that the Farmton Sand Flat is the largest single potential sand source in state waters for the northeast Florida Atlantic continental shelf.

In federal waters, the Volusia Bank, St. Johns Bank, Sawgrass Bank, Farmton Sand Flat, and Duval Ridge Field make up the largest areas with potential sand resources (Table 7). These morphosedimentary units respectively make up the following areal percents under federal jurisdiction: 12%, 10%, 6%, 8%, and 10%. These mapping units collectively make up nearly half (46%) of the shelf area under federal control. Undifferentiated seafloor with sand ridges makes up an additional 30% of seafloor area under federal jurisdiction. Although these morphological mapping units account for a majority of the shelf area mapped, the spatial extent is not the complete answer for sand resource investigations. Sediment volume needs to be considered as well and in this respect, sand waves should be considered even though their percentage areal distributions are relatively small (Summer Haven Sand Wave, 4%; Palm Coast Sand Wave, 1.88%; Flagler Sand Wave, 4%) (Table 7).

**AREAS NOT TESTED ENOUGH TO DETERMINE**

**SAND RESOURCE POTENTIAL**

Large areas of the continental shelf were covered by low-resolution NOAA bathymetry that could not be reformatted to grid spacing closer than 1000 feet (Zone D) or 1500 feet (Zone F). As a result, large tracts had to be mapped as undifferentiated seafloor in federal waters. The area accounts for about 409,860ha seaward of the state-federal boundary (Table 7) and is comprised by the following mapping units: Undifferentiated Seafloor with Anastomosing Ridges (133,671 ha), Undifferentiated Seafloor with Transverse Ridges (101,440), and Undifferentiated Seafloor with Linear Sand Ridges (174,749). Of the total federal shelf area mapped, about 30% is comprised by the Undifferentiated Seafloor mapping unit (Table 7).

For state waters, the problem of low resolution bathymetric data is most prevalent in northern Nassau County where there are no surveys based on 500-foot data spacing (Zone C). A small nearshore section occurs as an extension of Zone A along the northern coast of Nassau County. New, more detailed bathymetric surveys are required in these areas to estimate sand resource potentials. Perusal of Figures 4a and 4b indicates that there is no reason to suspect that the seafloor mapped as ‘undifferentiated’ is any different than adjacent areas. The fact that large-scale banks, sand waves, and ridge fields could be interpreted from the low resolution bathymetric data in ‘undifferentiated’ areas indicates that similar features are likely to occur in these areas and that they will be identified using the new bathymetry. With the present bathymetric data, it is not possible to produce reliable interpretations of seafloor morphologies in areas now designated as ‘undifferentiated’ (Zone D), except for the presence of large-scale bathymetric features such as mega sand ridges.

Most of the shelf area based on reformatted NOAA data in Zone D contains acquisition bathymetric data points that are too widely spaced for meaningful interpretation of seafloor morphology. Except for shelf areas of northern Nassau County, most of the Undifferentiated Seafloor mapping unit occurs seaward of the 3-mile limit and extends to the seaward mapping boundary at 45 m isobath. Mapping of morphosedimentary units in Zone C is considerably more reliable than seaward data grids. New estimates of potential sand resources on the continental shelf along the northeast Florida Atlantic coast will undoubtedly increase if new bathymetric data is obtained at grid scales of 500 feet or less.

For the remaining areas of seafloor that have been interpreted in terms of morphosedimentary units (*i.e*. transverse bars, ridge fields, sand flats, banks, sand waves, and shoals), it is emphasized that the interpretations are based on reconnaissance NOAA bathymetry that was reformatted to closer grid spacing where possible. Assumptions were made as to the thickness of sedimentary bodies, based on local relief as measured from the bathymetry. These assumptions, summarized in Tables 3 through 6, provided a means of measure for this reconnaissance survey but require refinement for more detailed investigations.

Numerous small detailed bathymetric surveys occur throughout the offshore zone in Nassau, Duval, and St. Johns counties. These survey areas are shown along with Minerals Management Service (MMS) seismic reflection profiling surveys in Figures 10a and 10b. Collectively, these more detailed surveys cover small parts of the following morphosedimentary features: Fort Clinch Ridge Field, Amelia Sand Ridge, Duval Ridge Field, Farmton Sand Flat, and the Espanda Ridge Field. MMS seismic surveys also cover small segments of the O’Neal Bank, Nassau Bank, Sawgrass Bank, Summer Haven Sand Wave, Palm Coast Sand Wave, Flagler Sand Wave, and Bunnel Ridge Field. Thus, in some way and at various levels of investigation, parts of morphosedimentary features in federal waters from the 3-mile limit to about 18 km seaward have been studied. These areas require more detailed study to better estimate potential sand resources. Nevertheless, at this point it is possible to identify salient morphological features that are obvious targets that are in addition to or partly included in MMS surveys.

In order to narrow down future searches for potential sand resources, areas of interest are identified here in terms of primary search areas that occur shoreward of the 3-mile limit and secondary search areas that occur seaward of the state-federal boundary. Primary search areas, indicated by red-colored polygons, are discussed for the nearshore zone by reference to Figures 10a and 10b. Offshore secondary search areas identify search areas that are beyond the state-federal boundary ranging from 8 to 35 km offshore. This arbitrary offshore distance is based on the premise of keeping dredging costs down by looking at potential sand resources closer to shore rather than farther from shore. Because potential sand resources contained in ridge fields, banks, and sand waves extend long distances offshore, potential search areas more seaward can be identified at a later point in time if the sites closer to shore do not prove out. Some areas of interest identified here have been variously sampled or studied at different levels of investigation. The areas identified are thus not exclusive of previous investigations but should nonetheless be (re)examined in closer detail than the information that is now generally available.

Surveys that are more detailed will no doubt identify additional areas to be looked at more closely. In the case of the Farmton Sand Flat, for example, it is quite possible that diabathic channels may occur alongshore as was the case in Palm Beach County. These features, described by Finkl, Benedet and Andrews (2006) and Finkl and Andrews (2007), contain good quality beach sand and are viewed as a new sand source for beach nourishment that lies close to shore. The present scale of reformatted NOAA bathymetry does not show these smaller-scale bed features on the sand flats, if they indeed exist in the study area. For now, the following areas of interest should be regarded as worthy of future survey for beach-quality sands.

**Areas of Interest in State & Federal Waters Offshore Nassau County**

The following areas within the 3-mile limit, identified by morphosedimentary features, should be investigated more carefully: Talbot Transverse Bar field (R040 to R080) and St. Mary’s Ebb-Tidal Delta (R000 to R035). Morphosedimentary features seaward of the 3-mile limit that should be studied in more detail for sand resource potential include the Fort Clinch Ridge Field (6 km to 12 km offshore), the Amelia Sand Ridge (8 km to 12 km offshore), and part of the Duval Ridge Field (9 km to 17 km offshore) (Figure 10a). Although the preceding three seafloor features were partly investigated by MMS seismic reflection profiling, individual ridges in these ridge fields (within the yellow-colored polygons) should also be surveyed in more detail.

**Areas of Interest in State Waters & Federal Offshore Duval County**

The following areas of interest within the 3-mile limit, identified by morphosedimentary features, should be investigated more carefully: Amelia Sand Ridge (4 km offshore), Talbot Transverse Bar field (bars extending seaward of the Tisonia – Nassau Sound Ebb-Tidal Delta), and Farmton Sand Flat (specific areas not shown, but where there are sequences of subdued sand ridges) (Figure 10a).

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Figure 10. Areas to be Tested More Carefully Along the Northeast Florida Atlantic Coast. (A) Showing locations of detailed bathymetric survey, prior seismic reflection profiles surveys, and beach nourishment projects in Nassau, Duval, and St. Johns counties. (B) Showing prior seismic reflection profiles surveys, in Flagler and Volusia counties. Areas to be tested more carefully in both (A) and (B) are shown as primary zones (red-colored polygons) shoreward of the 3-mile limit and secondary zones (yellow-colored polygons) (seaward of the 3-mile limit). Some of the areas to be tested more carefully may contain morphosedimentary features that have been partly studied at reconnaissance levels. →

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Seaward of the 3-mile limit, individual sand ridges throughout the Duval Ridge Field require more detailed investigation, especially on the shoreward shoaling flanks of the ridge field demarcated by the yellow-colored polygon box outline (6 km to 17 km offshore).

**Areas of Interest in State & Federal Waters Offshore St. Johns County**

Obvious areas shoreward of the 3-mile limit to further investigate include sand ridges of the Duval Ridge field offshore from R000 to R010, R020 to R050, and R120 to R145 (Figure 10a). The subdued ridge extension from R055 to R100 on the Farmton Sand Flat off the northern distal flank of the St. Augustine Ebb-Tidal Delta along with the individual ridges in the Duval Ridge Field seaward of the 3-mile limit (up to 15 km or so offshore) should be further investigated for potential sand resources. Individual ridges within the Crescent Ridge Field (about 10 km offshore) should be additionally tested for sand resource potential.

**Areas of Interest in State & Federal Waters Offshore Flagler County**

The Beverly Shoal (Figure 10b) is the most obvious area that should be investigated shoreward of the 3-mile limit. This morphosedimentary feature has been investigated by the MMS seaward of the state-federal boundary. Other seafloor features partially surveyed by MMS seismic reflection profiling include two tracklines across the Espanda Ridge Field and the Bunnel Ridge Field. One trackline crosses small segment of the Flagler Sand Wave.

**Areas of Interest in State & Federal Waters Offshore Volusia County**

Morphosedimentary features lying in state waters off Volusia County that should be further investigated for sand resource potential include the Allandale Shoal (R090 to R105), Oak Hill Shoal (R200 to R230), and Canaveral Transverse Bar field (Figure 10b) just north of the Volusia – Brevard county line. Parts of the Allandale and Oak Hill shoals lying in federal waters should also be studied for sand resource potential. Shoreward parts of the Korona Ridge Field (Figure 10b), lying about 6 km to 8 km offshore (R020 to R120), and the Edgewater Ridge Field (R120 to R165 and R200 to 240), as well as a shoal portion of the Volusia Bank (offshore R200 to R230) (about 18 km offshore) about 2 km seaward of the seaward of the Edgewater Ridge Field.

**PROMISING AREAS NOT PREVIOUSLY INVESTIGATED**

Sand flats occur in state waters on the northeast Florida Atlantic coast. At the present scale of mapping and grid spacing of bathymetric data (500-foot NOAA data reformatted to a regular 250-foot grid in Zone C), it is not possible to reliably break down the sand flat units into smaller morphosedimentary units. More detailed bathymetry of shelf area under state jurisdiction will permit interpretation of seafloor features that will contain the same kinds of morphosedimentary bodies already identified in adjacent areas (as occur along the central Florida Atlantic coast) where bathymetric control is sufficient for feature recognition. At this juncture, it is not possible to single out potential sand targets on sand flats that would have priority over more obvious sand resources as occur in ridges, banks, sand waves, and shoals. Nevertheless, sand flats contain enormous sediment volumes and they should not be neglected as potential sand resources, especially when they occur close to shore.

An important consideration in the appraisal of areas not previously investigated is recognition of mapping unit homogeneity. The location maps showing seafloor physiographic units (Figures 1a, 1b, 2, and 3) and the subdivision of these units by characteristics of their sedimentary covers in the form of morphosedimentary units (Figures 4a and 4b) contains broad-scale reconnaissance mapping units. These mapping units are mostly made up of complex sedimentary bodies that have more than one morphological expression. That is, swales or intervening lower-elevation areas must exist in order for a unit to have positive topographic expression. Mapping units for ridge fields thus comprise ridge and swale topography and may include wider lower-lying areas between sand ridges. Spacing of NOAA bathymetric grids determines what can be extracted from the bathymetric data giving limits to levels of interpretation.

Since most areas that have not previously investigated have no detailed bathymetric surveys, this study relied on broadly spaced bathymetric data points. The quality of the mapping units would be increased by re-surveying the continental shelf area. The reformatting of the NOAA bathymetric data was a stopgap effort to extract as much information from the digital files as possible. Digital geospatial information in the form of bathymetric data to a large extent determined the scale of observation and level of classification of seafloor features.

The precision of any predictions (*e.g*. targets for future sand searches) that are made using the classification presented in this study is dependent on the homogeneity of the mapping unit and on the spatial variability within mapping units. The spatial variability is typically not ascertained, and without a measure of the spatial variability within each mapping unit, little is known regarding the reliability of the modal morphosedimentary unit. Continuous classification is made possible by using different types of geostatistical tools that are capable of accounting for the continuous nature of mapping units and allow an individual morphosedimentary unit to be assigned totally, partially or not at all to a particular class. For the purposes of this study, the typology that resulted from visual inspection of bathymetric patterns was considered adequate for reconnaissance work.

Promising areas not previously investigated as borrows for beach renourishment include the primary and secondary areas of interest previously identified in Figures 10a and 10b. Although these areas are not strictly ‘not previously investigated’ because some MMS seismic reflection profiling lines occur in part of some morphosedimentary units, the features identified here should be investigated in more detail to determine their sand resource potential.

**LIMITATIONS OF SAND RESOURCE POTENTIALS**

Sand resource potentials are limited by the quality of the bathymetric data that were used to interpret seafloor features. Because the grid spacing of data points varied with bathymetric survey, seafloor topography was not mapped uniformly over the study area. Large areas of continental shelf contained low resolution (widely spaced data points) bathymetric data and it was not possible to reliably interpret seafloor features. These areas were mapped as undifferentiated seafloor, that is, they were not interpreted. From the 3-mile limit to the 45 m isobath, about 409,860ha were not mapped (except for large sand ridges) due to low resolution bathymetric data (Table 7).

Of the morphosedimentary features that were mapped (for areas see Table 7), several assumptions were made regarding unit thickness. Local relief, determined from the digital bathymetric maps in a GIS platform, was acquired for each type of morphological feature and noted as a minimum, maximum, and average. This information was presented by morpho-sedimentary feature by county in a series of tables viz. Nassau County (Table 2), Duval County (Table 3), St. Johns County (Table 4), Flagler County (Table 5), and Volusia County (Table 6). In addition to local relief, another variable was the estimated mean areal coverage of sediment ridges *per se* in the ridge field mapping unit. Actual ridges might cover only 30% of the ridge field mapping unit, for example, and so it was important to disclose the estimate of areal coverage. Error in the estimation of percent coverage would affect volume calculations.

Sand resource potentials also depend on interpretation of seafloor topography in terms of morphosedimentary units such as sand ridges, shoals, sand flats, transverse bars, *etc*. The morphological interpretation is based on experience and requires familiarity with marine geomorphology and topographic expression as depicted in bathymetric data. Whether a particular unit is interpreted as a shoal, bank, sand wave, or ridge field may not be as crucial as recognition of a positive relief feature and its spatial relationships with surrounding relief forms. Thus, the salient point here is recognition of morphosedimentary features and determination of their morphometric properties, which are in turn used to calculate sediment volumes.

In sum, there are thus several caveats related to interpretation of bathymetric features and calculation of potential sediment volumes. In a general reconnaissance survey such as this, recognition of primary features is a first cut in the bathymetric data in hand. Work that is more detailed will improve spatial delineation and volume calculations.

**DISCUSSION**

There are many ways to describe seafloor conditions, ranging from remote sensing techniques to actual physical sampling. Depending on the nature of the information that is being sought, several techniques are commonly used in conjunction in order to acquire the most complete information possible. Typical remote sensing techniques focus on tomographic approaches where slices of sub-bottom are obtained in cross-section as, for example, in seismic reflection profiling. Images of the seafloor surface are often obtained by sidescan sonar surveys and physical samples are acquired for geotechnical purposes via grab samples and vibracores. Bathymetric surveys provide information on water depth. In the present study area, most of these techniques have been applied at various levels of detail in different areas.

Because the purpose of this study was to attempt to locate areas of potential sand resources for beach nourishment, it was clear that data acquisition had to be based on techniques that provided information on the spatial distribution of seafloor features that could be interpreted in terms of bottom types. The survey procedures had to be regional in scope and that scale requirement eliminated seismic reflection profiling due to its limited scope along track lines. Sidescan sonar surveys were not available, but there was complete bathymetric coverage of the entire study area. The presence of NOAA bathymetric data points (ranging from surveys in 1929 through 1999) throughout the study area was good news. The bad news was that the survey grid spacing was highly variable, ranging from data points spaced 1000 to 1500+ feet apart to small detailed surveys where data were acquired on 100-foot grids. Putting all this together in some sort of mappable format presented quite a challenge, one that was eventually resolved by merging disparate data sets into one contiguous map sheet that contained different acquisition grid resolutions. Low resolution data occurred farther offshore with more detailed survey data lying closer to shore and especially in navigational corridors to major ports. Settling on a comprise grid spacing of about 250 feet, the NOAA bathymetric data sets were reformatted into a single new data set that integrated numerous prior surveys into a new map of seafloor topography. A Data Reliability Zone Map was thus created for the study area to show how the data sets were compiled (see Figure 3, for example).

The resulting reformatted map based on modified NOAA bathymetry showed a myriad of morphological features, but in offshore areas data quality was generally degraded to the point where it was not possible to reliably identify bottom types beyond pronounced large-scale features such as sand ridges. Although Zone D bathymetric patterns are interpretable from widely spaced data points, it must be appreciated that more detailed descriptions are not possible here. Bathymetric detail associated with Zones A and C, for example, indicate that more closely spaced data points provide better spatial resolution of seafloor topography and that this detail most likely occurs throughout Zone D but cannot be seen in the present data. Nevertheless, it was still possible to subdivide the seafloor into distinct topographic regions where similar landforms were grouped. Similarly, because of these landform assemblages, it was possible to differentiate zones of dissimilarity and thereby regionalize spatial distribution patterns of bottom topography.

This explanation of mapping procedures is offered because of its importance to this project. Use of NOAA data that were not reformatted would not have produced usable maps that met the needs of this project. This procedure is thus emphasized because this project is based solely on the premise that the reformatted NOAA data sets and resulting maps of seafloor topography could be interpreted in terms of morphological units and backup collateral data from prior reports and geophysical-geotechnical surveys. Patterns of variation in seafloor topography were clear enough to distinguish recognizable morphologies that could be interpreted in terms of unconsolidated sedimentary deposits. Prior reports (*e.g*. Duane et al., 1972; Milliman, 1972; Swift et al., 1972; Field and Duane, 1974; Meisburger and Field, 1975; Dean and O’Brien, 1987; Hollister, 1985; Marino, 1986; Hine, 1997; Powell, Thieke, and Mehta, 2006; Finkl and Andrews, 2007) verify the general sedimentary nature of the shelf surface with widely distributed sand deposits, especially ridges, shoals, and ebb-tidal deltas. More recent studies of MMS seismic reflection profiles in the northern parts of the study area (in federal waters) verify the presence of sediment accumulation on the shelf floor (Phelps *et al*., 2007). The seafloor topography is thus interpreted as morphosedimentary units where shape and form are combined with material composition, mostly fine- to medium-grained sands.

These morphosedimentary units form the basis for mapping units on this sediment-rich continental shelf where there are very large accumulations of relict (mostly Holocene in age) sand deposits that take the form of sand ridges, banks, shoals, sand waves, or flats. This regionalization of the northeast Florida Atlantic continental shelf provides a rational basis for understanding and managing sand resources within the context of a geological model. Without the advantage of a geological model that shows spatial relationships between different types of seafloor units, it is not possible to make sense of a bewildering array of sub-bottom profiles, surface grab samples, and scattered vibracore logs. These maps of morphosedimentary features thus pull together a wide range of factors that bear on solutions for locating suitable sand resources. The maps provide feature continuity that was generally heretofore not available so that individual sand ridges, for example, can be identified and tracked in the spatial context of the geological model.

The geological model and associated morphosedimentary maps provide a rational basis for recommending future search areas where more detailed information would be useful for estimating sand resource potential. Whether in state or federal waters, the suggested areas for further investigation (see Figures 10a and 10b) are logically based on known morphosedimentary features where further investigation would seem warranted. Sand resource potential can in this way be better estimated using the geological model in preference to blanket exploratory surveys that by chance cross over parts of morphosedimentary features.

There are limitations to applying the geological model to identify potential sand resources on the continental shelf. The model is based on reformatted NOAA bathymetry that cannot improve the input data. The model therefore provides a starting point for additional work that can be based on the morphosedimentary units already recognized. Anticipated future work should focus on refinement of the units already recognized. More detailed information obtained from meso- and micro-scaled survey work will increase the usefulness of this seminal description of seafloor mapping units along the northeast coast of Florida. More detailed surveys will supercede limitations of the present work by building on knowledge so far acquired by reformatting old NOAA bathymetric data.

Potential sand volumes were estimated by interpreting the reformatted NOAA bathymetry to produce a reconnaissance classification of bottom types in terms of morphosedimentary units. Morphometric properties of the various units were then determined in an effort to quantify volume estimates on a sound basis, even though the effort was conducted on large-scale features. Total sediment volumes indicated the presence of massive sand resources on the continental shelf. Summarized by county, total potential sand resources are: Nassau County (6.2 x 109 m3), Duval County (13.5 x 109 m3), St. Johns County (28 x 109 m3), Flagler County (9 x 109 m3), and Volusia County (21.7 x 109 m3). Although extensive sand resources occur in sand flats, the most easily extractable deposits are most likely associated with shoals, banks, bars, and ridges. Suggested sand targets worthy of more detailed investigation, as summarized in this report, are indicated as a first cut in regional assessments. Detailed studies in the form of strategic sand searches, as described by Finkl, Khalil and Andrews (1997) and Finkl and Khalil (2005), are required for more accurate determination of sand reserves. These volumes, determined from reconnaissance survey, indicate the presence of significant offshore sand resources along the northeast Florida Atlantic coast of Florida.

Buried fluvial channels on the continental shelf have been mapped by the MMS and Florida Geological Survey off Nassau, Duval, and St. John counties (Phelps *et al*., 2007). The paleochannels are reported to contain variable quality sediments ranging from fine-grained materials to coarse sands that might be suitable for beach renourishment. The channels are covered by relatively thin overburden that could be removed to exploit the underlying fluvial sediments. Quantities of potential sediments in these paleochannnels are not yet quantified and so it is not possible to estimate the sand resource potential. In any case, there are so many other surficial morphosedimentary units that are worthy of more detailed investigation that they should be investigated first. Parts of the paleochannels are overlain by sand flats and sand ridges that are readily accessible to dredging, suggesting that the easiest (exposed on the surface of the seafloor) sand resources should be evaluated prior to or concomitantly with subsequent more detailed surveys. Although paleochannels on the continental shelf are always an option for further study, they are not recommended here as primary or secondary targets of study. As tertiary sand resources, the channels provide opportunity for further study as an ancillary resource.

**ENVIRONMENTALLY SENSITIVE AREAS**

Environmentally sensitive areas, shown in Figures 11a and 11b, include artificial reefs, and various types of critical habitat. Other than dredged materials disposal sites in the Duval Ridge Field off Nassau and Duval counties, the right whale critical habitat, and the aquatic preserve on the Farmton Sand Flat off St. Johns County, most critical habits are onshore. The latter category includes but it not limited to areas associated with the National Estuary Program, Coastal Barrier Resource System, Rare and Imperiled Waters, Nature Conservancy Ecological Areas, and saltmarsh. All of these types of areas are shown in relation to offshore morpho-sedimentary features or onshore occurrences in relation to cadastral features. Thus, most of the environmentally sensitive areas do not occur offshore, but are restricted to estuarine waters that lie landward of barrier islands.

The data sources used to compile the geographic distributions of environmentally sensitive areas are summarized in Table 8. Although this list is not definitive, it provides the major sources of information where further information may be obtained, including GIS shape files.

The open ocean beach-dune system is more complicated than offshore environmentally sensitive areas. Here, sea turtle nesting sites are generally pervasive through the study area. Piping plover critical habitat occurs near R080 (Nassau County) to R030 in Duval County (Figure 11a) within an aquatic preserve. Information related to environmentally sensitive areas may be found by visiting websites of the organizations listed in Table 8. More detailed information regarding environmentally sensitive areas should be obtained from the appropriate agency.

It is emphasized here that no effort is made to indicate seasonality of restricted access or methods of access, survey, and investigation that are applicable. Each environmentally sensitive area retains it own specialized requirements for transit or access and that the appropriate agency should be contacted to ensure conformation to rules and regulations. Even though most offshore potential sand resources are not severely impacted by environmental constraints, included here are examples of nearshore, onshore, and backshore environmentally sensitive areas that are sometimes involved in beach renourishment projects, especially in the case of dune restoration in consociation with beach nourishment (berm building). The geographic distribution of environmentally sensitive areas shown in Figures 11a and 11b are thus examples of the types of environments that might be affected. The figures should not be construed as a final disposition and for that reason, appropriate agencies need to be contacted if and when beach nourishment activities are contemplated.

Table 8. *Data sources used to compile Figures 11a and 11b showing environmentally sensitive areas on the northeast Florida Atlantic coast.*

|  |  |
| --- | --- |
| **DATA** | **SOURCE** |
| Aquatic Preserves1 | Florida Department of Environmental Protection |
| Artificial Reefs2 (Deployment Events) | Florida Fish and Wildlife Conservation Commission, Division of Marine  Fisheries Management |
| Beach Renourishment Projectsa | Beach Erosion Control Project Monitoring Database, Florida State University |
| Coastal Barrier Resource System3 | National Oceanic Atmospheric Administration, Coastal Service Center |
| Johnson's Seagrass Critical Habitat4 | National Coastal Data Development Center |
| Manatee Critical Habitat | United States Fish and Wildlife Service |
| Mangroves5 | Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute |
| National Estuary Program Areas6 | National Oceanic Atmospheric Administration, Coastal Service Center |
| Nature Conservancy Priority Ecological Resource Areas7 | Florida Natural Areas Inventory |
| Piping Plover Critical Habitata | United States Fish And Wildlife Service |
| Right Whale Critical Habitat8 | Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute |
| Saltmarsh Locations9 | Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute |
| Seagrass10 | Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute |
| Sea Turtle Nesting Sitesa | Florida Fish and Wildlife Conservation Commission |
| State Parks11 | Florida Department of Environmental Protection |
| Watershed Locations Of Rare & Imperiled Fish12 | Florida Fish and Wildlife Conservation Commission |

1 1997 publication date.

1. Need to update with online report.

2 2006 publication date.

3 1998 ground condition.

4 USACE version not complete.

5 1994 ground condition.

6 2006 publication date.

7 1991 ground condition.

8 2002 ground condition.

9 1999 publication date.

10 1999 publication date.

11 2006 publication date.

12 2003 publication date.

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Figure 11. Environmentally Sensitive Areas Along the Northeast Florida Atlantic Coast showing sensitive environments in relation to morphosedimentary mapping units and onshore areas landward of the beach-dune system or in estuaries. (A) Coverage for Nassau, Duval, and St. Johns counties. (B) Coverage for Flagler and Volusia counties. →

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**PREVIOUS BEACH NOURISHMENTS**

Numerous beach nourishments have taken place along the northeast Florida Atlantic coast. The few beach nourishment projects discussed below are but brief summaries of files obtained from the Bureau of Beaches and Coastal Systems (Tallahassee, Florida). Additional information for the beach nourishments in Nassau, Duval and St. Johns counties (five projects) can be obtained from the Florida Department of Environmental Protection’s Beach Erosion Control Project Monitoring Database Information System (<http://beach15.beaches.fsu.edu/>). The summary table developed here for the study area puts the lengths of beach renourishment projects into perspective, relative to length of beachfront and project length (Table 9). Total beach length in the study area (all five counties) amounts to 234,381 m. Flagler and Volusia counties respectively contain 29,182 m and 78,959 m of beachfront, but are not included in Table 9 because no beach renourishment projects were on file in the Beach Erosion Control Project Monitoring Database Information System.

It is interesting to note that about one-quarter of the beach lengths in Nassau and Duval counties has been protected by beach renourishment. The percent of shoreline protected by renourished beaches for the study areas as a whole is rather small, mainly due to the fact that projects are not recorded for the southern-most two counties (Flager and Volusia counties).

Table 9. *Beach nourishment projects along the northeast Florida Atlantic coast in Nassau, Duval, and St. Johns counties in relation to length of county beachfront and percents of total beach length covered.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **County** | **Beach Restoration Project** | **Beach Front (m)1** | **Project Length (m)1** | **% County Beach Front1** | **%**  **Study Area1** |
| Duval | Duval County November 1995 Beach Nourishment | 38,074 | 10,366 | 27.23 | 4.42 |
| Nassau | South Amelia Beach Restoration | 22,024 | 5,801 | 26.34 | 2.48 |
| Nassau | South Amelia Beach Restoration (Maintenance Dredging) | 22,024 | 1,273 | 5.78 | 0.54 |
| Nassau | South Amelia Beach Island Shore Stabilization, Phase 1 - Beach Restoration | 22,024 | 5,679 | 25.79 | 2.42 |
| St. John's | St. John's County Shore Protection | 66,142 | 6,163 | 9.32 | 2.63 |
| **Total** |  |  | **29,281** |  | **12.49** |

**1** Beach and project lengths based on GIS measurements.

**Nassau County - South Amelia Island**

The **South Amelia Beach Restoration** project included about 2,600,000 cy that was placed between R060 and R078 (5801 m shoreline length) in 1994 (Figure 10a, Table 9). The volume density was estimated to be about 153 cy/ft along about 26.34% of county beachfront. The borrow source was located about 3000 to 3900 ft offshore the south end of the project. The **South Amelia Island Design Parameters** project (May to September 1997) took place between R073 and R078 (1273 m). The volume placed was about 300,000 cy giving a volume density of about 67 cy/ft. The borrow source was the Intracoastal Waterway through Nassau Sound. The **South Amelia Island Shore Stabilization, Phase I – Beach Restoration** project (June to September 2002) placed about 1,900,000 cy of fill between R060 and R079.5 (about 5679 m) to give a volume density of about 106 cy/ft. The borrow source was located about 4600 to 11,700 ft offshore the south end of the project.

**Duval County**

In the **Duval County November 1995 Beach Nourishment** project (Figure 10a, Table 9), about 1,187,279 cy of fill were placed (June to November 1995) between R045 to R080 (about 10,366 m shoreline length) along a coastal segment where the alongshore transport rate is estimated to be on the order of 111,000 cy per year to the south. The constructed berm width was 135 ft. The volume density was about 32 cy/ft along about 27% of county beachfront (Table 9).

**St. Johns County**

The St. Johns County Shore Protection project (Figure 10a, Table 9) took place between T132 and R152, from September 2001 through January 2003, along 3.8 miles (6136 m) of beach. The volume placed was about 4,383,000 cy to give a volume density of about 218 cy/ft. The average construction beach width was about 315 ft (construction berm width of about 200 ft). The longshore drift rate is estimated to be between 200,000 and 300,000 cy/yr. The borrow source was the St. Augustine ebb-tidal delta.

**CONCLUSION**

By reformatting reconnaissance NOAA bathymetric data, it was possible to map large areas of seafloor along the central Florida Atlantic coast. Of the total survey area (1,470,718 ha; 14,707 km2), about 409,860 ha (about 28% of the survey area) were designated as ‘Undifferentiated Seafloor’ due to low resolution bathymetric data. The remaining area (1,060,858 ha; 10,609 km2) contained bathymetric grid spacing of sufficient density to identify large-scale seafloor features. These features were classified and mapped to produce a seafloor topology that would provide a basis for estimating sand resources. The unifying mapping principle was based on the shape, form, and spatial distribution patterns of morphologically similar features that could be grouped together in relatively homogeneous patterns. Since the shelf floor is dominated by sedimentary cover, the morphological units were interpreted as morphosedimentary units where form and material composition were indicative of dynamic coastal ocean processes. These morphosedimentary features, which were described in terms of bars, ridge fields, sand flats, sand waves, banks, shoals, and ebb-tidal deltas accounted for about 78.5 billion cubic meters of sediment that have potential as sand resources. Although sand flats are areally extensive and contain large sediment volumes, banks, shoals and ridge fields are also obvious targets for further study. It is recommended that geophysical surveys in federal waters be extended shoreward into state waters to better understand the nature and distribution of the morphosedimentary features that make up sand resource potential on the continental shelf. Additionally, more detailed bathymetric surveys in state and federal waters are required to better estimate spatial distribution patterns of sedimentary bodies that have potential as sand resources for beach nourishment.

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