Geophysical Mapping of Oyster Habitats in a Shallow Estuary; Apalachicola Bay, Florida

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Section 1: Introduction

This report presents high-resolution geophysical data, interpretive maps, and a preliminary discussion about the oyster habitat and estuary-floor geology within Apalachicola Bay, Florida (fig. 1). During two research cruises, conducted in 2005 and 2006, approximately 230 km² of the bay floor were surveyed using interferometric-bathymetry, sidescan-sonar, and chirp seismic-reflection techniques. The research was conducted as part of a cooperative program between the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration Coastal Services Center (CSC), and the Apalachicola Bay National Estuarine Research Reserve. The Apalachicola Bay National Estuarine Research Reserve was established in 1979 to provide opportunities for long-term monitoring and research to provide a basis for more informed coastal management decisions for this estuary.

Apalachicola Bay is the largest oyster fishery in Florida (Whitfield and Beaumariage, 1977), and the primary objective of this program is to develop a suite of maps that define oyster habitat distribution and estuary-floor geology within the bay. The resulting maps will assist in effective management of oyster resources and provide a reference geologic framework for future scientific and applied research.

Section 2: Data Collection and Processing

Survey Platforms

Two survey platforms were used to collect geophysical data in Apalachicola Bay (fig. 2). The *RV Rafael*, a 6.3 m outboard motor propelled vessel with an ~ 1.5 m draft, was used to survey sections of the bay where water depths exceeded 2 m. An Autonomous Surface Vehicle (*ASV*), *IRIS*, was used to survey sections of the bay where water depths were between 0.75 and 2 m. *ASV IRIS* is a 2-m long, battery powered remote vehicle that surveys pre-programmed tracklines. Bathymetric, sidescan-sonar, seismic-reflection, and navigation data were all collected from both platforms.

Bathymetric Data

Aboard the *RV Rafael*, an SEA Submetrix 2000 Series interferometric sonar, operating at a frequency of 234 kHz, was used to collect bathymetric data along survey track lines spaced ~ 100 m apart (fig. 3). The instrument was mounted on a rigid pole at the bow of the vessel, and was deployed 1 m below the water surface. A GPS antenna was mounted on top of the pole over the sonar head to record ship position during the surveys. The interferometric-sonar system has two channels that collect depth data in a continuous swath on both sides of the vessel. The width of the swath was generally 7-10 times the water depth. For example, in water depths of 3 m, the interferometric sonar can achieve a 15 m range to each side of the ship's track, or 30 m total swath width. Within Apalachicola Bay, swath widths were generally between 20 and 40 m.

Single-beam bathymetry was derived from chirp, seismic-reflection profiles collected by *ASV IRIS* along track lines that were spaced ~ 75 m apart (fig. 3). The bay floor along each chirp profile was digitized and sampled at 50 shot intervals, or approximately every 3-5 m along the survey track, depending on vessel speed. Depths were digitized in two-way travel times and converted to depths in meters using a velocity of sound in water of 1500 m/s, and exported as XYZ soundings.

On both vessels, motion (heave, pitch, roll, and yaw) was recorded with a TSS DMS 2-05 Attitude Sensor. Aboard the *RV Rafael*, the sensor was mounted immediately above the SEA Submetrix 2000 Series transducers, and on *ASV IRIS* it was mounted on the mast at the center of the vessel. Navigation was recorded using Real Time Kinematic Differential Global Positioning System (RTK-DGPS). The interferometric sonar is an angle-measuring system; depth accuracy decreases with increasing horizontal range. The combined angular accuracy of the SEA Submetrix 2000 Series and the TSS DMS 2-05 attitude sensor is documented as 0.1 degrees. Assuming constant angular accuracy, and using the International Hydrographic Organization (IHO, http://www.iho.shom.fr/) standard requirement of 0.3 m accuracy in < 30 m water depth, all data collected during the two surveys fall within the IHO accuracy standards. However, vertical accuracy is also directly affected by the accuracy of navigation data and tidal measurements. RTK-DGPS vertical accuracy is assumed to be 0.05 to 0.1 m.

The real-time RTK setup included a reference base station on St. George Island and a radio repeater on the highest section of the Bryan Patton Bridge to ensure complete area coverage. The GPS reference station was established on St. George Island using a 3 day average of positions from six 12 hour datasets. The positions were calculated for these datasets using the Online Position Service (OPUS) provided by the National Geodetic Service (http://www.ngs.noaa.gov/OPUS/What_is_OPUS.html). The GPS-RTK vertical was calibrated to the tidal benchmark MLLW at the Apalachicola River Station ID 8728690.

Seamless bathymetric coverage for the entire survey area was not feasible, due to the bay's relatively shallow nature and time constraints. Instead, survey lines were designed to provide 100% coverage with sidescan-sonar data, but using the wider swath of the sidescan-sonar coverage resulted in gaps between adjacent interferometric bathymetry swaths. Data gap widths varied as a function of water depth. In the deepest portion of the survey area, near West Pass, data gaps were 10-20 m, and in the shallowest section, south of the town of Apalachicola, data gaps were ~ 80 m (fig. 3). Swath data were processed and gridded using Linux-based SwathEd software (UNB, 2005). The bathymetric data have a vertical resolution of approximately 1% of water depth. The final swath bathymetric grid was produced using a 2 m/pixel resolution, and delivered as a GeoTIFF raster image.

Swath and single-beam bathymetric data were used as inputs for a regional bathymetric model that provided 100% coverage of the area through interpolation (fig. 4 and Mapsheet 1). Production of the model required three processing steps. First, a Triangulated Irregular Network (TIN) model was generated using the track-line swath (5 m cell size, including interline gaps), and single-beam (derived from *ASV IRIS* seismic-reflection profiles) bathymetric data. Second, the TIN model was converted to a 25 m cell-size raster grid using the Natural Neighbors method. Finally, a low-pass, 3 x 3 filter was applied to smooth irregular features within the 25 m grid. Complete details of these methods are described in the raster metadata in Section 5.

Sidescan-Sonar Imagery

Acoustic backscatter data were collected using two sidescan-sonar systems. A Klein 3000 dual-frequency (100/400 kHz) sidescan sonar was deployed from *RV Rafael*, and towed alongside the vessel ~ 1 m below the surface. Track lines were spaced 100-125 m apart, and the sidescan swath was 75-100 m to each side of the track. *ASV IRIS* collected backscatter data with an Edgetech 4200FS sidescan sonar. The sidescan transducers were mounted on a metal frame between the two pontoons ~ 0.5 m below the sea surface. The sidescan was set to image 50 m to each side of the track lines.

Backscatter intensity, as recorded with sidescan sonar, is an acoustic measure of variations in the physical properties of the sea floor (fig. 5 and Mapsheet 2). Sidescan-sonar imagery was processed such that high backscatter (relatively strong acoustic returns) is represented by white, and low backscatter (relatively weak acoustic returns) is represented by black. In Apalachicola Bay, backscatter variability is generally caused by sea-floor roughness. Due to the low incidence angles associated with towed systems, topographic highs and lows can be interpreted based on acoustic shadows.

All sidescan-sonar data were acquired using Triton-Elics ISIS acquisition software, and were processed using LINUX-based Xsonar/Showimage (Danforth 1997) to sub-sample the data to 8-bit imagery, correct slant-range and beam-angle distortions, and remove striped noise. Sonar data from each survey line were mapped in geographic space with Xsonar, using a 1-m pixel resolution, then imported as raw image files to PCI Geomatics GCPworks (PCI Geomatica version 8.2), where they were combined to create composite mosaics (Paskevich, 1996). The mosaic was exported as a GeoTIFF raster image for further analysis in ArcGIS (ESRI, Inc).

Both 100 and 400 kHz data were collected with each sidescan-sonar system, but 100 kHz data were used for the final 1-m mosaic covering the main portion of the bay, surveyed by *RV Rafael*, because the lower frequency data contained less acoustic noise. The data collected from *R/V Rafael* is distributed in 3 images, separated by field season and variations in acquisition parameters. *ASV IRIS* acquired 15 survey days of backscatter data over the shallowest sections of the Bay, including known oyster bars (fig. 3). Mosaics of these data are distributed in 13 images, due to substantial geographic separation. The backscatter data collected with the *ASV IRIS* were processed using the same methods as the data collected from the *RV Rafael*, except the high frequency data (400 kHz) data were used and were mosaiced to a range of 20-30 meters to remove the noise in the far range of the data.

Seismic-Reflection Data

High-resolution, seismic-reflection profiles were collected from both the *R/V Rafael* and *ASV IRIS* along 2,372 km of track line, which were spaced ~ 75 - 100 m apart (fig. 3). During the first seven survey days of the 2005 cruise aboard the *R/V Rafael* (Julian Days 76-83), seismic data were acquired using a Knudsen 320b chirp system (3.5-12 kHz). The remaining seismic data, collected from both survey vessels during 2005 and 2006, were acquired using Edgetech FSSB 424 (4-24 kHz) systems. The Knudsen was used initially because of easier side-mount deployment from *R/V Rafael* in shallow water environments. However, profile comparisons showed that the Edgetech FSSB-424 provided higher-quality data, so it was used throughout the subsequent survey periods. The seismic data from the *R/V Rafael* were acquired as SEG-Y files using Delph Seismic+ in 2005 and SBLogger in 2006. On *ASV IRIS* they were acquired as .jsf using jstar, and then converted to SEG-Y. All seismic data were processed using SIOSEIS (http://sioseis.ucsd.edu/) and Seismic Un*x (http://www.cwp.mines.edu/cwpcodes/) to produce jpg images of each of the seismic profiles.

Section 3: Preliminary Geologic Interpretation

Setting

Apalachicola Bay is a large estuary located along the coast of the Florida panhandle between Tallahassee and Pensacola (fig. 1). It is approximately 65 km long and 5.5 to 12 km wide, except at its western end, where it narrows to less than 2 km. The estuary is shallow, having a mean depth of 2 to 2.4 m. It is divided into four provinces: St. George Sound, Apalachicola Bay, East Bay, and St. Vincent Sound (fig. 1). The western end and southern side of the estuary are shielded from the open Gulf of Mexico by a string of barrier islands: Dog Island, St. George Island, Little St. George Island, and St. Vincent Island. The eastern end of the estuary is open to the Gulf of Mexico. Salt water exchange occurs at its eastern end and through four inlets: East Pass, between Dog and St. George Islands, Government Cut, between St. George and Little St. George Islands, West Pass, between Little St. George and St. Vincent Islands, and Indian Pass, at the western end of St. Vincent Island.

The Apalachicola River delivers freshwater to this estuary where it enters through East Bay. It is the largest river in the state of Florida (Leitman and others, 1983), and its drainage basin includes large parts of eastern Alabama and western Georgia. Its headwaters are in northern Georgia (fig. 1).

The Quaternary geology of the Apalachicola Bay region records several dramatic changes in sea level that were caused by periodic glacial retreat and advance (Riggs, 1980). During glacial periods, when sea level was low, the Apalachicola River incised channels across the present coastal and inner-shelf region (Donoghue, 1993), building deltas on the middle and outer shelf (McKeown and others, 2004; Gardner and others, 2005). During interglacial periods, sea level rose and the paleo-river channels were filled with deltaic and estuarine deposits (Schnable and Goodell, 1968). The present Apalachicola Bay estuary appears to have formed starting 3,000 to 4,000 years ago with the formation of the barrier islands that rim the bay (Stapor, 1975; Donoghue and White, 1995). After the initial formation of the barrier islands, sea level continued to rise, and the delta continued to retreat (Donoghue and White, 1995). Fine-grained prodelta sediment accumulated beyond the delta front, but largely within the bay, with little escaping to offshore regions (Bedosky, 1987). It is in this estuarine setting that oysters thrive.

Estuary-Floor Morphology

Apalachicola Bay is a broad shallow estuary that contains four subareas: East Bay, St. Vincent Sound, Apalachicola Bay, and St. George Sound (fig. 4). Navigation charts (NOAA, 1996; 2000) show that East Bay, the area adjacent to the Apalachicola River delta, is the shallowest part of the estuary, having no depths greater than 2 m. Much of St. Vincent Sound is also less than 2 m deep, but a narrow 5-7 m deep trough extends approximately 6 km eastward from Indian Pass. The data collected during this survey cover the Apalachicola Bay and St. George Sound sections of the estuary, which are its deepest parts. No data were collected in East Bay or St. Vincent Sound. Within these areas, the estuary has a generally smooth floor that increases in depth southward from 2 m in the north to 4 m in the south (fig. 4 and Mapsheet1). Depths locally exceed 15 m on the shoreward side of West Pass. St. George Sound is the deepest part of the estuary, and much of its floor is smooth, with depths of 3 to 4m. Depths increase to 4 - 6 m in the eastern part of this sound, where the sea floor is more irregular and shaped into a series of broad, low-relief depressions and mounds.

Deviations from the smooth, regional, bathymetric pattern are caused by three forms of shoals: shore-attached lobate shoals, linear shoals, and small shoals. Shoal locations and names, identified by the Apalachicola Bay National Estuarine Research Reserve, or from NOAA navigation charts (NOAA, 1996; 2000), are shown on figure 6. Lobe-shaped shoals extend northward from St. George and Little St. George Islands into the southern side of the bay. The largest are Pelican Bar, in St. George Sound, and Cedar Point and Higgins Shoals, in Apalachicola Bay. Higgins Shoal is located shoreward of a former inlet on Little St. George Island that was open in 1860 (fig. 7). It appears to be the remnant of a flood-tidal delta that formed while the inlet was active. The other lobate shoals, located along the north side of the islands, may have also originated in flood-tidal delta settings.

Linear shoals exceeding 4 km in length are found in St. George Sound and Apalachicola Bay (fig. 6). All of these shoals trend roughly perpendicular to the long axis of the bay, and four of the six have one end attached to the shore. The largest, St. Vincent Bar, is located at the western end of Apalachicola Bay. It extends southeastward from the northeastern tip of St. Vincent Island to within 1.5 km of Little St. George Island. A deep channel extends eastward from West Pass, separating the southern tip of St. Vincent Bar from Little St. George Island (fig. 4). The bar is 7 km long, 0.7 - 1.3 km wide, and rises to within 0.5 - 1 m of the bay surface.

Other large linear shoals include Norman's Bar, which is separated from Hotel Bar by the Intracoastal Waterway, Cat Point Bar, East Hole Bar, Platform Bar, and Porter's Bar. Cat Point Bar extends southeastward from the eastern side of Cat Point and connects with Platform Bar. East Hole Bar extends northwest from St. George Island and merges with Cat Point Bar (fig. 6). This complex of bars forms a nearly continuous string of shoals across the bay that is only broken by two narrow, deeper gaps. The channel between Pelican and Platform Bars exceeds 6 m depth. The channel that separates Cat Point Bar from East Hole Bar was not completely surveyed by this study, but, where surveyed, the channel reaches 4.9 m immediately west of the Bryan Patton Bridge at its northwestern end and 3.2 m at its southeastern end near Platform Bar. The navigation chart shows that the section not surveyed by this study reaches depths between 1.5 and 2 m (NOAA, 1996). The Intracoastal Waterway is dredged through East Hole Bar to depths exceeding 4 m (fig. 8). The easternmost of the large linear shoals is Porter's Bar, which extends from the northern shore of St. George Sound southeastward for 4 km. The crests of the linear shoals rise to within 1 m of the bay surface, with the exception of Norman's Bar, whose crest is 2 - 2.5 m deep. The linear shoals are unique because they are asymmetrical, with steeper, west-facing sides (fig. 9).

The small shoals are less than 1.5 km in length, are isolated from the shoreline, and have a variety of orientations (fig. 6). One cluster of these shoals, located east of St. Vincent Bar, includes Cable Lumps, North Spur, Sugar Lumps, and West Lumps. A second cluster lies south of the John Gorrie Bridge. It includes a discontinuous string of linear to circular mounds that lie immediately north of Norman's Bar, and the East Lumps. Two small shoals, Green Point Bar and an unnamed shoal, are found east of Porter's Bar.

The small shoals have varied orientations. In the eastern part of St. George Sound, Green Point Bar and the unnamed shoal trend northwest-southeast, while shoals north of Norman's Bar trend north-south, and shoals in the western part of Apalachicola Bay, West, Cable, Sugar Lumps, and North Spur, display no dominant orientation. These smaller shoals have less relief than the large linear shoals, and their crests are generally deeper than 2 m. Most of the small shoals are asymmetrical, with steeper, west-facing sides (fig. 9), but several symmetrical shoals lie in the central part of Apalachicola Bay, between Norman's Bar and the John Gorrie Bridge.

A pronounced, anthropogenic feature of the bay floor is the Intracoastal Waterway. This dredged channel starts near the eastern edge of the survey area, weaves around the shoals in St. George Sound, cuts across East Hole Bar, and extends westward to the central part of Apalachicola Bay, where it turns north and leads to the mouth of the Apalachicola River (fig. 4). The channel is 3 - 5 m deep along much of its length, and dredge spoils have been deposited along its southern side, and is clearly visible on figure 6. Along some sections of the channel, the spoils form a continuous ridge with a crest as shallow as 1.7 m, while in other areas, they form discrete, circular mounds that are less than 200 m in diameter with crests 1.9 - 3.5 m deep (fig. 8).

Subsurface Geology

The late Pleistocene and Holocene history of the northern Florida shelf region has been generally described by Schnable and Goodell (1968); Schmidt (1984); Otvos (1985); Donoghue (1992; 1993); Donoghue and White (1995); McKeown and others (2004); Gardner and others (2005). The dense grid of chirp profiles collected during this survey provides a refined view of Apalachicola Bay's Holocene history specifically. Facies interpreted from the seismic-reflection profiles are shown in figure 11, their regional distribution is shown in figure 12, and the profile locations are shown in figure 13. A conceptual model showing the evolution of the bay since the last lowstand of sea level is shown in figure 14. During several Pleistocene lowstands of sea level, the ancestral Apalachicola River incised a large valley southward across the region, depositing a series of well-developed deltas on the middle and outer shelf, south of the present location of the estuary (fig. 14A). This valley was cut to depths of approximately 15 m (20 ms) into Pleistocene and earlier sediments beneath the bay (Donoghue, 1992; fig. 12). As sea level rose during the Holocene, the section of the valley underlying the outer shelf was filled during the Early Holocene, and the section underlying Apalachicola Bay was filled by the Middle-to-Late Holocene (fig. 14B). The acoustic facies filling the valley are as much as 8m (13 ms) thick and consist of parallel continuous reflections (fig. 11). These deposits are interpreted to be fine-grained, estuarine deposits. A well-defined horizon, interpreted to be the flooding surface associated with submergence of the bay during the late Holocene (fig. 14B), marks the top of this acoustically laminated facies (fig. 11). Under much of the bay, this horizon can be traced away from the paleo-river valley onto adjacent, subsurface, topographic highs (fig. 12).

In the western part of St. George Sound and most of Apalachicola Bay, east of St. Vincent Bar, the flooding surface is buried by younger sediment delivered by the Apalachicola River. Chirp profiles show that the youngest deposits in the bay compose a delta system that is overlain by modern prodelta mud that continues to be supplied by the Apalachicola River (fig. 12). The delta system developed in the central part of the bay (fig. 14C) comprises sandy delta lobe facies with muddy prodelta deposits between and beyond the sandy lobes. The sandy parts of this delta system produce a highly-reflective, irregular surface in the chirp profiles, which stands in relief, relative to the surrounding muddy deposits, displaying a weakly-reflective, smooth surface (fig. 11). The shallow, sandy parts of the delta are organized into several fingers that protrude into the bay (fig. 14C). The tops of most of these fingers are less than 4 m below present sea level, while the adjacent lows are 4 - 5 m deep. The distribution of the shallow ridges in the seismic dataset suggests they represent two sets of delta lobes that advanced into the estuary. One set underlies the western part of Apalachicola Bay covering the area under and immediately east of St. Vincent Bar, and the second underlies the eastern part of the Bay under and east of Norman's Bar (fig. 12A, B). The two sets of delta lobes suggest two separate deltas. Donoghue and White (1995) report that the Apalachicola River shifted its course approximately 6,000 years ago. Initially, the river drained into the estuary west of the present town of Apalachicola, and then shifted eastward to its present course. Perhaps the two delta complexes were deposited before, and after the eastward shift documented by Donoghue and White (1995).

The youngest unit is the modern, prodelta mud that overlies the mid-to-late Holocene delta and prodelta deposits. Its surface is the present estuary floor (fig. 11). This unit is as much as to 2.5 m thick adjacent to the mouth of the Apalachicola River, but thins to the east and west where it onlaps and locally buries the older delta deposits (fig. 12). Along the southern edge of the bay it onlaps the back of the barrier island system (fig. 12C). The areal extent of this unit is the same as the mud unit identified in the sidescan-sonar imagery, and it is interpreted to be prodelta mud deposits associated with the modern Apalachicola River system (fig. 14D).

Geologic Controls on Oyster Bed Distribution

The stratigraphic evolution of Apalachicola Bay has heavily influenced the present distribution of oyster bars in the estuary. Oyster beds in the Apalachicola Bay part of the estuary rest mainly on late Holocene delta deposits (fig. 14D and fig. 15). Small beds also occur on late Holocene flood-tidal delta deposits and anthropogenic deposits of dredged material along the Intracoastal Waterway (fig. 10). The seismic profiles show that the oyster beds consistently sit on high-amplitude reflections and are absent in areas where only low amplitude reflections are present. This relationship suggests that the surfaces colonized by the oysters were sandier than the surrounding sea floor. The bathymetry and present distribution of oyster beds, as defined by the sidescan-sonar imagery, suggest that some sections of the delta surfaces were colonized and grew vertically, while other sections were either never colonized, or were abandoned at a later time because of burial by prodelta muds (fig. 15B). Sediment cores will be required to determine if oyster beds in the Apalachicola Bay part of the estuary initially had a broader aerial extent that has receded with time.

In the St. George Sound part of the estuary, oysters have colonized abandoned flood tidal deltas that extend into the bay along the northern edge of St. George Island, linear ridges of uncertain origin that rest on Pleistocene sands, and mounds of dredged material (fig. 10). Sand waves cover some of the broad shoals in the eastern part of the Sound, which is well removed from the muddy, prodelta deposits, suggesting that tidal and storm generated currents are strong enough to sculpt the sandy estuary floor (fig. 10, and fig. 15C). Through sand wave migration, larger shoals are generated, and where salinity is appropriate, these shoals can be colonized by oysters. Green and Porter's Bars may be shoals that were formed by sand wave migration then stabilized when oysters colonized the tops.

Summary

Apalachicola Bay is the largest oyster fishery in Florida, and an updated map of oyster bed distribution was needed for the continued management of this resource. Because of the large size of the study area (35 km long by 8 km wide), and high turbidity of the bay waters, acoustic mapping tools were employed. Sidescan sonar, interferometric bathymetry, single-beam bathymetry, and chirp seismic-reflection systems allowed for detailed mapping of oyster bed locations and extents as well as defining their relationship to the morphology of the bay floor and underlying geologic features. Analysis of the resulting datasets has revealed strong relations between the stratigraphic and morphologic evolution of the estuary and the locations and extents of the oyster beds. Integration of the sidescan-sonar imagery and the bathymetric data shows that all oyster beds occur on shoals that stand in relief relative to the surrounding bay floor, but not all shoals are colonized by oyster beds. Seismic-reflection data show that many oyster beds developed on older deltaic deposits underlying the bay. While a variety of conditions influence oyster distribution in the bay, this study demonstrates that the underlying geology, particularly what appear to be late Holocene delta systems, has significant control over oyster distribution by providing appropriate habitat for their growth.

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Section 5: Maps

Three large-format mapsheets (1:30,000) illustrate the bathymetry, sidescan-sonar backscatter, and surficial geology of the Apalachicola Bay and St. George Sound survey areas. These mapsheets are distributed as Adobe portable document format (PDF) files that can be printed out on a large format plotter at 45 x 32 inches (http://pubs.usgs.gov/of/2006/1381/html/maps.htm).

Mapsheet 1. Bathymetry, presents a regional bathymetric model for the area using a 25-m grid cell resolution.

Mapsheet 2. Sidescan-sonar backscatter, shows distribution of backscatter values over the survey area.

Mapsheet 3. Surficial Geology, shows the interpreted surficial geology with the locations of oyster bars draped over sun-illuminated bathymetry.

Spatial Data

This appendix describes the data collected for this project, where they are located, and how to access them depending on the software you have. The primary data format for vector data are personal geodatabase feature classes in the Universal Transverse Mercator (UTM) coordinate system, Zone 16. As a secondary format for users without access to ArcGIS 9.0, all feature classes in the geodatabase are also delivered as individual shapefiles in Geographic projection. The primary format for distribution of raster data are ESRI raster and GeoTIFF. All spatial data are distributed with FGDC compliant metadata.

The organization and schema of data in the geodatabase is based on the ArcMarine data model developed by the ArcMarine Working Group (http://dusk2.geo.orst.edu/djl/arcgis/). Some of the feature classes in the geodatabase are linked to tables through relationship classes that maintain data integrity and establish joins between spatial data and a table objects. These relationships are established as a basis for joins so the user can easily see which features are related to which tables (see fig. 16). The relationships tab in the feature class properties also displays which table objects are related to the feature. The figure below (fig. 17) illustrates that the SurveyLines feature class participates in three different relationships that can be used as joins.

These relationship classes can also be used as a basis for a select query. For example the SurveyLines feature class has tracklines from two different surveys (05001 and 06001), and two different MeasuringDevices (swath bathymetry and sidescan-sonar). If a user wants to see what survey an individual surveyline is from using the inquire tool, the identify popup box automatically shows that line l202f1 was collected during 05001 (fig. 18). This is the information stored in the SurveyInfo table that is linked by a relationship class to the Surveylines feature class.

You can also use these attributes in a definition query to display only features with certain attributes. For example, a user might want to display only the bathymetric surveylines from the survey rafa05001 (SurveyID = 1). Using the Definition Query tab in the feature class properties, you can build a query based on SurveyID attribute (fig. 19).

The general organization of spatial data on this DVD is listed below.

GIS- parent folder for all spatial data

OFR_1381.mxd- ArcGIS 9.2 map document with all data loaded in the table of contents.

OFR_1381.pmf- ArcReader map document for use with free ArcReader Software. You can download Arcreader free of charge on the WWW at http://www.esri.com/software/arcgis/arcreader/index.html

Apalachicola.apr- Arcview 3.3 project file.

USGS_ApalachicolaFL.mdb- ArcGIS 9.2 personal geodatabase with all vector data stored in feature class format. See data catalog below for more information.

RASTER- folder containing all raster data in ESRI grid or GeoTIFF Formats.

ASV- Sidescan backscatter data collected by *ASV IRIS* in GEOTiff Format

ASV_SEISIMAG- Seismic profile images in jpg format collected by *ASV IRIS*. These are not hyperlinked to ASV tracklines in the ArcMap document OFR1381.mxd. A user can move these jpgs into the /GIS/Seisimag directory to use the relative path feature for hyperlinks in ArcMap.

BATH- Raster bathymetry ESRI grid and GeoTIFF Formats.

SEISIMAG- Seismic profile images in jpg format collected from *R/V Rafael* They are hyperlinked to the seismic tracklines in the ArcMap document OFR_1381.mxd distributed with this OFR.

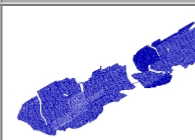
SIDESCAN- Sidescan-sonar backscatter mosaics of collected by *R/V Rafael* in GeoTIFF format.

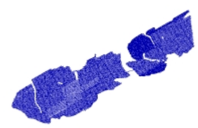
SHAPEFILES- Individual shapefiles of feature classes stored in the geodatabase for users without ArcGIS. Shapefiles are in geographic projection.

THUMBNAILS- Small "thumbnail" graphic of each data layer linked to the metadata.

Data Catalog

Vector Data- The vector data are stored and delivered together in single personal geodatabase. A user with ArcGIS 9.1 or higher can download the single zip file below and access all the vector data and associated metadata. A user without ArcGIS 9.1 or higher can access the layers stored in the personal geodatabase as individual shapefiles in geographic coordinate system.

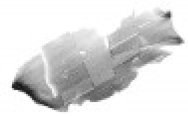
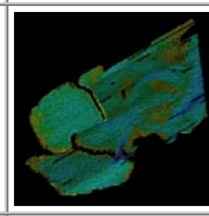
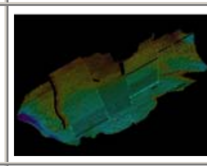
Layer (metadata)	Description	View	Download
USGS_ApalachicolaFL.mdb	**ARCGIS 9.2 personal geodatabase including all layers below and FGDC metadata in xml format.**		**Geodatabase**
SurveyLines	Vessel navigation from *R/V Rafael* representing actual tracklines along which bathymetry and sidescan were collected		Geodatabase Shapefile

SurficialGeology	Interpreted bottom type		Geodatabase Shapefile
Basemap			
ApalachicolaBaseMap	Basemap data of land features		*Geodatabase Shapefile*
Seismics			
ASV_SeismicLines	*ASV IRIS* survey lines hyperlinked to seismic profile image		Geodatabase Shapefile
ASV_SeismicShot500	*ASV IRIS* seismic shot navigation at 500 shot intervals		Geodatabase Shapefile
SeismicLines	*R/V Rafael* survey lines hyperlinked to seismic profile image		Geodatabase Shapefile
SeismicShot500	*R/V Rafael* seismic shot navigation at 500 shot intervals		Geodatabase Shapefile

Raster Data-

The raster data are stored and delivered outside and separate from the personal geodatabase in either GeoTIFF or ESRI Grid format. All raster data are in the UTM Coordinate system. Four raster data layers are available in geographic coordinates system denoted by the "_geog.zip" in the download column.

Layer (metadata)	Description	View	Download
Bathymetry			
St. George Sound -Swath Bathymetry	2 meter resolution bathymetry in ESRI Grid format		stg2mbath.zip

Apalachicola Bay- Swath Bathymetry	2 meter resolution bathymetry in ESRI Grid format		apbay2mbath.zip
St. George Sound-Swath Bathymetry	2 meter resolution hillshaded color bathymetry in GeoTIFF format		StGSnd2m_Bath.zip
Apalachicola Bay- Swath Bathymetry	2 meter resolution hillshaded color bathymetry in GeoTIFF format		ApBay2m_Bath.zip
Bathymetric Model	25 meter resolution bathymetric model of Apalachicola Bay and St. George Sound in Geo TIFF format		apbaybath25m.zip
Bathymetric Model Hillshade	Gray-scale hillshade of 25 meter resolution bathymetric model of Apalachicola Bay and St. George Sound in GeoTIFF format		UTM Z16 apbay25hs.zip Geographic apbayhs_geog.zip
Backscatter			
Apalachicola Bay Sidescan-Sonar Mosaic	1 meter sidescan-sonar mosaic of Apalachicola Bay in GeoTIFF format		URM Z16 ApBayMos1m.zip Geographic ABMos_geog.zip
St. George Sound Sidescan-Sonar Mosaic	1 meter sidescan-sonar mosaic of St. George Sound in GeoTIFF format		UTM 16 StGSndMos1m.zip Geographic SGSMos1m_geog.zip
St. George Sound Sidescan-Sonar Mosaic (Julian Day 098)	1 meter sidescan-sonar mosaic of St. George Sound (Julian Day 098) in GeoTIFF format		UTM Z16 StGSndJD0981m.zip Geographic SGSjd98_geog.zip
ASV Backscatter			
ASV Backscatter Julian Day 154	1 meter sidescan-sonar mosaic from ASV IRIS collected in JD154 in GeoTIFF format		asv154.zip

ASV Backscatter Julian Day 157	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD157 in GeoTIFF format		asv157.zip
ASV Backscatter Julian Day 158	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD158 in GeoTIFF format		asv158.zip
ASV Backscatter Julian Day 160	1 meter sidescan-sonar mosaic from ASV IRIS collected in JD160 in GeoTIFF format		asv160.zip
ASV Backscatter Julian Day 162	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD162 in GeoTIFF format		asv162.zip
ASV Backscatter Julian Day 165	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD165 in GeoTIFF format		asv165.zip
ASV Backscatter Julian Day 172	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD172 in GeoTIFF format		asv172.zip
ASV Backscatter Julian Day 173	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD173 in GeoTIFF format		asv173.zip
ASV Backscatter Julian Day 174	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD174 in GeoTIFF format		asv174.zip
ASV Backscatter Julian Day 175	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD175 in GeoTIFF format		asv175.zip
ASV Backscatter Julian Day 176	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD176 in GeoTIFF format		asv176.zip

ASV Backscatter Julian Day 177	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD177 in GeoTIFF format		asv177.zip
ASV Backscatter Julian Day 178	1 meter sidescan-sonar mosaic from *ASV IRIS* collected in JD178 in GeoTIFF format		asv178.zip

To hyperlink these seismic image profiles with the seismic tracklines use the "Image Title" attribute in the feature class to use as the hyperlink field.

Layer (metadata)	View	Download
Seismic JPEGS		
Seismic Reflection Profiles		seisimag.zip
ASV Seismic Reflection Profiles		asv_seisimag.zip

Acknowledgments

Funding for this project was provided by the NOAA Coastal Services Center (CSC). We wish to thank Linda Rowe and Pace Wilbur of NOAA CSC for their assistance in the early stages of the project. In addition, we also acknowledge the interest, support, and assistance of Mark Finkbeiner, also of NOAA CSC, during the later stages of the project. Survey work was conducted by the following personnel from the USGS Sea-Floor Mapping Group in Woods Hole; Barry Irwin, Chuck Worley, Bill Danforth, Jane Denny, Tom O'Brien, and Emile Bergeron. Additional vessel support was provided by the crew at Florida DEP in Apalachicola, Florida, including Lauren Levi, Jenna Wanat, Megan Lamb, and Stephanie Fahrny. This report benefited from reviews by Kathy Scanlon, Wayne Baldwin, and Valerie Paskevich.

Figures 1-19

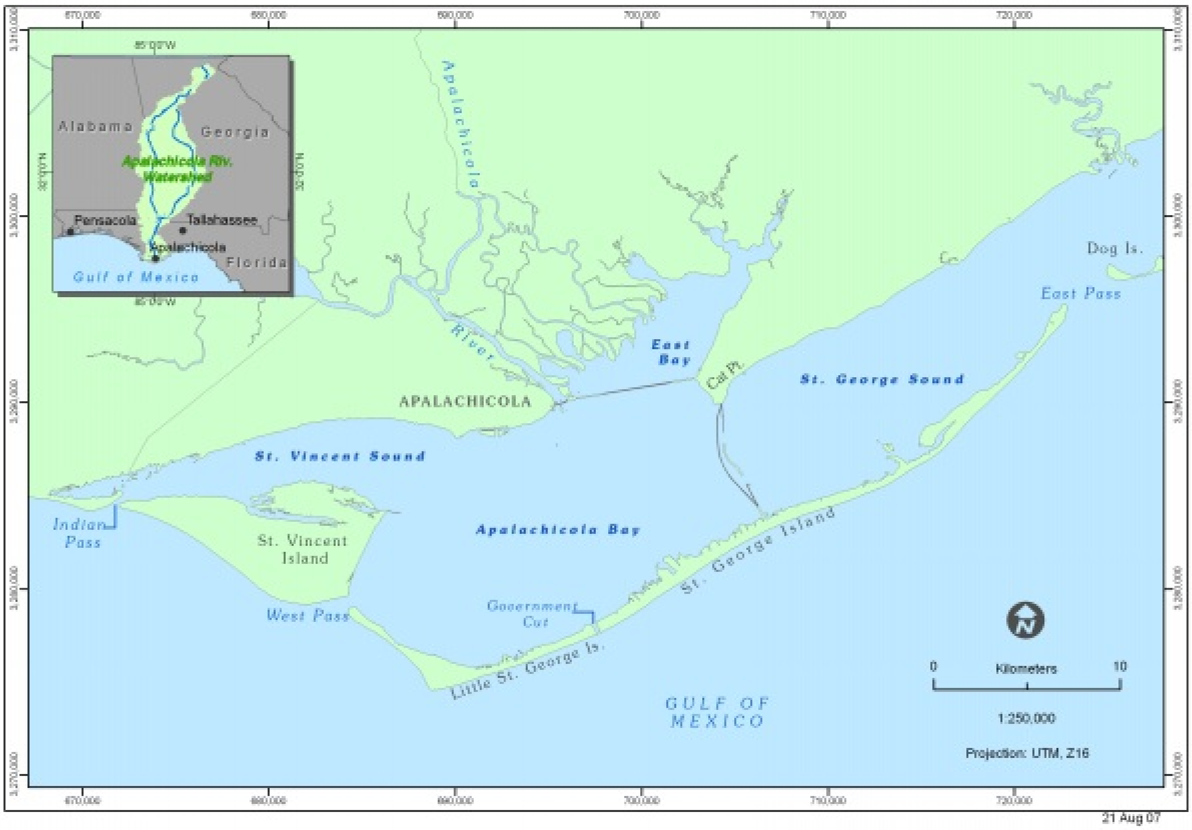


Figure 1. Map of Apalachicola Bay identifying regional geographic locations, physiographic features, and water bodies. Inset illustrates the location of the bay within the southeastern United States.

R/V Rafael

ASV IRIS

Figure 2. Photographs of the survey platforms used in this study: *R/V Rafael* and *Autonomous Surface Vehicle IRIS*.

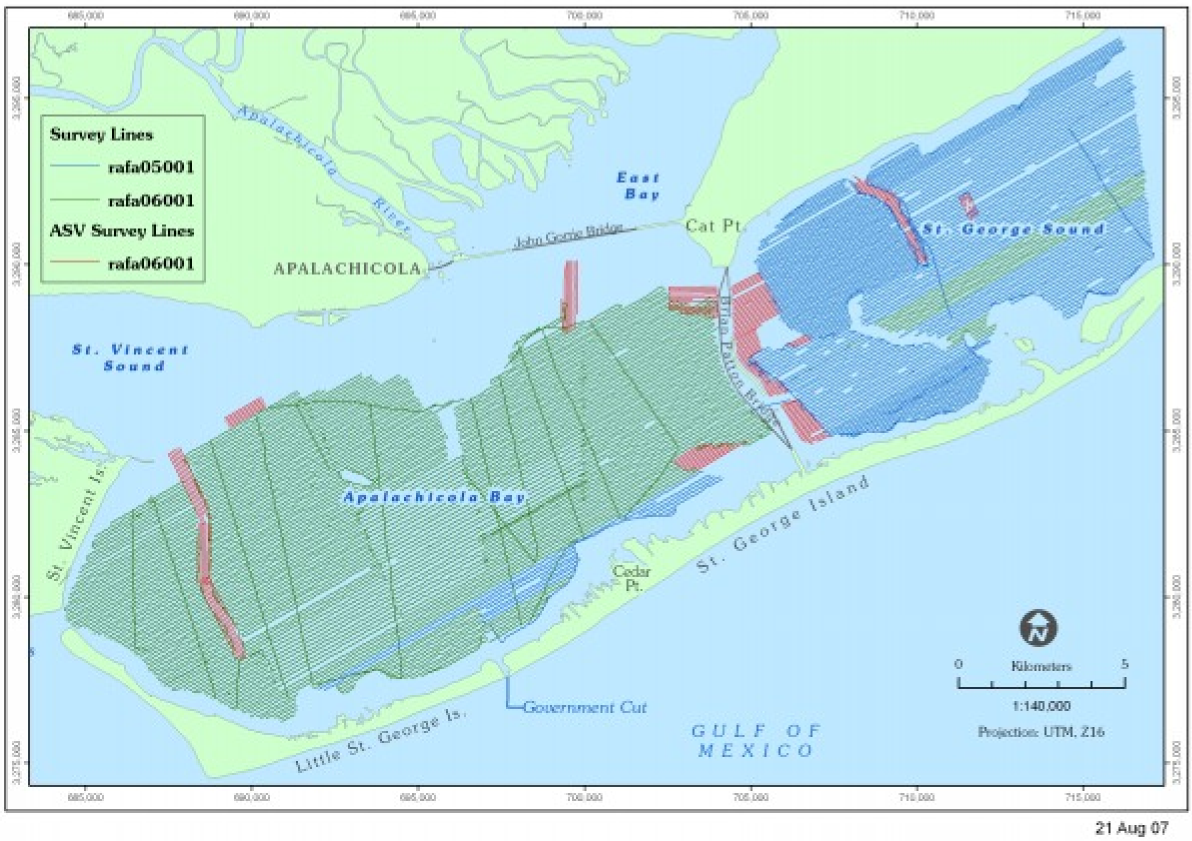


Figure 3. Map showing geophysical track lines occupied by *R/V Rafael* and *Autonomous Surface Vehicle IRIS* during survey cruises in 2005 and 2006.

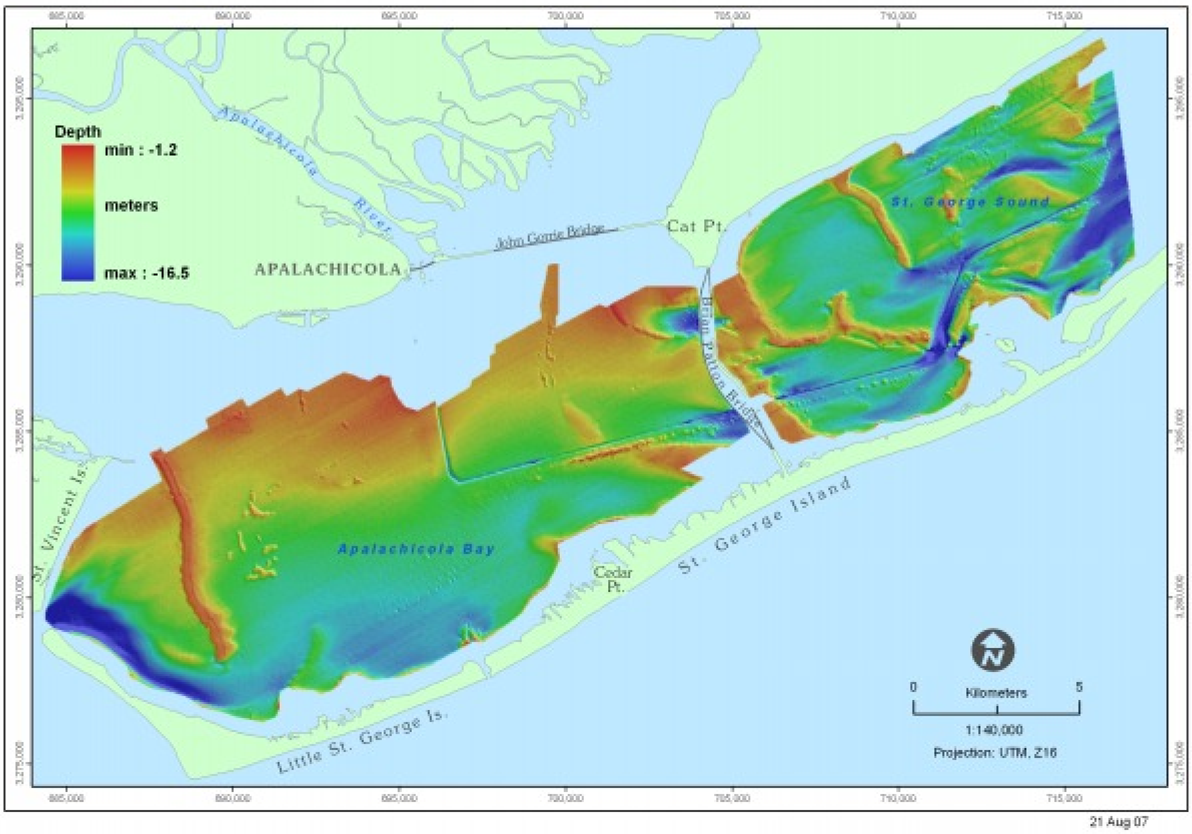


Figure 4. Bathymetric map of the Apalachicola Bay estuary. See also Mapsheet 1

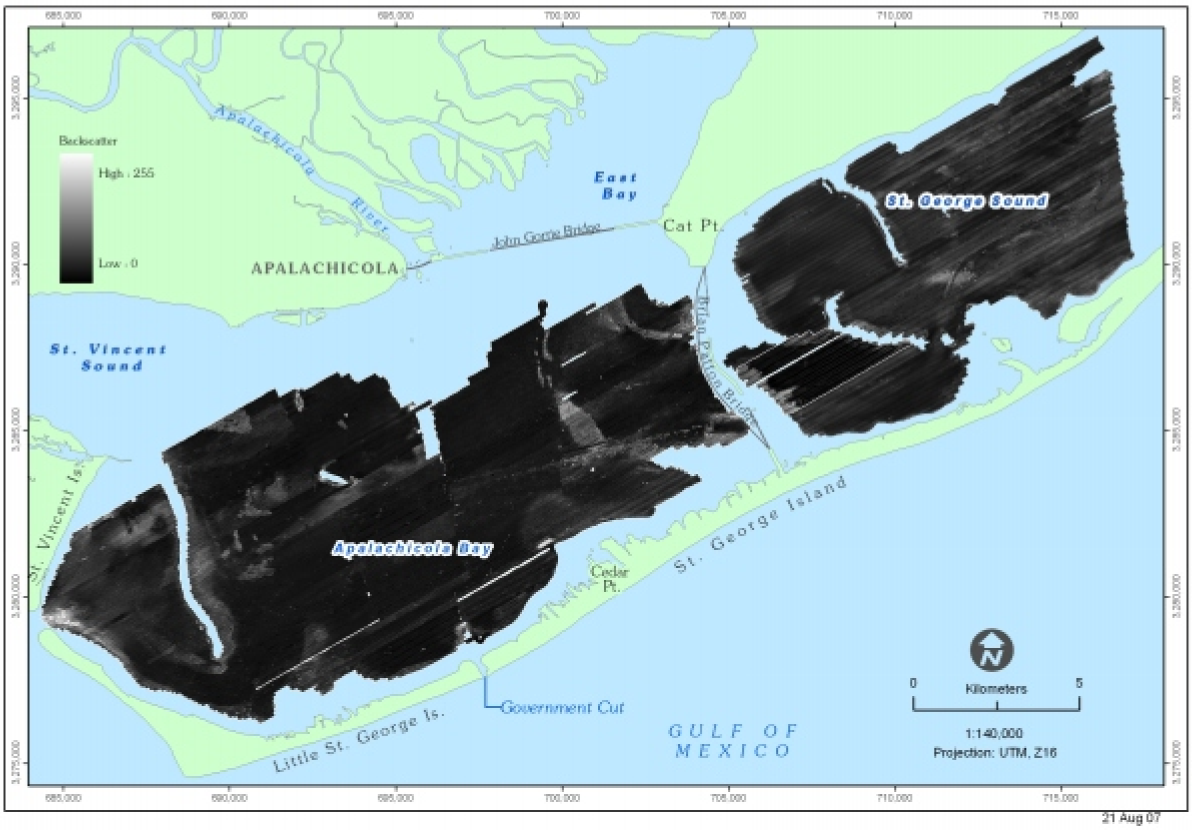


Figure 5. Sidescan-sonar image of the Apalachicola Bay estuary. See also Mapsheet 2*.*

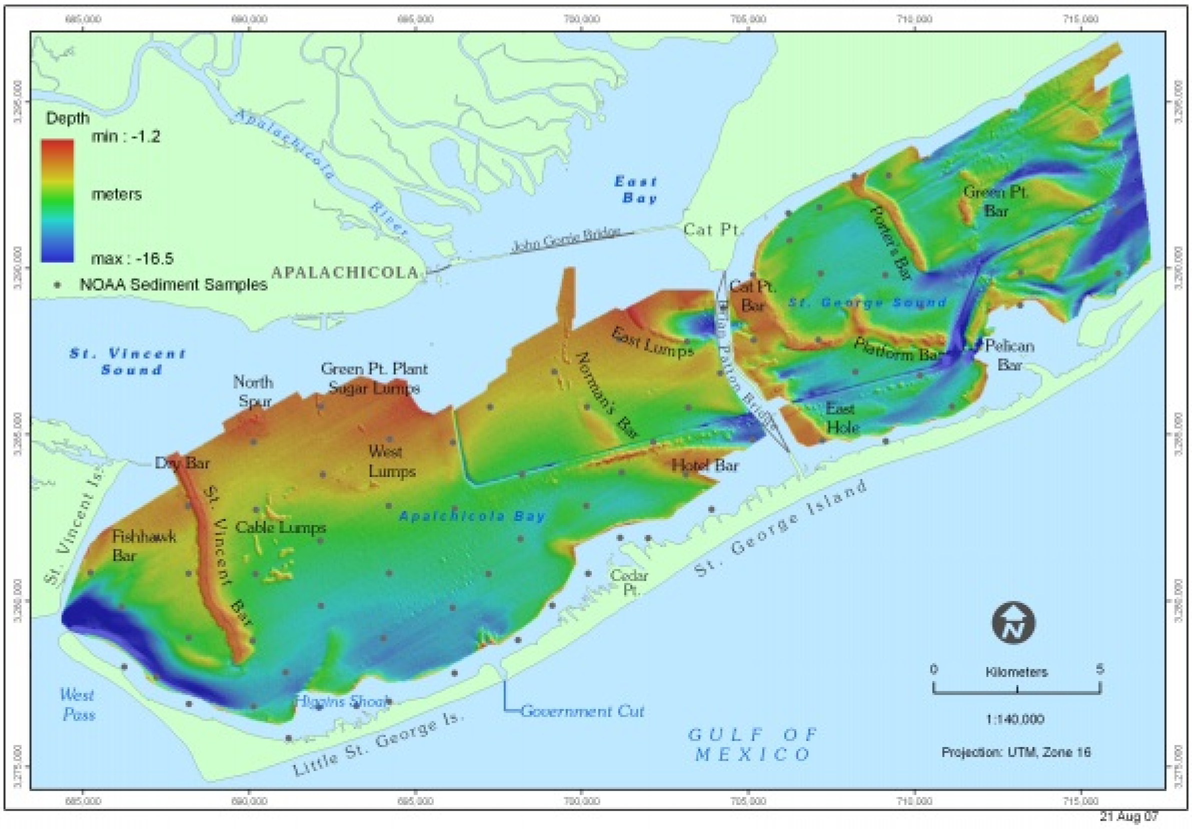


Figure 6. Map showing the names of bay-floor and geographic features within the Apalachicola Bay study area. Locations of sediment samples collected by NOAA Coastal Services Center (NOAA, 1999) that were used to verify the sidescan-sonar interpretation are shown.

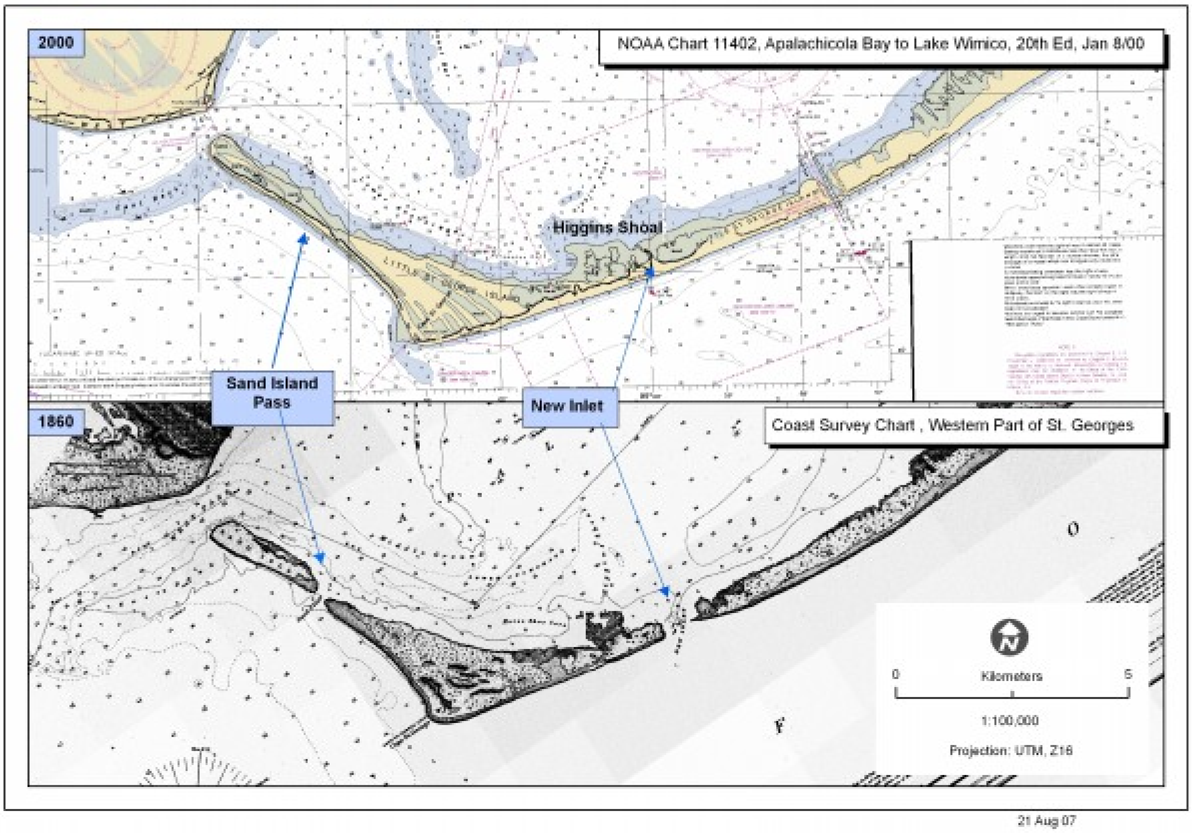


Figure 7. 2000 NOAA Chart (top panel) and 1860 NOAA chart (bottom panel) showing the location of New Inlet, a former tidal inlet near Higgins Shoal that presently is sealed (NOAA, 1860; 2000).

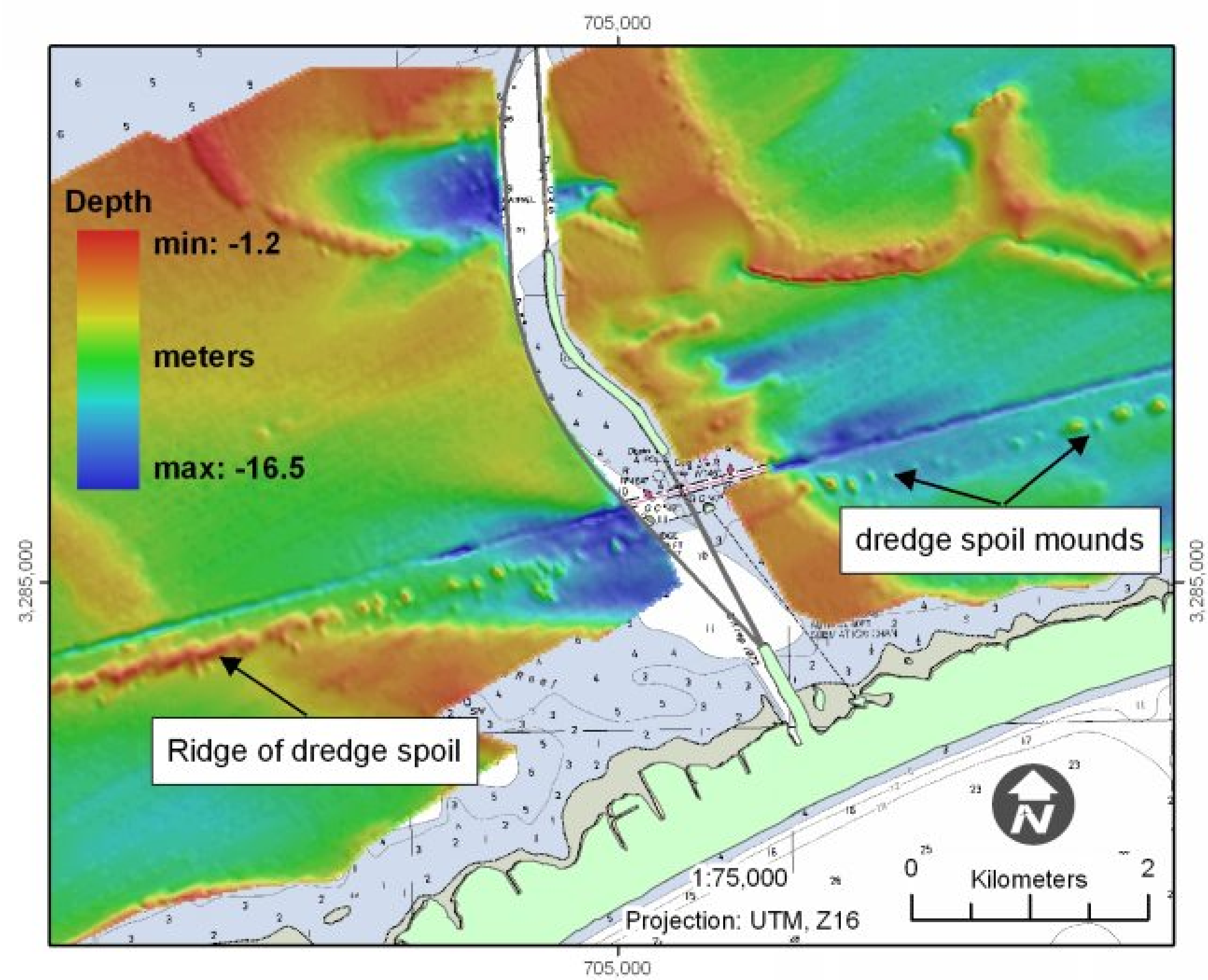


Figure 8. Bathymetric map of the Intracoastal Waterway near the Brian Patton Bridge) showing dredged material south of its channel.

Figure 9. Map showing the slope of the bay floor. The steepest slopes are found along the flanks of the Intracoastal Waterway, along the margins of the bay, and on the western sides of linear bars (eg. St. Vincent's Bar and Porter's Bar).

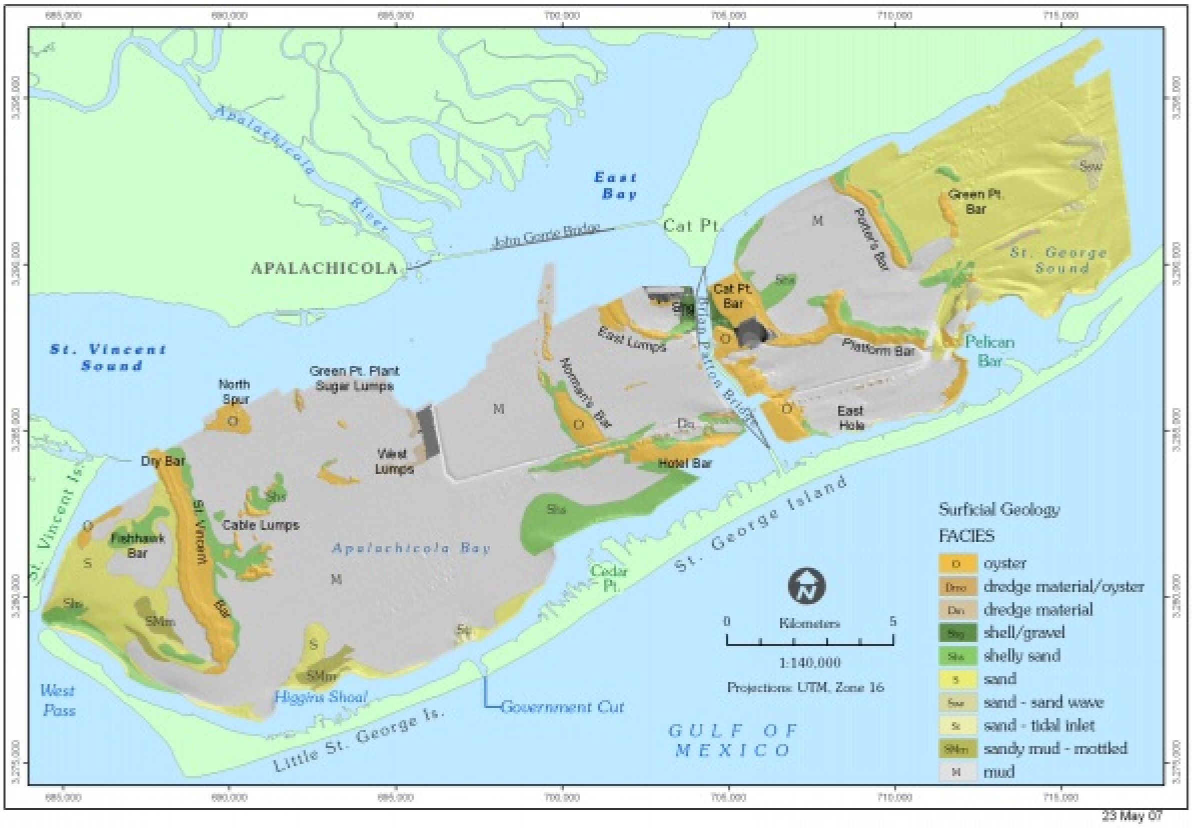


Figure 10. Map showing the distribution of eleven sedimentary facies identified on the floor of Apalachicola Bay superimposed on a shaded-relief image of the bathymetry.

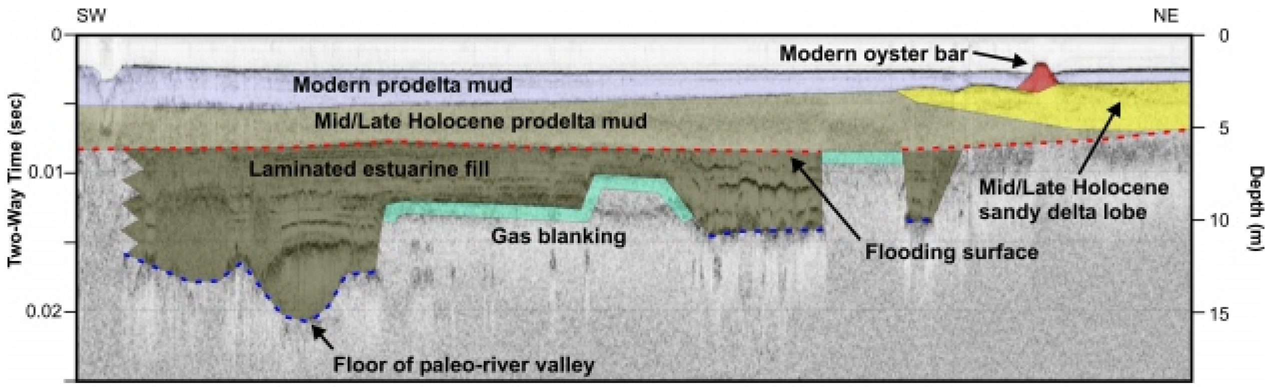


Figure 11. Interpreted seismic profile showing the stratigraphic intervals underlying Apalachicola Bay. The deepest horizon imaged is the floor of a Pleistocene river valley. This valley was filled during the Early and Middle Holocene by estuarine deposits. During the Late Holocene, a delta system advanced into the bay. Presently mud derived form the Apalachicola River blankets large parts of these older stratigraphic intervals. Vertical scales for the seismic profile are provided in milliseconds (Two-Way Travel Time) and approximate depth in meters (assuming a seismic velocity of 1500 m/s). The location of profile 11 is identified on seismic profile A of figure 12 and also in figure 13.

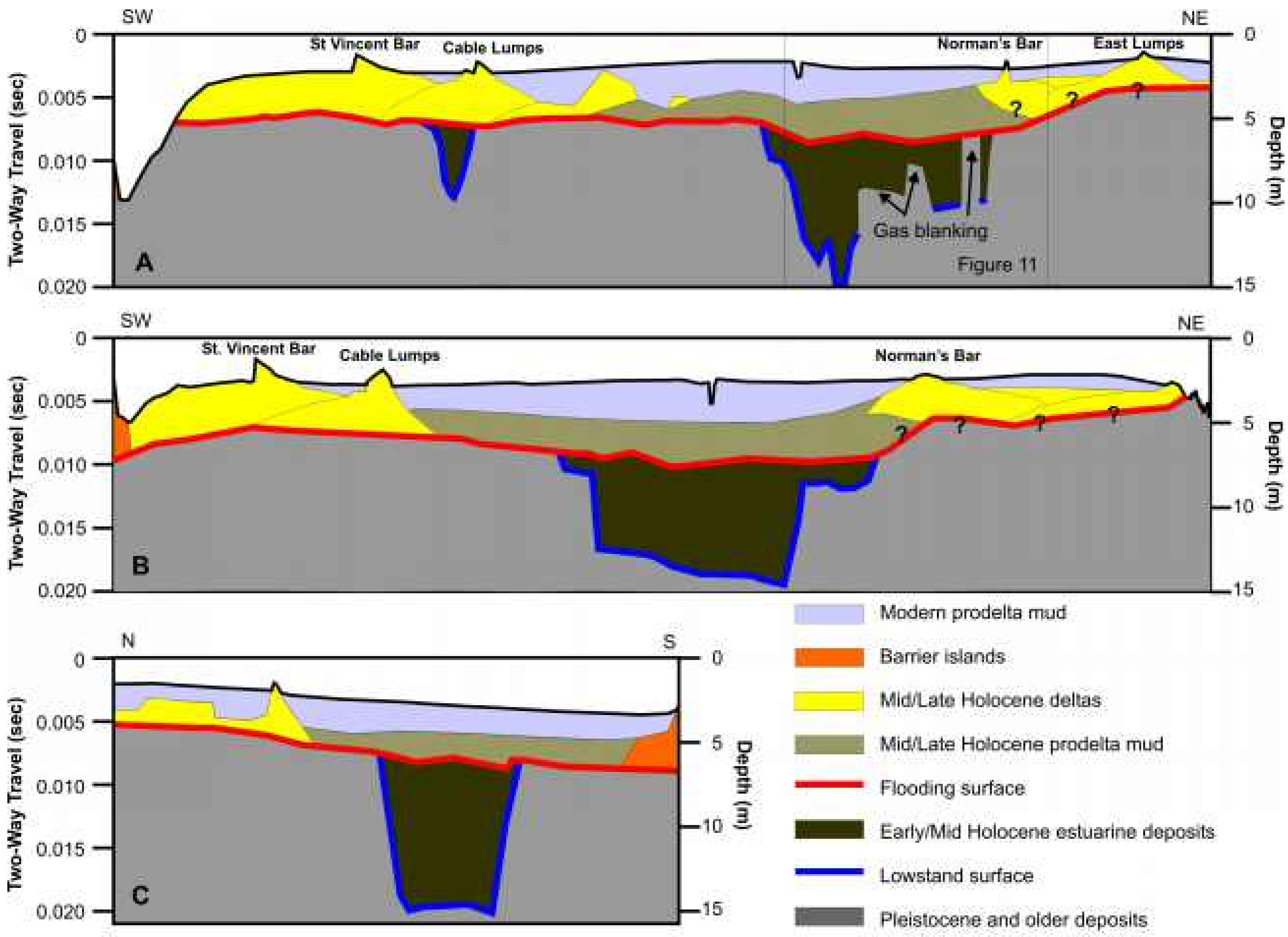


Figure 12. Line-drawing interpretations of three seismic profiles that show the estuary's shallow stratigraphy. Vertical scales for the profile interpretations are provided in milliseconds (Two-Way Travel Time) and approximate depth in meters (assuming a seismic velocity of 1500 m/s). Profile locations are shown in figure 13. Ages associated with the units are inferred.

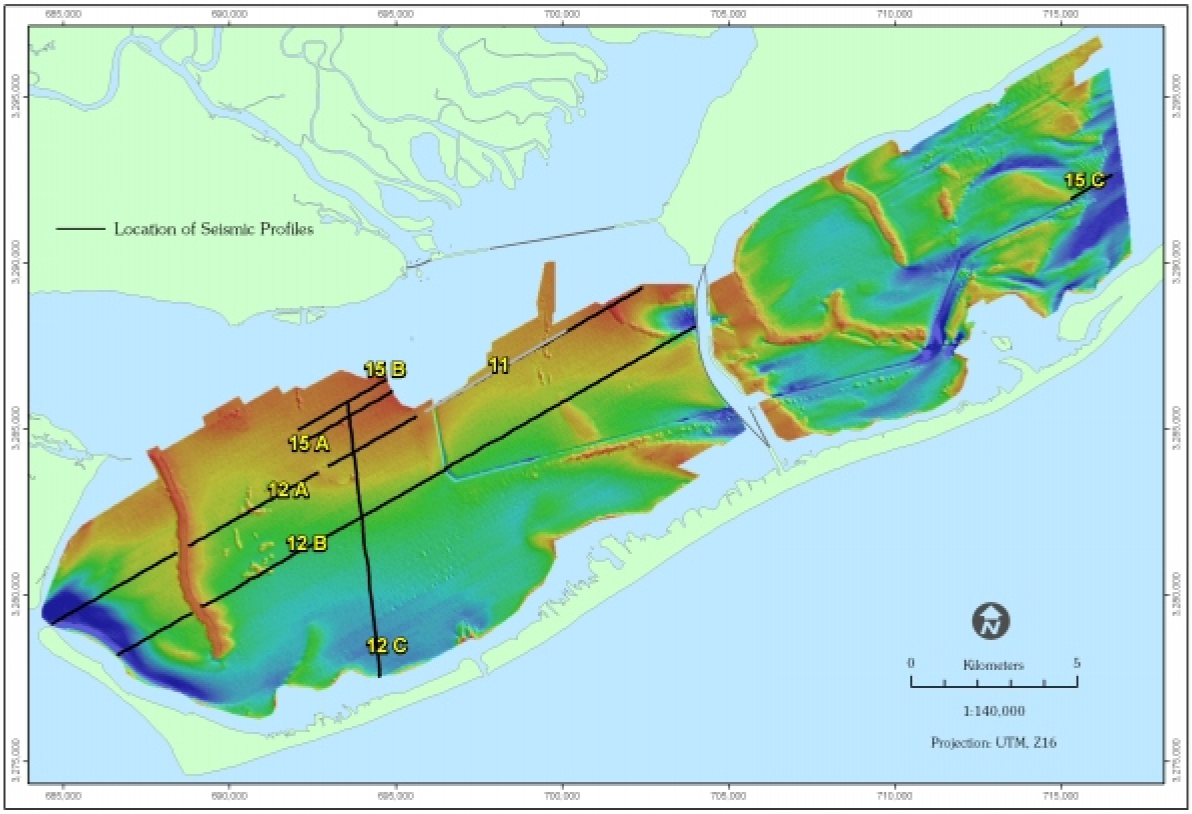


Figure 13. Map showing the location of the seismic profiles shown in this report. The location of Figure 11, which is part of profile A in figure 12 is marked by the gray line.

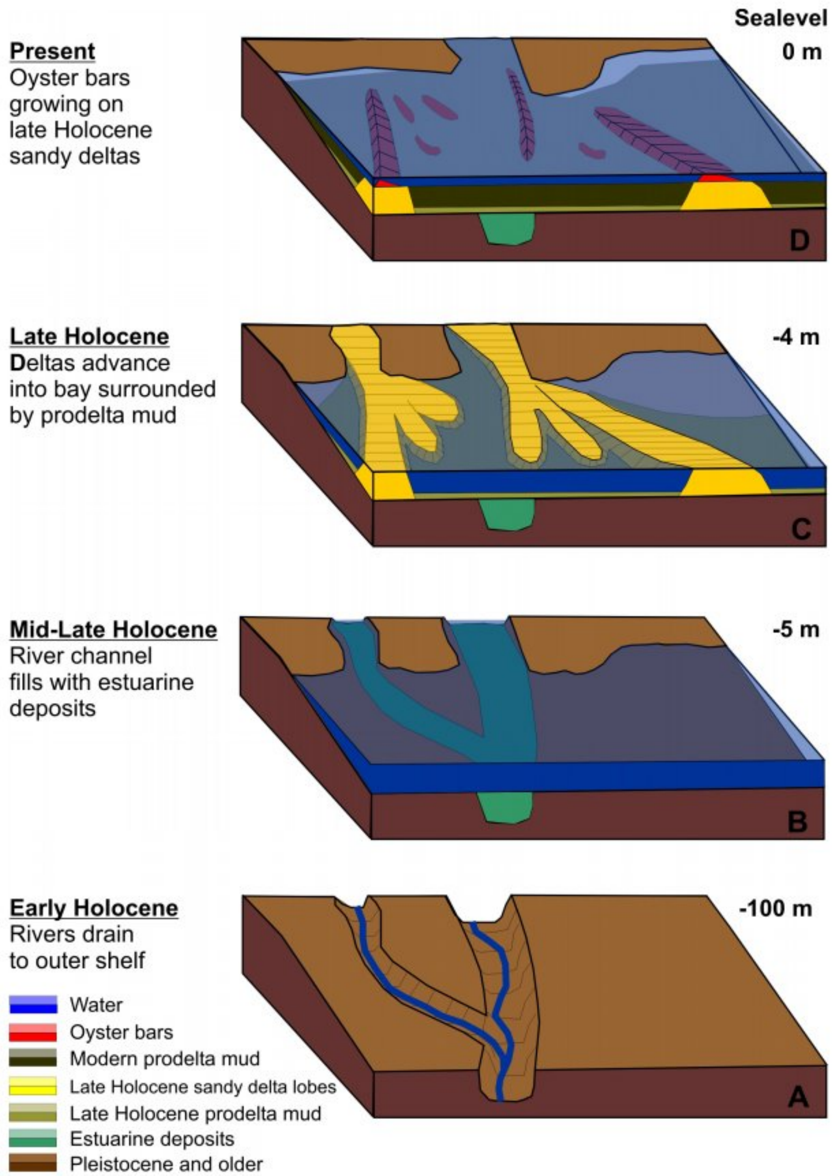


Figure 14. Schematic block diagram showing important steps in the evolution of the Apalachicola Bay region since the last lowstand of sea level.

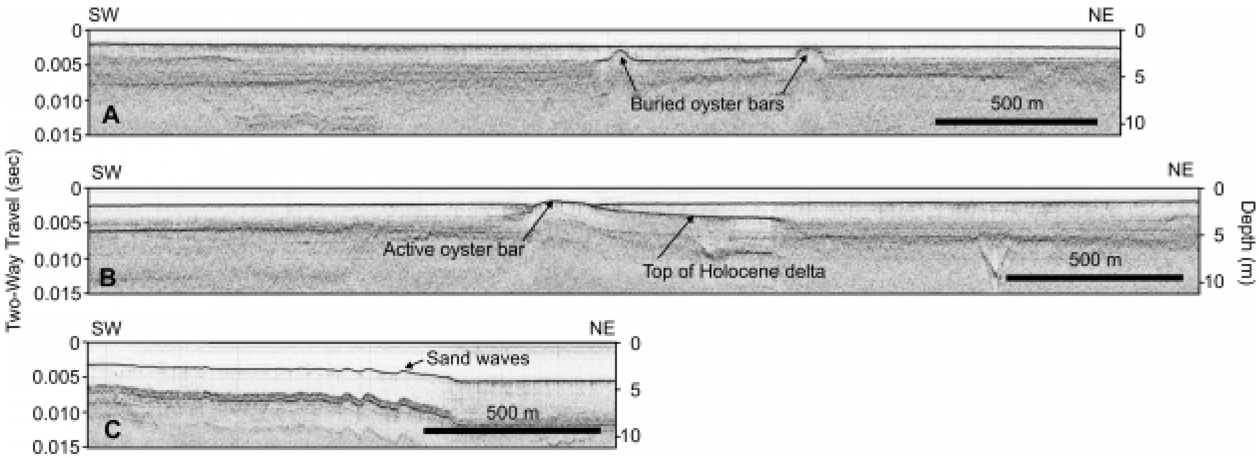


Figure 15. Seismic profiles showing (A) oyster mounds that accumulated on an older, sandy-delta surface, and were subsequently buried by younger mud, (B) an oyster bar that accumulated on an sandy-delta surface, and remains exposed at the sea floor, and (C) sand waves in the eastern part of St. George Sound. The full extent of the sand waves is shown on figure 10. Vertical scales for the seismic profile are provided in milliseconds (Two-Way Travel Time) and approximate depth in meters (assuming a seismic velocity of 1500 m/s). Profile locations are shown on figure 13.

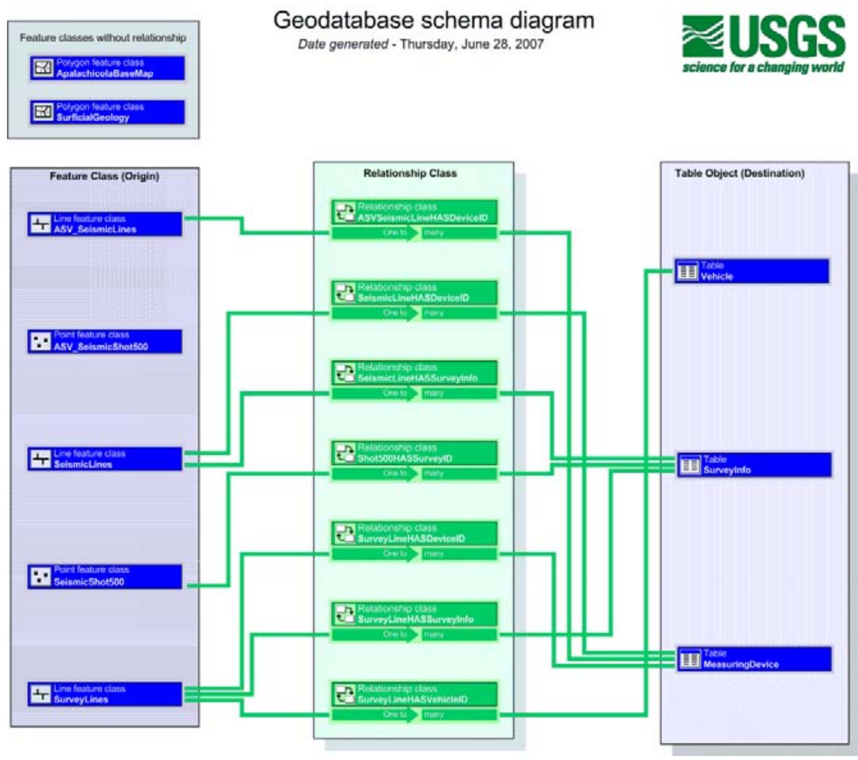


Figure 16. Diagram of personal geodatabase showing origin and destination tables of relationship classes.

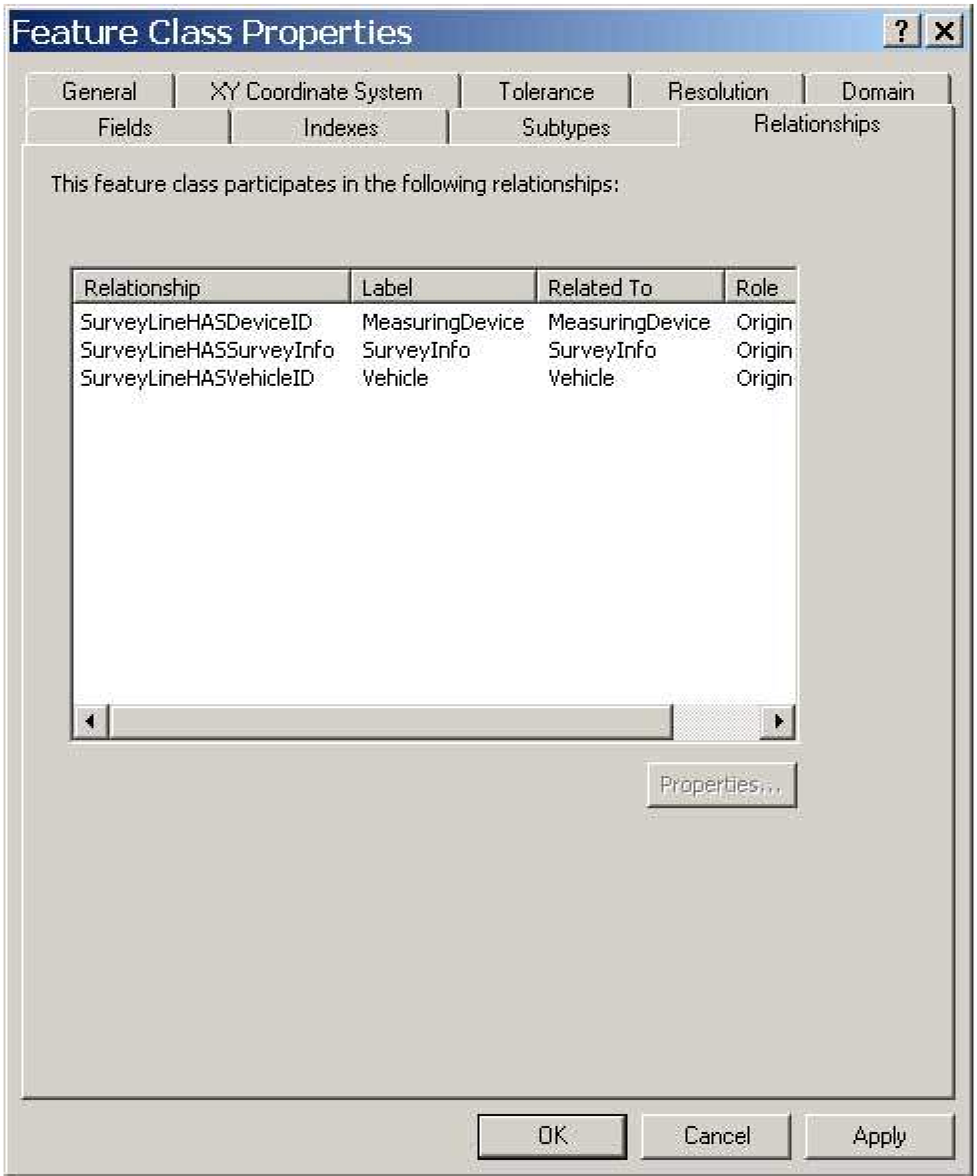


Figure 17. ArcGIS identify results dialog box showing attributes and relationships for selected feature.

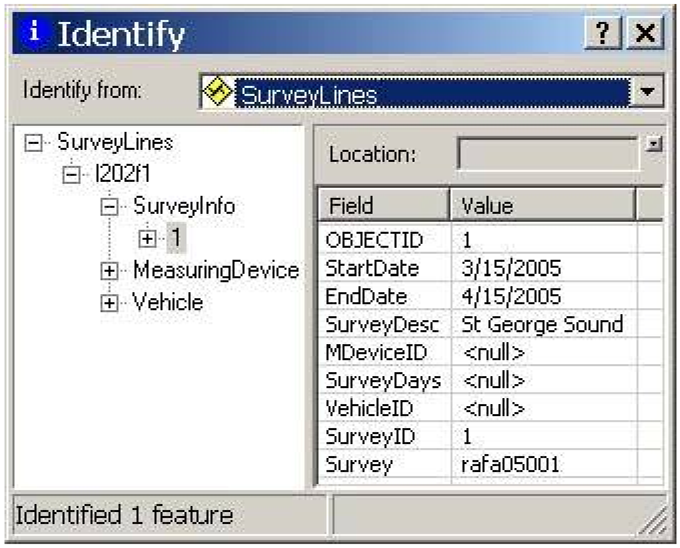


Figure 18. The general organization of spatial data on this DVD is listed below.

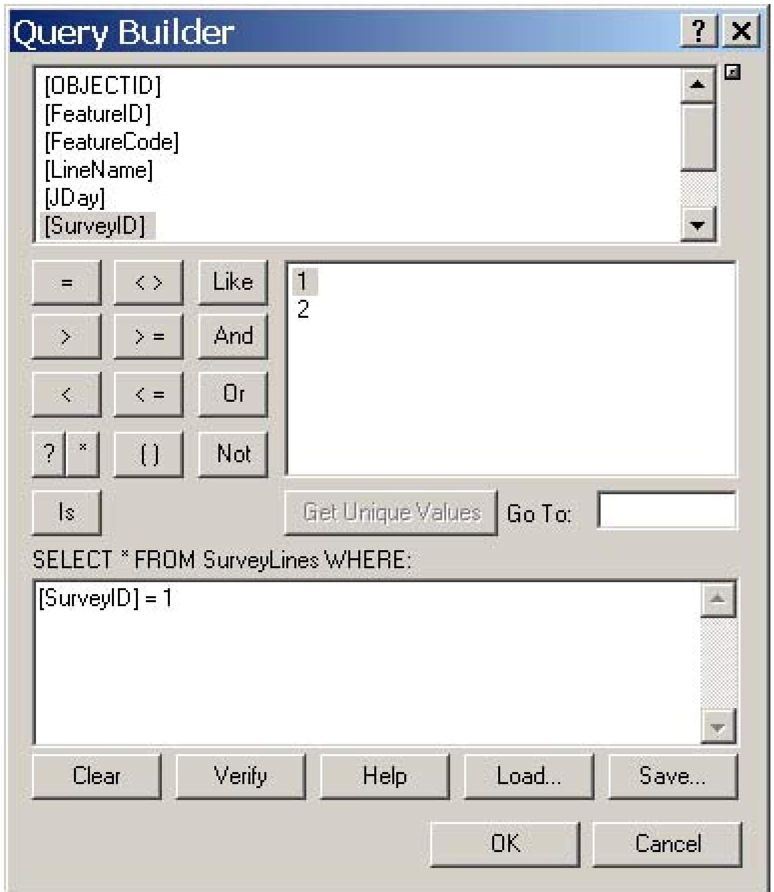


Figure 19. Example of ArcGIS Query Builder dialog box with query syntax.