3.0 REGIONAL GEOMORPHIC CHANGE

Nearshore sediment transport processes influence the evolution of shelf sedimentary environments to varying degrees depending on temporal and spatial response scales. Although micro-scale processes, such as turbulence and individual wave orbital velocities, determine the magnitude and direction of individual grain motion, variations in micro-scale processes are considered noise at regional-scale and only contribute to coastal response in an average sense. By definition, regional-scale geomorphic change refers to the evolution of depositional environments for large coastal stretches (10 km or greater) over extended time periods (decades or greater) (Larson and Kraus 1995). An underlying premise for modeling long-term morphologic change is that a state of dynamic equilibrium is reached as a final stage of coastal evolution. However, the interaction between the scale of response and forces causing change may result in a net sediment deficit or surplus within a system, creating disequilibrium. This process defines the evolution of coastal depositional systems.

Topographic and hydrographic surveys of coastal and nearshore morphology provide a direct source of data for quantifying regional geomorphology and change. Historically, hydrographic data have been collected in conjunction with regional shoreline position surveys by the U.S. Coast and Geodetic Survey (USC&GS); currently Coast and Geodetic Survey of the National Ocean Service [NOS], National Oceanographic and Atmospheric Administration). Comparison of digital bathymetric data for the same region but different time periods provides a method for calculating net sediment movements into (accretion) and out of (erosion) an area of study. Coastal scientists, engineers, and planners often use this information for estimating the magnitude and direction of sediment transport, monitoring engineering modifications to a beach, examining geomorphic variations in the coastal zone, establishing coastal erosion setback lines, and verifying shoreline change numerical models. The purpose of this portion of the study is to document patterns of geomorphic change throughout the sand resource areas and quantify the magnitude and direction of net sediment transport over the past 60 to 100 years. These data, in combination with wave and current measurements and model output, provide a temporally integrated technique for evaluating the potential physical impacts of offshore sand mining on sediment transport dynamics.

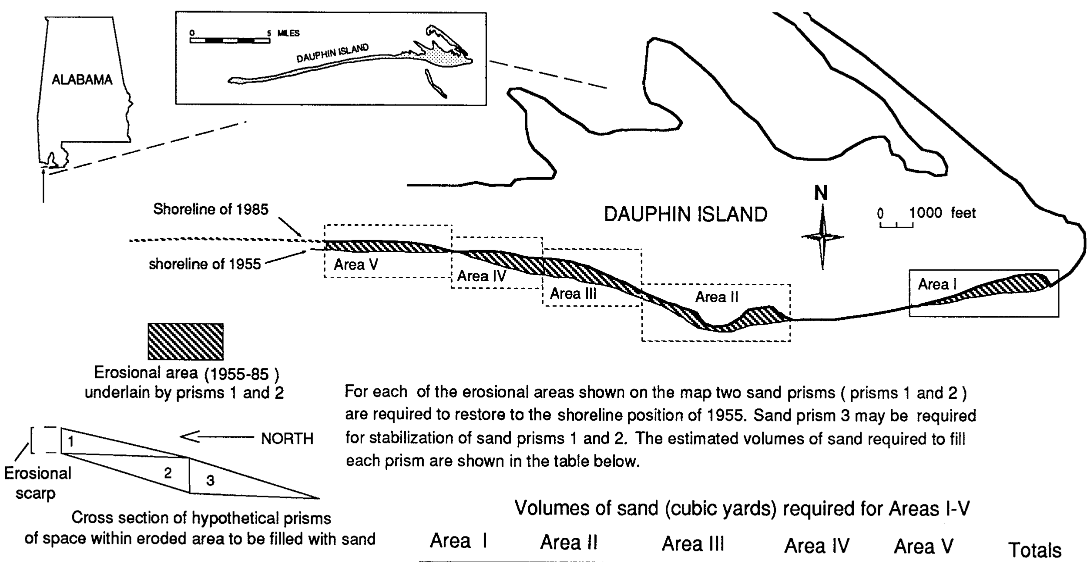
3.1 SHORELINE POSITION CHANGE

Creation of an accurate map is always a complex surveying and cartography task, but the influence of coastal processes, relative sea level, sediment source, climate, and human activities make shoreline mapping especially difficult. In this study, shoreline surveys are used to define landward boundaries for bathymetric surfaces and to document net shoreline movements between specified time periods. Consequently, net change results can be compared with wave model output and nearshore sediment transport simulations to evaluate cause and effect. Results integration provides a direct method of documenting potential environmental impacts related to sand dredging on the OCS.

3.1.1 Previous Studies

The Gulf shoreline of Alabama is dissected by the entrance to Mobile Bay, creating a barrier island shoreline to the west (Dauphin Island) and a peninsular barrier beach to the east (Morgan Peninsula). Hardin et al. (1976) used USC&GS topographic sheets and U.S. Geological Survey (USGS) 7.5-minute quadrangle maps for the dates 1917/18, 1942, 1958, and 1974 to document shoreline advance and retreat. The 1917 shoreline illustrated a hurricane breach along central Dauphin Island (about 8.5 km wide) that filled with sediment by 1942. Concurrently, the western end of the island extended about 1.3 km into Petit Bois Pass (Hardin et al., 1976). Between 1942 and 1974, Hardin et al. (1976) documented shoreline retreat along most of western two-thirds of Dauphin Island (about 3 m/yr) and westward migration of the island of about 2 km. Byrnes et al. (1991)

quantified the lateral migration rate of western Dauphin Island for the period 1848 to 1986. They documented a rate of 55.3 m/yr (slightly higher than that reported by Hardin et al. [1976]), or about 7.6 km for the period of record. Parker et al. (1993, 1997) updated the analysis of Hardin et al. (1976) by including a 1985 shoreline interpreted from aerial photography. Because most inhabitants live on the eastern third of Dauphin Island, specific attention was given to shoreline change trends in that area between 1955 and 1985. Figure 3-1 documents specific areas of erosion with estimates of sand volume necessary to restore the beach back to its 1955 condition (Parker et al. 1993, 1997). Hummell and Smith (1996) updated the findings of Parker et al. (1993, 1997) to 1995, concluding that increased erosion in this area between 1985 and 1995 resulted in a sand volume requirement of about 1.85 MCM to restore beaches to the 1955 condition.



Volumes of sand (cubic yards) required for Areas I-V

	Area I	Area II	Area III	Area IV	Area V	Totals
PRISM 1	96,125	96,124.	94,355	32,394	75,943	394,941
PRISM 2	172,382	144,186	283,065	122,165	113,915	835,713
PRISM 3	140,423	158,226	211,207	67,961	45,303	623,120
TOTAL	408,930	398,536	588,627	222,520	235,161	1,853,774

Figure 3-1. Map of southeastern Dauphin Island Gulf shoreline showing principal areas of erosion during the period 1955 to 1985 and estimated volumes of sand required for restoration of eroded areas (shaded) to the approximate position of the 1955 shoreline (from Parker et al., 1997).

For the Gulf shore of the Morgan Peninsula, from Mobile Point to Perdido Pass (about 50 km long), Hardin et al. (1976) monitored shoreline position change at five specific locations. For the period 1917 to 1974, they documented about 6 m/yr shoreline advance near Mobile Point, -0.5 m/yr at Gulf Highlands, no significant change at Gulf Shores, and -0.8 m/yr at Romar Beach. A detailed analysis of shoreline change at Perdido Pass also was included in Hardin et al. (1976), illustrating the dynamic nature of the inlet system between 1867 and 1974. Parker et al. (1997) updated this data set to 1985, documenting coastal structure placement associated with erosion hot spots (Figure 3-2) and sand volume requirements to restore beaches to 1955 conditions (about 120,000 cubic meters). Significant hurricane impacts near Gulf Shores and Orange Beach over the past few years has resulted in a reassessment of sand volume needs along the Morgan Peninsula (Hummell, 1999). It is now estimated that approximately 750,000 cubic meters of sand may be needed for beach restoration in this area in the near future.

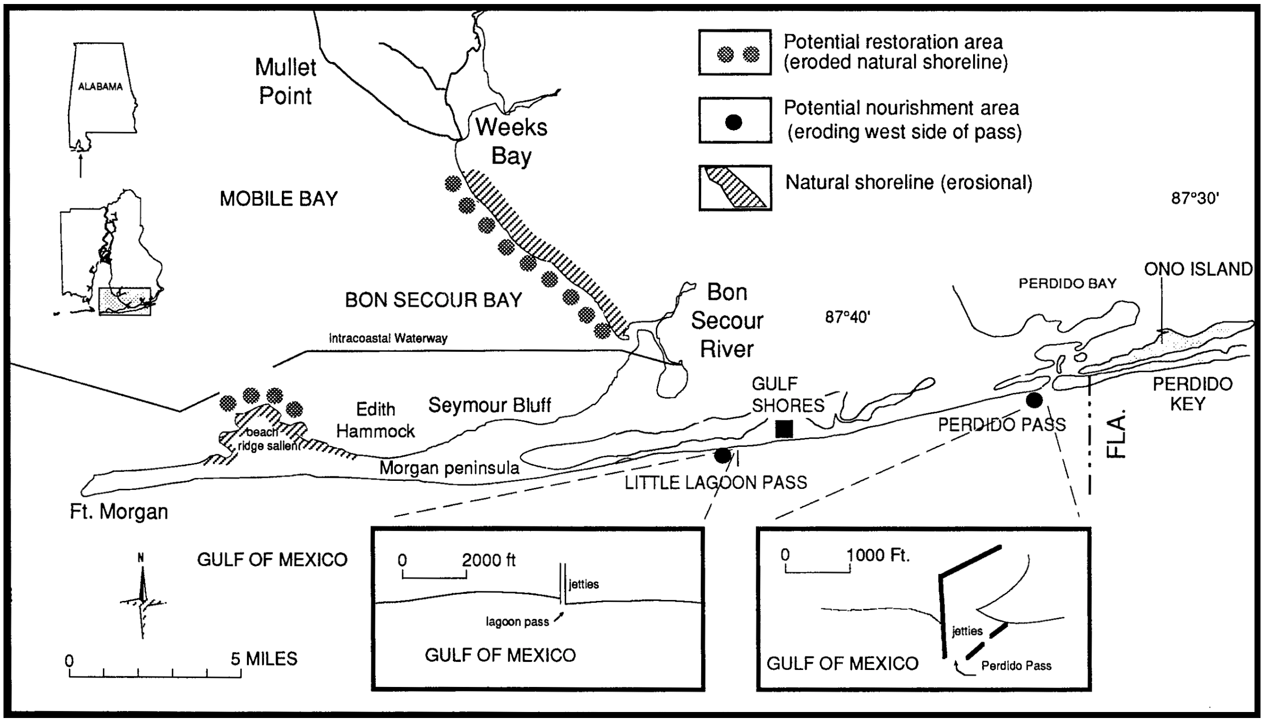


Figure 3-2. Gulf and Bon Secour Bay shoreline of Baldwin County, Alabama, showing locations of potential shoreline restoration and nourishment (from Parker et al., 1997).

3.1.2 Shoreline Position Data Base

For the present study, five primary outer coast shoreline surveys, conducted by the U.S. Coast and Geodetic Survey (USC&GS; predecessor to NOS) in 1847/67, 1917/18, 1934, 1957, and 1978/82 between Petit Bois Pass (west) and Perdido Pass (Table 3-1), were used to quantify historical shoreline change. The 1847/67 and 1917/18 surveys were completed as field surveys using standard planetable techniques, whereas the final three shoreline surveys were interpreted from aerial photography. Methods used for compiling and analyzing historical data sets are described in Byrnes and Hiland (1994a, b).

When determining shoreline position change, all data contain inherent errors associated with field and laboratory compilation procedures. These errors should be quantified to gage the significance of measurements used for research/engineering applications and management decisions. Table 3-2 summarizes estimates of potential error for the shoreline data sets used in this study. Because these individual errors are considered to represent standard deviations, root-mean-square error estimates are calculated as a realistic assessment of combined potential error.

Positional errors for each shoreline can be calculated using the information in Table 3-2; however, change analysis requires comparing two shorelines from the same geographic area but different time periods. Table 3-3 is a summary of potential errors associated with change analyses computed for specific time periods. As expected, maximum positional errors are associated with the oldest shorelines (1847/67 and 1917/18) at smallest scale (1:40,000), but most change estimates for the study area document shoreline advance or retreat greater than these values.

Table 3-1. Summary of shoreline source data characteristics for the coast between western Dauphin Island (at Petit Bois Pass) and Perdido Pass, Alabama.

Date	Data Source	Comments and Map Numbers
1847/67	USC&GS Topographic Maps 1:10,000 (T-1035, T-1042) 1:20,000 (T-240, T-245, T-277)	First regional shoreline survey throughout study area using standard planetable surveying techniques; 1847 - western end of Dauphin Island to entrance to Mobile Bay (T-245, T-240); 1849 - outer coastline south of Bon Secour Bay (T-277); 1867 - shoreline south of Shelby Lakes east to Perdido Pass (T-1035, T-1042).
1917/18	USC&GS Topographic Maps 1:40,000 (T-3711, T-3714)	Second regional shoreline survey along the seaward coast of the study area using standard planetable surveying techniques (regional-scale reconnaissance survey); 1917 - Dauphin Island (T-3711); 1918 - Mobile Point east to Perdido Pass (T-3714).
June/July 1934	USC&GS Topographic Maps 1:10,000	First regional shoreline survey completed using aerial photography; central Dauphin Island (T-5537); shoreline adjacent to Mobile Bay Entrance (T-5536); outer shoreline south of Bon Secour Bay (T-5535); shoreline south of Little Lagoon (T-5534); Gulf Shores (T-5497); shoreline south of Shelby Lakes (T-5498); Perdido Pass (T-5495) .
November 1957	USC&GS Topographic Maps 1:10,000	All maps produced from interpreted aerial photography; Dauphin Island (T-sheets 10761, 10762, 10770, 10771, 10772); Morgan Peninsula east to shoreline south of Shelby Lakes (T-sheets 10773, 10774, 10775, 10776, 10993, 10994, 10996).
1978/82	USC&GS Topographic Maps 1:20,000	All maps produced from interpreted aerial photography; 1978 - shoreline south of Little Lagoon east to Perdido Pass (TP-sheets 00542, 00543); 1981/82 - Mobile Bay east to shoreline south of Bon Secour Bay (TP-sheets 00931, 00932); Dauphin Island (TP-sheets 00929, 00930).

Table 3-2. Estimates of potential error associated with shoreline position surveys.

Traditional Engineering Field Surveys (1847/67, and 1917/18)			
Location of rodded points	±1 m		
Location of plane table	±2 to 3 m		
Interpretation of high-water shoreline position at rodded points	±3 to 4 m		
Error due to sketching between rodded points	up to ±5 m		
Cartographic Errors (all maps for this study)	**Map Scale**		
	1:10,000	1:20,000	1:40,000
Inaccurate location of control points on map relative to true field location	up to ±3 m	up to ±6 m	up to ±12 m
Placement of shoreline on map	±5 m	±10 m	±20 m
Line width for representing shoreline	±3 m	±6 m	±12 m
Digitizer error	±1 m	±2 m	±4 m
Operator error	±1 m	±2 m	±4 m
Aerial Surveys (1934, 1957, 1978/82)	**Map Scale**		
	1:10,000	1:20,000	1:40,000
Delineating high-water shoreline position	±5 m	±10 m	±20 m
Sources: Shalowitz, 1964; Ellis 1978; Anders and Byrnes, 1991; Crowell et al., 1991.			

Table 3-3. Maximum root-mean-square potential error for shoreline change data from western Dauphin Island (at Petit Bois Pass) to Perdido Pass, Alabama.				
	1917/18	**1934**	**1957**	**1978/81**
1847/67	±31.7[1]	±17.3	±17.3	±22.6
	(±0.5)[2]	(±0.2)	(±0.2)	(±0.2)
1917/18		±20.9	±20.9	±32.4
		(±1.7)	(±0.7)	(±0.5)
1934			±11.8	±18.7
			(±0.5)	(±0.4)
1957				±18.7
				(±0.8)

[1] Magnitude of potential error associated with high-water shoreline position change (m); [2] Rate of potential error associated with high-water shoreline position change (m/yr).

3.1.3 Historical Change Trends

Regional change analysis completed for this study provides a without-project assessment of shoreline response for comparison with predicted changes in wave-energy focusing at the shoreline resulting from potential offshore sand dredging activities. It differs from previous studies in that continuous measurements of shoreline change are provided at 100 m alongshore intervals for the period 1847/67 to 1978/82 (see Appendix A). This way, model results (wave and sediment transport) at discreet intervals along the coast can be compared with historical data to develop process/response relationships for evaluating potential impacts. The following discussion focuses on incremental changes in shoreline response (1847/67 to 1917/18, 1917/18 to 1934, 1934 to 1957, 1957 to 1978/82) relative to net, long-term trends (1847/67 to 1978/82).

3.1.3.1 1847/67 to 1917/18

Shoreline response along Dauphin Island was dramatic for the earliest time interval, illustrating a large gap in the central portion of the island in response to storm wave impacts (Figure 3-3). Although the exact timing of hurricane impact relative to this feature is not know, the U.S Army Corps of Engineers (1967) reported significant storm surge associated with the 1915 hurricane, where erosion along the Mississippi Sound barrier islands was particularly severe. The hurricanes of 1916 and 1917 likely sustained the large barrier breach, but they inflicted less damage to coastal areas than the 1915 event. The absence of a high-water shoreline in 1917 for the central portion of Dauphin Island signifies the importance of overwash processes on island evolution; however, longshore sediment transport have had a profound influence on lateral migration of western Dauphin Island into Petit Bois Pass. The rate of lateral island migration for this time period is about 54 m/yr to the west.

Along the eastern third of Dauphin Island, zones of shoreline retreat and advance alternate from the entrance of Mobile Bay to the central island breach (Figure 3-3). Shoreline retreat adjacent to the breach is consistent with the formation of ephemeral inlet features, and zones of shoreline advance away from this area mimic long-term change trends. Shoreline advance along the eastern 4.6 km of Dauphin Island averages about 1 m/yr; however, a short zone of retreat is present in the middle of this shoreline reach (Figure 3-3) where natural wave energy focusing by nearshore ebb-tidal shoal deposits is persistent.

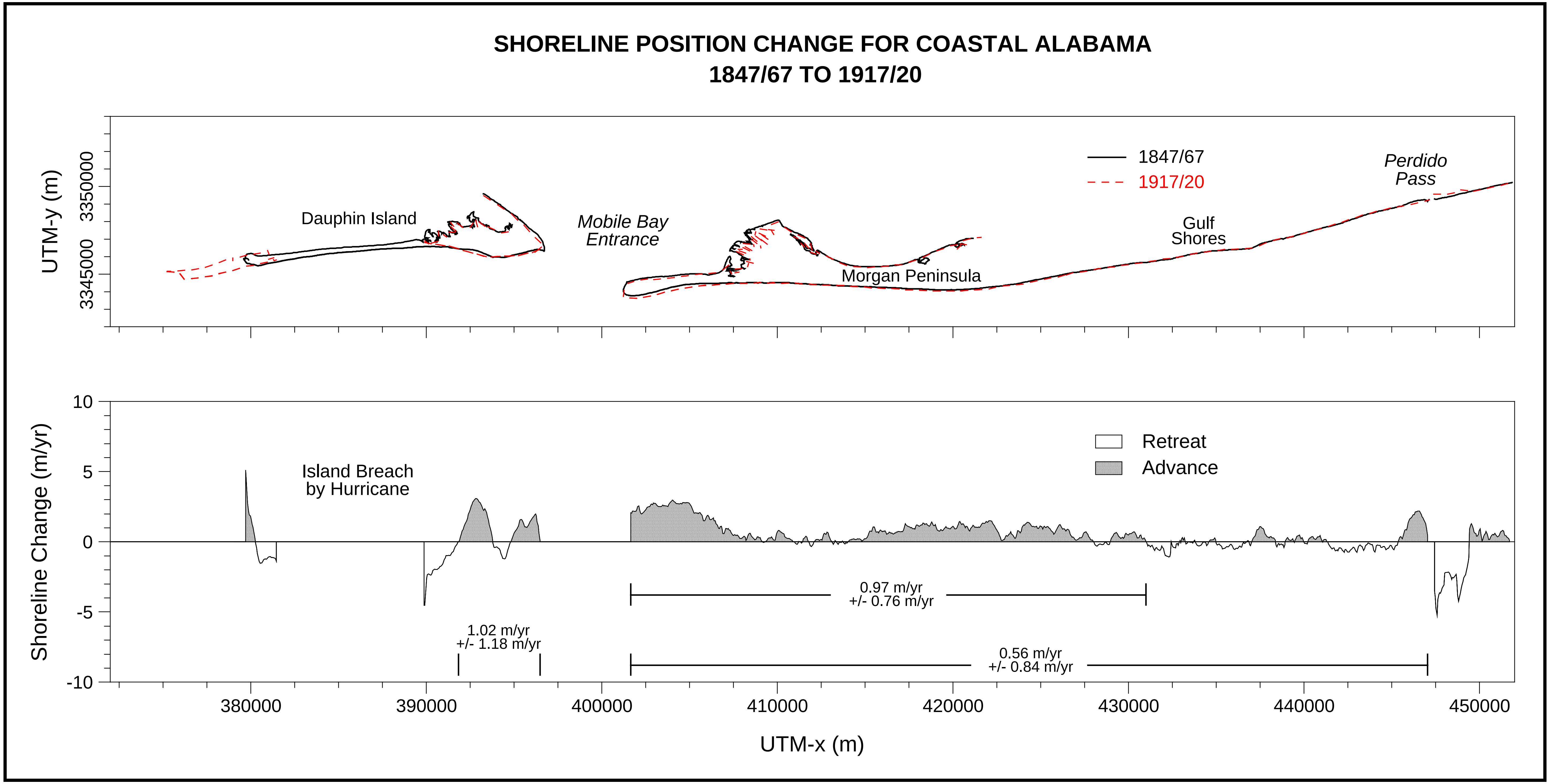


Figure 3-3. Shoreline position change along the Alabama coast, 1847/67 to 1917/20.

To the east, along the Morgan Peninsula, average shoreline advance of about 1 m/yr is recorded for the western 29 km of beach. In fact, the entire 45 km of outer coast from Perdido Pass to Mobile Point (Figure 3-3) averages about 0.6 m/yr shoreline advance. Net shoreline retreat does occur within the 16 km of beach downdrift of Perdido Pass; however, on average, the shoreline is stable. The most significant change in this area is associated with Perdido Pass, particularly the shoreline east of the inlet where maximum retreat rates are greater than 5 m/yr and average change is -2.9 m/yr. Overall, spatial change trends along the Morgan Peninsula indicate a net surplus of sediment to the beaches between 1867 and 1918.

3.1.3.2 1917/18 to 1934

Between 1917/18 and 1934, major changes in shoreline position occurred throughout the study area. Whether the magnitude of change reflects reality or inaccuracies in mapping procedures is debatable. The 1917/18 shoreline was mapped as a reconnaissance shoreline at a scale of 1:40,000, whereas the 1934 shoreline represents the first interpreted shoreline from aerial photography. Inherent mapping errors at a scale of 1:40,000 would be approximately double those associated with field mapping at a scale of 1:20,000. Potential error associated with interpretation of high-water shoreline position from the 1934 photography could be substantially greater. In addition, the period of time between surveys is quite short (17 years); the longer the time period, the smaller the rate of change due to natural averaging of short-term event impacts. Regardless, it is expected that the trend of change is reasonable for the analysis period (Figure 3-4).

Although fluctuations in shoreline advance and retreat characterize eastern Dauphin Island, the dominant direction of shoreline movement is advance at an average rate of 0.2 m/yr. Relative to potential error estimates (Table 3-3), this value does not seem significant, but if zones of shoreline retreat and advance are evaluated separately, average change rates are -1.6 m/yr and 1.8 m/yr, respectively. Similar to changes documented for 1847/67 to 1917/18, a noticeable zone of erosion exists just downdrift of eastern Dauphin Island where wave energy focusing occurs in relation to the position of shallow offshore shoals associated with the ebb-tidal delta of Main Pass.

The western 30 km of the Morgan Peninsula exhibits average shoreline retreat of about 4.1 m/yr. Compared with the previous time interval, the magnitude of change is much greater and the trend of change is opposite (see Figures 3-3 and 3-4). Farther to the east towards Perdido Pass, shoreline change trends continue to indicate average shoreline retreat, but areas of accretion are present near Gulf Shores and a few other locations. The area of shoreline retreat east of Perdido Pass for the previous time period has been replaced by shoreline advance. For this 17-yr period of record, a net sediment deficit is indicated throughout the study area.

3.1.3.3 1934 to 1957

Shoreline position change along the eastern 60% of Dauphin Island for this 23-yr period is dominated by shoreline retreat. Small areas of accretion exist along the eastern end of the island, consistent with trends for the previous two time periods (Figure 3-5). Average shoreline retreat for the central and eastern erosion zone (14 km long) is about 1.5 m/yr. Although shoreline position in 1934 was not available for the western third of the island, it is expected that shoreline retreat would persist west of the erosion area shown on Figure 3-5, and lateral migration into Petit Bois Pass would continue at historical rates.

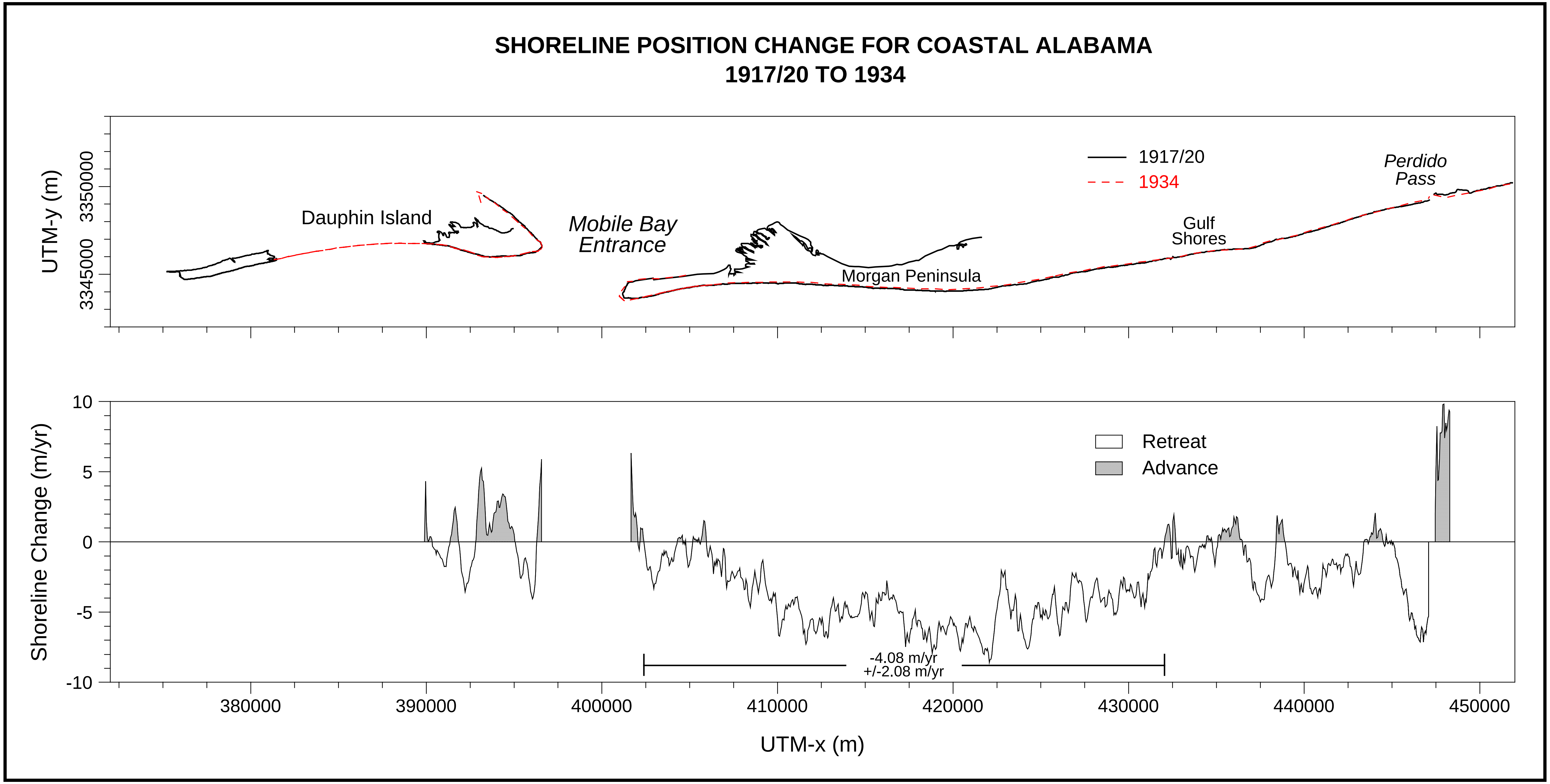


Figure 3-4. Shoreline position change along the Alabama coast, 1917/20 to 1934.

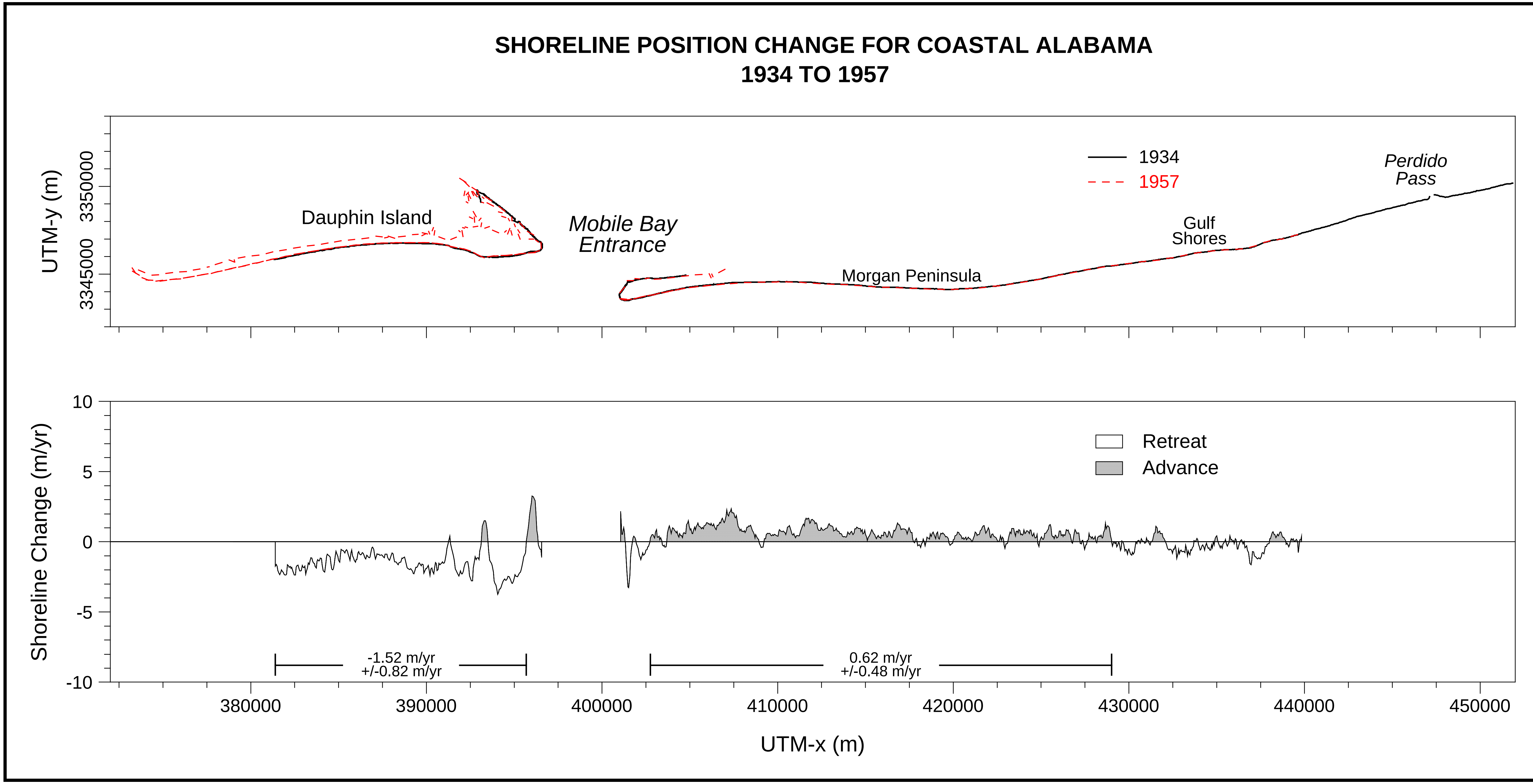


Figure 3-5. Shoreline position change along the Alabama coast, 1934 to 1957.

Except for a short length of beach along the western end of the Morgan Peninsula, shoreline change for a 26 km stretch of beach west of Gulf Shores is dominated by accretion at an average rate of about 0.6 m/yr. West of this area to the limit of data coverage, shoreline retreat is common, but the average rate of change is relatively small (-0.3 m/yr; Figure 3-5). Overall, shoreline advance along the Alabama Gulf shoreline west of Mobile Bay averaged 0.3 m/yr between 1934 and 1957. Although this trend is contrary to the previous time interval, it is consistent with change results identified for the period 1847/67 to 1917/18.

3.1.3.4 1957 to 1978/82

Shoreline change calculations relative to shoreline position in 1955 were used by Parker et al. (1993, 1997) to estimate sand volume requirements for maintaining beaches along the Alabama coast. Hummell and Smith (1995, 1996) updated these calculations to 1995. Shoreline retreat and advance for the period 1957 to 1978/82 illustrates regional trends relative to specific areas of concern identified by Parker et al. (1997). Comparison of change trends with earlier time intervals provides a means of gauging the reliability of results relative to the entire historical record.

The spike of sand accretion along western Dauphin Island is the result of lateral island migration. East of this point, shoreline retreat is dominant for about 20 km at an average rate of about 3 m/yr (Figure 3-6). Patterns of shoreline advance and retreat along eastern Dauphin Island are similar to those for all other time intervals. Parker et al. (1997) identified these same trends in their analysis of shoreline change along eastern Dauphin Island (Figure 3-1). Rates of change for independent analyses (present analysis versus Parker et al., 1997) were similar for the erosion zones identified in Figure 3-1 (about -2.5 m/yr on average).

Along the Morgan Peninsula, rates of shoreline position change exhibit relatively small variations (1.1 to -1.7 m/yr); however, average change for the easternmost 32 km of coast (Figure 3-6) is about -0.35 m/yr. Other than the 1917/18 to 1934 period, this 23-yr time interval is the only one recording a net sediment deficit for eastern Alabama beaches. Impacts from hurricanes over the past few years have at least maintained this trend and have likely increased the long-term rate of shoreline retreat for areas directly effected by extreme storm conditions.

3.1.3.5 Cumulative Shoreline Position Change (1847/67 to 1978/82)

Shoreline position change between 1847/67 and 1978/82 documents dramatic lateral migration of western Dauphin Island (about 7.3 km or 55 m/yr) into Petit Bois Pass and constant shoreline retreat along the western 60% of the island (about -2.2 m/yr; Figure 3-7). Following the trend of incremental change data, the eastern end of Dauphin Island exhibits net shoreline advance of 0.4 m/yr, even though a small erosion zone persists throughout the period of record. Although shoreline retreat dominates the record of change along the island, concurrent lateral growth of the beach to the west appears to balance losses recorded elsewhere.

Historical rates of change to the east along the Morgan Peninsula document net deposition within 6 km of the Mobile Bay entrance (about 1 m/yr; Figure 3-7). West of this area for the next 28 km, net shoreline retreat is persistent at an average rate of about 0.3 m/yr (average net retreat of 40 m). Averaging shoreline change rates along the eastern Alabama coast yields a net change of about 0, indicating a net sediment balance in this area. In addition, sediment accretion along the western margin of the Morgan Peninsula illustrates the dominant east to west direction of transport.

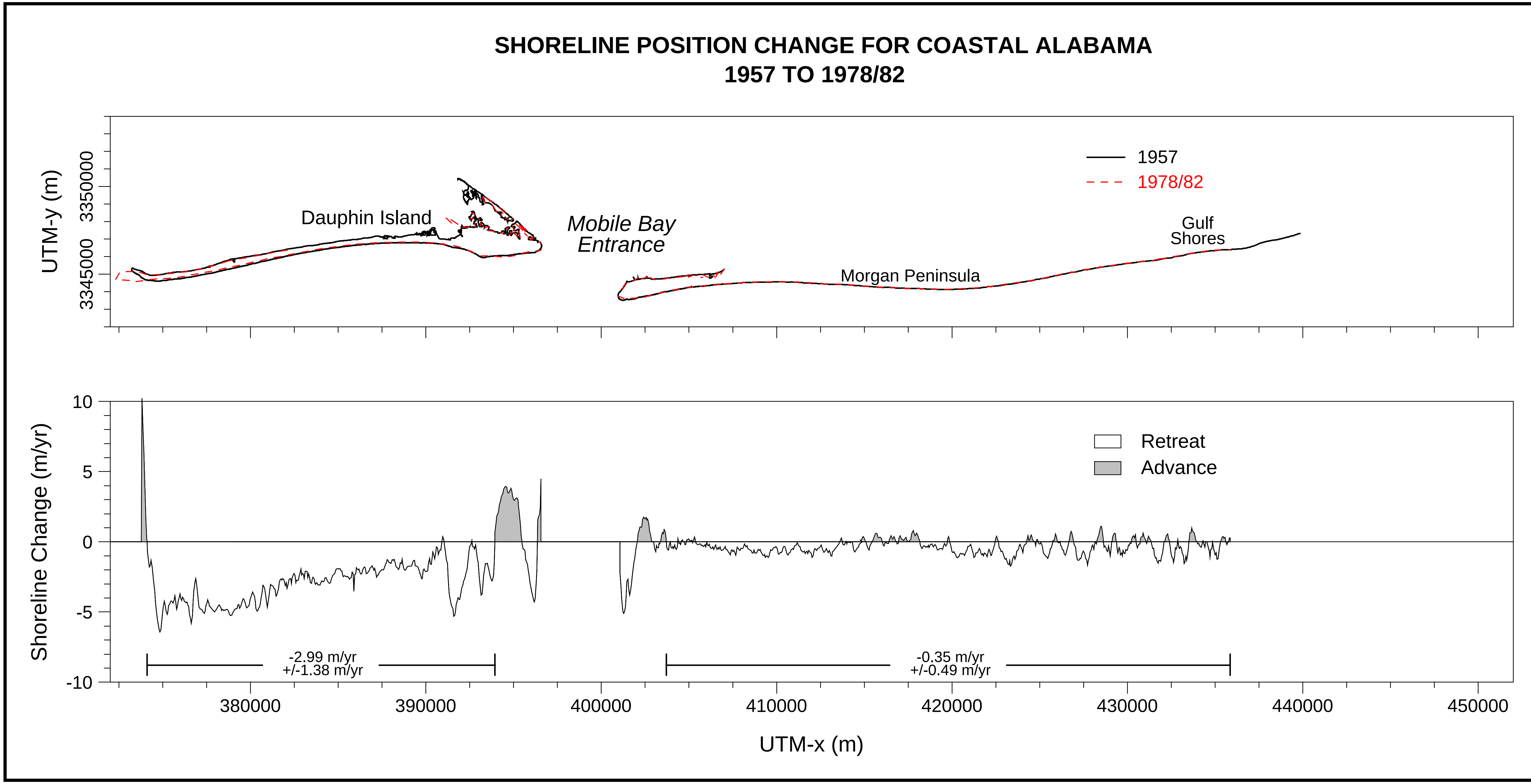


Figure 3-6. Shoreline position change along the Alabama coast, 1957 to 1978/82.

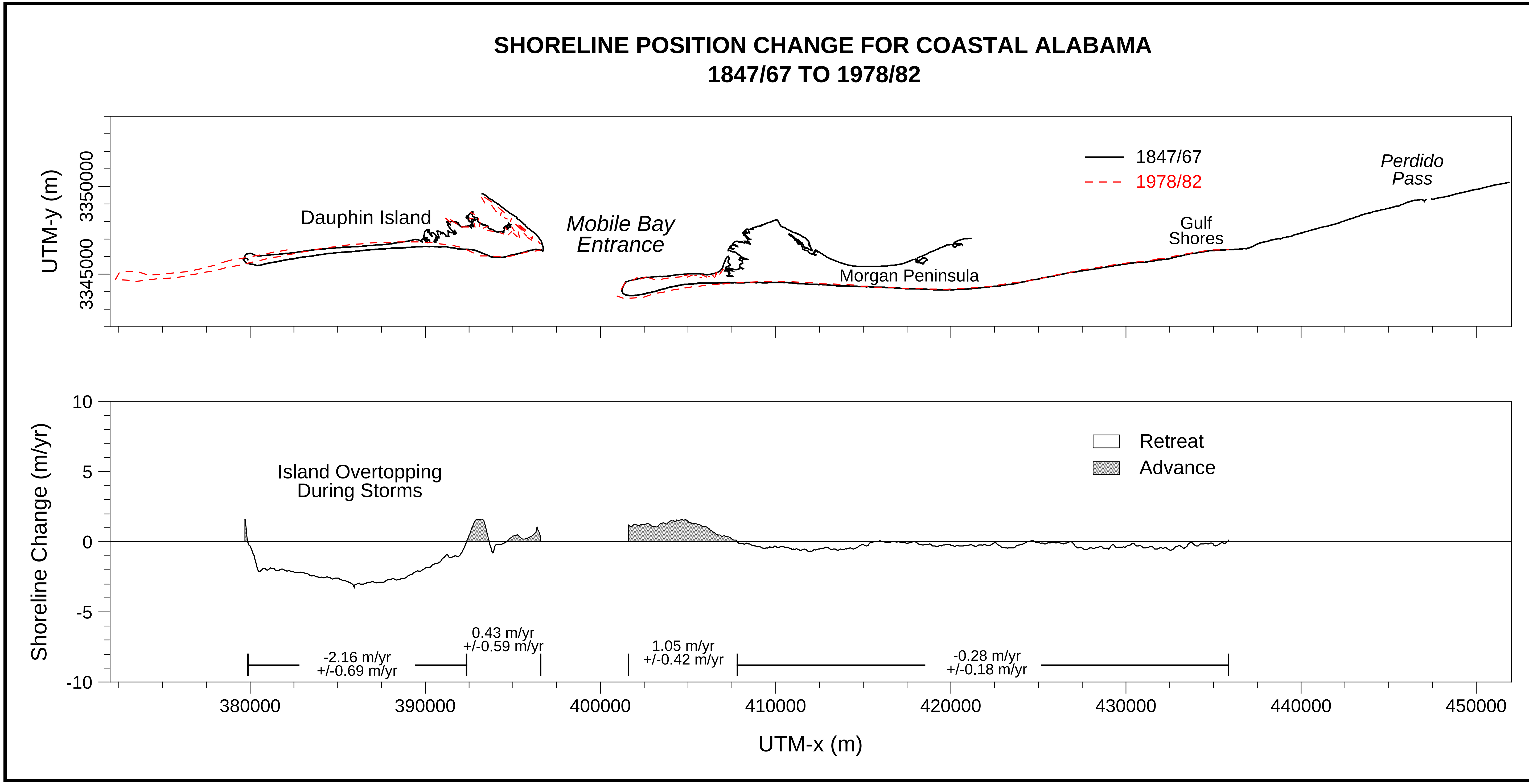


Figure 3-7. Shoreline position change along the Alabama coast, 1847/67 to 1978/82.

3.2 NEARSHORE BATHYMETRY CHANGE

3.2.1 Bathymetry Data Base and Potential Errors

Seafloor elevation measurements collected during historical hydrographic surveys are used to identify changes in nearshore bathymetry for quantifying sediment transport trends relative to natural processes and engineering activities. Two USC&GS bathymetry data sets were used to document seafloor changes between 1917/20 and 1982/91. Temporal comparisons were made for an 85-km coastal segment from 34 km west of Main Pass at the entrance to Mobile Bay to 51 km east of Main Pass at the Alabama/Florida border (Perdido Pass). Data extend offshore to about the 30-m depth contour (about 20 km offshore). The survey sets consist of digital data compiled by the National Geophysical Data Center (NGDC) and analog information (maps) that had to be compiled in-house using standardized digitizing procedures (see Byrnes and Hiland, 1994b).

The first regional USC&GS bathymetric survey was conducted in 1917/20 (Table 3-4); data were registered in units of feet. The scale of the surveys (1:40,000 and 1:80,000) suggests that they were primarily reconnaissance surveys used to provide a regional overview of bathymetry for that time period. The density of points was good for characterizing coastal and shelf topography; however, the most recent survey (1982/91) recorded many more points for describing surface characteristics in the same area. The 1917/20 offshore survey recorded an adequate number of depths along a survey line, and longshore spacing of lines was about 1 km. As such, depth values appear reasonable for describing bathymetric features and compared well with the 1982/91 survey set. The 1982/91 bathymetry data were available as digital data from the National Geophysical Data Center (NGDC).

Table 3-4. Summary of bathymetry source data characteristics for the offshore area between western Dauphin Island (at Petit Bois Pass) and Perdido Pass, Alabama.

Date	Data Source	Comments and Map Numbers
1917/20	USC&GS Hydrographic Sheets 1:40,000 (H-4020, H-4023, H-4023a) 1:80,000 (H-4139, H-4171)	First regional bathymetric survey that includes all potential resource sites in the study area; 31°05'00'', 88°25'00" to 30°15'00", 87°30'00" (western Dauphin Island east to Perdido Pass); 1917/18 – Dauphin Island to Gulf Shores (H-4020, H-4-23, H-4023a); 1919/20 - Offshore and east of Gulf Shores to Perdido Pass (H-4139); 1920 - Offshore Mobile Bay Entrance and Dauphin Island (H-4171)
1982/91	USC&GS Hydrographic Sheets 1:20,000 (from NGDC data set) 1:10,000 (from NGDC data set)	Most recent offshore regional bathymetric survey; 1982 - Perdido Pass and Offshore (H-10041); 1983 - Gulf Shores to Perdido Pass and offshore (H-10114); 1984 - seaward of Little Lagoon (H-10151a); 1985 - Morgan Peninsula and offshore (H-10179); offshore Petit Bois Pass (H-10208); 1986 - offshore Main Pass and eastern Dauphin Island (H-10226); 1987 - offshore Dauphin Island and Petit Bois Pass (H-10247, H-10261); 1991 - offshore Mobile Bay entrance, including USACE placement of Mobile Outer Mound (H-10393 and H-10394)

As with shoreline data, measurements of seafloor elevation contain inherent errors associated with data acquisition and compilation. Potential error sources for horizontal location of points are identical to those for shoreline surveys (see Table 3-2). These shifts in horizontal position translate to vertical adjustments of about ±0.3 to 0.5 m based on information presented in USC&GS and USACE hydrographic manuals (e.g., Adams, 1942). Corrections to soundings for tides and sea level change introduce additional errors in vertical position of ±0.1 to 0.3 m. Finally, the accuracy of the depth measurement adds error that is variable depending on the measurement method. Using this information, it is estimated that the combined root-mean-square error for bathymetry surface comparisons between 1917/20 and 1982/91 is about ±0.6 m. This estimate was used to denote areas of no significant change on surface comparison maps.

Because seafloor elevations are temporally and spatially inconsistent for the entire data set, adjustments to depth measurements were made to bring all data to a common point of reference. These corrections include changes in relative sea level through time and differences in reference vertical datums. Vertical adjustments were made to each data set based on the time of data collection. All depths were adjusted to NGVD and projected average sea level for 1991. The unit of measure for all surfaces is meters, and final values were rounded to one decimal place before cut and fill computations were made.

3.2.2 Digital Surface Models

Historical bathymetry data within the study area provide geomorphic information on characteristic surface features that form in response to dominant coastal processes (waves and currents) and relative sea level change. Comparing two or more surfaces documents net sediment transport patterns relative to incident processes and sediment supply. The purpose for conducting this analysis throughout the study area is to document net sediment transport trends on the shelf surface and to quantify the magnitude of change to calibrate the significance of short-term wave and sediment transport numerical modeling results. Net sediment transport rates on the shelf are determined using these historical data sets to address potential infilling rates for sand borrow sites.

3.2.2.1 1917/20 Bathymetric Surface

Bathymetry data for the period 1917/20 were combined with the 1917/18 shoreline data to create a continuous surface from the shoreline seaward to about the 30-m depth contour (NGVD). The most prominent geomorphic feature throughout the study area is the ebb-tidal delta associated with Main Pass at the Mobile Bay entrance (Figure 3-8). A series of well-defined ebb shoals (primarily on the western side of the entrance) and a prominent entrance channel dominate the entrance area to a distance approximately 10 km offshore. The channel exits the coast in a northeast-southwest direction, and the shape of the shoal is skewed to the west. This observation is consistent with all other geomorphic evidence documenting the dominant direction of net sediment transport along the shelf and shoreline to the west.

The linear sand shoal east of the Main Pass and parallel to the channel represents a zone of net deposition supplied by longshore sand transport from the east. Channel currents create a dynamic diversion to east-west transport (Todd, 1968), resulting in a shoal that parallels the channel to the seaward margin of the ebb-delta (Figure 3-8). Extensive subaerial and subaqueous islands and shoals have formed and dissipated during the historical evolution of the ebb-delta (Hummell, 1990). All of these deposits exist west of Main Pass, indicating the dominant direction of net transport is from east to west. Petit Bois Pass, at the western margin of Dauphin Island, illustrates the same pattern of deposition, where the ebb shoals and main channel are skewed to the west (Figure 3-8). Between these two passes, offshore depth contours appear relatively straight and parallel to shoreline orientation.

East of Mobile Pass (Figure 3-9), shelf bathymetry is dominated by a large shore-oblique sand shoal (northeast-southwest orientation) just west of Little Lagoon, a relatively steep shoreface west of this deposit, and numerous northwest-southeast trending sand ridges to the east (McBride and Byrnes, 1995). The prominent sand shoal extending southwest from Little Lagoon reaches approximately 11 km offshore and has topographic relief of about 6 m. The steep shoreface and deep trough west of this sand ridge may be the remnant of a Pleistocene paleochannel for Mobile Bay (Hummell and Parker, 1995). However, Parker et al. (1997) show with vibracore data that the extensive sand shoal east of this bathymetric low contains Holocene sediment, indicating a depositional process of formation during Holocene sea level rise.

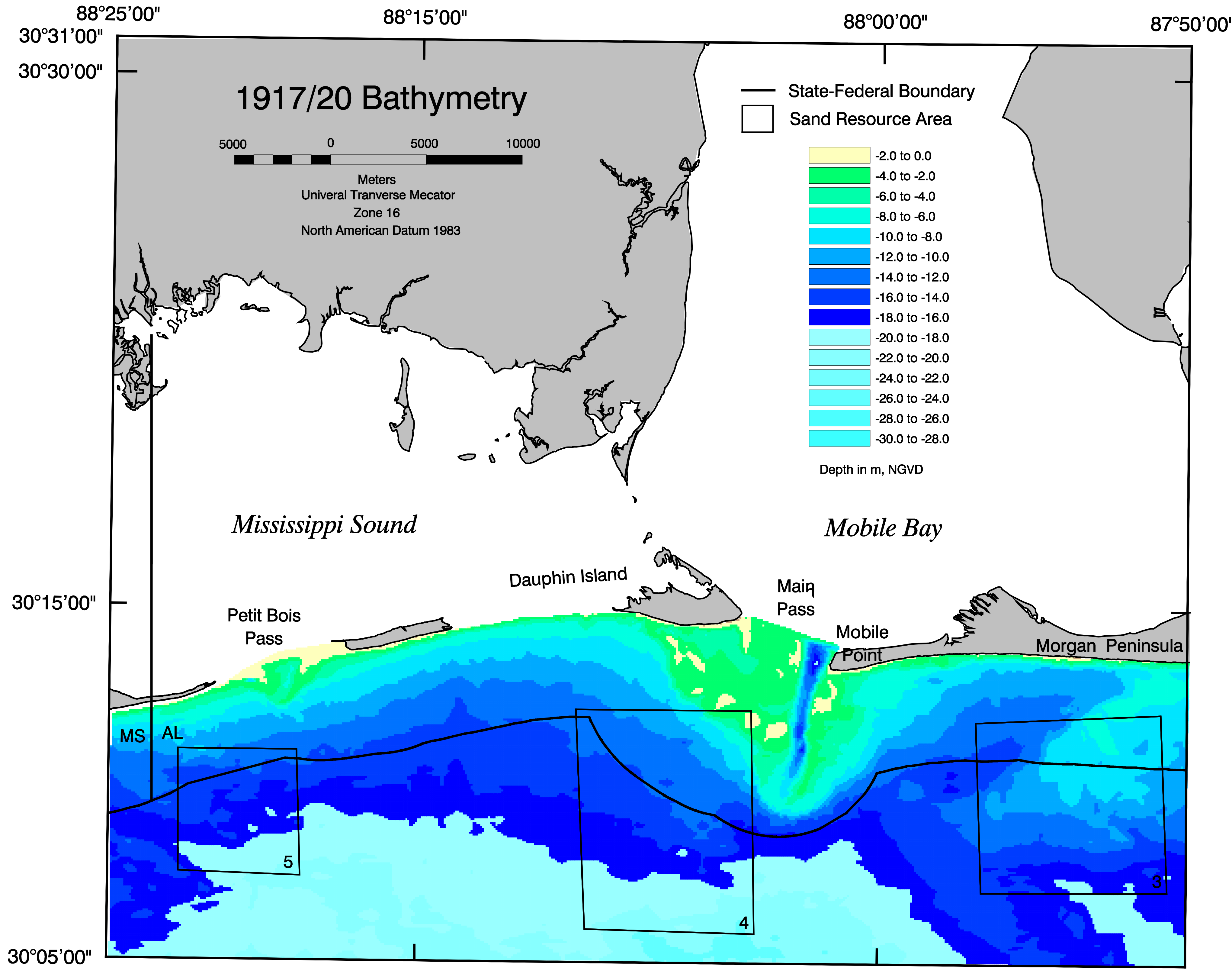


Figure 3-8. Nearshore bathymetry (1917/20) for the southwestern Alabama coastal zone.

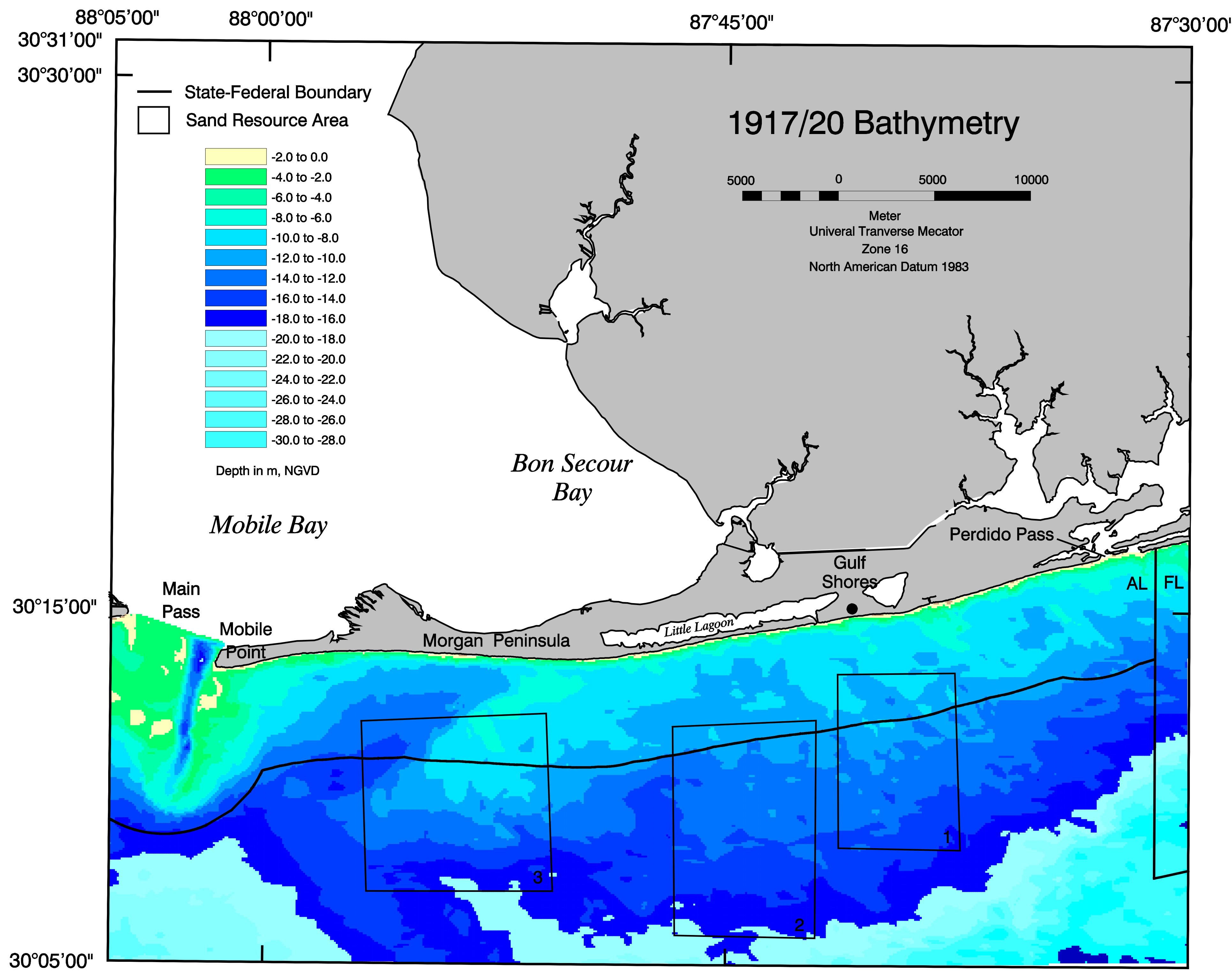


Figure 3-9. Nearshore bathymetry (1917/20) for the southeastern Alabama coastal zone.

3.2.2.2 1982/91 Bathymetric Surface

The general character of the bathymertic surface for the period 1982/91 is very similar to the 1917/20 surface with a few exceptions (Figure 3-10). First, geomorphic features are better defined because the number of data points is larger for the most recent time period. The general shape and position of shoals is consistent for both surfaces. Second, subaqueous deposition seaward of the western end of Dauphin Island changed in shape and position due to rapid migration of the beach to the west during the intervening years (see Byrnes et al., 1991). Third, an elongated sediment shoal was deposited to the southwest of the ebb-tidal delta by the U.S. Army Corps of Engineers between 1988 and 1990. Approximately 13 MCM of sediment was deposited about 10 km southwest of the Mobile Bay entrance in 14-m water depth as an experimental berm for dissipating wave energy (Hands, 1994). Known as the Mobile Outer Mound, sediment accumulation thickness was about 6 m. The sand resource target identified in Area 4 for the present study is due south of this deposit in 14- to 16-m water depth.

Shoal geometry for the ebb-tidal delta at Main Pass was better defined than in 1917/20. Main Pass channel is now on a routine maintenance schedule, and the channel extends farther seaward in 1982/91. The shoal east of the channel remains prominent in 1982/91, and sand deposits on the dominant western portion of the ebb-delta have become more extensive. Pelican Island is very well-defined and appears to be bypassing sand to the beach along eastern Dauphin Island. Shoal deposition along western Dauphin Island illustrates that sediment transport trends are dominant from east to west (Figure 3-10).

For the eastern portion of the study area, shelf morphology is characterized by three prominent features: 1) a large northeast-southwest shoal trending seaward from the Little Lagoon area; 2) a substantial nearshore bathymetric low and shoreface steepening west of the shoal; and 3) a well-defined sand ridge field (northwest-southeast trending) on and east of the large sand shoal, extending seaward to 20-m water depth (Figure 3-11). The entire shelf surface in this area is composed of clean, medium-to-fine sand. As such, almost any site within the potential sand resource areas provides quality sand for beach replenishment.

3.2.3 Shelf Sediment Transport Dynamics

Although bathymetric surfaces appear similar for 1917/20 and 1982/91, a comparison of bathymetry data yields a difference plot that isolates areas of erosion and accretion between the two surfaces for documenting sediment transport patterns and quantifying trends (Figures 3-12 and 3-13). The most significant changes occurring during the 68-yr interval were associated with deposition (and erosion) at and seaward of the Mobil Bay entrance, erosion along Dauphin Island, deposition along the Morgan Peninsula shoreline, and alternating patterns of erosion and deposition on the shelf surface in the northwest-southeast-trending sand ridge field east of Mobile Bay.

Fluid flow and sediment transport at and seaward of the entrance to Mobile Bay is most dynamic for the study area. Spring runoff and storm water outflow from Mobile Bay export substantial quantities of sediment to the shelf surface seaward and west of the entrance through suspended sediment transport (Stumpf and Gelfenbaum, 1990). Polygons of green in this area represent zones of natural deposition and human-induced deposition through dredged material disposal (large dark green areas west of the channel near the State-Federal boundary; Figure 3-12). North of this site, deposition landward of an erosion zone near Pelican Island suggests a net flux of sediment towards the beaches from offshore shoals, feeding the longshore sediment transport system. However, significant sand transport to the beach has not occurred by 1986 because beach erosion is present landward of this accretion zone. In the western portion of the study area, south of Petit Bois Pass, alternating bands of erosion and accretion illustrate the dynamic nature of shelf sand ridge deposits.

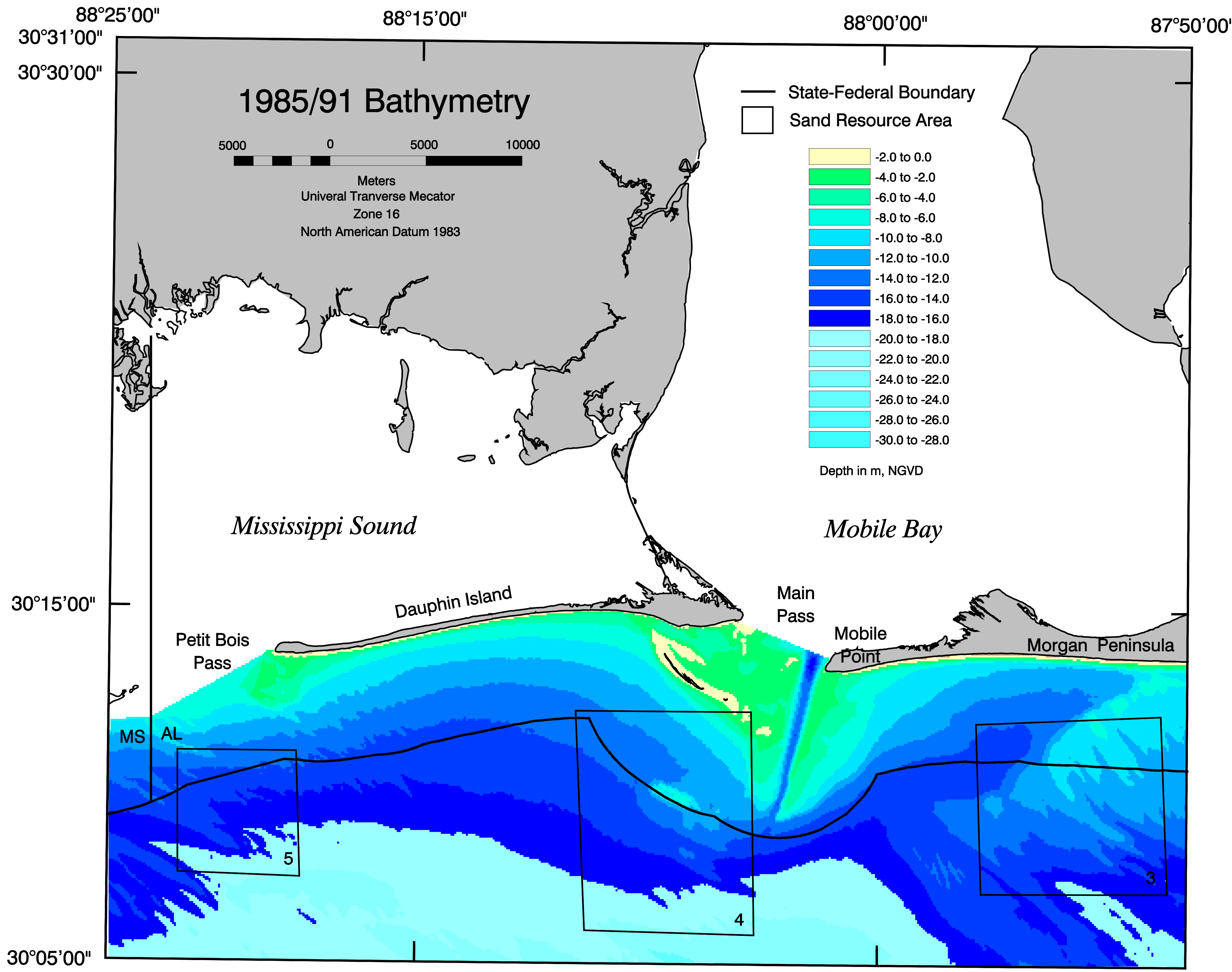


Figure 3-10. Nearshore bathymetry (1985/91) for the southwestern Alabama coastal zone.

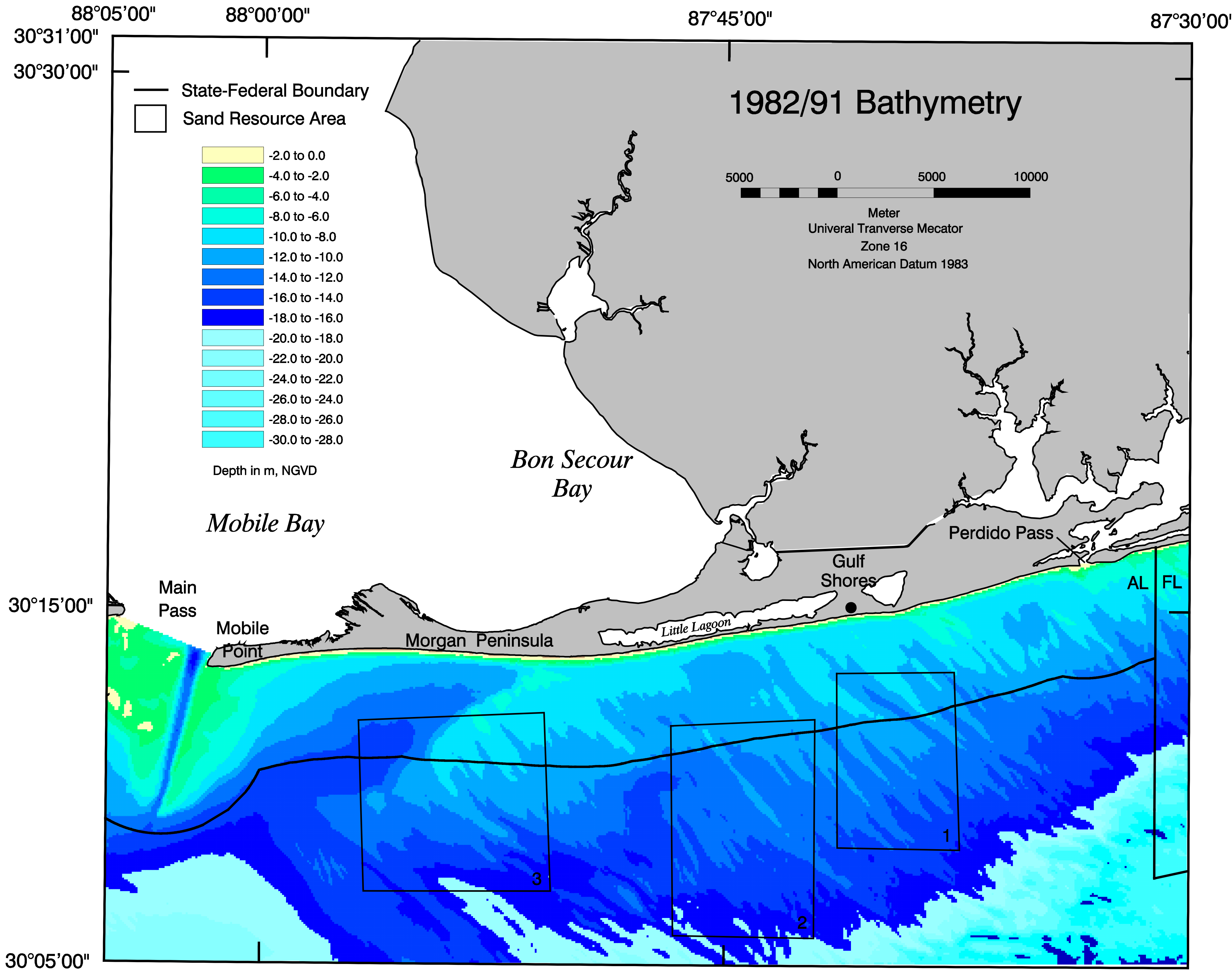


Figure 3-11. Nearshore bathymetry (1982/85) for the southeastern Alabama coastal zone.

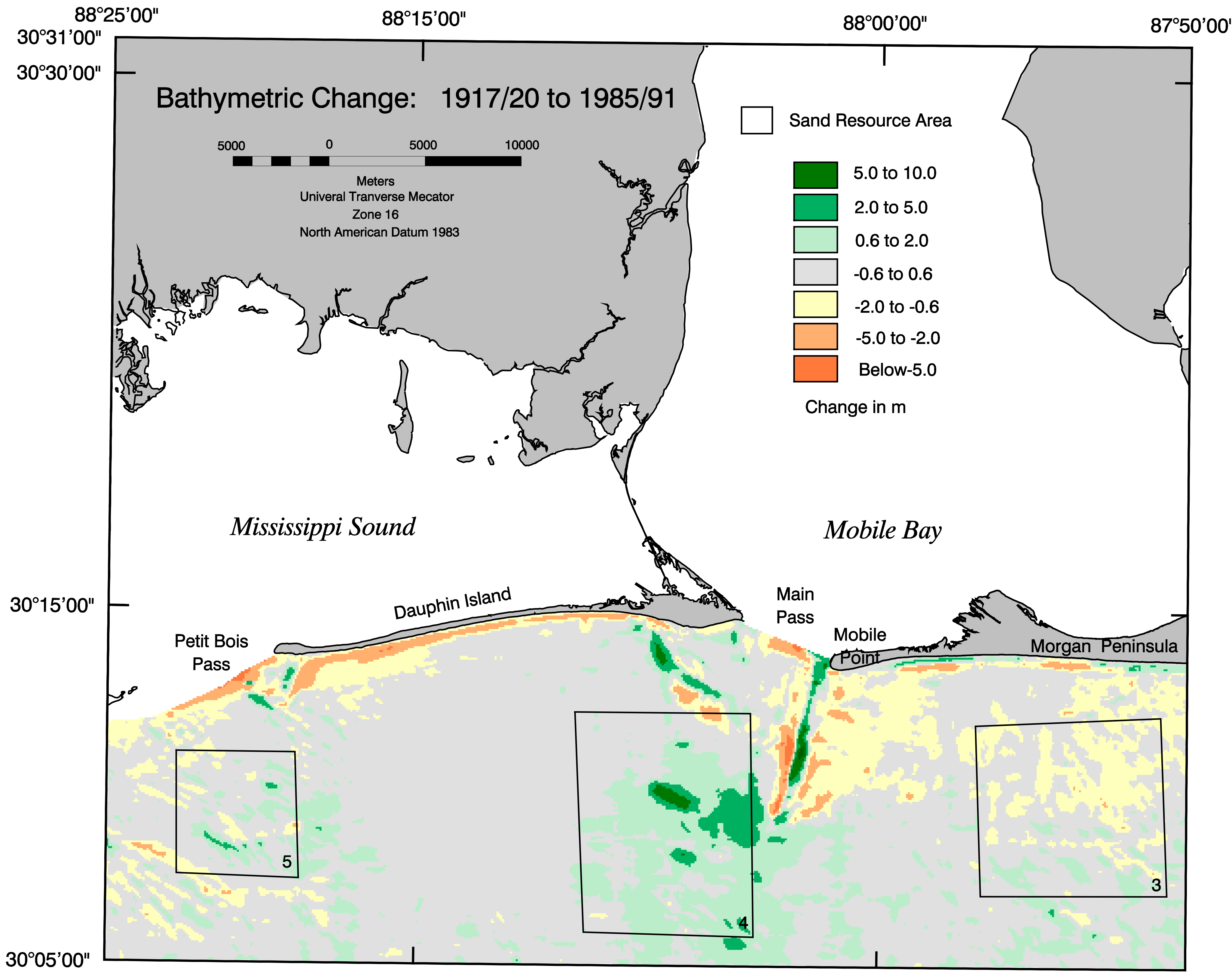


Figure 3-12. Nearshore bathymetry change (1917/20 to 1985/91) for the southwestern Alabama coastal zone.

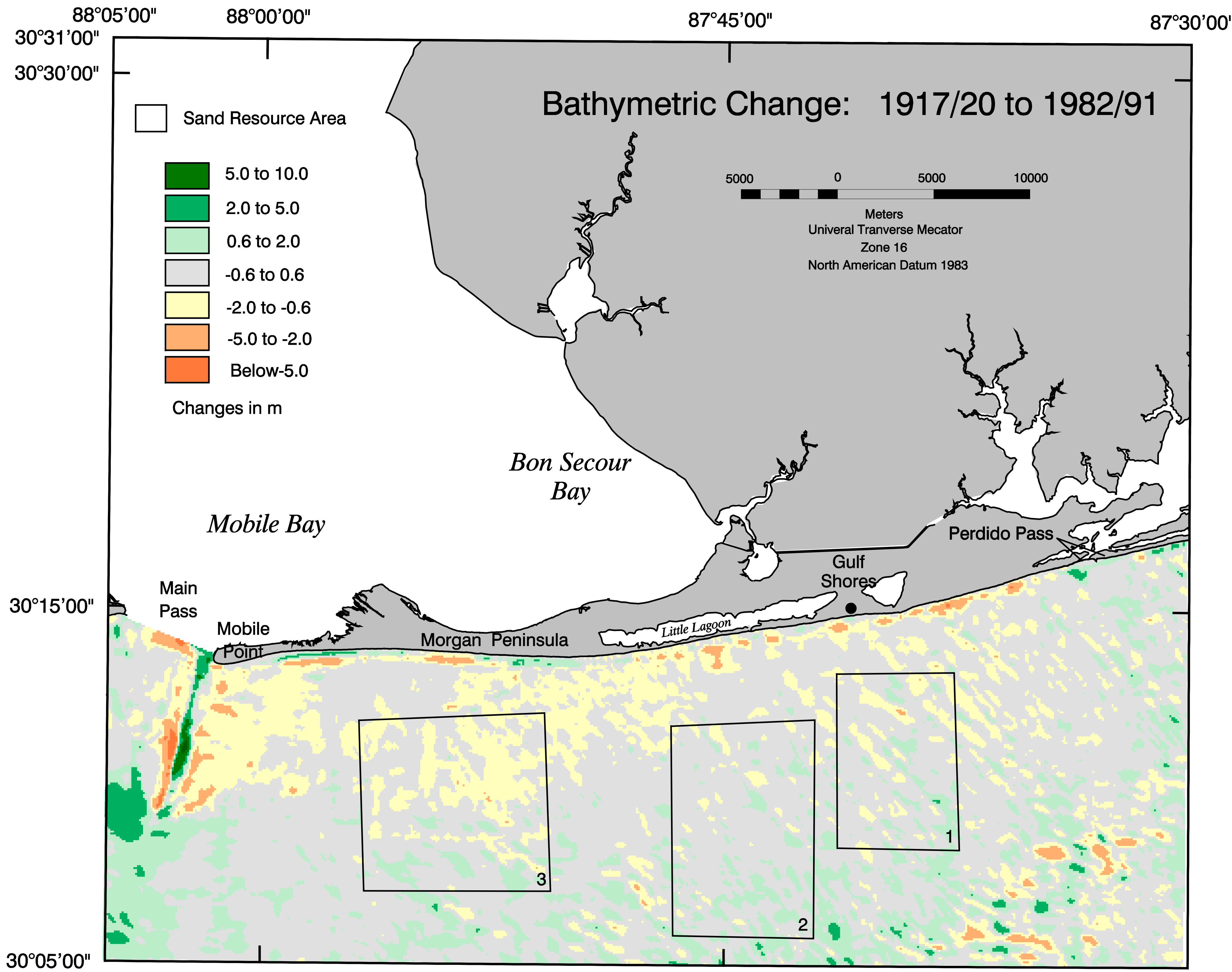


Figure 3-13. Nearshore bathymetry change (1917/20 to 1982/85) for the southeastern Alabama coastal zone.

Figure 3-13 illustrates historical sediment transport patterns east of Mobile Bay. Deposition and erosion in a thin band paralleling the coast indicates the zone of littoral sand transport. Seaward of this zone, shelf sediment transport is reflected by the migration of shoreface sand ridge deposits and alternating bands of erosion and accretion. Sand volume change calculations for these zones are used to estimate net sand transport rates along the shore and on the shelf surface (see Sections 3.2.4 and 3.2.5). Historical transport rates are used to calibrate simulations of borrow site infilling and nearshore sand transport (Section 5.2).

3.2.4 Magnitude and Direction of Change

Patterns of seafloor erosion and accretion on the continental shelf seaward of the Alabama coast documented the net direction of sediment transport throughout the study area (Figure 3-12 and 3-13). For the period 1917/20 to 1982/91, net sediment movement is to the west. This direction of transport is consistent with historical shoreline change trends and dredging practice at Main Pass channel (disposal is always west of the channel). Although overall trends are helpful for assessing potential impacts of sand extraction from the OCS, the specific purpose of the historical bathymetry change assessment is to quantify sediment erosion and accretion and to derive transport rates specifically related to potential sand extraction sites. Of the five potential borrow sites, four were chosen for evaluating sand extraction scenarios based on discussions of beach replenishment needs with Geological Survey of Alabama personnel (Hummell, 1999). Area 5 at the western end of the study area was not evaluated as a sand borrow source because it is substantially removed from beach areas of greatest replenishment needs and the sediment was least compatible with native beach sand (see Parker et al., 1997).

For Sand Resource Area 4, sediment deposition resulting from water and sediment outflow from Main Pass and dredged material disposal by the USACE was prominent on the change surface. Three specific sub-sites documented sediment deposition at 1) the potential sand resource area, 2) the Mobile Outer Mound (constructed by the USACE), and 3) the dredged material disposal site used by the USACE (and approved by EPA) during channel dredging operations (Figure 3-14). For the resource site, total sediment deposition was about 4.8 MCM between 1917/20 and 1991, or about 66,000 m^3/yr accretion. At the dredged sediment disposal site, approximately 23.5 MCM was deposited since 1917/20. At the Mobile Outer Mound, where about 13 MCM of sediment was placed by the USACE between 1988 and 1990, net deposition since 1917/20 was about 13 MCM (equal to the amount placed by the USACE as reported by Hands [1994]).

For Sand Resource Area 3, primarily erosion is indicated at the sand resource site. The total amount of sand volume change at the site between 1917/20 and 1982/85 was about 585,000 m^3 or about 8,800 m^3/yr. At Sand Resource Area 2, a well-defined zone of erosion exists adjacent to a zone of deposition as a shoreface sand ridge migrates to the west under the influence of incident shelf processes (Figure 3-15). The zone of deposition indicates an accretion rate of about 6,200 m^3/yr, whereas the erosion rate is calculated as about 9,100 m^3/yr (rates of change are normalized using the potential resource site surface area). As such, the average, long-term transport rate for the resource site is 7,300 m^3/yr.

At Sand Resource Area 1, the rates of erosion and accretion associated with sand ridge migration were quite variable over short distances. Shoal migration near the sand resource site illustrated net transport from east to west, but associated transport rates vary from 34,000 to 9,000 m^3/yr, respectively. Net sand volume change at the proposed resource site indicated no significant movement for the period of record; however, absolute sand volume change averaged about 8,500 m^3/yr. Although the potential for transport (and borrow site infilling) is high in this area, the average sand transport rate is consistent with other sand resource areas south of the Morgan Peninsula.

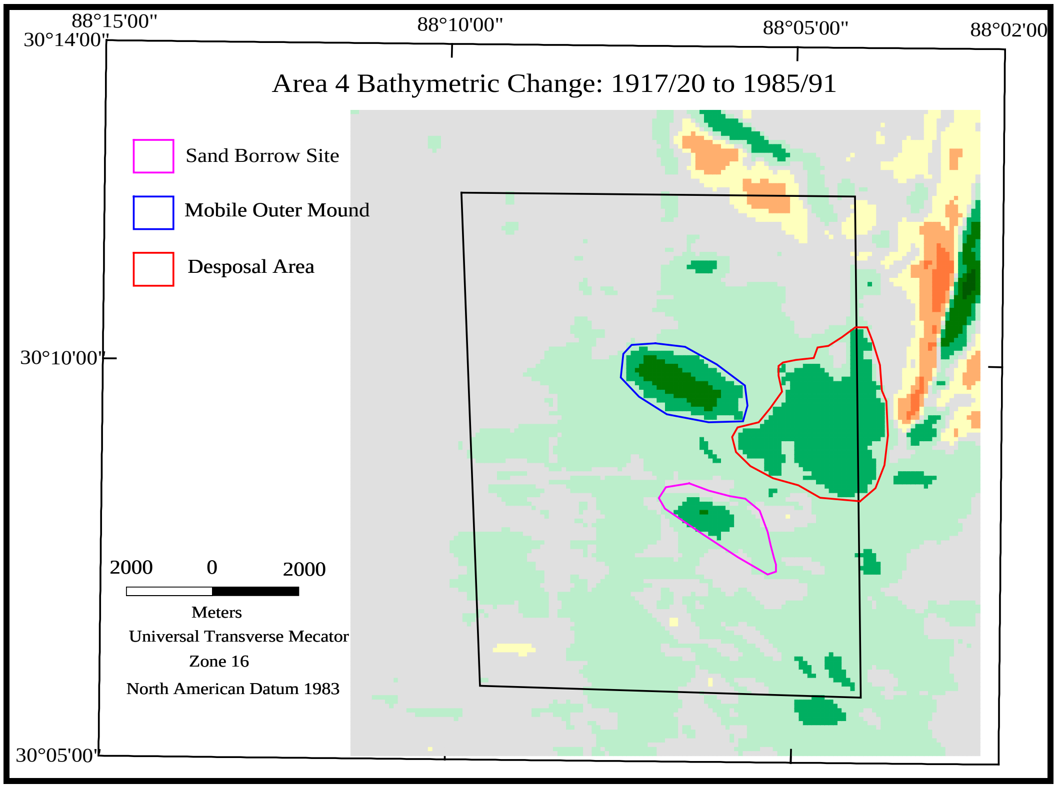


Figure 3-14. Sand resource site location relative to dredged material deposition for Resource Area 4.

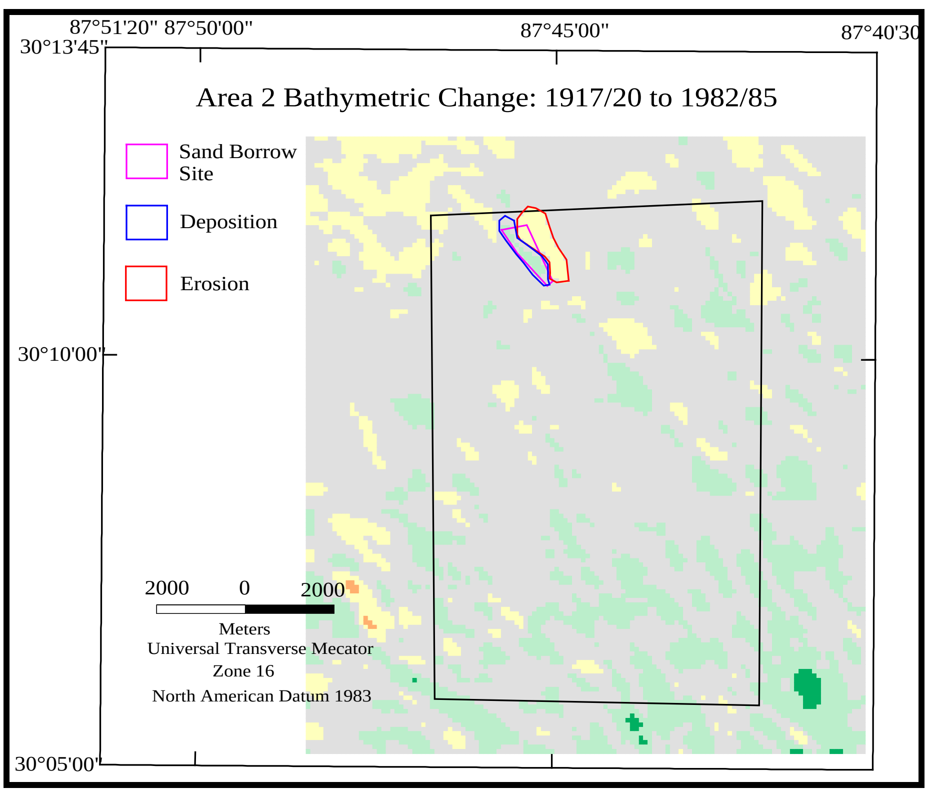


Figure 3-15. Sand resource site location relative to sand ridge erosion and deposition in Resource Area 2.

3.2.5 Net Longshore Sand Transport Rates

Well-defined zones of erosion and accretion are documented in Figure 3-13 as the region of littoral sand transport along the Morgan Peninsula. This zone extends seaward to about the 6-m (NGVD) depth contour (see Figure 3-11), which represents the approximate depth of closure (based on calculations of d_l from Hallermeier [1981] using USACE Wave Information Study [WIS] data statistics). Between Perdido Pass and Main Pass, alternating zones of erosion and accretion were evaluated with respect to the net sediment budget to determine a net longshore sand transport rate for the area. With the western boundary defined by the present location of Main Pass channel, the net long-term sand transport rate was determined as approximately 106,000 m^3/yr. Unfortunately, an estimate of sand transport for the littoral zone of Dauphin Island could not be determined from the existing data set, due in part to the absence of a 1917/20 shoreline boundary along much of the island (see Figure 3-4). However, because incident wave processes do not vary significantly throughout the study area (see Section 4), it is expected that the longshore sand transport rate determined for the area east of Main Pass is representative for Dauphin Island as well.

3.3 SUMMARY

Shoreline position and nearshore bathymetry change document four important trends relative to study objectives. First, the predominant direction of sediment transport throughout the study area is east to west. Western Dauphin Island has migrated at a rate of 56 m/yr to the west since 1917. The ebb-tidal shoals at Main Pass and Petit Bois Pass are skewed to the west, and the natural channel at Petit Bois Pass is aligned in a northeast-southwest direction. Deposition associated with outflow from Mobile Bay is illustrated primarily west of the channel, and a pattern of downdrift deposition (west) and updrift erosion (east) is documented for shoreface sand ridge deposits seaward of Morgan Peninsula.

Second, the most dynamic portion of the study area, in terms of sediment transport, is the ebb-tidal delta at Mobile Bay entrance. Areas of significant erosion and accretion are documented for the period 1917/20 to 1982/91, reflecting USACE channel dredging and sediment disposal practice, wave and current dynamics at the entrance and influence on sediment deposition seaward and west of the ebb-delta, and the contribution of littoral transport from the east to channel infilling adjacent to Mobile Point.

Third, alternating bands of erosion and accretion on the continental shelf east of Main Pass illustrate relatively slow but steady reworking of the upper shelf surface as sand ridges migrate to the west. The process by which this is occurring suggests that a borrow site in this areas would fill with sand transported from an adjacent site at a rate of about 10,000 m^3/yr. Sand Resource Area 1 illustrates the largest variability in potential transport rates, whereas Areas 2 and 3 are fairly consistent for the period of record. Although long-term sand transport rates are relatively low, sediment filling the borrow area(s) would be primarily sand because the shelf surface in the area contains about 95% sand (Parker et al., 1993, 1997; Hummell and Smith, 1995, 1996; McBride and Byrnes, 1995). For Sand Resource Area 4, the potential borrow site area appears to be accreting at a fairly rapid rate (approximately 66,000 m^3/yr), but much of the sediment encountered near the surface is silt and clay.

Finally, the net longshore transport rate determined from seafloor changes in the littoral zone between Perdido Pass and Main Pass indicate a gradient in transport to the west at a rate of about 106,000 m^3/yr. Variations in transport rate are evident in the patterns of change recorded on Figure 3-13. It appears that areas of largest net transport exist just east of Gulf Shores where coastal erosion is greatest in the littoral zone.