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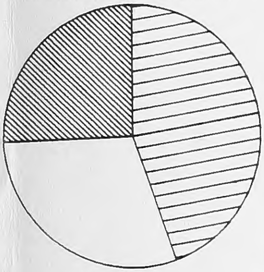

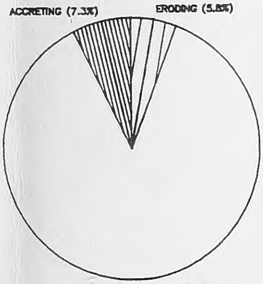

TECHNICAL REPORT CERC-83-1

SHORELINE MOVEMENTS

Report 2

TYBEE ISLAND, GEORGIA, TO CAPE FEAR, NORTH CAROLINA, 1851-1983

by

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The history of shoreline change along the coast of South Carolina is examined. Maps depicting the entire shoreline at various points in time were prepared by the National Oceanic and Atmospheric Administration, National Ocean Service, and the South Carolina Division of Research and Statistical Services. These maps were used by Staff of the US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, to analyze changes in shoreline position over the past 150 years.

The shoreline maps were digitized at an along-the-coast interval of 50 m. Cross-shore transects were established at each location to facilitate examination of shoreline position changes. Shoreline position was compared both spatially and temporally to determine net and average rate of change. Data are summarized in this report for each transect, defined segments of shoreline, each barrier island or mainland beach, and defined

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geomorphic regions. The technique allows quantification of shoreline change in an onshore-offshore direction. Pronounced alongshore changes, such as often occurs at inlets or capes, were examined using manual techniques to measure areal changes. Results are presented for the entire Atlantic coast from Tybee Island, Georgia to Cape Fear, North Carolina, in both graphic and tabular format. Erosion and accretion were variable spatially and temporally throughout the period of record. Results show that long-term erosion (>1 m/year) predominated throughout the region of coast fronted by barrier islands. Mainland beaches, such as those along the "Grand Strand" were relatively stable. In both regions, erosion rates were most variable and greatest in the vicinity of inlets.

A variety of factors were compared with the shoreline change data to determine the cause for measured patterns of erosion and accretion. Proximity to inlets was a major cause for variable erosion present along the barrier island coastline. Lack of inlets could also be a major reason for stability of "Grand Strand" beaches, along with the shallow depth to less erodible pre-Holocene sediments. Human impacts in the coastal zone had localized measurable effects on erosion/accretion patterns. Maximum wave height also correlated well with erosion, suggesting that susceptibility to storms was an important factor in determining shoreline stability. Other factors, such as nearshore bathymetry and shoreline orientation showed little effect on shoreline changes.

PREFACE

This report is the result of a cooperative effort of the National Ocean Service (NOS), National Oceanic and Atmospheric Administration (NOAA), US Department of Commerce; the Division of Research and Statistical Services (DRSS) of the State of South Carolina; and the Coastal Engineering Research Center (CERC) of the US Army Engineer Waterways Experiment Station (WES). The study, based on a comparison of historic survey data contained in the NOS archives, was funded jointly by Headquarters, US Army Corps of Engineers (HQUSACE), NOAA, and the State of South Carolina. All survey data reduction, quality control, and publication of the shoreline maps were performed by NOS with support from DRSS; data analyses and report preparation were completed by CERC under the Barrier Island Sedimentation Studies work unit of the Coastal Program. Dr. C. Linwood Vincent was the Coastal Program Manager, and Messrs. John H. Lockhart, Jr., and John G. Housley were HQUSACE Technical Monitors.

The report was prepared by Messrs. Fred J. Anders, David W. Reed, and Edward P. Meisburger, CERC. Work was carried out under the general supervision of Dr. Steven A. Hughes, Chief, Coastal Processes Branch, Research Division (RD), CERC; Ms. Joan Pope, Chief, Coastal Structures and Evaluation Branch, Engineering Development Division (EDD); Mr. H. Lee Butler, Chief, RD; Mr. Thomas W. Richardson, Chief, EDD; Dr. James R. Houston, Chief, CERC, and Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC. Original programs to analyze shoreline change data were developed by Mr. Steven Knowles, formerly of CERC. The section describing map production procedures was modified from a report by Everts et al. (1983)(see References at the end of the main text). Numerous contributions by all members of the Coastal Geology Unit, CERC, including review of the manuscript, are gratefully acknowledged. This report was edited by Ms. Lee T. Byrne of the Information Technology Laboratory, WES.

Shoreline change maps for Tybee Island, Georgia, to Cape Fear, North Carolina, are included as a separate enclosure to this report.

Commander and Director of WES during publication of this report was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
foot-pounds (force)	1.355818	metre-newtons or joules
knots (international)	0.5144444	metres per second

SHORELINE MOVEMENTS

TYBEE ISLAND, GEORGIA, TO CAPE FEAR, NORTH CAROLINA, 1851-1983

PART I: INTRODUCTION

1. This is the third and final report in a series of shoreline change studies undertaken cooperatively between the National Oceanic and Atmospheric Administration (NOAA); National Ocean Service (NOS); and the Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station (WES). Maps accompanying this report received additional support from the Division of Research and Statistical Services of the State of South Carolina. The study area comprises the ocean coast of northern Tybee Island, Georgia, the entire ocean coastline of South Carolina; and the contiguous coastline of North Carolina to Cape Fear (Figure 1). Unlike previous series reports, map data were insufficient to include bay side shorelines of barrier islands. Changes in ocean shoreline position from 1852 to 1983 were available using survey data from NOS and its predecessor, the US Coast and Geodetic Survey (USC&GS). Shoreline change maps for Tybee Island, Georgia, to Cape Fear, North Carolina, are included as a separate enclosure to this report.

2. Evolution of the shoreline has become a point of increasing concern within the coastal community during the last two decades. Evidence is based on the increasing number of reports in the scientific literature which use shoreline change information. Coastal managers, engineers, and scientists have recognized the value of these data sets for management and engineering decisions in the coastal zone. Historic shoreline change data are easy to acquire, exhibit, and update as new data become available. Also, with some reservations, shoreline change data can be carefully extrapolated to predict future shoreline changes resulting from natural and man-made causes.

3. Use of maps and aerial photos to examine spatial and temporal changes in the shoreline has a long history; however, quantitative assessment of shoreline change from photos and maps was not well documented until 1970 (Langfelder, Stafford, and Amein 1970; Stafford 1971;, Stafford and Langfelder 1971). Since then, coastal scientists have used a variety of techniques to measure shoreline change (Fisher 1977; Dolan, Hayden, and Heywood 1978; Leatherman 1983). Aerial photographs can be used to provide detail and short-time

Figure 1. Map of the study area: the coastline from Tybee Island, Georgia, to Cape Fear, North Carolina

interval data required for evaluating processes shaping the coastline. However, until the many episodic events that form the coastline are integrated, a detailed understanding and interpretation of long-term processes and morphological response are precluded. Use of historical maps expands the temporal view of the coastline, smoothing peaks and valleys of short-term changes, allowing managers, engineers, and scientists to view long-term coastal trends.

4. This investigation of shoreline change used up to a 132-year span of NOS/USC&GS map data derived from original field and air photo surveys. Maps depicting shoreline position are available prior to the first USC&GS map used here (1851); however, accuracy of earlier maps cannot be determined.

Likewise, additional maps are available between dates of those used in this investigation, but their level of accuracy and/or scale were not suitable. Accuracy in original data sets and in their interpretation is an essential ingredient in producing believable shoreline change information.

5. This study is intended to enhance and explain the accompanying shoreline change maps. The maps were used to establish transects perpendicular to shoreline trend at a 50-m alongshore interval. Shoreline position at each survey date was digitized on the transect allowing linear comparisons of shoreline position to calculate shoreline change. Average and maximum net rate of change and standard deviation of shoreline change are among data presented for each transect. Shoreline change transect data are presented in summary form (a) in short, defined alongshore coastal segments; (b) by Barrier Island/Mainland beach; (c) by defined coastal reach; (d) by geomorphic zones; and (e) for the entire study area. Extremely dynamic changes around inlets and capes were not measurable using this technique and had to be specially treated. Where possible, temporal and alongshore spatial variations in shoreline change rates were compared with physical characteristics of the coast and process information to explain observed variability.

6. Several important differences exist between this report and the previous two. First, very limited bay side shoreline information was available on the NOS maps, and where it was present, shoreline change was so small as to fall outside accuracy limits of this technique. Consequently, no bay shoreline data are presented, only data from coastlines facing the open ocean. This factor allowed the use of linear measurement of shoreline change, as in Report 3 (Knowles and Byrnes, in preparation), not aerial changes as in Report 1 (Everts, Battley, and Gibson 1983). A second difference is the length of shoreline examined in this report. Report 1 covered 210 km of generally linear barrier island coastline. Report 3 covered 208 km of mixed linear, elongated barriers and short barriers with frequent inlets. This report covers over 336 km of shoreline composed of short barriers with frequent inlets and a wide range of coastal orientations, shallow open-water bays, and long, arcuate coastal headlands. The length of shoreline required subdivision of the coastline into smaller reaches to allow presentation of data. For this study, the shoreline change maps were produced by NOS in a south-to-north direction, opposite of previous reports. This necessitated some changes in procedures used to obtain quantitative information.

PART II: STUDY AREA

Geographical Setting

7. The study area encompasses approximately 336 km of open Atlantic coastline from the northern end of Tybee Island, Georgia, north along the South Carolina coast to Cape Fear, North Carolina (Figure 1). The southern portion of this reach is composed of numerous barrier islands averaging 7 km in length, separated by frequent tidal inlets. Many of these inlets are large, representing the point of debouchere for major coastal plain rivers. From south to north, these include Tybee Roads/Calibogue Sound, Port Royal Sound, St. Helena Sound, Charleston Harbor, Bull Bay, and Winyah Bay. Tybee, Hilton Head, Pritchards, Hunting, Edisto, Seabrook, Kiawah, Folly, Morris, Sullivans, Isle of Palms, Dewees, Capers, Bull, and Cape Island are the major barrier islands within this section from south to north. This segment of the coastal plain, often referred to as the "Carolina low country" because of its low relief, is also characterized by wide salt marshes, dissected by meandering tidal creeks, between the barrier islands and mainland. Freshwater swamps are abundant throughout the region. The general orientation of the coastline in the southern section is northeast to southwest.

8. Cape Island, which includes the prominent Cape Romain, lies roughly in the middle of the study area (Figure 1). At Cape Romain, the shoreline reorients to north-northeast. North of Cape Island, the shoreline changes under influence of the Santee, Waccamaw, Pee Dee, Sampit, and Black Rivers. The Santee had the fourth largest discharge of any river on the east coast (Kjerfve 1976). Small barrier islands, backed by wide expanses of salt marsh, dominate this deltaic coastline.

9. North of this region, bordering Long Bay, begins a coastal reach characterized by relatively few and small inlets, little coastal marsh, mainland beaches, and limited barrier islands, referred to as the "arcuate strand" (Brown 1977). This arcuate segment of coastline extending from Winyah Bay to Cape Fear, North Carolina, is generally less than 8 m above mean sea level (MSL) and has an orientation of north-northeast to south-southwest in the south, reorienting to approximately east-west at Cape Fear. North, Murrells, and Little River are the major South Carolina inlets within this reach. Debidue, Pawleys Island, Litchfield, Huntington, Garden City,

Surfside, Myrtle, and North Myrtle are beaches from south to north that are located in South Carolina. These beaches have been important in the recreation industry of the state. The North Carolina segment is composed of mainland beach and six barrier islands separated by small inlets. From east to west, these include Smith, Oak, Ocean Beach, Ocean Isle Beach, Sunset Beach, and Bird islands. They are separated from the mainland by marsh, tidal creeks, and the Atlantic Intercoastal Waterway. Most are less than 5 m above MSL. Inlets from east to west include New Inlet, which is north of Cape Fear; Cape Fear River; Lockwood Folly; Shallotte Sound; Tubbs; and Mad Inlet.

Coastal Environment

Winds and waves

10. Along this reach of coast, south and southwest winds prevail, especially during spring and summer months (Figure 2*). During fall and winter, north, northeast, and easterly winds prevail. Northeast quadrant winds are generally strongest and thus dominate in effect on the coastline. Initiation of sediment motion by wind requires a minimum velocity of 16 km/hr, and at least 25 km/hr are required to sustain transport (Bagnold 1941). Winds of this velocity are most likely to occur from the northeast quadrant.

11. Wind direction is influential in controlling wave approach along this coastline. Sea and swell data for the block of 30- to 35-deg north latitude and 75- to 80-deg west longitude (US Army Corps of Engineers (USACE) 1974, taken from the US Naval Oceanographic Office, Oceanographic Atlas) indicate the effect of wind in controlling wave direction (Figure 2). Predominant seas are from the northeast and southeast, and swell most frequently occurs from the northeast and east followed by the southeast. Seasonal directionality of offshore waves are indicated in Figure 3. Bloomer (1973) concluded that water circulation patterns on the south Atlantic inner shelf are controlled primarily by wind direction and secondarily by tides. Wave direction is the driving force behind movement of littoral drift, which is predominantly to the southwest along this entire stretch of coast (Brown 1977). Local reversals because of nearshore bathymetry and coastal orientation do occur.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 7.

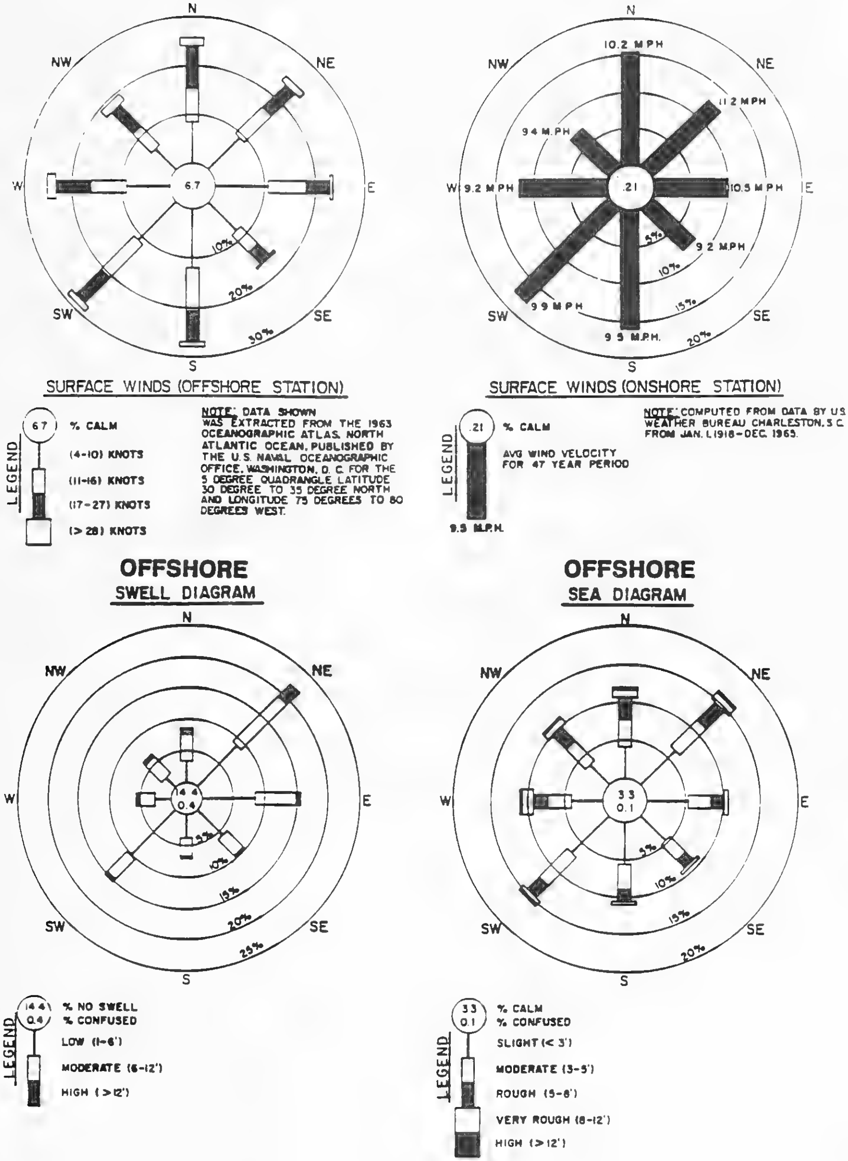


Figure 2. Summarized wind and offshore wave conditions near Charleston, SC (USACE 1974)

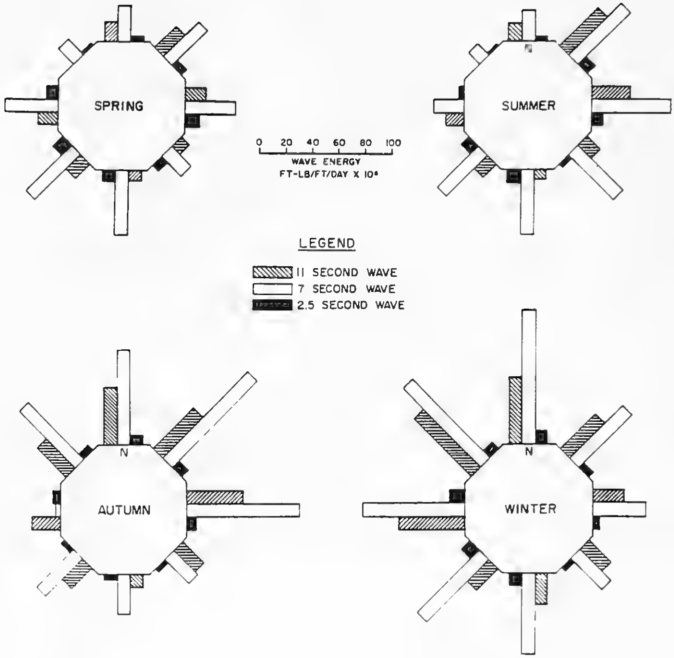
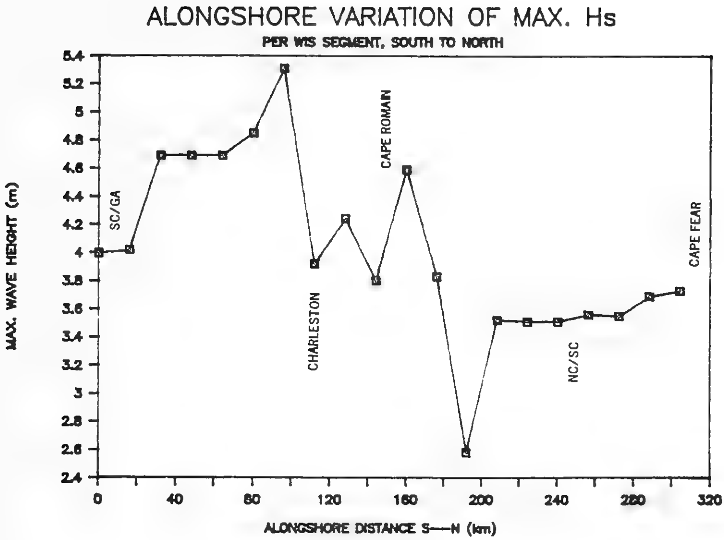


Figure 3. Seasonal directionality of offshore wave conditions near Charleston, SC (USACE 1974)

Net rate of littoral drift was estimated to be 128,000 cu m/year at Murrells Inlet (Kana 1977); 290,000 cu m/year at Bull Island (Knoth and Nummedal 1977); 130,000 cu m/year at Capers Island (Kana 1977); and 200,000 cu m/year at Charleston (FitzGerald, Fico, and Hayes 1979).

12. Hubbard, Barwis, and Nummedal (1977) and Nummedal et al. (1977) noted wave energy flux for South Carolina and the South Atlantic coast of the United States decreased from north to south. Wave energy flux, the amount of energy expended by a wave per unit distance per unit time, is related to wave period and the square of wave height. Height and period data for the study area were obtained from the Phase III, USACE, Wave Information Study (WIS) (Jensen 1983), which contains inner shelf wave statistics hindcast from a 20-year period of meteorological data (1956-1975) at an along-the-coast interval of 16 km. Average significant wave height, maximum significant wave height, and average period were plotted from WIS data and show alongshore variation within the study area (Figures 4 and 5). Wave height and period



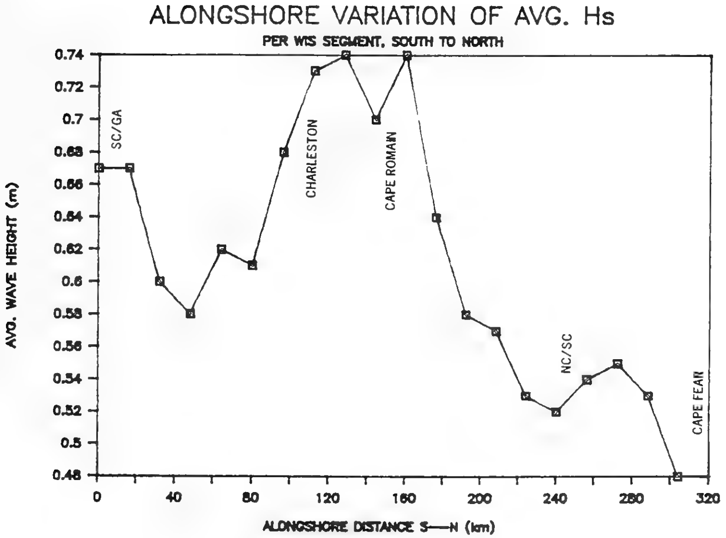
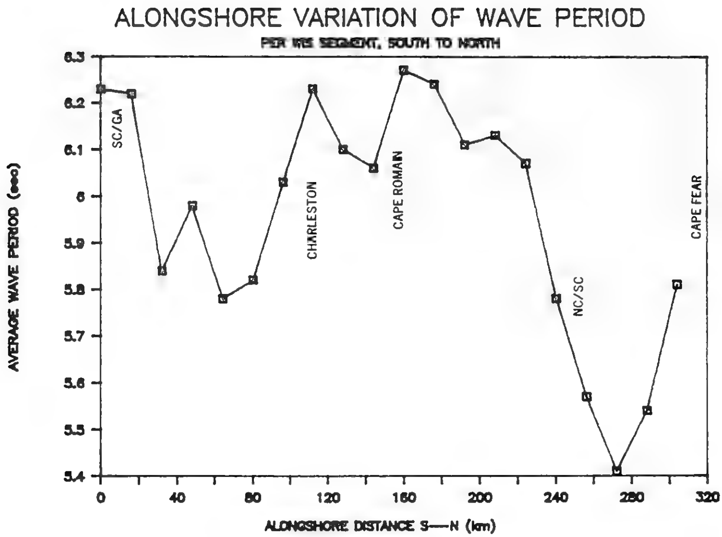


Figure 4. Alongshore variation of wave height within the study area



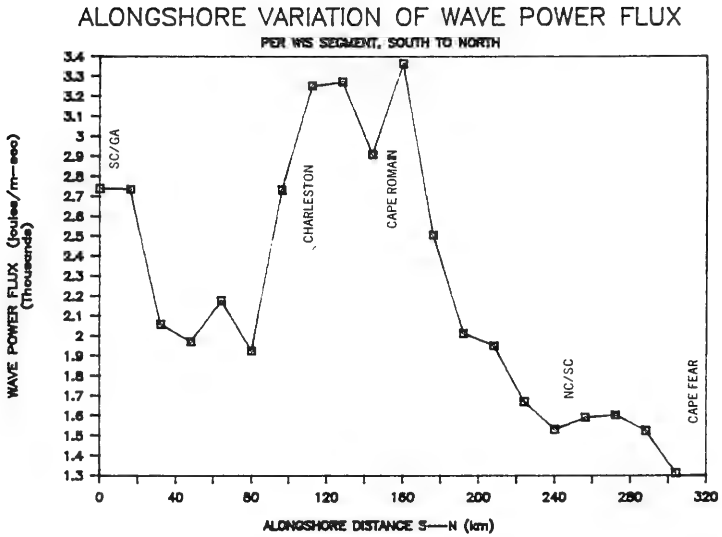


Figure 5. Alongshore variation of wave period and wave power flux within the study area

were generally lowest in northern sections of the study area, increasing rapidly southward towards Cape Romain and Charleston, and then decreasing towards Savannah, GA. Wave power flux calculated from WIS data (Figure 5) mimics the general trends of average wave height and period. A net increase in wave energy flux of approximately 80 percent is evident from the northern end of the study area to the southern end. This does not agree with Hubbard, Barwis, and Nummedal (1977) and Nummedal et al. (1977), who based their conclusions on 1970 Naval Weather Service Command data Summary of Synoptic Meteorological Observations (SSMO). The WES investigators feel that the differences are a result of the longer period of record and more frequent along-the-coast interval of WIS data.

Tides

13. The coast of South Carolina has been classified as mesotidal (2- to 4-m tidal range) by Hayes (1975) based on a classification system by Davies (1964). Brown (1977) and Hubbard, Hayes, and Brown (1977) indicate mean tidal range and spring tidal range increase towards the south along this coast (Figure 6). Calculations based on predicted tide tables (US Department of Commerce 1986) show an increase of 1.7 to 2.4 m in maximum tidal range from Wilmington, NC, to Charleston, SC, and an increase of 2.4 to 3.2 m from Charleston to Savannah, GA. Overall, there is an 88-percent increase in maximum tidal range from north to south in the study area, while wave power flux increased 80 percent from north to south. Finley (1978) describes the tide at North Inlet as being semidiurnal, with a diurnal inequality averaging 0.37 m. Annual variations in tide level are also present (Figure 6). Annual variation is due to a variety of factors including effects of storms.

Storms

14. Short-term increases in tidal height within the study area occur with passage of storms. Coastal flooding is one of the most significant storm damages in this area because adjacent land elevations are so low. The study area is subject to late summer and fall tropical cyclones (minimum wind speed of 64 km/hr) and hurricanes (minimum wind speed of 118 km/hr), and extratropical northeast storms during winter. The scientific literature includes discussions of relative damages produced by northeast storms and tropical storms along the east coast of the United States; however, most researchers (e.g., Machemehl 1974; Myers 1975) contend that extratropical storms play a subordinate role within this study area. Simpson and Miles (1971) report a

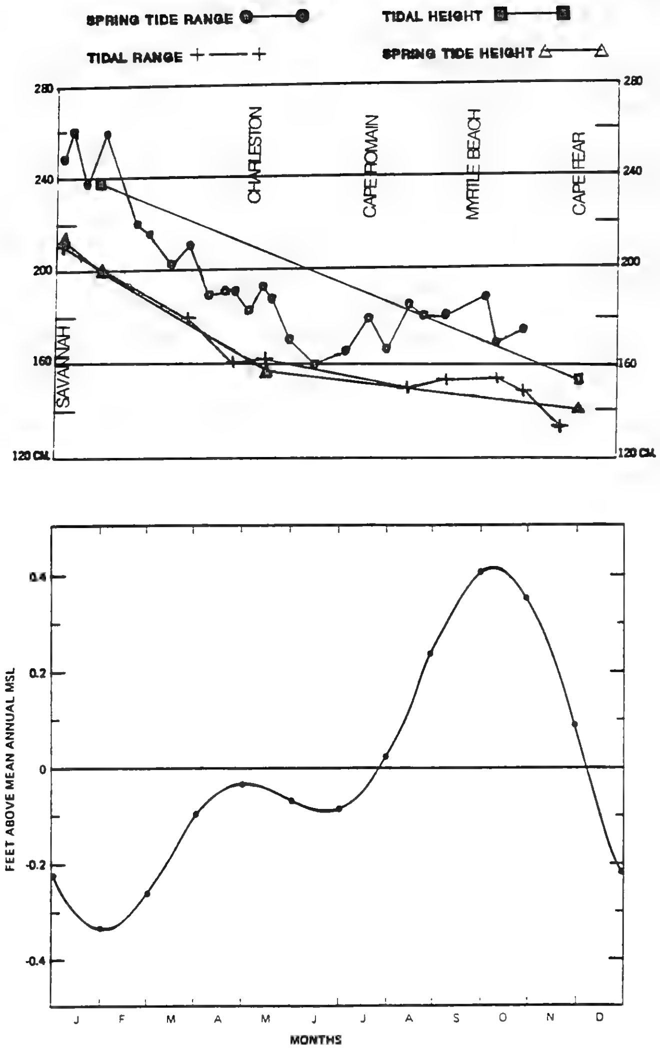


Figure 6. Alongshore variation in the tide conditions (modified from Brown 1977) and average annual tidal variation at Charleston (Myers 1975)

16-percent probability of some type of tropical storm striking the South Carolina-Georgia border area in any one year and a 7-percent chance that it will be a hurricane. The probability decreases northward to 8 percent for a tropical storm, with a 5- to 8-percent chance of a hurricane. The region around the North Carolina- South Carolina border increases again to 13-percent probability for a tropical storm in any one year and a 6-percent chance of it being a hurricane. Table 1 is a listing of known major storms affecting the coast of South Carolina. Figure 7 shows tracks of late 19th-century and 20th-century hurricanes affecting the study area.

15. Increased tidal elevation along the coast during both tropical and extratropical storms results from surge that accompanies the storm. Storm surge is due to a combination of low pressure over water allowing the water to bulge upward under the storm and rapid wave advance inshore resulting in wave buildup at the shoreline and limited return flow offshore. Increased water levels of 0.3 to 1 m above MSL can be expected along this coast, and records up to 5.8 m above MSL have been reported for major hurricanes (USACE 1974). Myers (1975) used data from South Carolina hurricanes to determine return intervals of total tidal height (astronomical tide height plus storm surge) at selected locations along the South Carolina coast (Figure 8). Along coast variation in total tidal height from hurricanes of various return intervals is plotted in Figure 9. These data indicate that a tropical storm with a 10-year return interval could be expected to produce a tide 2.1 m above MSL at Charleston and a storm with a 500-year return interval (probability of occurrence is once in 500 years) would produce a tide 5.3 m above MSL at Charleston.

16. Alongshore variation in tidal height for any given return period (Figure 9) was explained by Myers (1975) as being due in part to a shoaling factor, which is a function of inner continental shelf bathymetry. In general, shallower water produces higher surge. Other factors that influence maximum surge height are strength of the storm, forward speed, radius of the maximum winds, and track of the storm with its distance from the coast. Surge dynamics vary from alongshore moving storms to inshore moving storms.

Long-term sea-level variations

17. Daily and seasonal water-level fluctuations play an important role in South Carolina coastal geomorphology, but in their examination of long-term trends in shoreline change, the WES researchers must also consider long-term

Table 1

Known Storms Affecting the South Carolina Coast

Year	Date	Year	Date	Name
1686	Sep 4-5	1904	Sep 15	
1700	Sep 16	1906	Sep 17	
1713	Sep 16-17	1906	Oct 20	
1728	Aug 13	1907	Sep 27-29	
1752	Sep 30	1911	Aug 27-28	
1781	Aug 10	1916	Jul 13-14	
1783	Oct 7-8	1920	Sep 20	
1787	Sep 19	1924	Sep 16-17	
1797	Oct 19-20	1927	Oct 1-3	
1804	Sep 3-9	1928	Aug 10-11	
1811	Sep 10	1928	Aug 14-15	
1813	Aug 27	1928	Sep 17-19	
1814	Jul 1	1929	Oct 1-2	
1815	Sep 28	1934	Jul 21-25	
1822	Sep 27	1940	Aug 11	
1830	Aug 12-17	1944	Oct 19	
1837	Sep 1	1945	Sep 17	
1837	Oct 8-9	1947	Oct 15	
1841	Sep 16	1949	Aug 28	
1844	Sep 14	1952	Aug 31	
1846	Aug 16	1954	Oct 15	HAZEL
1850	Aug 24	1955	Aug 12	CONNIE
1851	Aug 24	1955	Aug 17	DIANNE
1852	Aug 27	1955	Sep 19	IONE
1854	Sep 7-8	1957	Sep 27	HELENE
1871	Aug 16-18	1959	Sep 29	GRACIE
1874	Sep 28	1962	Oct 18	ELLA
1878	Sep 11-12	1963	Oct 25	GINNY
1881	Aug 21-27	1964	Sep 12-13	DORA
1882	Oct 11	1964	Oct 30	CLEO
1885	Aug 24-25	1966	Jun 10	ALMA
1888	Oct 11	1968	Jun 7	ABBY
1889	Sep 23	1968	Oct 19	GLADYS
1893	Aug 22-30	1972	Jun 20-21	AGNES
1894	Sep 26-17	1979	Sep 5	DAVID

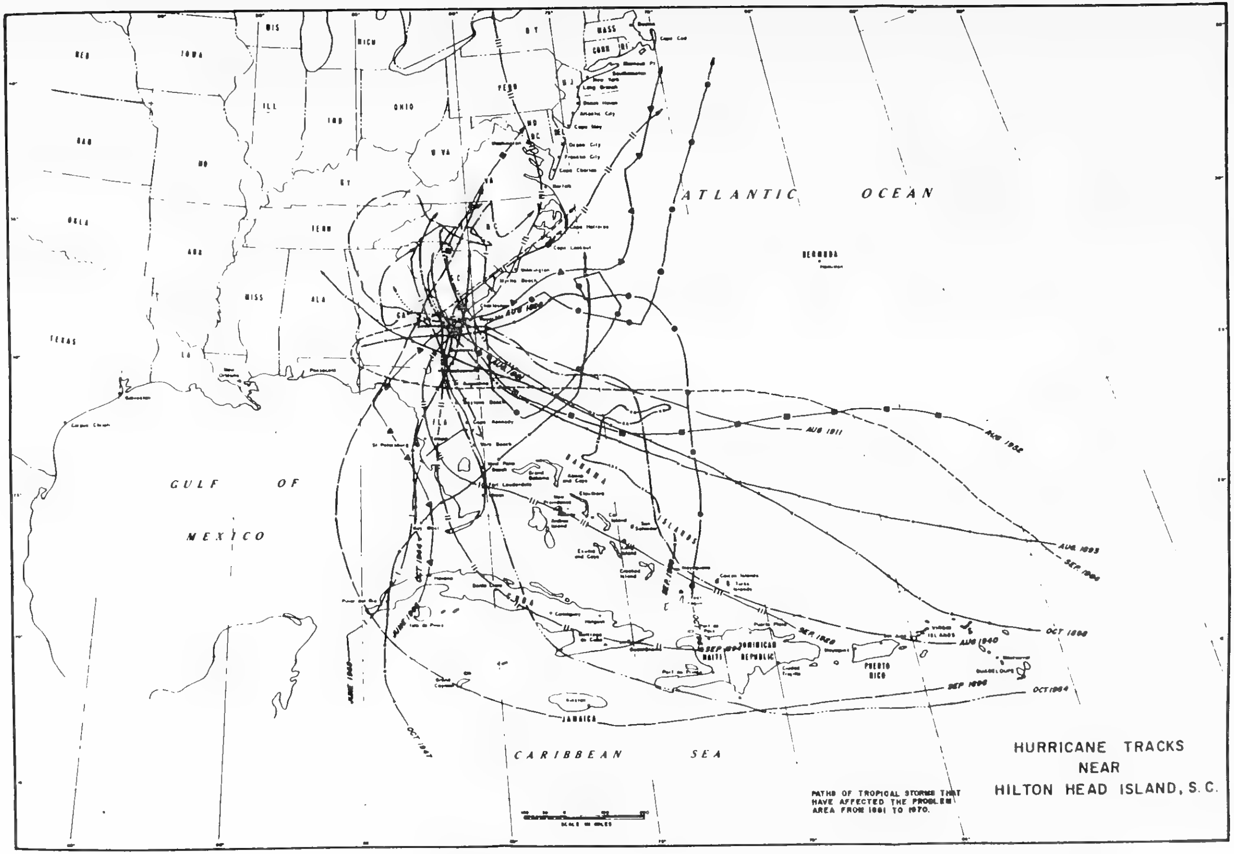


Figure 7. Tracks of known hurricanes affecting the area between 1890 and 1970 (USACE 1974)

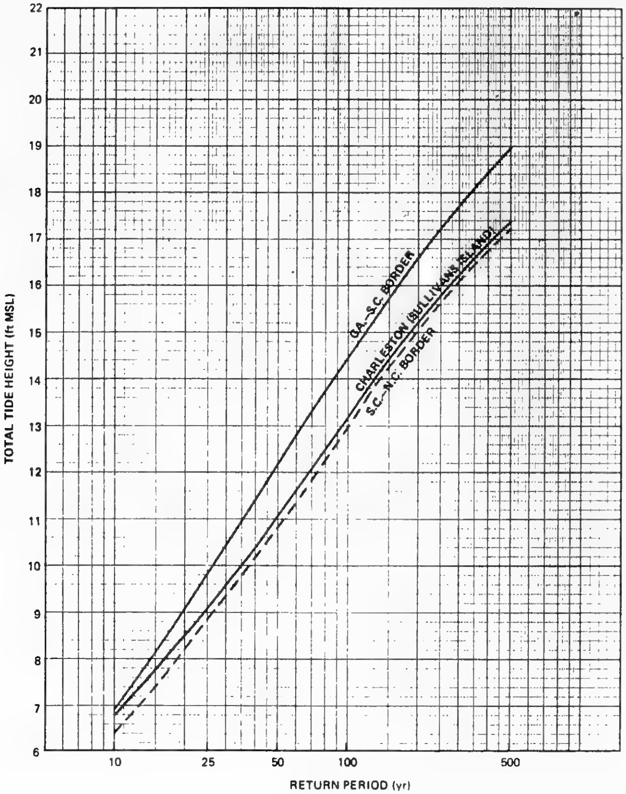


Figure 8. Tide frequencies at selected points on the South Carolina coast, based on hurricane specifications (Myers 1975)

changes in sea level. Sea level changes can be examined from two points of view, eustatic rise and relative rise. Eustatic rise deals with worldwide changes in sea level resulting from continental and alpine glacier advance and retreat, thermal expansion and contraction of ocean waters, and global scale changes in ocean basin dimensions. Relative rise also incorporates local shoreline movements due to tectonics or subsidence, which influence the perception of water levels along the coastline.

18. Several geological investigations have shown a steady rise in sea level for the last 15,000 years (e.g., Millman and Emery 1968). This correlates with continued climatic warming since maximum glacial ice advance during

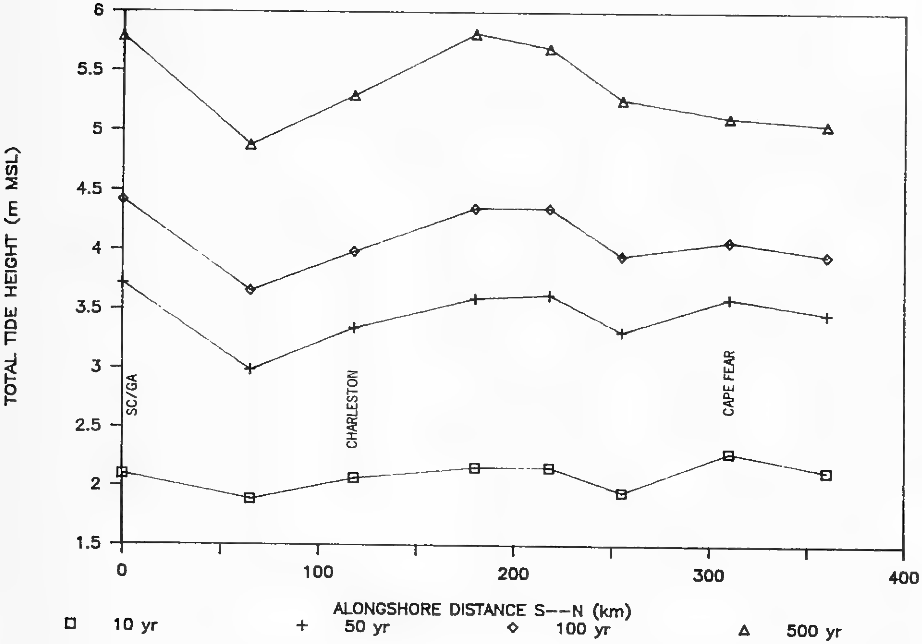


Figure 9. Alongshore variation in total tidal height at various return intervals (modified from Myers 1975 and Ho and Tracey 1975)

the Wisconsin age. Sea level rise curves show a definite break in slope to a much slower rate of rise about 4,000 years BP. Along the South Carolina coast Colquhoun and Brooks (1986) postulate a curve (Figure 10), which shows an episodic rise and fall of sea level since 4,000 years BP. This curve, based on a combination of archeological and geological (C14) dating, shows a slow overall rise in sea level to present day.

19. Examination of tide gage data in the vicinity of the study area shows a highly variable but steady overall rise in relative sea level during the recent past (Figure 11). Since the late 1920's, relative sea level at Charleston Harbor, South Carolina, has risen approximately 15 cm. General trends in long-term eustatic (15,000 years BP) rise and present relative rise along the study area coincide, suggesting continued sea level rise for the

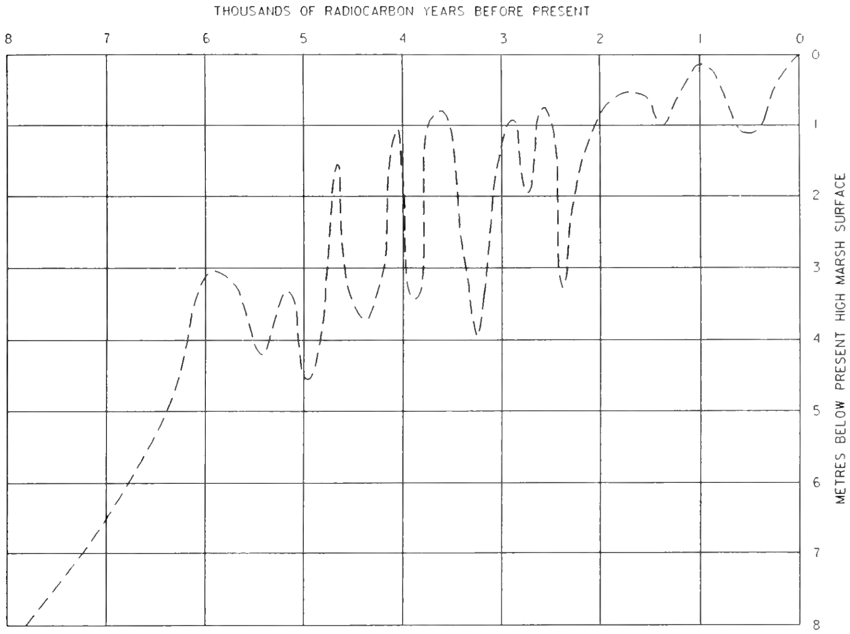


Figure 10. Regional sea level versus time curve developed from South Carolina data (after Colquhoun and Brooks 1986)

near future. Rate of rise in the future is presently the subject of much debate.

Geology

Pre-Holocene

20. Approximately 40 percent of the State of South Carolina is coastal plain (Hubbard, Hayes, and Brown 1977) of pre-Holocene age (more than 10,000 years BP). The Atlantic Coastal Plain, which extends along the entire east coast of the United States, is composed of sands, silts, and clays of Cretaceous, Tertiary, and Quaternary age. It overlies and is bounded on the west by older rocks of the Piedmont Province. The Piedmont in turn is bounded

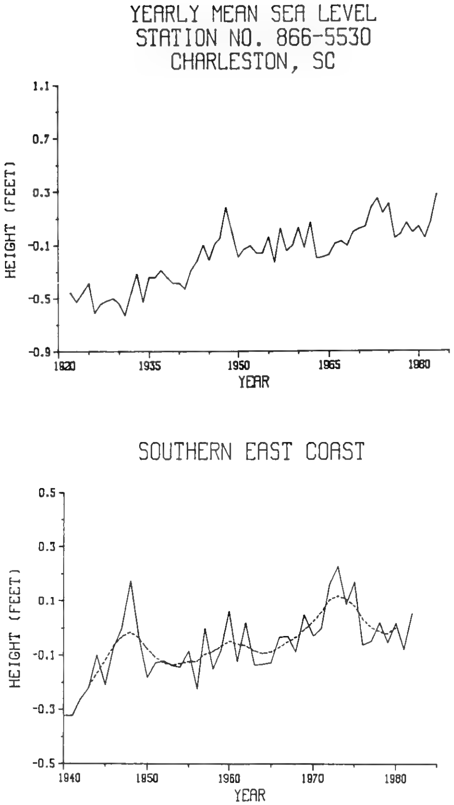


Figure 11. Relative sea level changes from tide gage data at Charleston, SC, and summary data for the southern east coast*

to the west by the Blue Ridge Province and/or the Valley and Ridge Province (Figure 12).

21. The coastal plain of South Carolina is divisible into Upper, Middle, and Lower sections (Cooke 1936; Richards 1945, 1967). The Upper section is composed of unconsolidated sediments ranging in age from Cretaceous to Early/Middle Miocene. Cretaceous sediments outcrop along the western edge of the coastal plain, adjacent to the fall line that separates them from

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* Personal Communication, 1985, Stacey Hicks, NOS, Rockville, MD.

Figure 12. General stratigraphy of the east coast (Richards 1967, reprinted by permission)

Pre-Cambrian and Paleozoic rocks of the Piedmont. Cretaceous sediments dip seaward beneath younger Tertiary age sediments and apparently underlie the entire coastal plain. Beneath the coastal plain in this study area are deeply buried crystalline rocks of the Piedmont. Major structural features are evident in these basement rocks underlying the Coastal Plain (Richards 1967). Cape Fear Arch is responsible for bringing basement rocks to within 365 m of the surface near Wilmington, NC. South of the Arch, basement rock dips down to the Beaufort Basin. These structural features influence thickness and depth of younger sediments. Cretaceous sediments have appeared in shallow vibracores on the nearshore shelf in the vicinity of Cape Fear (Meisburger 1979). Evidence is presented from a variety of sources (Richards 1967) to suggest that parts of the Carolina coastal plain are underlain by Triassic Basin rocks.

22. Topography of the Middle and Lower Coastal Plain is dominated by marine "terraces," as they were first named by Cooke (1936). These terraces were named chiefly on the basis of topography. Their origin is related to

eustatic fluctuations in sea level that resulted in alternating submergence and emergence of the landscape. The sequence of events forming each terrace was similar. Sea level rose to some maximum altitude during a period of submergence (transgression). Submergence resulted in formation of a barrier island chain with associated lagoonal/marsh sediments on the landward side, similar to the present coastline. Inlet deposits, estuarine and channel sediments, and a seaward thinning wedge of offshore sediments were also deposited much as present day. This cycle was terminated by climatic changes that resulted in shoreline emergence (regression). When climate once again shifted, a new cycle of submergence began, with sea level stabilizing at an altitude slightly lower than a previous cycle. The new barrier complex (terrace) formed seaward and lower than the first one. Geological evidence indicates that from North Carolina south into Georgia, these cycles of submergence followed by emergence occurred at least three times over the Middle Coastal Plain and six times over the Lower Coastal Plain. Present barrier/marsh/lagoon sequences constitute a seventh cycle. Advance of the sea landward in each instance was less than prior cases, thus preserving the old shoreline. Likewise, withdrawals of the sea were probably not of similar magnitude. Some may have been relatively minor. Field recognition of terraces in the Middle Coastal Plain is made difficult by long exposure to erosive forces.

23. The Middle Coastal Plain is separated from the Upper Coastal Plain by the Orangeburg Scarp (Colquhoun 1965), which is the landward margin of the Duplin Formation. The Duplin Formation was deposited during a marine transgression; the Duplin shoreline has a maximum altitude of 65 m above MSL. According to Colquhoun (1974), subsequent overall slow recession with episodic transgressions or still stands resulted in formation of the Coharie (65 m above MSL), Sunderland (52 m), and Okefenokee (41 m) terraces. Colquhoun assigns the transgressive Duplin and terrace deposits to late Miocene age. The Miocene sea level rise was followed by a slow emergence during Pliocene.

24. Tertiary sediments of the Middle Coastal Plain are separated from Quaternary sediments of the Lower Coastal Plain by the Surry Scarp. Terraces formed during early Pleistocene include the Wicomico (33 m) and the Penholoway (21 m) of Colquhoun (1974). The Talbot (12 m), Pamlico (8 m), and Princess Anne (5 m) appear to have formed during the Sangamon inter-glacial period of late Pleistocene. The youngest Pleistocene terrace is the Silver Bluff (3 m), which is assigned to Sangamon age by Colquhoun (1974) and to mid-Wisconsin by

Hoyt and Hails (1974). Figure 13 is a cross section through the Lower Coastal Plain of Georgia showing relationships between the terraces. The cross section is similar to that presented by Colquhoun (1974) for central South Carolina. In the vicinity of the North Carolina-South Carolina border, a similar number of terraces in the Lower Coastal Plain, with similar elevations, have been recognized by DuBar (1971). Terrace names in this locality differ from those recognized by authors previously discussed; however, their mode and timing of formation are the same. The most seaward Pleistocene terrace is termed Myrtle Beach.

25. Elevation of terraces above present sea level suggests a progressive, although episodic, drop in sea level since Miocene time. An alternative explanation for elevation of the terraces above the modern coast is offered by Cronin (1981). According to Cronin, sediment loading in a Mesozoic/Cenozoic trough 200 km seaward of the South Carolina coast could be resulting in corresponding uplift of the Coastal Plain lithosphere in excess of 1 to 3 cm/ 1,000 years. This could have resulted in a 60-m uplift of the Orangeburg Scarp since Miocene time and corresponding uplift of each of the terraces. If some part of the elevation of terrace sediments is due to upward flexure of the lithosphere, it would imply that the magnitude of eustatic changes in sea level since Miocene would be less than presently supposed.

<u>Holocene</u>

26. Superimposed on the long-term (approximately 20 million years) trend of falling sea level since Miocene time are Holocene sea level curves. These curves generally show a worldwide rise in sea level during the last 15,000 years (Figure 14), with a decrease in rate of rise from 4,000 years BP to present. Data collected by Colquhoun and Brooks (1986) show rise in sea

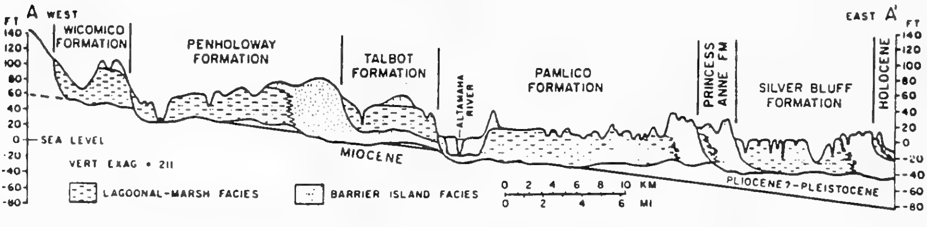

Figure 13. Lower Coastal Plain marine terraces (Hoyt and Hails 1974, reprinted by permission)

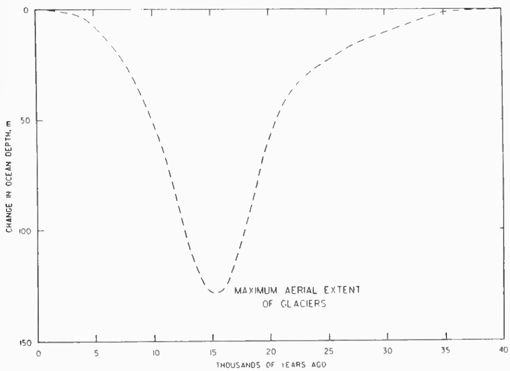

Figure 14. Sea level curve for the last 35,000 years (after Millman and Emery 1968)

level over the last 4,000 years has been very episodic (Figure 10). The same rising sea level trend is visible on modern tide gage data (Figure 11).

27. Evolution of the modern coastline of South Carolina is intimately linked with the present episode of sea level rise, sediment supply, bathymetry, ancient topography, and various environmental factors such as tide and wave conditions. All of these factors, except for sediment supply and bathymetry, have been discussed previously for the modern coast of South Carolina. Erosion, accretion, or stability measured in this report is a function of all these factors. This report has briefly examined the magnitude of each factor in contributing to measured erosion and accretion.

28. Sediment supply. Present day erosion/accretion patterns of barrier islands and beaches within the study area depend on sediment supply along the coast. Two potential origins for sediment are fluvial input and sources on the continental shelf. Meade (1982) concluded that in recent time, a decrease in cropland area and improved management practices have resulted in decreased soil erosion. Additionally, all of South Carolina's rivers, except for the Santee (which has been dammed and diverted since 1942), are headwatered in the Coastal Plain and therefore do not have large discharges. Meade's conclusion is that little sand size sediment is reaching the coast from fluvial sources. Further, he estimates only 5 percent of that sand reaches the inner continental shelf; most sand is being trapped in estuaries and bays. This may have been different in the not-too-distant past. Carver (1971) traced the origin of heavy minerals along the Georgia coast to the Santee River, suggesting it

may have previously contributed a large amount of sediment to the coastal zone.

29. Consistent with this discussion, Pilkey et al. (1969) noted that sedimentation on the outer shelf is presently very slow. Pilkey and Field (1972) conclude that much of the modern beach sand along South Carolina originates from onshore transport across the inner continental shelf. Carver (1971) postulated that most modern beach sediment along the Georgia coast was from reworked Pleistocene Silver Bluff sediments. These reworked sands intermixed with fluvial input from the Santee River. Swift et al. (1972) suggest deposition of ebb-tidal delta complexes on the inner shelf during Pleistocene low sea level stands, and likewise deposition in estuaries which would have been seaward of the present shoreline, provide the principal sediment source for modern beaches. Pleistocene estuary, inlet, and barrier deposits form a 20- to 40-km-wide lens of sand (up to 30 m thick) along the inner continental shelf of the South Atlantic coast. According to Swift et al. (1972), erosional shoreface retreat during Holocene transgression has moved these sediments in a landward direction, assisting in construction of the modern shoreline.

30. Shelf topography. In addition to sediment supply, topography of the inner continental shelf affects shoreline erosion and accretion. Wave refraction over shelf topography creates zones of potential erosion and deposition along the coastline. Wave refraction also influences direction of wave approach to the shoreline and therefore can influence littoral drift. Wave convergence or divergence because of refraction may be influential in shaping a large portion of South Carolina's coastal morphology. For example, Fico (1978) conducted a wave refraction analysis along selected portions of coastline within the study area. She concluded that long-term erosion on Bull and Capers islands was due in part to concentration of wave energy along these shorelines by refraction across the shelf.

Present Geomorphology

31. In describing the modern coastline geomorphology, many authors (e.g., Brown 1977; Nummedal et al. 1977; Hubbard, Hayes, and Brown 1977) have considered the study area as being transitional between the microtidal (less than 1.5-m tidal range) coastline of North Carolina and the mesotidal coast of

Georgia. North Carolina, with a small tidal range and dominance of wave energy, has long, narrow barrier islands with few inlets, backed by large, open lagoons. Georgia has short, stubby barrier islands, numerous and large inlets, large ebb deltas and no flood deltas, and marsh-filled lagoons, resulting from a dominance of tidal effects over wave influence. Nummedal et al. (1977) note that North Carolina lagoons have 30-percent or more open water, but southern South Carolina lagoons have a maximum of 20-percent open water. The coast within the study area ranges from high microtidal/low mesotidal in the north to mesotidal in the south. Nummedal et al. (1977) illustrate a variety of factors, including tidal range, which vary along the South Atlantic coast (Figure 15). Variation in these factors influences the nature of the shoreline transition from north to south.

Arcuate strand

32. Brown (1977) recognized three distinct geomorphic zones along South Carolina's coast. Northernmost is the arcuate strand, extending from Winyah Bay north to the state border. This is the most stable area of the coast, being immediately backed by the Myrtle Beach (DuBar 1971) Pleistocene beach ridge terrace. Dunes are well developed along this coast. Hubbard et al. (1977) measured erosion rates along the arcuate strand of 1 m/year or less. Erosion rates for the North Carolina extension of the arcuate strand were also less than 1 m/year in an investigation by Wahls (1973). Nearshore cores collected by Meisburger (1979) and cores recently collected for the US Army Engineer District, Charleston,* show Pleistocene, Tertiary, and/or Cretaceous sediments within a few metres of the surface in this area. Partially consolidated pre-Holocene sediments are probably more stable against erosion.

33. Hubbard et al. (1977) noted that an exception to stability of the arcuate strand coastline was in the vicinity of inlets. They measured changes up to 15 m/year at Murrells Inlet. Miller (1983), in investigating beach profile changes at Holden Beach, North Carolina, noted that largest variations occurred near inlets. The arcuate strand has relatively few inlets, and they are small in comparison to those farther south. FitzGerald, Hubbard, and Nummedal (1978) note that only 2 percent of northern South Carolina coast is occupied by inlets, compared with 20 to 25 percent in southern South Carolina.

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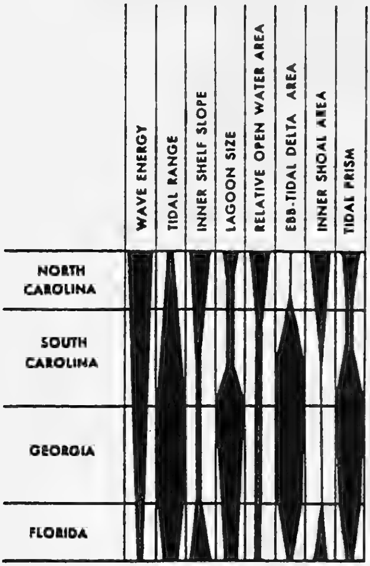
* Personal Communication, 1987, T. W. Kana, Coastal Science & Engineering Inc., Columbia, SC.



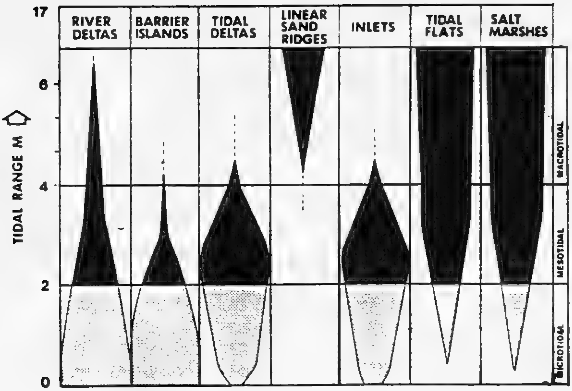


Figure 15. Environmental parameter changes along the coast as a function of distance (Nummedal et al. 1977, reprinted by permission) and tidal range (Hayes 1975, Copyright 1975 by Academic Press, reprinted by permission)

Arcuate strand inlets have both flood and ebb-tidal deltas (Nummedal et al. 1977). In discussing North Inlet, Finley (1976) indicates that although the inlet is in a microtidal range, its morphology is more closely aligned to mesotidal inlets.

34. Origin of sediments on arcuate strand beaches appears to be pre-Holocene sediments immediately behind and under it. Few rivers drain into this area. Examination of sediment grain size by Brown (1977) reveals a wide range of size and sorting values, with no consistent alongshore trends. Mean grain size is approximately 0.175 mm. Nearshore bathymetry is fairly steep. Brown measured an average slope of 7.4 m/km for the first 0.8 km offshore. Beyond this is a fairly level, uniform, slope out to -15 km.

Cuspate delta

35. The cuspate delta area, extending from Winyah Bay south to Bull Bay, was the second geomorphic zone defined by Brown (1977). Most sediment composing the delta originated from the Santee River. The Santee headwaters in the Blue Ridge and Piedmont Provinces. Before 1942, the Santee had the fourth largest discharge of any east coast river (Kjerfve 1976). Brown notes the delta was constructional until the early 1940's, when damming and diversion of the Santee into the Cooper River occurred. Kjerfve indicates an 88-percent loss in discharge reaching the Santee delta. It is the largest delta complex on the east coast, but since diversion, it has been eroding, as evidenced by washover terraces and truncated beach ridges. Hubbard et al. (1977) indicate an erosion rate similar to the arcuate strand, but with much more variability at any point alongshore.

36. Proximity of cuspate delta beaches to sediment source results in a coarse, but variable, beach sediment size (average = 0.248 mm). These generally immature sediments accompany steep, narrow beaches, with a gently sloping but irregular shelf. Average nearshore slope is about 2.0 m/km (Brown 1977).

37. One of the prominent features of the cuspate delta region is Cape Romain. Together with Cape Fear at the northern end of the study area, it is part of the Carolina Capes extending south from Cape Hatteras, North Carolina. Brown (1977) attributes the origin of Cape Romain to convergence of waves and littoral drift over a yearly cycle. Hoyt and Henry (1971), in a review of theories on origins of the Carolina Capes, note most authors attribute cape origin to wave and current actions. They observe, however, the association of capes with major rivers and their similarity to ancestral capes of the region.

White (1966) believes capes are merely the present stage of a long temporal sequence of capes. He feels the capes are self maintaining because of continuous emergence of off-cape shoals during emergence of the Coastal Plain. During rising sea level, relict capes formed by major rivers localized younger capes. Present capes, while modified by local conditions, are the present stage in sequences of capes that endured through long periods of sea level change and shoreline migration.

Barrier islands and tidal inlets

38. The third geomorphic zone of Brown (1977) is a 160-km-long stretch of barrier islands and tidal inlets extending from Bull Bay south to the South Carolina-Georgia border. This zone is characterized by barriers averaging 7 km in length, separated from the mainland by a zone of salt marsh that increases in width southward. Beach face slopes are gentle (1.5 to 2.5 deg), and sediment is finer (average = 0.143 mm) and better sorted than beaches to the north (Brown 1977). Greater textural maturity of these sediment indicates their reworking and implies limited new sources of sediment. Offshore slopes are gentle, but irregular spatially depending on their mode of origin; mid-barrier offshore profiles differ considerably from inlet offshore profiles.

39. Brown recognized two predominant types of barriers occurring within this zone. Transgressive barriers, generally less than 6 km long, are characterized by having a thin pocket of sand overlying back barrier sediments. These rapidly retreating barriers have wide washover terraces, no dunes, narrow beaches, and straight shorelines. Morris Island, Edingsville Beach, and Bay Point are examples of transgressive barriers. The transgressive nature of these barriers is due in large part to reduction in sediment supply. Wagener (1970) measured over 275 m of retreat for Morris Island between 1949 and 1964 as a result of sediment starvation downdrift of the Charleston jetties.

40. Regressive barriers, also called beach-ridge barriers, are the most common in South Carolina (Brown 1977). They are characterized by a bulbous updrift (northern) end, a straight to crescentic central portion, and downdrift recurved spits. These barriers are generally unstable at the north ends, prograding at the downdrift end, and stable or slightly accretional in their central portions (Hubbard et al. 1977). They generally exceed 6 km in length and have numerous vegetated beach ridges.

41. Kiawah Island is an example of a beach-ridge barrier that has been extensively studied. Hayes et al. (1975) recognized the prograding nature of

this island through recent time. Moslow and Colquhoun (1981) examined multiple beach ridges and attempted to correlate them with recent sea level rise. They suggest Kiawah originally formed between 6,000 to 8,000 years BP and transgressed landward under rapidly rising sea level until about 4,000 years BP. Since then Kiawah has been episodically prograding seaward because of an excess in sediment supply over sea level rise.

42. The erosional/accretional nature of South Carolina's barrier islands is intimately connected with tidal inlets and associated ebb-tidal deltas. Nummedal et al. (1977) point out increasing tidal range toward the south because of widening of the continental shelf towards Georgia. The result is a tide-dominated coastline where inlet size is relatively large and inlets are strongly ebb dominant. This in turn leads to seaward-directed sediment transport and large ebb-tidal deltas extending far out onto the shelf. These inlets exert a strong influence over erosion and accretion of the barriers. As Hubbard et al. (1977) note, only where there is 10 to 15 km between inlets does one get away from their influence.

43. The large ebb deltas in the vicinity of Kiawah and other barriers have resulted in its bulbous updrift end (Hayes et al. 1975). This is a result of wave refraction over ebb shoals and protection of updrift ends of islands from storm waves (Figure 16). Wave refraction results in localized alongshore drift reversals toward the north. Large storm waves are attenuated as they break across shoals, thus protecting landward shorelines from storm damage. As a result, sediment accumulates on updrift ends of the barriers. Finley (1976) examined North Inlet, near Winyah Bay, and found that following inlet stabilization, ebb shoals are efficient sediment traps for littoral drift. FitzGerald and Hayes (1980) suggest ebb-tidal delta development could result in sand starvation of downdrift beaches. Measurements of ebb delta volume by Hayes (1977) showed that volume of sand in ebb deltas adjacent to Kiawah Island are 78 percent of the volume of the barrier itself.

44. Three primary types of shoreline changes were recognized by FitzGerald, Hubbard, and Nummedal (1978) and were associated with three types of inlets found along the South Carolina coast (Figure 17). Stable inlets, in which the ebb channel appears to be anchored in pre-Holocene cohesive sediments, influence shorelines depending on ebb delta size and position. As discussed previously, wave refraction around an ebb shoal causes local drift reversals. Wave shoaling over the delta shelters the barrier from storm waves

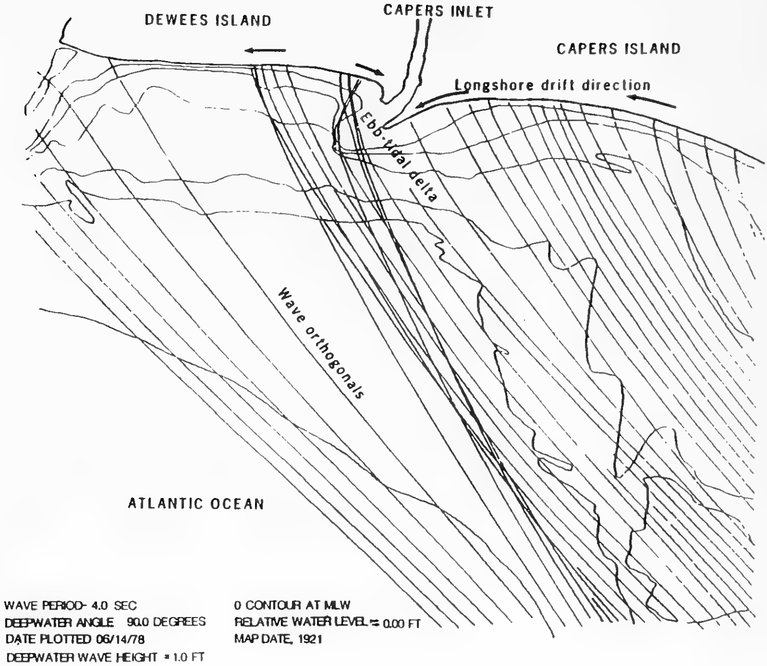


Figure 16. Wave refraction diagram showing drift reversal as a result of ebb delta bathymetry (Fico 1978, reprinted by permission)

and forces landward migration of swash bar complexes that periodically nourish the shoreline. Migrating inlets, which are shallow and not anchored in pre-Holocene material, move under the influence of littoral drift. Typically, southward migration is accompanied by spit elongation on the north side of an inlet. Eventually, the elongated inlet channel becomes inefficient, and a new channel breaches the spit to the north, renewing the cycle. The severed spit generally welds to the downdrift beach. A third type of inlet is one in which the ebb channel, under influence of the littoral drift, is pushed south across the delta until it becomes inefficient. It then cuts a new channel to the north side of the ebb delta, where it again begins its southward migration. Sand along the old southern channel migrates landward and welds to the beach,

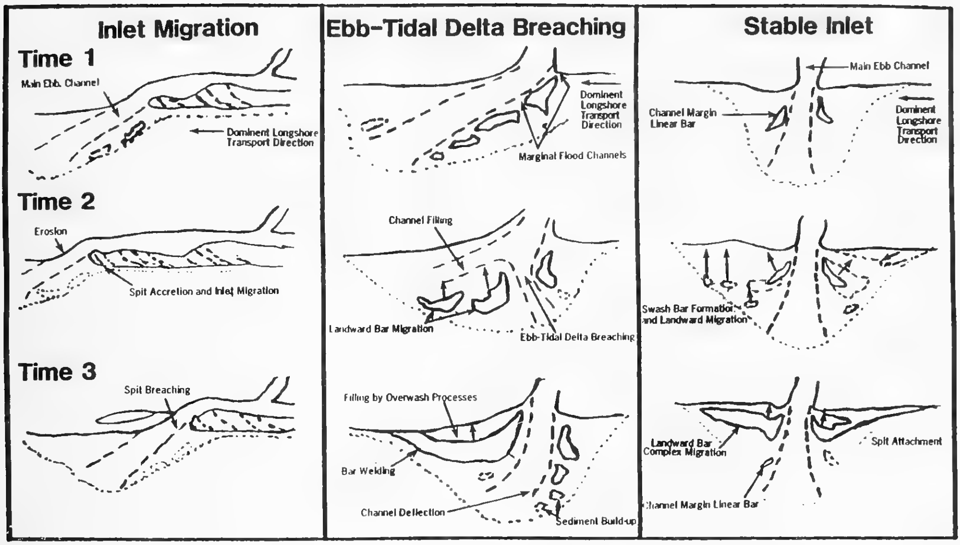


Figure 17. Three types of shoreline change resulting from inlet processes (FitzGerald, Hubbard, and Nummedal 1978, reprinted by permission)

causing rapid accretion. Hubbard et al. (1977) measured short-term shoreline changes along central portions of South Carolina's barriers, but found regions around inlets too variable for accurate measurement.

PART III: METHODOLOGY

45. Procedures used for selection of data sources, shoreline definition, and map production were established by the NOS and were common to all three shoreline reports in this series. The first report (Everts, Battley, and Gibson 1983) clearly outlines methodology used to construct the shoreline change maps. Text in this part of the report covering map-making procedures borrows heavily from Everts, Battley, and Gibson (1983); however, procedures for map analysis are substantially different.

Data Sources

46. Thirty-two 1:24,000-scale US Geological Survey (USGS) quadrangles were selected as base maps for this project (Figure 18). They were revised by the Cartographic Revision Section of the Photogrammetry Division of NOS with 1:24,000-scale color photography taken in 1982-83 at near high water, covering all of the ocean coast within the project area. Historical shoreline data, obtained from NOS and USC&GS topographic surveys (T sheets) compiled since the early 1800's, were added to the base maps. Table 2 lists dates of historical T sheet surveys available for each base map. A particular sheet may often be listed on more than one base map; each base map usually comprises sheets of varying scales and area limits.

47. Copies of all historical maps used as source data in this study were obtained from the NOS vault in Riverdale, MD, through the NOS Reproduction Division. Copies were initially bromide prints (a photographic process that provides a long shelf-life copy) and were later made into more stable matte-finish film positives.

48. Topographic surveys are the basis for delineation of shorelines on nautical charts published by NOS. Present and historical surveys map the mean high-water line (MHWL) as the shoreline. According to Shalowitz (1964), the authority on historical significance of early topographic surveys of NOS, "The most important feature on a topographic survey is the high-water line." Accuracy of the early surveys was addressed before any of the historical dates were used in this study.

49. About 1840, Ferdinand Hassler, the first Superintendent of the Survey, issued the earliest instructions for topographic work. Those

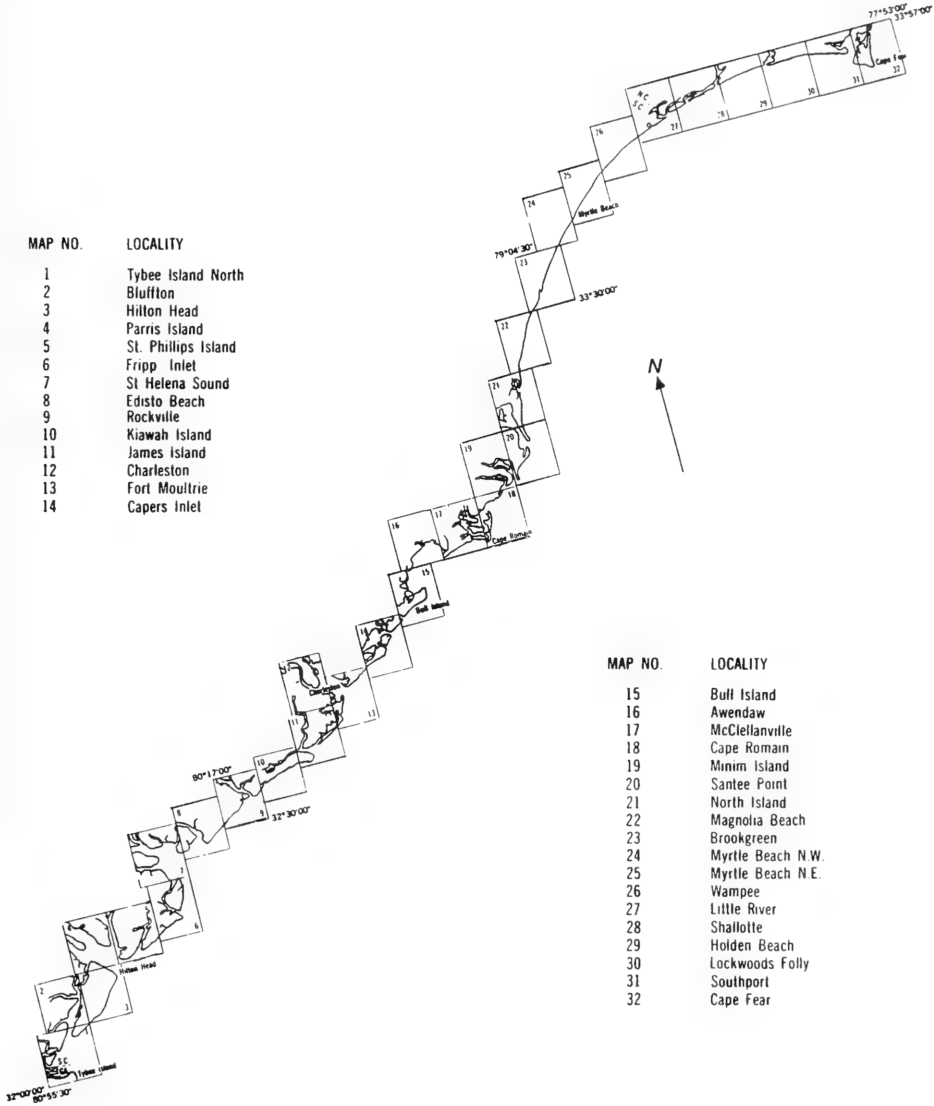


Figure 18. Map of the study area showing location of quadrangles selected as base maps

Table 2

Dates of Historical T Sheets Used in

Shoreline Change Map Production

Map No.	Map Name	Dates of Historical T Sheets
1	Tybee Island North	1852, 1859/63, 1870/74, 1900, 1964, 1970/71
2	Bluffton	1859/60, 1870/71, 1920, 1964, 1970/71
3	Hilton Head	1859/60, 1920, 1955, 1963, 1970/71
4	Parris Island	1859/60, 1864/65, 1870/71, 1921, 1955, 1964, 1971/74
5	St. Phillips Island	1859/60, 1865, 1920/21, 1955, 1964, 1971/74
6	Fripp Inlet	1856/59, 1920, 1955, 1964, 1971
7	St. Helena Sound	1856/59, 1920, 1952/55, 1964, 1971
8	Edisto Beach	1852, 1856/59, 1920, 1933, 1952/55, 1964, 1970/74
9	Rockville	1851/54, 1920/21, 1933, 1964, 1970/74
10	Kiawah Island	1854, 1921, 1933, 1955, 1964, 1970/71
11	James Island	1854/58, 1862/64, 1900, 1921, 1933, 1955, 1962/64, 1970/71
12	Charleston	1857/58, 1916, 1933, 1962/63
13	Fort Moultrie	1857/58, 1862/64, 1875, 1900, 1921, 1933/34, 1955, 1962/64
14	Capers Inlet	1856/57, 1875, 1921, 1934, 1962/63
15	Bull Island	1875, 1921, 1934, 1962
16	Awendaw	1874/75, 1921, 1934, 1962/63
17	McClellanville	1874, 1925, 1934, 1962/63
18	Cape Romain	1873/74, 1925, 1934, 1962/63
19	Minim Island	1873, 1925, 1934, 1962/63
20	Santee Point	1857/58, 1872/73, 1925, 1934, 1962/63
21	North Island	1857/58, 1872, 1925/26, 1934, 1962
22	Magnolia Beach	1872, 1926, 1934, 1962/63
23	Brookgreen	1872, 1926, 1934, 1963, 1969/70
24	Myrtle Beach, NW	1872/73, 1926, 1934, 1962, 1969/70
25	Myrtle Beach, NE	1873, 1926, 1934, 1962, 1969/70
26	Wampee	1873, 1925/26, 1934, 1962/63, 1969/70
27	Little River	1873, 1924/26, 1933/34, 1962/63, 1969/70

(Continued)

Table 2 (Concluded)

Map No.	Map Name	Dates of Historical T Sheets
28	Shallotte	1857/59, 1924, 1933, 1962/63, 1969/70
29	Holden Beach	1857/59, 1924, 1933, 1962/63, 1969/70
30	Lockwoods Folly	1856/57, 1924, 1933/34, 1962, 1969/70
31	Southport	1878, 1914, 1923/24, 1933/34, 1962, 1969/70
32	Cape Fear	1878, 1914, 1923, 1933/34, 1972/73/75

instructions (Everts, Battley, and Gibson (1983), taken from Volume 17, Coast Survey, Scientific, 1844-1846, handwritten) included the following:

> On the sea shore and the rivers subject to the tides, the high and low-water lines are to be surveyed accurately; and the kind of ground contained between them, whether sand, rock, shingle or mud marked accordingly. The low-water line is taken by offsets while running the high water, and when not too far apart from each other, but when their distance is great, they must be surveyed separately: a couple of hours before the end of the ebb, and the same time during the commencement of the flood tides will be the proper time for taking the low-water line, and your operations must be so timed, as to be on the shore on those periods.

50. The first specific instructions regarding the nature of the line to be surveyed is contained in the "Plane Table Manual" (Wainswright 1889), which states: "In tracing the shoreline on an exposed sandy coast, care should be taken to discriminate [sic] between the average high-water line and the storm water line." Still later, Shalowitz (1964) elaborated by stating:

> The mean high-water line along a coast is the intersection of the plane of mean high water with the shore. This line, particularly along gently sloping beaches, can only be determined with precision by running spirit levels along the coast. Obviously, for charting purposes, such precise methods would not be justified, hence, the line is determined more from the physical appearance of the beach. What the topographer actually delineates are the markings left on the beach by the last preceding high water, barring the drift cast up by storm tides. On the Atlantic coast, only one line of drift would be in evidence

> . . . . If only one line of drift exists, as when a higher tide follows a lower one, the markings left by the lower tide would be obliterated by the higher tide and the tendency would be to delineate the line left by the latter, or possibly a line slightly seaward of such drift line.
>
> In addition to the above, the topographer, who is an expert in his field, familiarizes himself with the tide in the area, and notes the characteristics of the beach as to the relative compactness of the sand (the sand back of the high-water line is usually less compact and coarser), the difference in character and color of the sun cracks on mud flats, the discoloration of the grass on marshy areas, and the tufts of grass or other vegetation likely along the high-water line.

51. Historical references are included to emphasize that it was the intention of all the agency's topographic surveys to determine the line of mean high water (MHW) for delineation on maps. With the exception of tidal marsh areas, where in most cases the outer limit of vegetation is mapped, MHW delineated on the surveys by the experienced topographer or photogrammetrist was that line at the time of survey or date of photography.

Map Production

52. The following procedures for producing shoreline change maps are identical to those used by Everts, Battley, and Gibson (1983). To make this study as current as possible, USGS quadrangle maps were revised to show a 1982/83 MHWL. Revision was made using 1982/83 color aerial photographs flown for this study. Date and time of photography were correlated with stage of the tide, and a detailed stereoscopic examination of the photographs was made to determine the MHW line. This process was completed by the Cartographic Revision Section of the Photogrammetry Division of NOS. Their method was by direct transfer of photo-interpreted lines (see paragraph 60) from 1:24,000-ratioed film positives to USGS base maps. Using the ratioed photography, base maps (manuscripts) were held planimetrically to local physical features. In the absence of triangulation stations to position manuscripts accurately against photographs, it is possible to use "hard" planimetric features, such as road intersections or other permanent physical structures without great relief, to assure good photographic positioning. In areas where there were

not enough features to assure proper positioning, stereo models were set on the National Ocean Survey Analytical Plotter (NOSAP). The NOSAP is a high-precision stereoscopic plotter that allows the operator to bridge over areas of sparse control and accurately determine correct relationships between photographic models and base maps. Because of time restraints, no field check of the office-determined MHWL was made. All shorelines compiled by this method were reviewed to assure a uniformity of photo-interpreted shoreline, accuracy of compilation, and proper symbolization. These maps were then checked and reviewed in the manner identical to that used for all historical source maps.

53. Digitizing of the shoreline on each historical map, and contemporary shoreline base maps, was then completed by the Data Translation Branch, Environmental Data and Information Service, Asheville, NC. Digitizing was completed on a Calma-Graphics III system, with a repeatability factor of ±0.025 mm and a maximum absolute error of ±0.076 mm. Digitized data tapes were processed using a program developed by the NOS Marine Data Systems Project for use with the NOAA UNIVAC computer (GPOLYT2); this program allows for conversion of digitized data to geographic positions (GP's). Since many of the historic sheets used in the study were completed before the North American Horizontal Datum of 1927 (NA1927) was established, GP's for these sheets were converted to that datum so that accurate comparisons between pre-NA and post-NA 1927 surveys could be made. Conversion was completed mathematically, based on conversion factors for triangulation stations in the area, with a program written by the NOS Marine Data Systems Project.

54. After processing of data was completed, plot tapes were generated using the NOS McGraphics program. Plot tapes were used with a Calcomp 748 plotter and Calcomp 925 Controller to plot the shoreline movement maps. This task was completed with the assistance of the NOS Automated Cartography Group.

55. All sections of shoreline from the source maps were digitized so that all shoreline points could be converted into GP's and replotted at any desired scale (before the final portrayal scale of 1:24,000 for the shoreline movement maps was chosen, other scales were tested to determine which map scale would portray the data in the most readable form). Digitizing also removed inherent media distortion caused by the age of the original manuscripts. Mechanics and mathematics of the digitizing system required that all projection (latitude and longitude) intersections completely enclose the data to be digitized. By assigning known and true values for each projection

intersection, the GPOLYT2 program adjusted each of the shoreline points enclosed within a projection cell based on true values of intersections versus digitized and computed values for those same intersections. Values for each shoreline point are thus correct in their position relative to known (true) projection intersections and to known triangulation data (Figure 19).

56. Following the digitizing process, each sheet was reviewed visually with use of a raw data plot in which shoreline positions were shown at the same scale as the original map. Plotted shorelines were superimposed on original maps and checked for completeness and accuracy of tracking during digitization. This review helped to minimize a potential source of human error that could occur during the digitizing process.

57. Other sources of potential error also were considered. The most difficult of these to determine precisely was location accuracy of the MHWL on source surveys and maps, on either (a) early surveys prior to approximately 1930 and (b) maps based on photogrammetric surveys. In discussing early surveys, Shalowitz (1964) has stated:

> The accuracy of the surveyed line here considered is that resulting from the methods used in locating the line at the time of survey. It is difficult to make any absolute estimates as to the accuracy of the early topographic surveys of the Bureau. In general, the officers who executed these surveys used extreme care in their work. The accuracy was of course limited by the amount of control that was available in the area.
>
> With the methods used, and assuming the normal control, it was possible to measure distances with an accuracy of 1 meter (Annual Report, US Coast and Geodetic Survey 192 (1880)) while the position of the planetable could be determined within 2 or 3 meters of its true position. To this must be added the error due to the identification of the actual mean high water line on the ground, which may approximate 3 to 4 meters. It may, therefore, be assumed that the accuracy of location of the high-water line on the early surveys is within a maximum error of 10 meters and may possibly be much more accurate than this. This is the accuracy of the actual rodded points along the shore and does not include errors resulting from sketching between points. The latter may, in some cases, amount to as much as 10 meters, particularly where small indentations are not visible to the topographer at the planetable.

Figure 19. Digitization procedure for correcting shoreline position locations when original shoreline movement map distortions exist (Everts, Battley, and Gibson 1983)

58. Accuracy of the high-water line on early topographic surveys of the Bureau was thus dependent upon a combination of factors, in addition to the personal equation of individual topographers, but no large errors were allowed to accumulate. By means of triangulation control, a constant check was kept on the overall accuracy of the work.

59. On aerial photographs, the MHW line is located to within 0.5 mm at map scale (USC&GS 1944). This translates to less than 5 m on the ground for a map scale of 1:10,000 or 9.99 m on the ground for a map scale of 1:20,000. Since the great majority of source maps were of a larger scale than the 1:24,000 base maps, the 0.5-mm accuracy of source maps made using aerial photography was at least maintained by reducing most source maps to the common base scale of 1:24,000. Present NOS survey maps are even more accurate. In a recent shoreline mapping project in the State of Florida using NOS charts, 36 random features such as road intersections and shoreline features, including points of marsh, were scaled from maps compiled from aerial photography. These features were located by field traverse, and geodetic coordinate values compared. The check revealed a maximum error of ±3.0 m. This accuracy is not claimed for all surveys, but it does serve as an indicator of accuracy of surveys conducted by NOS.

60. The last source of potential error in map production is conversion of digitized values to GP's. Digitizing equipment automatically recorded 1,000 coordinate values for every inch of shoreline traced, which were

corrected to true latitude and longitude positions as previously discussed. The GPOLYT2 program printout provided a final error column each for "Latitude Y" and "Longitude X," which were examined on each printout. In the event any errors exceeded 0.5 mm (at map scale), the digitizing effort was rejected, and the original sheet was redigitized. Maximum allowable error from this source was 4.99 m on the ground for a 1:10,000-scale map and 9.99 m on the ground for a 1:20,000-scale map. However, rarely were error column values as high as 0.5 mm; in most cases, they were 0.2 mm or smaller. Possible errors from this source were more likely to be on the order of 1.99 m on the ground for a 1:10,000-scale map and 3.99 m on the ground for a 1:20,000-scale map. Since most data were finally portrayed at a scale smaller than maps being digitized, the shoreline movement maps produced are well within map accuracy standards. Table 3 is a listing of the GP's of each base map used in this study.

Data Analysis

61. Data for this shoreline analysis report were obtained by digitizing shoreline positions on 30 of the 32 base maps produced by NOS (Figure 18). Maps 12 and 19 did not contain any information on oceanic shoreline changes. Shorelines were digitized from individual mylar copies of each survey since composite mylars were unavailable and paper is an unsuitable medium for accurate results because of shrinkage and expansion. Digitizing is the process by which map data are transformed into a digital format. In the case of shoreline analysis, coordinate pairs are assigned to shoreline locations relative to some arbitrary axis system. Data pairs were compared by employing various numerical techniques to produce estimates of mean shoreline movements, variations in the rate and direction of movements, and maximum net movements.

62. The entire coastline for this report was divided into segments based on general orientation and natural breaks in shoreline continuity, i.e. inlets (Figure 20). Baselines were chosen for each segment to lie as parallel as possible with the natural trends of the shoreline. Start and end points were located on the composite paper copies midway between the most landward and seaward shorelines. Baseline end points were superimposed onto the individual mylar copies to define the baseline for each segment for each map. A standard Cartesian coordinate system was then assigned to each segment with the positive x-axis directed generally north to south and the positive y-axis

Table 3

Geographical Positions of Base Maps

Map No.	Name	Central Long.	NW Corner	NE Corner	SE Corner	SW Corner
1	Tybee Island North	8051	32 07 30 80 55 30	32 07 30 80 46 30	32 00 00 80 46 30	32 00 00 80 55 30
2	Bluffton	8050	32 15 00 80 54 00	32 15 00 80 46 30	32 07 30 80 46 30	32 07 30 80 54 00
3	Hilton Head	8043	32 15 00 80 46 30	32 15 00 80 39 30	32 07 30 80 39 00	32 07 30 80 46 30
4	Parris Island	8043	32 22 30 80 47 00	32 22 30 80 39 30	32 15 00 80 39 30	32 15 00 80 47 00
5	St. Phillips Island	8036	32 22 30 80 39 30	32 22 30 80 32 00	32 15 00 80 32 00	32 15 00 80 39 30
6	Fripp Inlet	8028	32 24 45 80 32 00	32 24 45 80 24 30	32 17 15 80 24 30	32 17 15 80 32 00
7	St. Helena Sound	8029	32 32 15 80 32 30	32 32 15 80 24 30	32 24 45 80 24 30	32 24 45 80 32 30
8	Edisto Beach	8021	32 34 30 80 24 30	32 34 30 80 17 00	32 27 00 80 17 00	32 27 00 80 24 30
9	Rockville	8013	32 37 30 80 17 00	32 37 30 80 09 30	32 30 00 80 09 30	32 30 00 80 17 00
10	Kiawah Island	8006	32 39 45 80 09 30	32 39 45 80 02 00	32 32 15 80 02 00	32 32 15 80 09 30
11	James Island	7958	32 43 30 80 02 00	32 43 30 79 54 00	32 36 00 79 54 00	32 36 00 80 02 00
12	Charleston	7958	32 51 00 80 01 30	32 51 00 79 54 00	32 43 30 79 54 00	32 43 30 80 01 30
13	Fort Moultrie	7950	32 47 42 79 54 00	32 47 42 79 46 30	32 40 12 79 46 30	30 42 12 79 54 00
14	Capers Inlet	7943	32 54 00 79 46 30	32 54 00 79 39 00	32 46 30 79 39 00	32 46 30 79 46 30
15	Bull Island	7935	32 59 00 79 39 00	32 59 00 79 31 30	32 51 30 79 31 30	32 51 30 79 39 00
16	Awendaw	7933	33 06 30 79 36 45	33 06 30 79 29 15	32 59 00 79 29 15	32 59 00 79 36 45
17	McClellanville	7926	33 06 30 79 29 15	33 06 30 79 21 45	32 59 00 79 21 45	32 59 00 79 29 15
18	Cape Romain	7918	33 07 30 79 21 45	33 07 30 79 15 00	33 00 00 79 15 00	33 00 00 79 21 45

(Continued)

Table 3 (Concluded)

Map No.	Name	Central Long.	NW Corner	NE Corner	SE Corner	SW Corner
19	Minium Island	7918	33 15 00 79 21 45	33 15 00 79 15 00	33 07 30 79 15 00	33 07 30 79 21 45
20	Santee Point	7911	33 15 00 79 15 00	33 15 00 79 07 30	33 07 30 79 07 30	33 07 30 79 15 00
21	North Island	7911	33 22 30 79 15 00	33 22 30 79 07 30	33 15 00 79 07 30	33 15 00 79 15 00
22	Magnolia Beach	7907	33 30 00 79 10 45	33 30 00 79 03 15	33 22 30 79 03 15	33 22 30 79 10 45
23	Brookgreen	7901	33 37 30 79 04 30	33 37 30 78 57 00	33 30 00 78 57 00	33 30 00 79 04 30
24	Myrtle Beach NW	7856	33 45 00 79 00 00	33 45 00 78 52 30	33 37 30 78 52 30	33 37 30 79 00 00
25	Myrtle Beach NE	7849	33 48 45 78 52 30	33 48 45 78 45 00	33 41 15 78 45 00	33 41 15 78 52 30
26	Wampee	7841	33 52 30 78 45 00	33 52 30 78 37 30	33 45 00 78 37 30	33 45 00 78 45 00
27	Little River	7834	33 57 00 78 37 30	33 57 00 78 30 00	33 49 30 78 30 00	33 49 30 78 37 30
28	Shallotte	7826	33 57 00 78 30 00	33 57 00 78 22 30	33 49 30 78 22 30	33 49 30 78 30 00
29	Holden Beach	7819	33 57 00 78 22 30	33 57 00 78 15 00	33 49 30 78 15 00	33 49 30 78 22 30
30	Lockwoods Folly	7811	33 57 00 78 15 00	33 57 00 78 07 30	33 49 30 78 07 30	33 49 30 78 15 00
31	Southport	7804	33 57 00 78 07 30	33 57 00 78 00 00	33 49 30 78 00 00	33 49 30 78 07 30
32	Cape Fear	7757	33 57 00 78 00 00	33 57 00 77 53 00	33 49 30 77 53 00	33 49 30 78 00 00

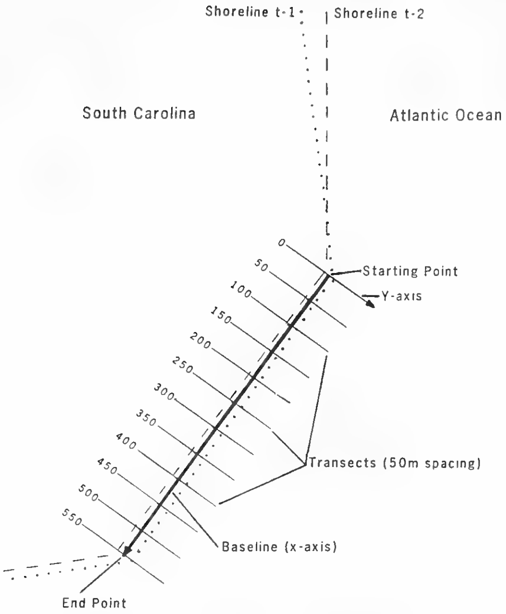


Figure 20. Idealized segment for digitizing shoreline change information

orthogonally seaward. Thus, in the resulting paired data sets, the x value was the distance from the origin along the baseline, and the y value was the corresponding perpendicular transect distance of the shoreline from the baseline. From 1 to over 25 segments were defined for each base map depending on the length and irregularity of the depicted shoreline. Within any segment, the same number of x-y pairs were digitized for each shoreline. The number of x-y pairs, or transects, depended on segment length.

63. Start and end points of each segment were punched into the mylar GP grid accompanying each base map to allow easy identification when placed on a light table. The individual survey mylars were overlaid onto this grid system. Each segment was then digitized with a NUMONICS Model 1224 Digitizer. As the cursor was traced across the shoreline, coordinate pairs were produced and recorded at equal intervals (50 m) along the x-axis from north to south. Each segment was digitized until the entire survey had been completed. The overlying mylar was replaced by the next survey and digitized in the same

manner. This process continued until all available surveys for the map were digitized. "Flags" were inserted where necessary to signal missing data. When one map was completed, the entire data set was sorted by combining the surveys of each particular segment for further analysis.

64. This procedure is suitable for coastlines where temporal reorientation and erosion/accretion is directed predominantly onshore-offshore. However, these conditions are usually not met in the vicinity of inlets and capes. Large aerial changes, abrupt reorientation of the shoreline, and pronounced alongshore changes required special analysis for most inlets and capes along this study area. Linear measurement of temporal alongshore changes and digitization of aerial differences were made from paper composite maps. Use of paper maps reduces precision of the measurements, and data presented here have been rounded off accordingly. However, because the magnitude of changes are large in these special areas relative to precision lost, the overall trends suggested by the data are valid.

65. FORTRAN programs to perform numerical analysis of digitized data were written on a Digital Equipment Corporation VAX 11/750 computer. Shoreline positions for each survey for each segment were compared at each 50-m transect. Mean change in shoreline position between the earliest and latest survey dates and interval changes in shoreline position between each survey date were calculated as follows:

$$\bar{S} = \frac{S_1 - S_n}{N_t} \qquad (1)$$

where

$\bar{S}$ = average change in shoreline position

$S_1 - S_n$ = net shoreline change between earliest and last dates

N_t = total number of years between earliest and last dates

$$S_I = \frac{Y_I - Y_{I+1}}{N_s} \qquad (2)$$

where

S_I = interval change

$Y_I - Y_{I+1}$ = difference in distance from the baseline between two consecutive surveys

N_s = number of years between consecutive surveys

Standard deviations were calculated and are an indication of relative variance among shoreline positions at each transect. Maximum shoreline change represents the difference between the most landward and seaward shoreline position, regardless of date. It thus defines the envelope of change for the shoreline over the range of data. Shoreline change statistics produced by this analysis are based on specific shoreline positions at distinct points in time. It is important to note that no attempt is made to identify or represent changes that may have occurred during the interval between successive surveys. The analysis simply distributes these changes uniformly over the entire period.

66. The length of coastal region investigated in this study (336 km) required that data presentation be subdivided into discrete reaches that could be plotted on report size paper at a reasonable scale. A total of seven reaches were defined based on a combination of natural morphology and political boundaries (Figure 21). Continuous plots of mean change in shoreline position, standard deviation, and maximum shoreline change are included here for each reach of coastline. Continuous plots of temporal divisions of average shoreline change are also presented for each reach. These plots were produced by FORTRAN computer programs generated with the aid of Display Integrated Software System and Plotting Package (DISSPLA), a proprietary product of Integrated Software Systems Corporation. Calculated quantities are graphed versus actual alongshore distance. Some alongshore distortion is introduced when individual segments of varying orientations are projected onto the nonparallel axis of the graph.

67. Summary tables list average shoreline movements for each possible time interval, for various geographic locations. The numbers displayed are averages obtained by summing interval shoreline position changes for each transect within boundaries of the geographic location and dividing by the total number of transects. The numbers in parentheses indicate the percentage of shoreline for which data were available during the particular period.

68. Information derived for each segment of each base map was compared with environmental data obtained for each segment to investigate the possible causes of measured shoreline changes. Data were compared for each of the seven coastal reaches and the entire shoreline with the use of LOTUS 1-2-3

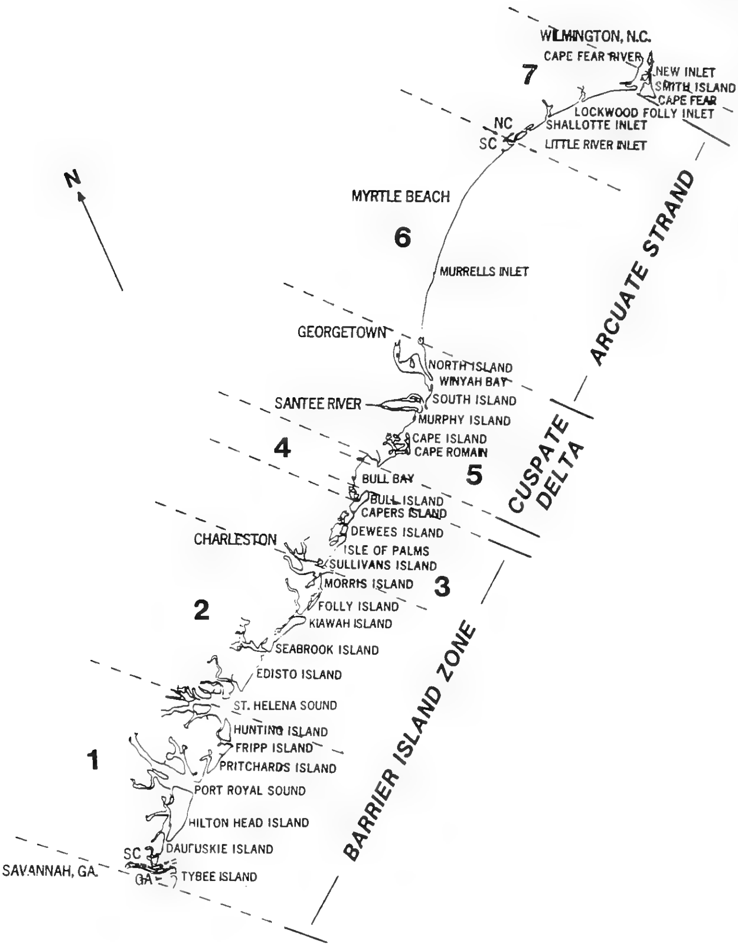


Figure 21. Map of study area showing division into geomorphic zones and subdivision into seven reaches

software, a product of Lotus Development Corporation, on a personal computer.

69. Several sources of error are possible in analysis of map data beyond those previously mentioned in producing base maps. The most basic is inherent in the digitizing equipment. The resolution of the NUMONICS Model 1224 digitizer is published to be 0.127 mm with an absolute accuracy of 0.508 mm. At a scale of 1:24,000, these specifications translate into a maximum resolution of ±3 m. This error potential was minimized by digitizing each

survey in short segments, causing the coordinate axes to be reset often.

70. Laboratory testing also discovered inaccuracies in the digitizer's axis rotation algorithms. Axis rotations of greater than 2 to 3 deg resulted in unacceptable measurements over extended distances. To compensate, the mylar grids remained fixed relative to the digitizer until all surveys for a particular map were completed, thereby keeping the angle of axis rotation to a minimum.

71. Actual tracing of the survey line with the digitizer cursor is a third potential source of error. At the 1:24,000 scale, errors resulting from tracing and actual line width are approximately 3 to 4 m. However, assuming such tracking errors to be random, they are dampened when averaged over finite distances of shoreline.

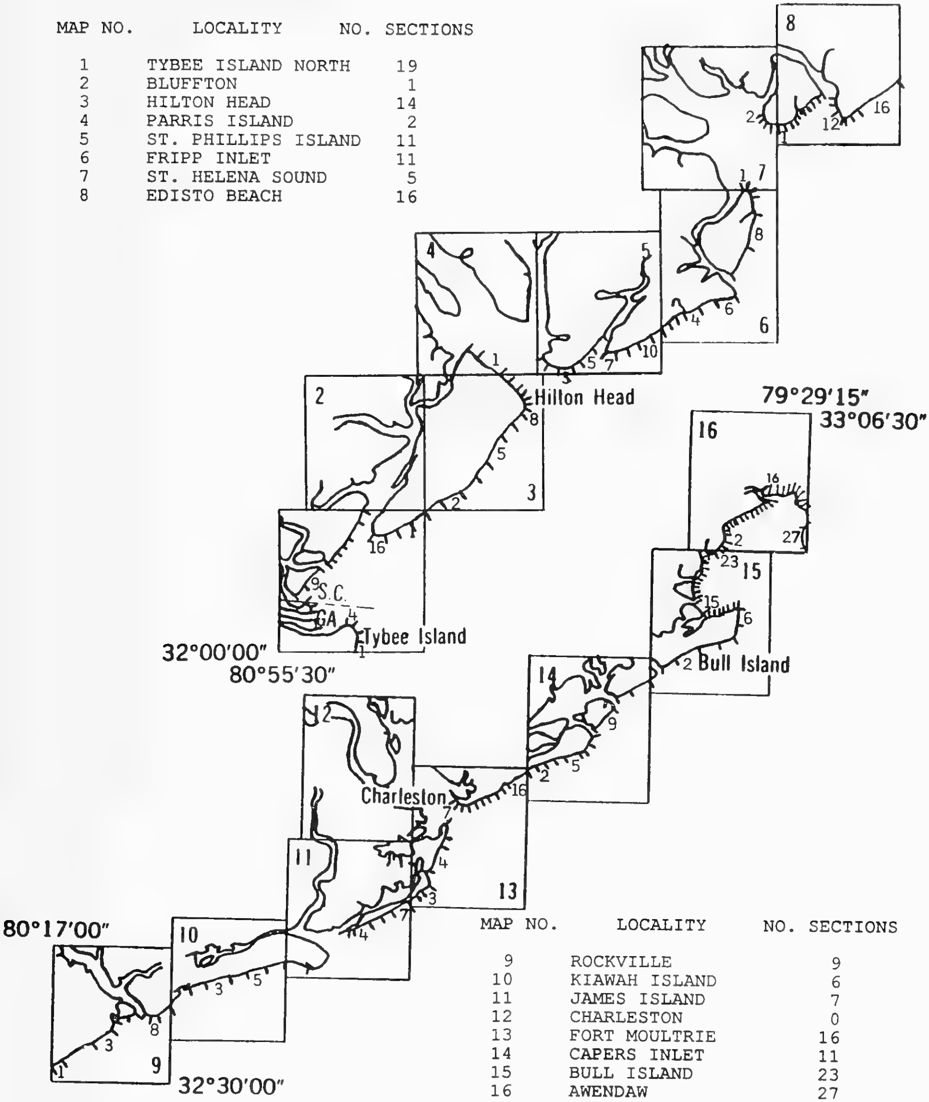
PART IV: SHORELINE DATA ANALYSIS

72. This part of the report presents the first level of analysis of data obtained from digitizing shoreline positions on the accompanying NOS map set. Length of coastline investigated in this study (336 km) prevented adequate display of shoreline change data at a scale suitable to page size format. Therefore, for display purposes, the coastline was subdivided into seven reaches (Figure 21). Reaches one (Tybee Island to St. Helena Sound), two (St. Helena Sound to Charleston), and three (Charleston to Bull Bay) correspond to Brown's (1977) barrier island geomorphic unit. Reach four is Bull Bay. Reach five (Bull Bay to North Inlet) and six (North Inlet to the North Carolina/South Carolina border) correspond to Brown's cuspate delta and arcuate strand geomorphic units respectively. Reach seven covers the remainder of the study area, which lies within the State of North Carolina (North Carolina-South Carolina border to New Inlet).

73. Within Part IV of the report, data for each reach are presented in both graphic and tabular format. Average shoreline change and standard deviation for the maximum range of years (e.g., 1856 to 1983) and several intervening shorter periods (e.g., 1850 to 1929, 1920 to 1965, 1960 to 1983) were calculated and displayed to show spatial and temporal changes in shoreline positions. Header dates presented on temporal graphs in this part of the report are not exact. Exact dates used in the comparison can be found by consulting Table 2. Maximum shoreline change during the period of study (the envelope of shoreline change) and the number of surveys and length of survey period used in data analysis are given for each coastal reach. Graphical scales are the same for comparison between reaches. Average shoreline movement for every temporal interval of data is presented for each barrier island or mainland beach within each coastal reach. For digitization, the shoreline of each map was divided into straight line segments (Figures 22a and b). Average maximum movement, average shoreline change, maximum movement, and maximum deviation are presented for each of these segments in Appendix A. Summaries of erosion and accretion are present for each reach, each geomorphic zone, and the entire study area.

74. Changes at inlets are presented as a separate section. Inlet changes are frequently quite radical and often occur in an alongshore direction rather than onshore or offshore. Methods used here to measure shoreline

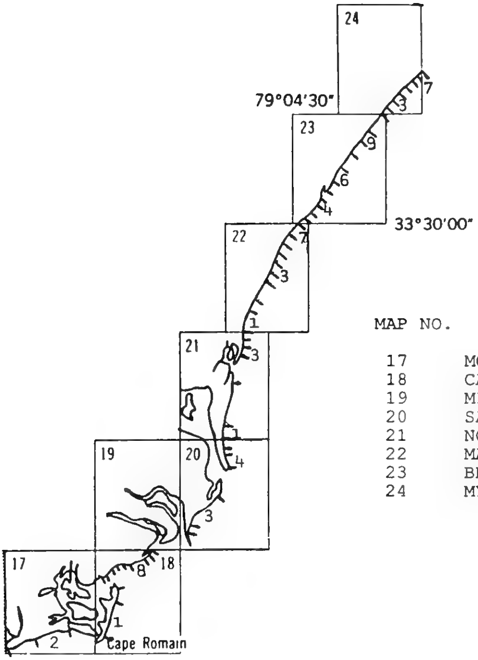
MAP NO.	LOCALITY	NO. SECTIONS
1	TYBEE ISLAND NORTH	19
2	BLUFFTON	1
3	HILTON HEAD	14
4	PARRIS ISLAND	2
5	ST. PHILLIPS ISLAND	11
6	FRIPP INLET	11
7	ST. HELENA SOUND	5
8	EDISTO BEACH	16



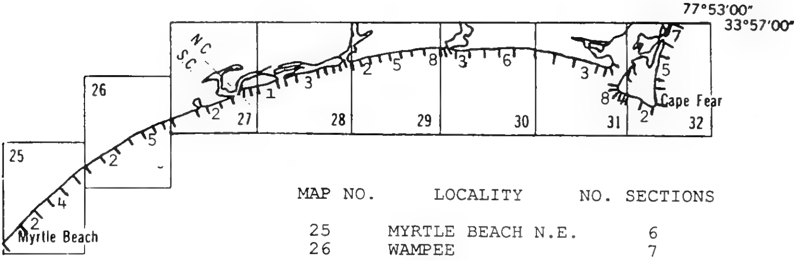
MAP NO.	LOCALITY	NO. SECTIONS
9	ROCKVILLE	9
10	KIAWAH ISLAND	6
11	JAMES ISLAND	7
12	CHARLESTON	0
13	FORT MOULTRIE	16
14	CAPERS INLET	11
15	BULL ISLAND	23
16	AWENDAW	27

a. Shoreline from Tybee Island, Georgia, to Bull Bay, South Carolina

Figure 22. Map of the study area showing division of the shoreline into short segments for digitizing and subsequent analysis (Continued)



MAP NO.	LOCALITY	NO. SECTIONS
17	MCCLELLANVILLE	2
18	CAPE ROMAIN	10
19	MINIM ISLAND	0
20	SANTEE POINT	6
21	NORTH ISLAND	5
22	MAGNOLIA BEACH	7
23	BROOKGREEN	10
24	MYRTLE BEACH N.W.	7



MAP NO.	LOCALITY	NO. SECTIONS
25	MYRTLE BEACH N.E.	6
26	WAMPEE	7
27	LITTLE RIVER	6
28	SHALLOTTE	7
29	HOLDEN BEACH	8
30	LOCKWOODS FOLLY	7
31	SOUTHPORT	11
32	CAPE FEAR	7

b. Shoreline from Bull Bay, South Carolina to Cape Fear, North Carolina

Figure 22. (Concluded)

change cannot adequately handle this type of data; therefore, measurements were made separately at each inlet to show associated alongshore and aerial changes.

Changes in Shoreline Position

Coastal reach 1

75. Average shoreline movement within coastal reach 1 (Tybee Island to St. Helena Sound), between 1852/59 and 1982/83, was quite variable, ranging from just over 10 m of accretion/year to 8 m/year of erosion (Figure 23). Overall, erosion dominated accretion in spatial distribution along this shoreline. Substantial accretion (defined here as greater than 1 m/year) occurred along a small segment of Tybee Island, the south end of Hilton Head Island, Bay Point Island, the southern and northern ends of Fripp Island, and the extreme northern terminus of Hunting Island. A small percentage of shoreline showed little net change (less than ±1 m/year) over the time span. The remainder of shoreline was strongly erosional.

76. Rate of shoreline change is quite variable spatially along the entire reach (Figure 23). Standard deviation is an indicator of variability of shoreline position changes. It is evident from this graph that magnitude of variability increases dramatically in the vicinity of inlets. It can be observed in the plot of standard deviation along the coast that every occurrence of a standard deviation in excess of 5 m/year is adjacent to an inlet. This agrees with conclusions reached by authors previously discussed, that shoreline position is most dynamic in the vicinity of inlets.

77. Maximum shoreline movement, the difference between the two most divergent shoreline positions regardless of temporal position, is quite large in this coastal reach (Figure 24). Range of shoreline movement is from approximately 50 m at Hilton Head to almost 1,400 m at Hunting Island over the period of record. In all cases where maximum shoreline movement has exceeded 500 m, it has been in the vicinity of inlets. Average shoreline movements summarized by barrier island for each interval of survey data are presented in Table 4.

78. Changes in average rate of shoreline movement are presented in Figure 25. Average shoreline movements are presented in three distinct time groups to observe temporal changes. Prior to the 1920's, the shoreline was strongly erosional. This same trend is visible right up to the last survey

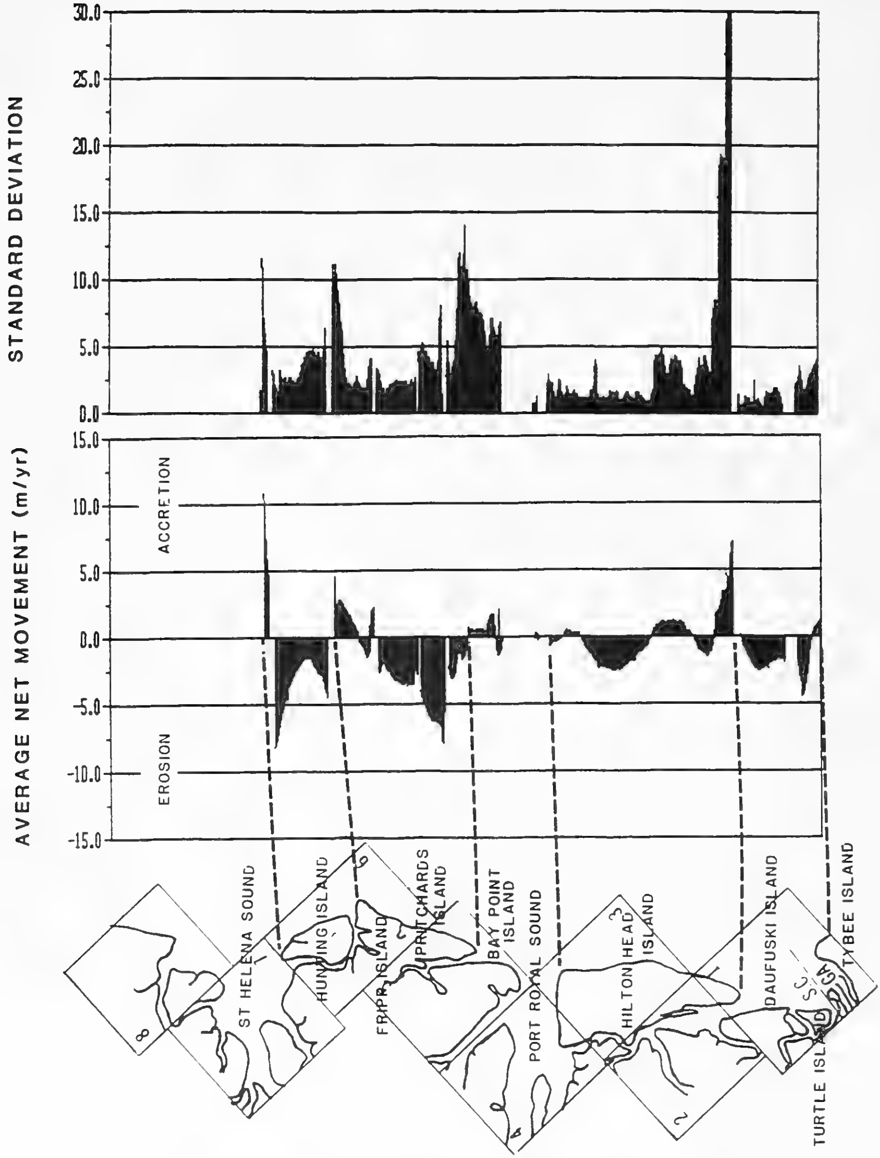


Figure 23. Average net shoreline movement and standard deviation of movement for coastal reach 1, 1852-1983

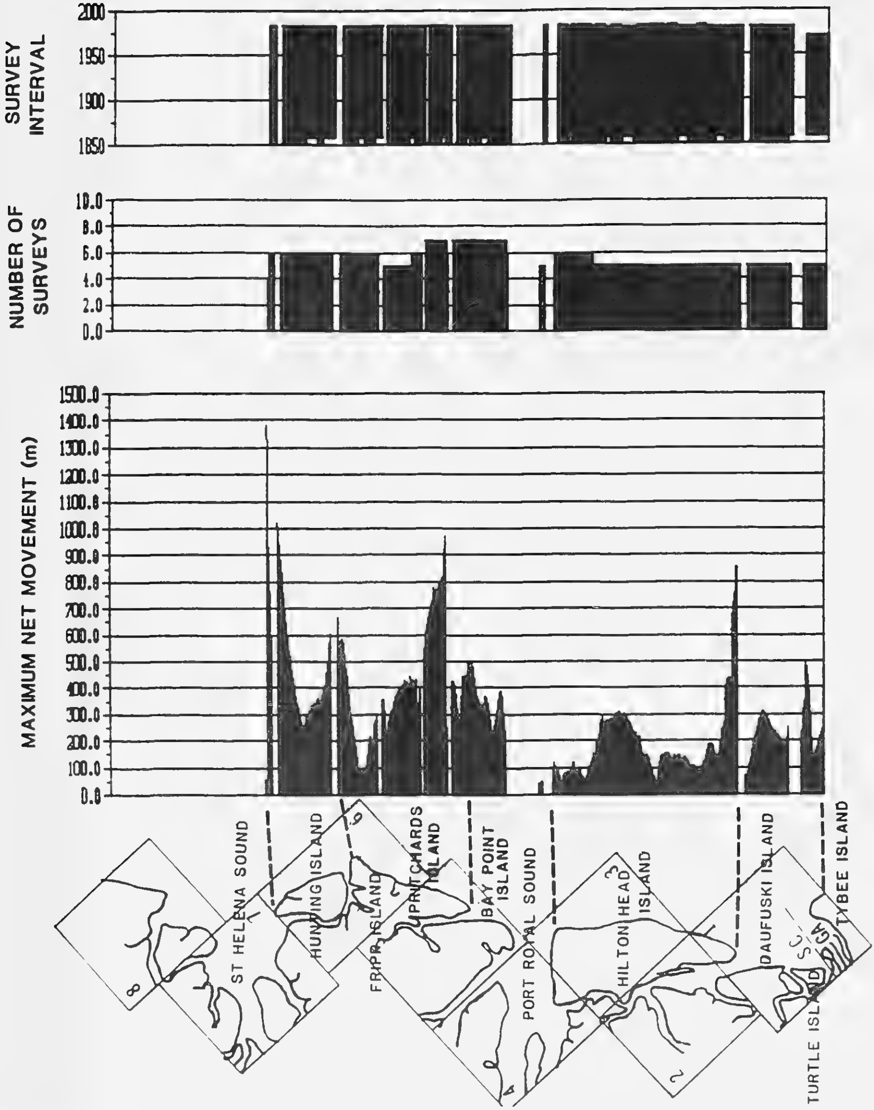


Figure 24. Maximum net shoreline movement, number of surveys used, and time interval of the surveys for coastal reach 1

Table 4

Average Shoreline Movement (metres/year), Tybee Island, Georgia, to St. Helena Sound, South Caroline

Location	Survey Dates 1852-1859	1859-1870	1859-1900	1859-1920	1859-1952	1859-1955	1859-1964	1860-1865	1865-1921	1865-1952	1870-1900	1870-1920	1900-1920	1920-1955	1920-1964
Tybee Island [1/1 - 1/4]		2.8 (18)	0.5 (82)								8.5 (18)		-5.9 (98)		-1.8 (97)
Cockspur Island [1/5]	1.5 (68)	16.7 (64)		7.5 (4)								3.4 (64)			2.0 (76)
Jones Island [1/6 - 1.7]															1.5 (86)
Turtle Island [1/8 - 1/9]	-3.0 (34)			-0.8 (97)			4.4 (1)								-1.5 (99)
Daufuskle Island [1/10 - 1/15]				-1.7 (98)											-1.6 (100)
Hilton Head Island (south) [1/16 - 3/4]				0.2 (99)											0.8 (99)
Hilton Head Island (north) [3/5 - 4/2]				-1.4 (64)	2.2 (23)	-2.1 (5)	-2.4 (7)							-0.1 (35)	-1.8 (30)
Daws Island [4/3]												-0.3 (100)			
Bay Point Island [5/1 - 5/6]								0.8 (99)	-1.4 (95)	2.5 (3)					1.7 (2)
Capera Island [5/7 - 5/10]				-3.3 (12)				0.5 (88)	-5.9 (85)	-4.3 (2)					
Pritchards Island [5/11 - 6/3]				-4.7 (98)		-1.8 (1)								-1.4 (80)	
Fripp Island [6/4 - 6/6]				1.1 (98)		2.3 (1)	2.8 (1)							3.0 (98)	
Hunting Island [6/7 - 6/8]				-2.0 (100)										-6.3 (99)	-3.0 (1)
Harbor Island [6/9 - 7/11]				13.4 (52)										0.4 (68)	

(Continued)

Note: Numbers in parentheses indicate percent shoreline surveyed during the given time interval. Numbers in brackets indicate the maps and segments contained in the data block; e.g., Harbor Island [6/9 - 7/1] extends from map 6 segment 9 to map 7 segment 1.

Table 4 (Concluded)

Location	Survey Dates 1921-1952	1921-1974	1952-1965	1952-1974	1952-1983	1955-1964	1955-1972	1964-1970	1964-1972	1965-1974	1965-1983	1970-1982	1972-1983	1974-1983
Tybee Island								-0.3						
[1/1 - 1/4]								(92)						
Cockspur Island								8.5						
[1/5]								(96)						
Jones Island								-0.9						
[1/6 - 1.7]								(100)						
Turtle Island								1.2				0.3		
[1/1-1/4]								(100)				(96)		
Daufuskle Island								0.6				-3.6		
[1/10 - 1/15]								(100)				(99)		
Hilton Head Island (south)								-13.5				7.1		
[1/16 - 3/4]								(99)				(100)		
Hilton Head Island (north)			0.2			0.3		1.6			-4.4	-1.6		
[3/5 - 4/2]			(23)			(40)		(77)			(23)	(77)		
Daws Island	0.1		1.4								-0.2			
[4/3]	(100)		(100)								(100)			
Bay Point Island	4.8	5.9	-7.3	-1.7	0.7					3.5	-7.1			-6.9
[5/1 - 5/6]	(90)	(4)	(89)	(3)	(1)					(89)	(2)			(97)
Capera Island	-4.7		-4.6		-6.4					-0.3				-14.7
[5/7 - 5/10]	(91)		(91)		(2)					(91)				(86)
Pritchards Island	-1.6		-1.4			1.1				0.7	-1.4			-5.2
[5/11 - 6/3]	(18)		(18)			(80)				(18)	(80)			(17)
Fripp Island						-3.7		-4.5				1.6		
[6/4 - 6/6]						(99)		(100)				(99)		
Hunting Island						-5.0		-0.3	-2.9		-0.5	0.0	-5.3	
[6/7 - 6/8]						(99)		(73)	(25)		(2)	(72)	(24)	
Harbor Island						-0.5	-0.6	2.5	6.4			-0.1	-3.3	
[6/9 - 7/11]						(76)	(24)	(24)	(52)			(28)	(64)	

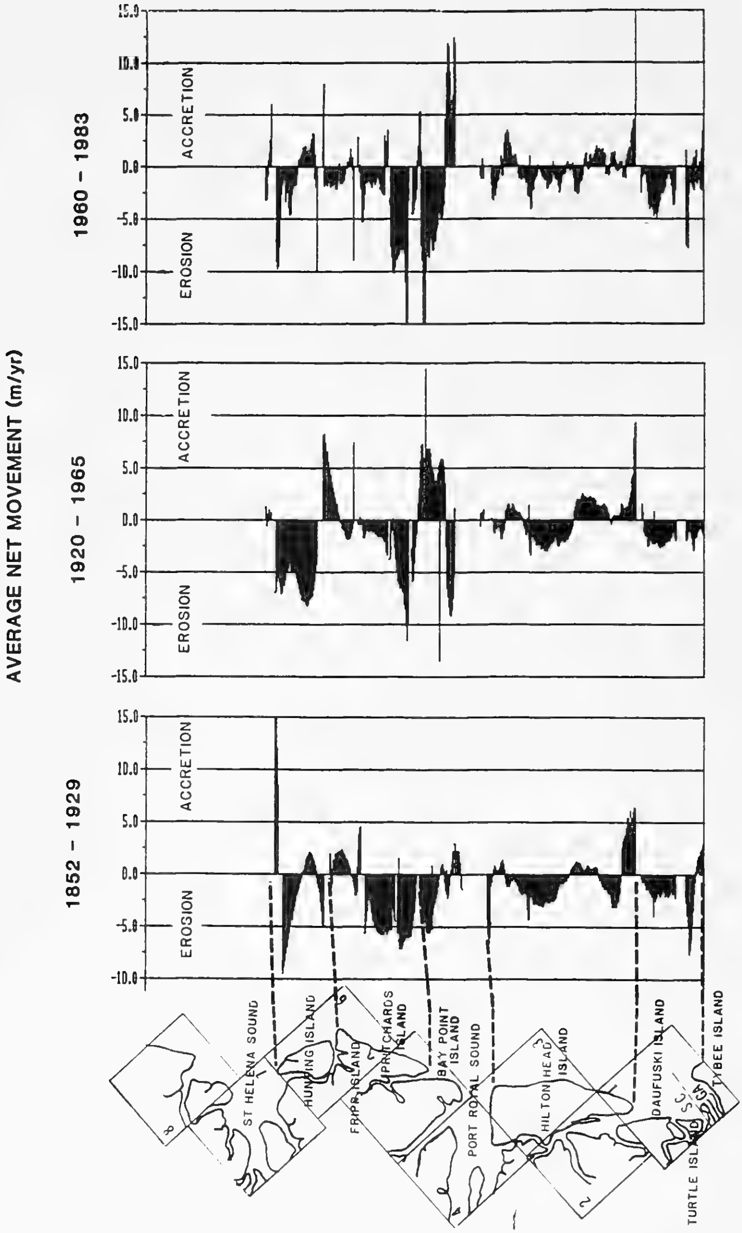


Figure 25. Temporal division of average net shoreline movement data for coastal reach 1

date (1982/83). Large spatial variability is evident during all three periods. The magnitude of erosion and accretion appears lowest along Hilton Head Island. In all three periods, large average shoreline movement rates appear to occur most often in the vicinity of inlets.

79. It is important to note that some localities, such as Pritchards Island, alternate between erosion, accretion, and erosion during the three time intervals represented. This points out that often erosion/accretion processes are not steady, but rather fluctuate with changes in environmental parameters. Magnitude of erosion and accretion appears to increase from the earliest to last period; however, this is probably due to a decrease in number of years over which data were averaged. Over shorter periods, extreme events have a greater influence on average shoreline movement rates. Aerial distribution of accretion also seems to increase slightly toward the most recent period, which may also be an artifact of decreasing length of time between survey dates. These data illustrate increased variability in the shoreline change rates over increasingly smaller intervals of time and underline the need for temporally large data sets when using historical shorelines to predict future shorelines.

80. Shoreline changes over the entire temporal range of data from each digitized transect were categorized into one of three modes: erosional (eroding more than 1 m/year), stable (less than or equal to 1 m/year of change), and accretional (accreting more than 1 m/year). Results were summed for each coastal reach and presented as pie graphs. The summary for coastal reach 1 (Figure 26) shows the majority of shoreline is erosional (54.9 percent) or stable (30.5 percent). Only a very small proportion (14.6 percent) of transects measured showed long-term accretion rates in excess of 1 m/year.

Coastal reach 2

81. Average shoreline movement within coastal reach 2 (St. Helena Sound to Charleston Harbor) is similar in character to reach 1. The range is from 7 m/year accretion to 12 m/year of erosion over the period of record (Figure 27). The northern end of this reach, which lies immediately downdrift of the Charleston Harbor jetties, is strongly erosional. This zone of strong erosion includes all of Morris Island and most of Folly Island. The north end of Kiawah Island is strongly accretional, changing to erosional toward its south end and back to strongly accretional on Seabrook Island. Almost the entire length of Edisto Island is strongly erosional, except for some

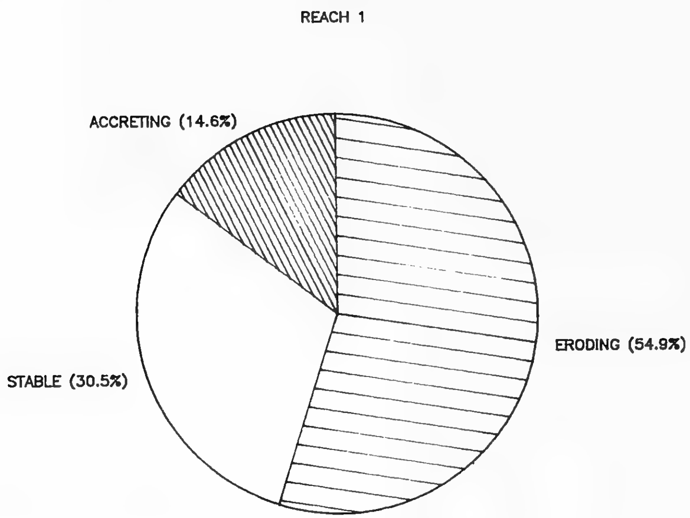


Figure 26. Summary of shoreline movement for coastal reach 1, 1852-1983

accretion on the south. This accretion may be attributed to groins built in this area to retard erosion. Otter Islands, which are partially sheltered in St. Helena Sound, are variable but mainly accretional. Spatially, erosion predominates over this reach during the total study time interval.

82. A pattern of highest variability in the vicinity of inlets is evident in reach 2. Each place where standard deviation of shoreline movement exceeds 5 m/year is in the immediate vicinity of inlets (Figure 27). Central portions of barrier islands, while still variable in long-term rate of erosion, are steady in shoreline change compared with areas adjacent to inlets. Variability of shoreline change is echoed in the maximum shoreline movement (Figure 28), which shows several changes in excess of 1,000 m over duration of the study. Only in the vicinity of inlets are shoreline changes found in excess of 500 m. Along central portions of barriers, maximum change over 130 years of record drops below 100 m in several areas.

83. Temporal examination of average rates of shoreline change (Figure 29) demonstrates the effect of jetty construction at Charleston Harbor. The jetties were completed around the turn of the century. The first period

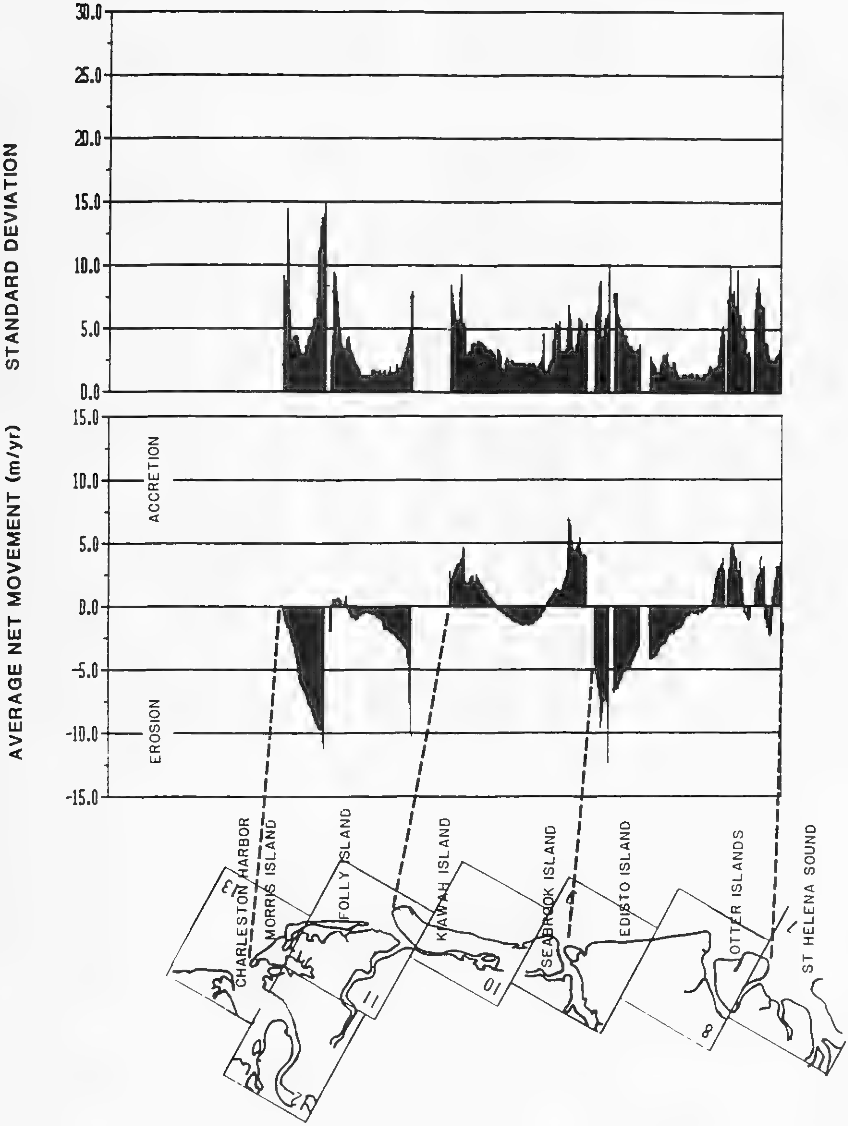


Figure 27. Average net shoreline movement and standard deviation of movement for coastal reach 2, 1851-1983

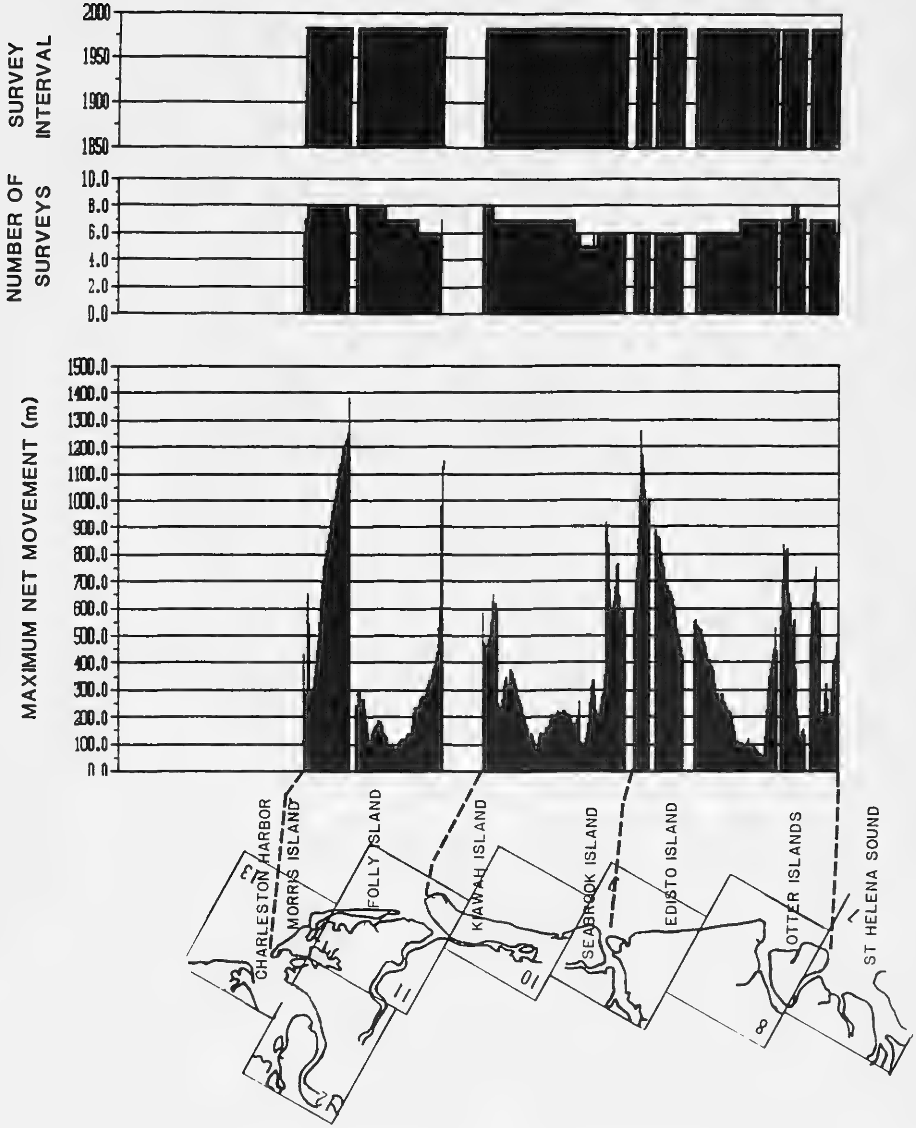


Figure 28. Maximum net shoreline movement, number of surveys used, and time interval of the surveys for coastal reach 20

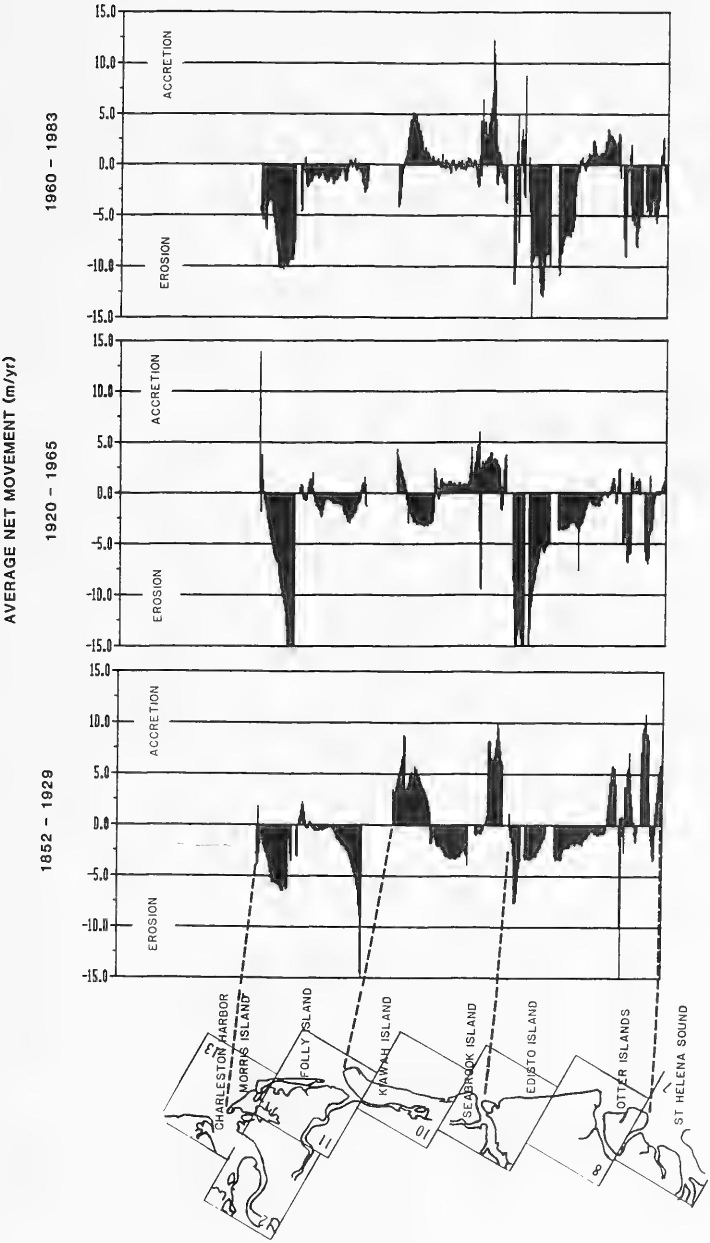


Figure 29. Temporal division of average net shoreline movement data for coastal reach 2

shown in this figure includes data mainly from preconstruction of the jetties. The result is an average erosion rate exceeding 5 m/year. The second period, from early 1920's to early 1960's, shows a postconstruction phase of erosion that has shoreline erosion rates exceeding 20 m/year. Morris Island is clearly sediment starved as a result of the jetties. The early 1960's to 1983 graph shows continued erosion of Morris Island; however, despite the shorter time interval represented, magnitude of the erosion has decreased. Erosion rates over this 20-year interval barely exceed 10 m/year. Folly Island is generally eroding during all three time intervals. Accretion along the length of Folly Island appears to be at a minimum during the 1960 to 1983 period. Along Kiawah Island, erosion and accretion seem to reverse with changing time intervals. The most recent period shows Kiawah to be largely accretional. Edisto Island has been erosional through time, except at the very southern end. Pine and Otter Islands were accretional during the 1850 to 1929 time period, but have been largely erosional since then. A summary of average shoreline change rates per island for every available time interval is presented in Table 5.

84. The summary of data within reach 2 (Figure 30) shows erosion to be dominant (40.0 percent). However, despite the effects of Charleston Harbor jetties, the percent occurrence of accretion is greater (28.5 percent) than in reach 1 (14.6 percent). Approximately 31.5 percent of the transects measured in reach 2 showed +1 m/year or less change between 1851 and 1983.

<u>Coastal reach 3</u>

85. Coastal Reach 3 (Charleston Harbor to Bull Bay) also falls within Brown's (1977) barrier island geomorphic zone and is similar in character to reaches 1 and 2 discussed previously (Figure 31). Average net accretion varies up to a maximum of approximately 6 m/year, and average net erosion exceeds 8 m/year. Sullivans Island and Isle of Palms, both immediately north of the Charleston Harbor jetties, predominantly show accretion. Rate of accretion increases toward the jetties, suggesting trapping of littoral drift as the reason for sediment accumulation. Dewees and Capers Islands, north of Isle of Palms, are predominantly erosional, although both show a small area of accretion near their northern ends. Bull Island, the northernmost barrier island in this reach and within Brown's barrier island geomorphic zone, starts out strongly accretional in the south and ends up strongly erosional at its northern terminus.

Table 5

Average Shoreline Movement (metres/year), St. Helena Sound to Charleston Harbor, South Carolina

Location	Survey Dates													
	1852-1859	1852-1921	1852-1933	1854-1921	1854-1934	1856-1920	1858-1864	1859-1900	1859-1920	1859-1933	1862-1921	1864-1900	1864-1921	1900-1921
Otter Islands	-0.2					5.4			3.8					
[7/2 - 8/5]	(66)					(15)			(76)					
Pine Island	-0.7								2.3	9.3				
[8/6 - 8/9]	(100)								(57)	(43)				
Edisto Beach		3.2												
[8/10 - 8/15]		(96)												
Edisto Beach St. Park (south)		-0.6												
[8/16 - 9/1]		(100)												
Edisto Beach St. Park (north)		-2.7	-2.9											
[9/2]		(88)	(12)											
Botany Bay Island		2.6												
[9/3]		(100)												
Edisto Island (north)		-3.7												
[9/4 - 9/6]		(97)												
Seabrook Island		6.4												
[9/7 - 9/9]		(100)												
Kiawah River Inlet				-0.5	-0.8									
[10/1]				(60)	(40)									
Kiawah Island (south)				-2.6										
[10/2 - 10/3]				(100)										
Kiawah Island (north)	-1.3	8.0		3.1					4.7					
[10/4 - 11/1]	(21)	(5)		(71)					(21)					
Folly Island	1.7	-4.8					5.3	1.7	-1.1		-7.6	0.4	-1.4	-2.0
[11/2 - 13/3]	(50)	(27)					(19)	(16)	(34)		(4)	(18)	(1)	(34)
Morris Island							-2.0					-6.3	-0.8	0.0
[13/4 - 13/6]							(98)					(89)	(6)	(86)

(Continued)

Note: Numbers in parentheses indicate percent shoreline surveyed during the given time interval. Numbers in brackets indicate the maps and segments contained in the data block; e.g., Morris Island [13/4 - 13/6] extends from map 13 segment 4 to map 13 segment 6.

Table 5 (Concluded)

Location	Survey Dates													
	1920-1955	1921-1933	1921-1952	1933-1952	1933-1964	1934-1955	1934-1971	1952-1964	1955-1964	1964-1971	1964-1974	1964-1983	1971-1983	1974-1983
Otter Islands [7/2 - 8/5]	2.9 (28)		-3.0 (65)					0.2 (66)	3.0 (32)	-0.5 (33)	0.0 (65)		-3.8 (33)	-5.4 (65)
Pine Island [8/6 - 8/9]		1.0 (29)	-1.9 (28)	-6.5 (72)				4.9 (100)			-4.1 (100)			-3.8 (100)
Edisto Beach [8/10 - 8/15]		2.4 (100)		0.5 (100)				-1.0 (100)			-1.5 (100)			4.5 (100)
Edisto Beach St. Park (south) [8/16 - 9/1]		-1.1 (100)		-1.6 (57)	-1.3 (43)			0.3 (57)			1.1 (99)			0.7 (99)
Edisto Beach St. Park (north) [9/2]		-6.4 (88)			-1.9 (100)						-5.5 (100)			-8.5 (100)
Botany Bay Island [9/3]		-2.3 (100)			-9.3 (98)						-3.0 (98)			-14.7 (100)
Edisto Island (north) [9/4 - 9/6]		-8.5 (100)			-15.1 (100)						-1.5 (100)			-3.2 (100)
Seabrook Island [9/7 - 9/9]		3.9 (100)			0.8 (100)						2.1 (100)			0.5 (100)
Kiawah River Inlet [10/1]		-2.6 (60)			4.4 (92)		7.1 (8)			2.0 (82)		4.1 (11)	1.9 (89)	
Kiawah Island (south) [10/2 - 10/3]		2.5 (100)			0.9 (10)	1.1 (90)			-2.7 (90)	1.6 (100)			-0.9 (100)	
Kiawah Island (north) [10/4 - 11/1]		-4.0 (100)				0.4 (100)			-0.4 (99)	6.2 (99)			-1.6 (100)	
Folly Island [11/2 - 13/3]	-2.2 (1)	0.3 (100)			-1.0 (1)	0.0 (99)			-4.2 (99)			-0.9 (99)		
Morris Island [13/4 - 13/6]	-0.5 (1)	-8.5 (92)				-8.2 (97)			-8.8 (100)			-6.9 (100)		

REACH 2

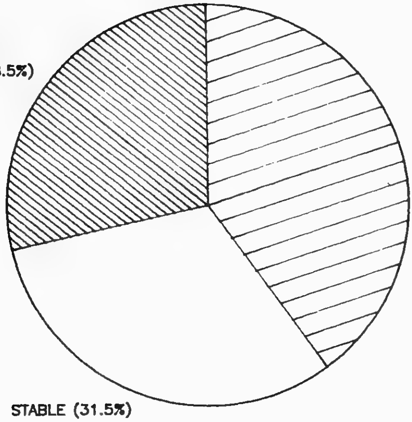


Figure 30. Summary of shoreline movement for coastal reach 2, 1851-1983

86. Standard deviations in excess of 5 m/year occur only in the vicinity of inlets (Figure 31). Central portions of islands appear more stable through time. Maximum shoreline movements (Figure 32) are not as large in magnitude as in previous reaches, but they do approach 1,000 m and are at a maximum in the vicinity of inlets.

87. Sullivans Island and Isle of Palms have generally been accretional throughout the period of data examined (Figure 33). From 1960 to 1983, the largest spatial distribution of accretion occurred along these two islands. Dewees Island has been consistently erosional through the period except near Capers Inlet. The most recent period shows erosion even in this area. Likewise, Capers Island has been dominated temporally by erosion. The most recent period shows some accretion in the vicinity of Price Inlet on Capers Island. Price Inlet has affected Bull Island to the north also. Erosion and accretion rates alternate and vary in magnitude along the southern portion of Bull Island, while the north end has been consistently eroding through time. A summary of average shoreline change rates per island for each possible data interval are presented in Table 6.

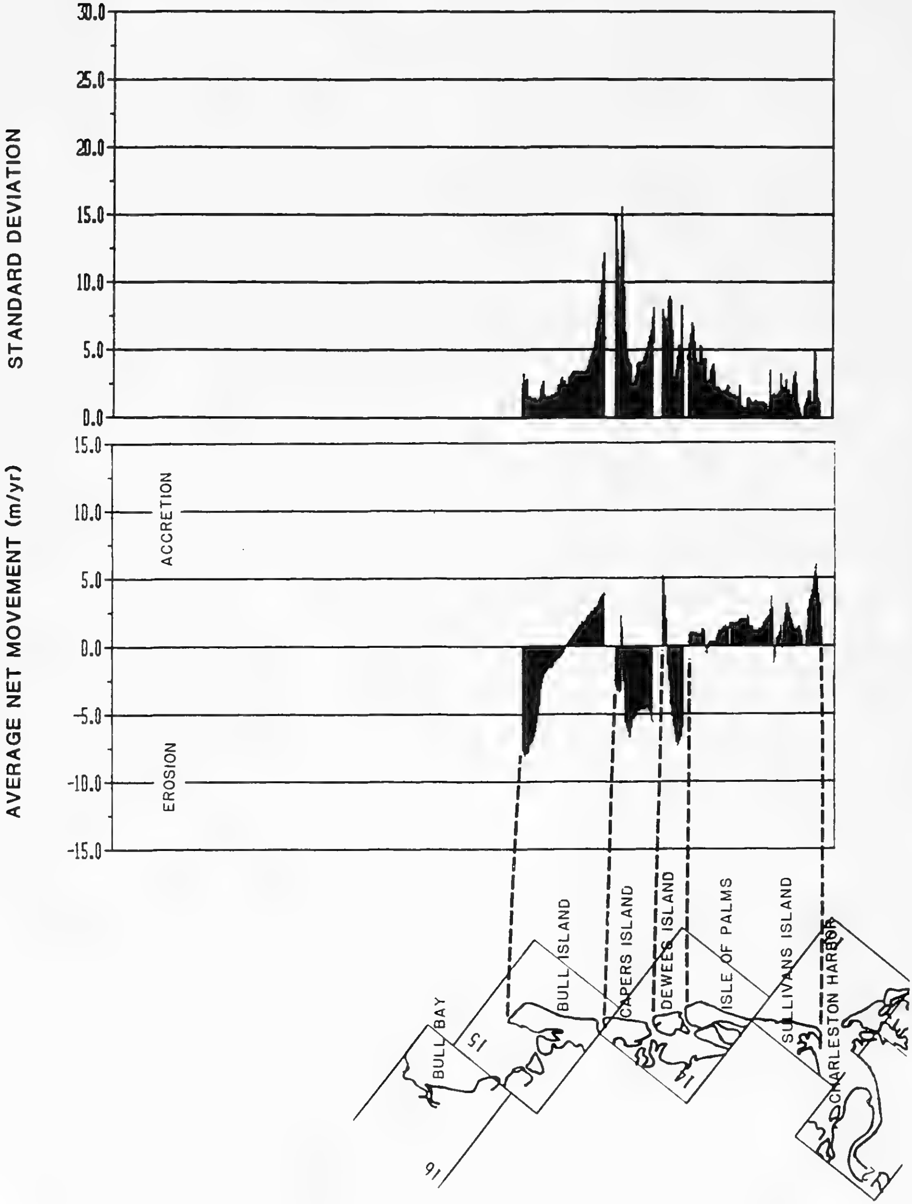


Figure 31. Average net shoreline movement and standard deviation of movement for coastal reach 3, 1857-1983

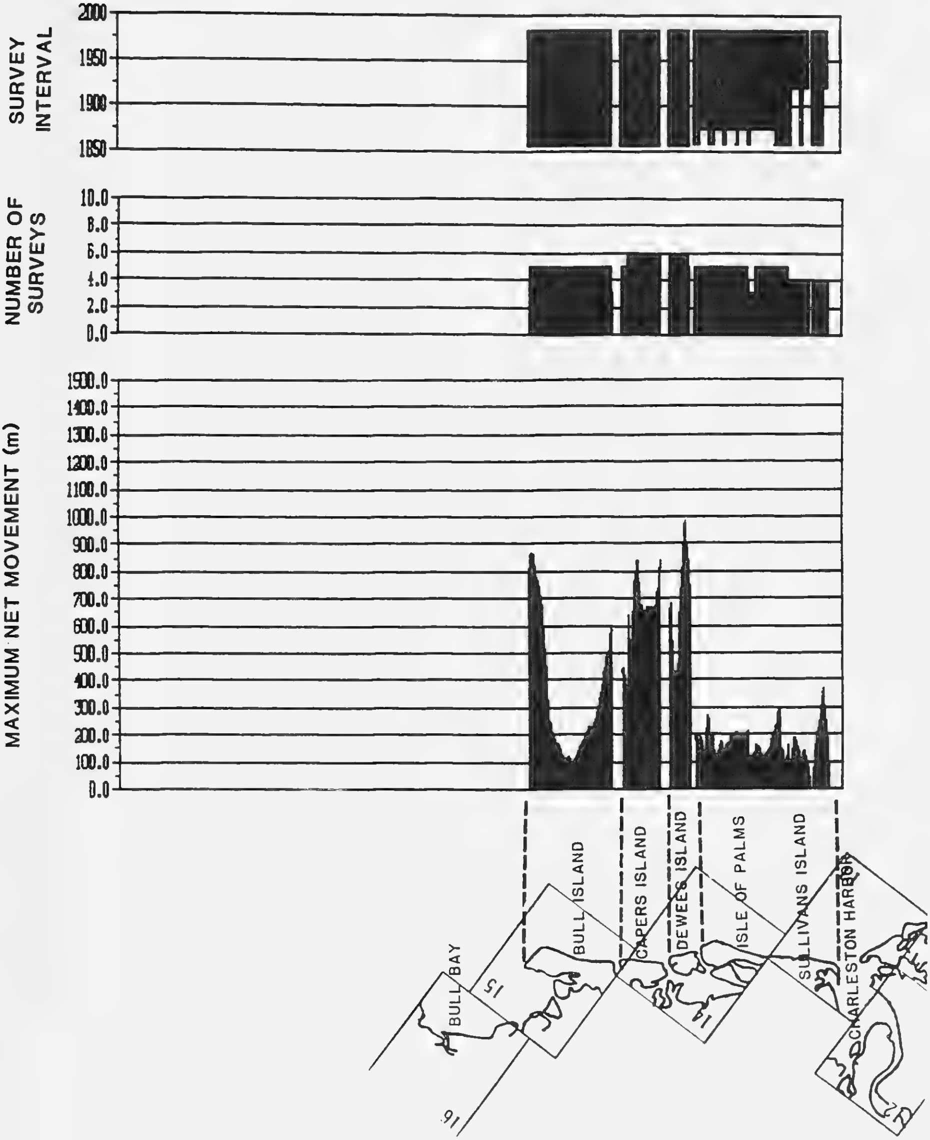


Figure 32. Maximum net shoreline movement, number of surveys used, and time interval of the surveys, for coastal reach 3

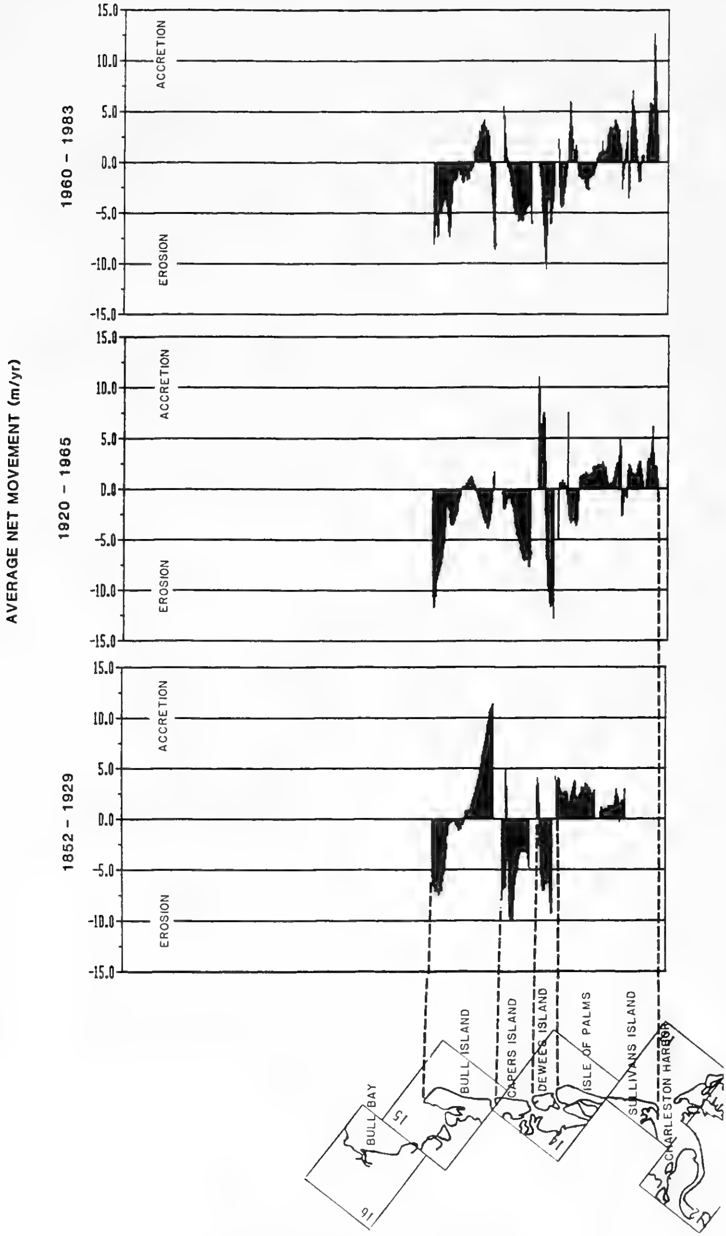


Figure 33. Temporal division of average net shoreline movement data for coastal reach 3

Table 6

Average Shoreline Movement (metres/year), Charleston Harbor to Bull Island, South Carolina

Location	Survey Date						
	1875-1921	1921-1933	1921-1964	1933-1964	1934-1962	1962-1983	1964 1983
Sullivans Island [13/7 - 13/13]	1.5 (15)	0.5 (94)		1.9 (94)			2.6 (94)
Isle of Palms [13/14 - 14/8]	2.1 (91)	-0.2 (92)	2.3 (8)	1.8 (28)	0.0 (63)	-0.5 (63)	2.1 (36)
Dewees Island [14/9]	-4.2 (96)	6.2 (96)			-4.7 (100)		-4.1 (100)
Capers Island [14/10 - 14/11]	-7.3 (100)	-1.1 (99)			-5.3 (99)		-1.5 (100)
Bull Island [15/1 - 15/6]	0.7 (99)	-1.9 (99)			-3.0 (98)		-1.5 (98)

Note: Numbers in parentheses indicate percent shoreline surveyed during the given time interval. Numbers in brackets indicate the maps and segments contained in the data block; e.g., Bull Island [15/1 - 15/6] extends from map 15 segment 1 to map 15 segment 6.

88. The summary of transect data for all of coastal reach 3 (Figure 34) is quite different from reaches 1 and 2. Accretion predominates (44.4 percent) in this reach over the 1857-1983 time interval. Undoubtedly, the trapping of littoral drift north of the Charleston Harbor jetties have played a strong role in this reach. Erosion (30.1 percent) is reduced from reaches 1 and 2 (54.9 percent and 40.0 percent, respectively). Only 25.4 percent of reach 3 can be considered stable over the long term.

Coastal reach 4

89. The marsh-bordered shoreline of Bull Bay comprises coastal reach 4. The sheltered nature of this bay is reflected in the long-term average shoreline change rates, which reach a maximum of approximately 3 m/year average erosion and 2 m/year average accretion (Figure 35). Average erosion and accretion in the bay is considerably less than along barrier islands to the south. Maximum rates of accretion occur on the northeast side of the bay, which is most sheltered from dominant northeast quadrant winds and waves.

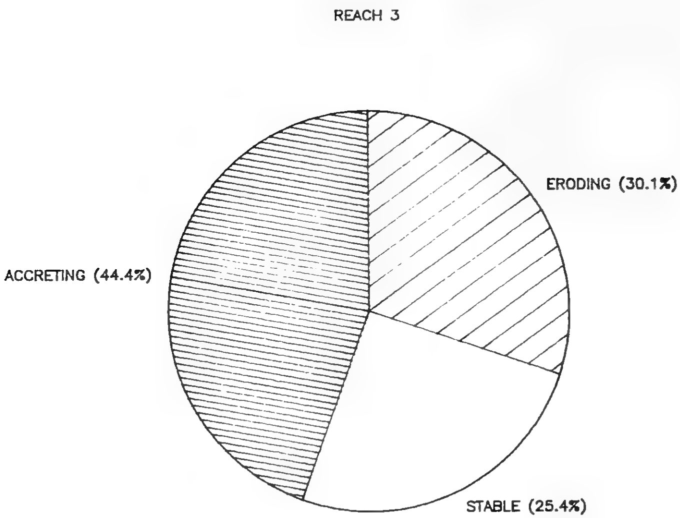


Figure 34. Summary of shoreline movement for coastal reach 3, 1857-1983

Much of the central section of the bay is slightly erosional or stable. The southwest portion, in the vicinity of Venning, Anderson, and Bull Creeks, has the most rapid erosion. Orientation of this segment of the bay makes it most susceptible to waves from the northeast. Overall, this shoreline appears stable to slightly eroding.

90. Standard deviation, a measure of variation in shoreline change rates, is small in comparison with reaches 1, 2, and 3 (Figure 35). Maximum standard deviations reach ±3 m/year, although most of the shoreline does not exceed ±2 m/year. The trend in reaches 1, 2, and 3 of greatest variability in shoreline position in the vicinity of inlets is not evident in this reach. The small tidal creeks entering Bull Bay have limited discharge and, therefore, limited ability to erode/deposit sediment.

91. Maximum net movement (Figure 36) reaches a peak in the northeast and southwest corners of the bay, where average accretion and erosion, respectively, were at their maximums. Maximum net movement up to 300 m is evident, but most of the shoreline has had a net change of less than 100 m over the span of record.

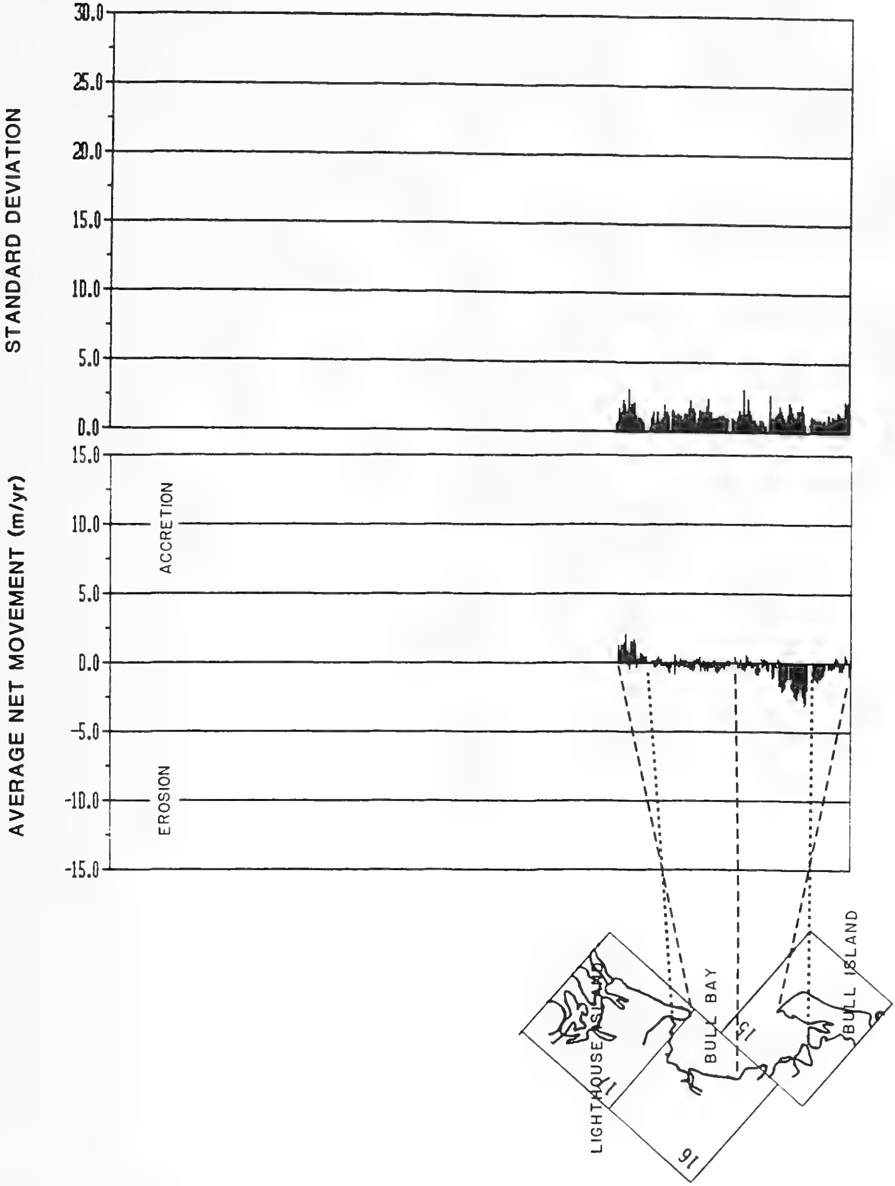


Figure 35. Average net shoreline movement and standard deviation of movement for coastal reach 4, 1874-1983

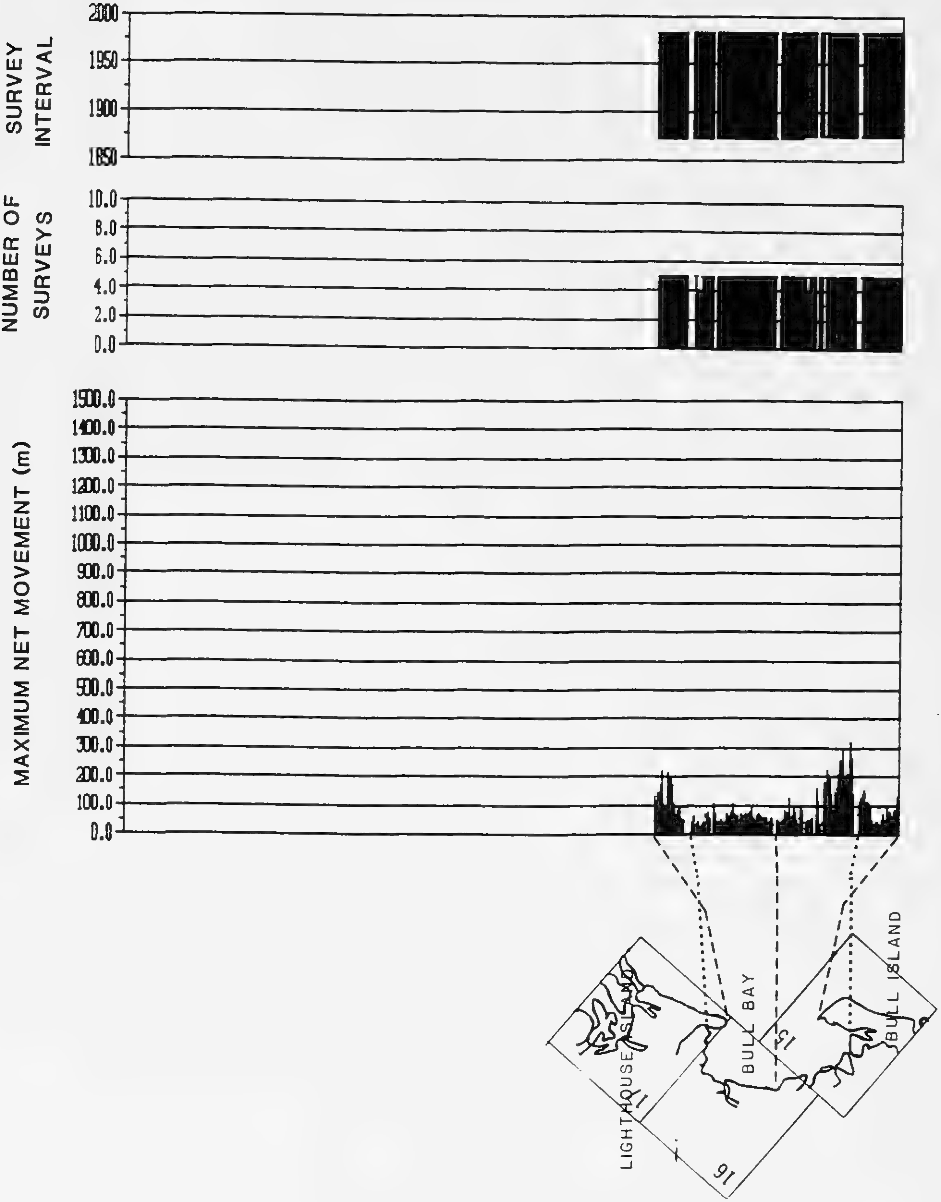


Figure 36. Maximum net shoreline movement, number of surveys used, and time interval of the surveys, for coastal reach 4

92. Separation of average net shoreline change rates into three periods reveals some changes in erosional character of the bay over the period of study (Figure 37). From 1850 to early 1920's, most of the bay was slightly accretional. The exception to this was the southwest corner, which is erosional during all periods, although magnitude of the erosion appears to be decreasing with time. The period from 1920 to early 1960 shows a mix spatially of erosion and accretion. The most recent period, from 1960 to 1983, is primarily erosional, with the center of the bay showing a strong erosional signature. Spatial distribution of accretion is at its lowest during the most recent period. Average net shoreline change rates for discrete sections of the bay for each possible survey interval are presented in Table 7.

93. Unlike the barrier coastline to the south, shoreline changes in Bull Bay are slow and reasonably predictable. Wind, wave, and storm effects are markedly reduced because of sheltering by Bull Island and Sandy Point and shallow bathymetry. With reduction of these parameters as shoreline change agents, the role of relative sea level rise increases. Wave refraction, long-term sea level rise, and short-term storm surge are probably key factors in spatial and temporal erosion/deposition of bay shoreline. Figure 38 demonstrates the stability of this reach. Over 82 percent of Bull Bay coastline has had less than ±1 m/year of shoreline change between 1874 and 1983. The remainder of Bull Bay is eroding (13.9 percent) or accreting (3.9 percent) depending on orientation to waves that can directly enter the bay.

<u>Coastal reach 5</u>

94. Coastal reach 5 (Bull Bay to North Inlet), which corresponds to Brown's (1977) cuspate delta geomorphic zone, is characterized by erosion/accretion trends similar to the barrier island zone (Figure 34). From Sandy Point north to Cape Romain Harbor entrance, including all of Cape Romain, erosion dominates. Maximum erosion rates of approximately 12 m/year occur in the vicinity of the cape. Murphy Island, just north of Cape Romain harbor, is strongly accretional at its southern end and erosional along most of its northern end. Cedar Island, between branches of Santee River, is entirely erosional. South Island, downdrift of the jetties at Winyah Bay, has generally been accreting over the duration of this data set. Maximum accretion for the entire reach, approximately 9 m/year, is at the southern end of this island. North of Winyah Bay, the area adjacent to the jetties is mildly accretional switching to erosional as North Inlet is approached. Overall,

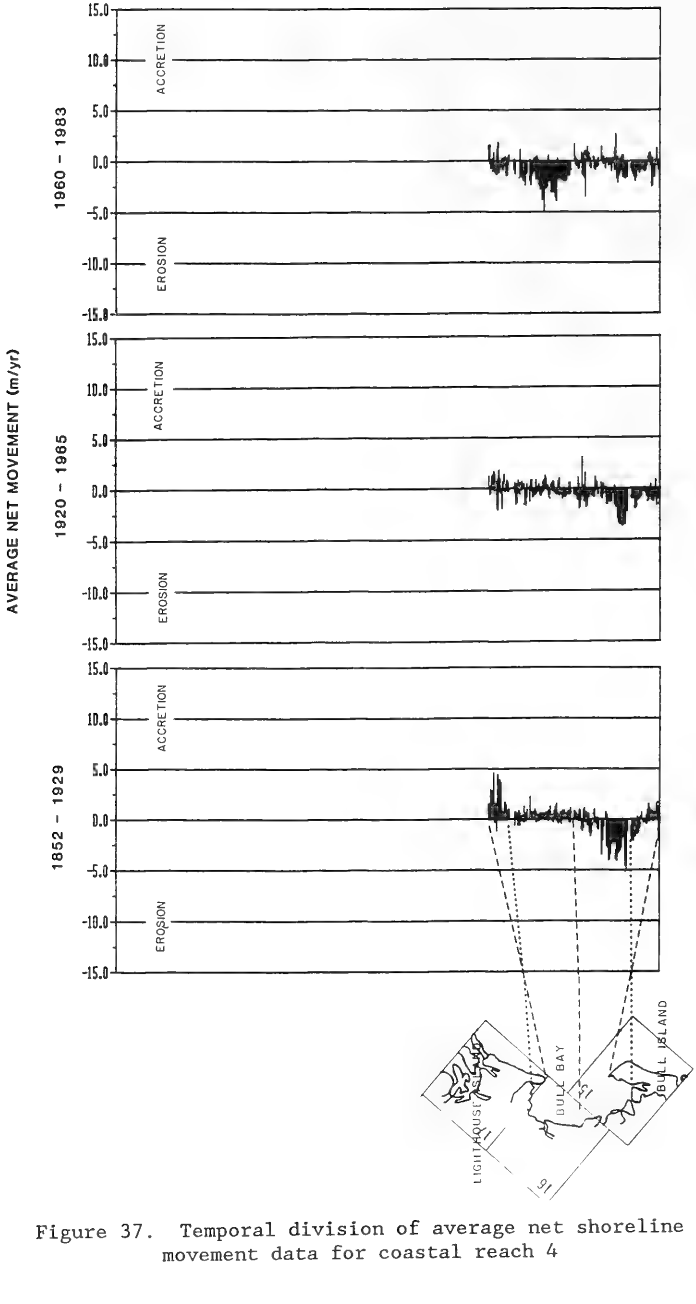


Figure 37. Temporal division of average net shoreline movement data for coastal reach 4

Table 7

Average Shoreline Movement (metres/year),

Bull Bay, South Carolina

Location	Survey Dates 1874-1934	1875-1921	1921-1934	1934-1962	1962-1983
Bull Harbor [15/7 - 15/15		-0.1 (100)	-0.8 (100)	-0.5 (100)	-0.5 (100)
Anderson Creek - Venning Creek [15/16 - 15/19]		-2.2 (83)	-2.3 (95)	-1.9 (98)	-0.4 (100)
Venning Creek - Graham Creek [15/20 - 16/2]		-0.5 (99)	-0.5 (99)	-0.4 (99)	0.1 (95)
Graham Creek - Harbor River [16/3 - 16/15]		0.4 (98)	-0.6 (98)	0.1 (99)	-1.4 (98)
Harbor River - Bull River [16/16 - 16/20]	-0.2 (5)	0.2 (95)	-0.8 (95)	0.1 (100)	-0.9 (73)
Bull River - Five Fathom Creek [16/21 - 16/26]		1.3 (97)	1.3 (100)	-0.2 (98)	-0.1 (98)

Note: Numbers in parentheses indicate percent shoreline surveyed during the given time interval. Numbers in brackets indicate the maps and segments contained in the data block; e.g., Bull River-Five Fathom Creek [16/21 - 16/26] extends from map 16 segment 21 to map 16 segment 26.

between 1874 and 1983, erosion dominated over accretion. Undoubtedly, the previously discussed diversion of the Santee River had a role in this.

95. Standard deviation along this reach varies from less than ±2 m/year up to ±30 m/year (Figure 39). South Island, which lies downdrift of Winyah Bay, shows extreme variability in shoreline position. A second peak of large standard deviations occurs in association with accretion along the central part of Murphy Island. Within reach 5, the pattern of highest variability in shoreline positions adjacent to inlets is not as apparent. The trend is not evident at all on Murphy Island, where the central section of the island is most variable. North and South Islands and Sand Point Beach do exhibit a more stable central portion with greater deviations toward inlets. The remainder of reach 5 has a vaguely linear trend between inlets.

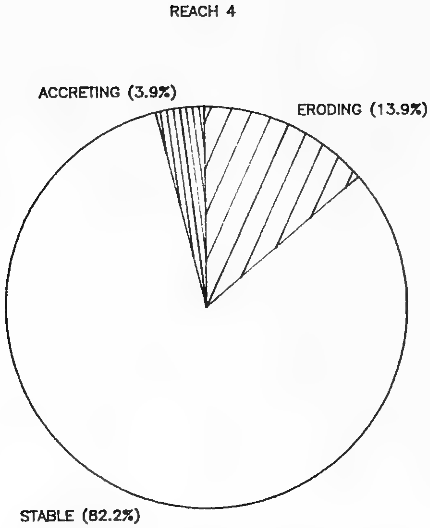


Figure 38. Summary of shoreline movement for coastal reach 4, 1874-1983

96. Maximum movement is quite high along this entire shoreline (Figure 40). Over the 1857 to 1983 time range, the only location that has less than a 100-m net change is central North Island. Movements over 1,300 m occurred near Cape Romain, and throughout the reach, movement in excess of 500 m is common.

97. Temporal separation of average shoreline movement data into three periods reveals steady erosion south of Cape Romain Harbor (Figure 41). Murphys Island was predominantly accretional prior to the early 1920's, except for the north end. From the early 1920's to early 1960, it was mainly erosional, except for the extreme southern end. During the most recent time interval, it has become strongly accretional again, but with erosion dominating adjacent to inlets. Cedar Island has changed from modestly accretional to erosional through time. South Island, south of the Winyah Bay jetties, was mixed spatially between erosion and accretion prior to the 1920's. Between 1920 and 1965, it was very strongly accretional, reaching a maximum of 48 m/year between 1926 and 1934. During the 1960 to 1983 time span, it was erosional to the south and accretional along the north end. North Island has

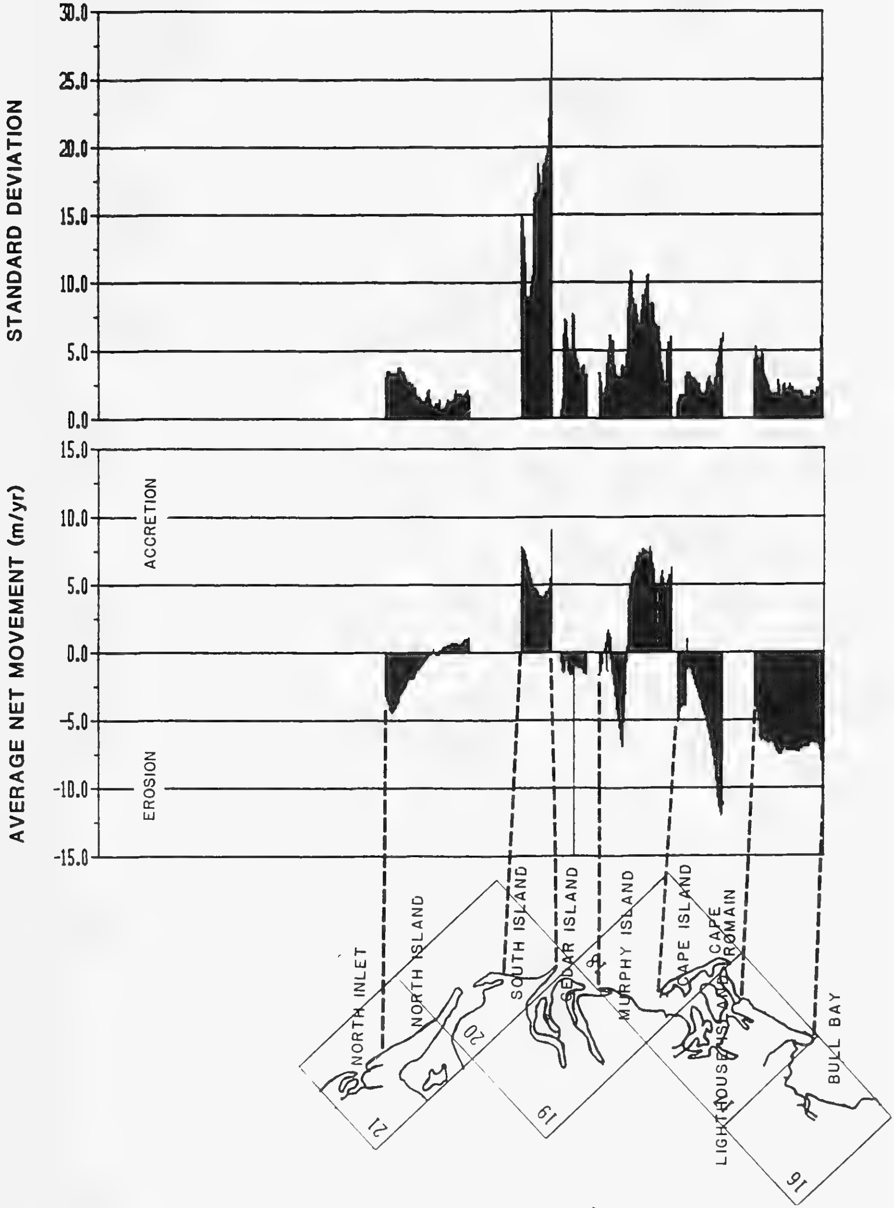


Figure 39. Average net shoreline movement and standard deviation of movement for coastal reach 5, 1857-1983

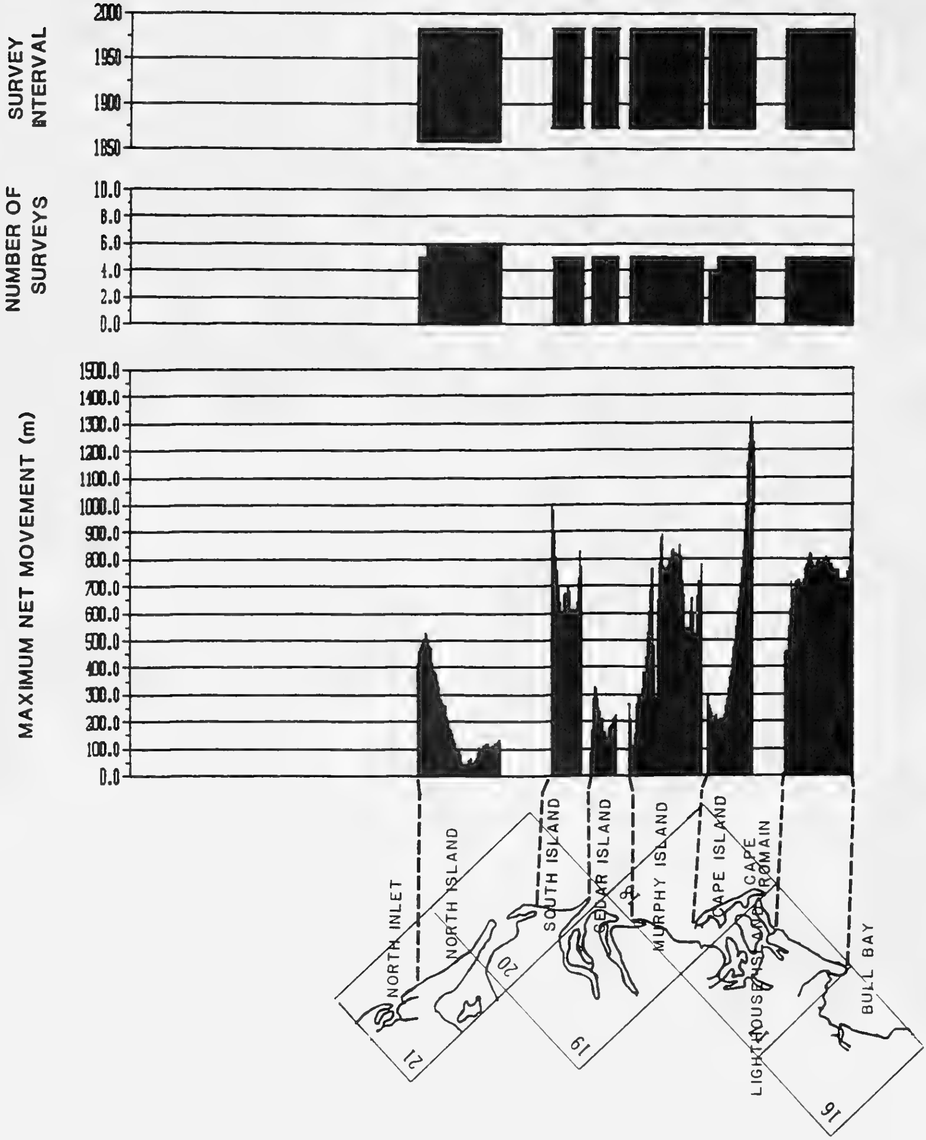


Figure 40. Maximum net shoreline movement, number of surveys used, and time interval of the surveys, for coastal reach 5

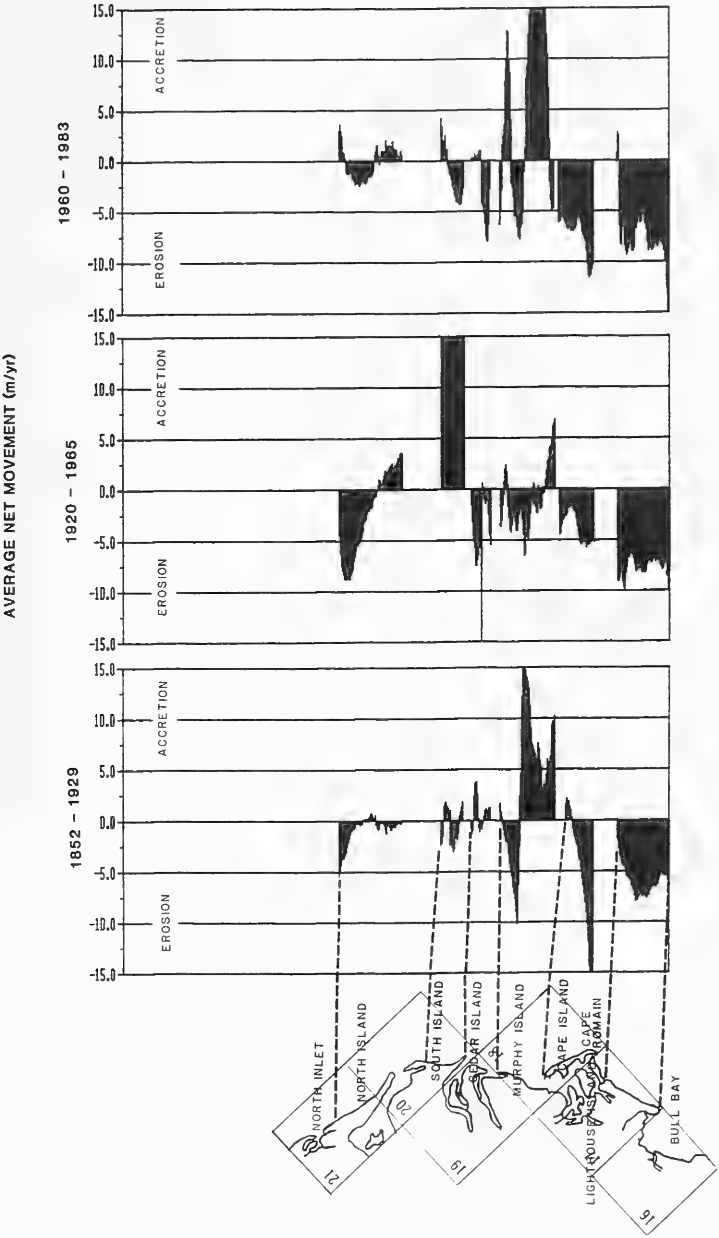


Figure 41. Temporal division of average net shoreline movement data for coastal reach 5

shown the same general pattern of strong shoreline erosion along its northern half and slight erosion to accretion along its southern half. The magnitudes of erosion and accretion were at their maximums in the 1920 to 1965 period.

98. Average net shoreline change rates for each barrier island or beach, for every possible survey interval, are presented in Table 8. It is interesting to note that accretion occurred on both sides of the Winyah Bay jetties during the 1920 to 1965 period. Jetty construction was completed about 1900. Typically, accretion occurs only on the updrift side, and erosion occurs downdrift. Morris Island, downdrift of Charleston Harbor jetties, is an ideal example of shoreline erosion caused by sediment starvation by jetties. However, South Island showed an amazing rate of accretion even though it is downdrift of the Winyah Bay jetties. A second interesting fact to consider is that damming and diversion of the Santee River were completed by

Table 8

Average Shoreline Movement (metres/year), Sandy Point to North Inlet, South Carolina

	Survey Dates				
Location	1874-1934	1875-1921	1921-1934	1934-1962	1962-1983
Bull Harbor [15/7 - 15/15]		-0.1 (100)	-0.8 (100)	-0.5 (100)	-0.5 (100)
Anderson Creek - Venning Creek [15/16 - 15/19]		-2.2 (83)	-2.3 (95)	-1.9 (98)	-0.4 (100)
Venning Creek - Graham Creek [15/20 - 16/2]		-0.5 (99)	-0.5 (99)	-0.4 (99)	0.1 (95)
Graham Creek - Harbor River [16/16 - 16/20]		0.4 (98)	-0.6 (98)	0.1 (99)	-1.4 (98)
Harbor river - Bull River [16/16 - 16/20]	-0.2 (5)	0.2 (95)	-0.8 (95)	0.1 (100)	-0.9 (73)
Bull River - Five Fathom Creek [16/21 - 16/26]		1.3 (97)	1.3 (100)	-0.2 (98)	-0/1 (98)

Note: Numbers in parentheses indicate percent shoreline surveyed during the given time interval. Numbers in brackets indicate the maps and segments contained in the data block; e.g., Bull River-Five Fathom Creek [16/21 - 16/26] extends from map 16 segment 21 to map 16 to segment 26.

1942. This should have led to erosion of the adjacent coastline since discharge and sediment supply were reduced at the river mouth by 90 percent. Instead, downdrift of the river mouth, South Island shows accretion. One possible explanation for these two anomalies is that with damming and diversion, reduced discharge at the mouth of the Santee may have allowed ebb-tidal sediments to migrate onshore to nourish downdrift beaches. The Santee was the fourth largest river on the east coast prior to 1942. Its large discharge probably moved large amounts of sediment onto the inner continental shelf. With a severe reduction in the freshwater input to the ebb flow, nearshore portions of the ebb delta may have migrated onshore under the influence of flood currents and/or waves.

99. Despite accretion immediately adjacent to Winyah Bay jetties, the majority of reach 5 can be classified as eroding over the long term (Figure 42). Approximately 54.5 percent of reach 5 showed erosion in excess of 1 m/year, undoubtedly related to reduction in sediment supply from the Santee River. This is surpassed only by erosion in reach 1. Accreting (24.1 percent) and stable (21.4 percent) transects are approximately equal along this shoreline.

Coastal reach 6

100. The arcuate strand geomorphic zone (Brown 1977), defined here as reach 6, has been primarily a stable shoreline (Figure 43). Unlike reaches 1, 2, 3, and 5, most of this shoreline has shown less than ±1 m/year of shoreline change over the period of record. Only downdrift of Murrells Inlet does an area exceed 2.5 m/year.

101. Standard deviations of average net rate of change are small throughout most of this reach, suggesting that shoreline change rates have not varied considerably (Figure 43). Maximum variability (±14 m/year) occurs immediately downdrift of Murrells Inlet. Most of the coastline has less than ±2.5 m/year of variability over 130 years of data. This variability tends to increase in the vicinity of those few inlets that punctuate this shoreline. Only at inlets does the standard deviation exceed ±5 m/year.

102. Maximum net movement is greatest in the vicinity of Murrells Inlet (over 500 m) and other inlets (Figure 44). Most of reach 6 has experienced less than 100 m of net change over the span of data. The magnitude of maximum net changes is small compared with changes occurring in the barrier island geomorphic zone, reaches 1, 2, and 3.

REACH 5

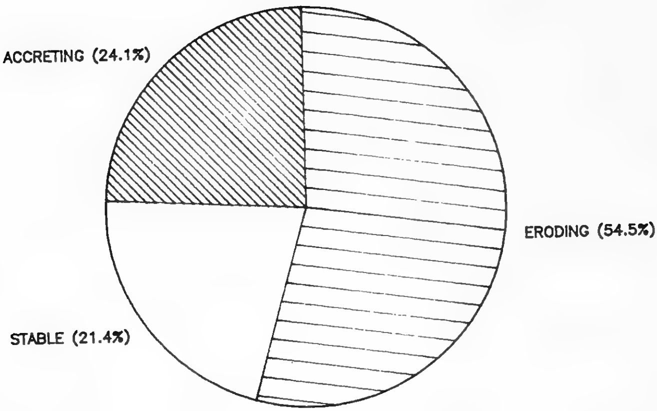


Figure 42. Summary of shoreline movements for coastal reach 5, 1857-1983

103. Temporal examination of average shoreline movement rates shows alternating erosion and accretion along the shoreline through time (Figure 45). Prior to 1929, most of the shoreline was mildly erosional, except near inlets where strong erosion and accretion were evident. From 1920 to 1965, most of the shoreline was accretional. Areas that were accretional during the previous period are now erosional. The most recent period, 1960 to 1983, alternates again, with erosion now predominant. Areas of erosion between 1920 and 1965 are now areas of accretion. These data suggest large changes in shoreline position occur, but net change over a long time interval is quite small, as indicated in Figure 43. This is further substantiated by the interval shoreline change data presented for each beach in Table 9.

104. The long-term stable nature of this coastline is demonstrated in Figure 46. Of the transects digitized in reach 6, 92.3 percent were stable over the 1872-1983 span. The remainder of shoreline was equally divided between accretion (4.4 percent) and erosion (3.3 percent). Temporal data suggest alternating erosion and accretion along the arcuate strand, but clearly, net changes for most of this reach are relatively minor.

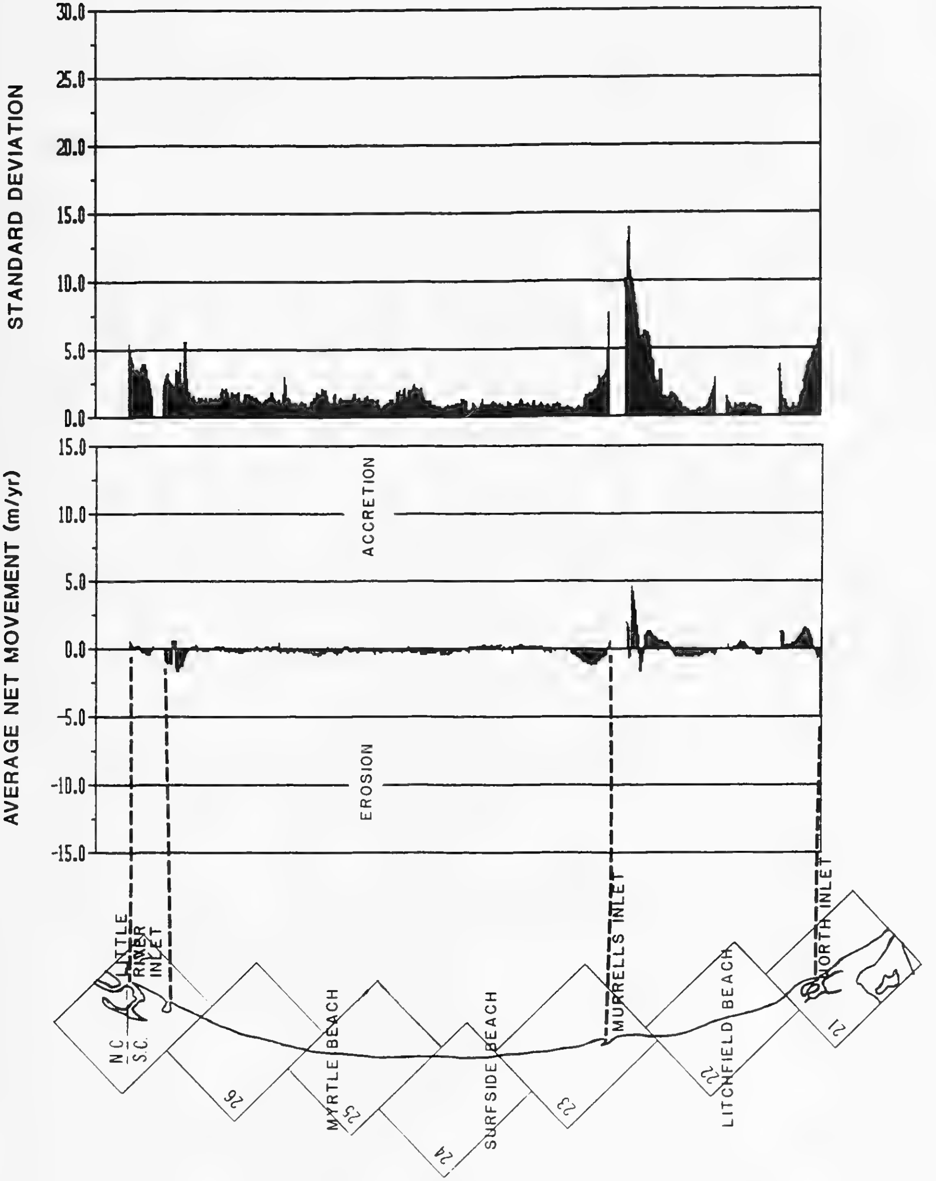


Figure 43. Average net shoreline movement and standard deviation of movement for coastal reach 6, 1872-1983

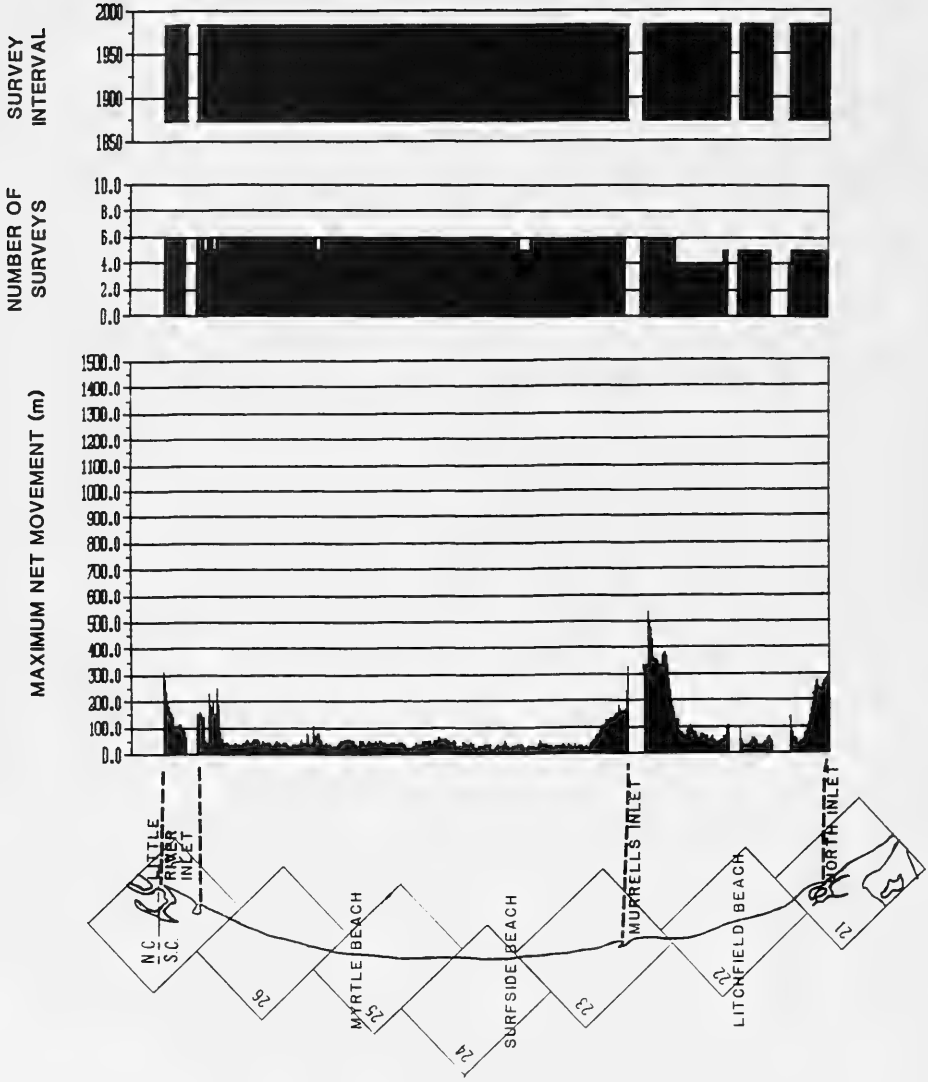


Figure 44. Maximum net shoreline movement, number of surveys used, and time interval of the surveys, for coastal reach 6

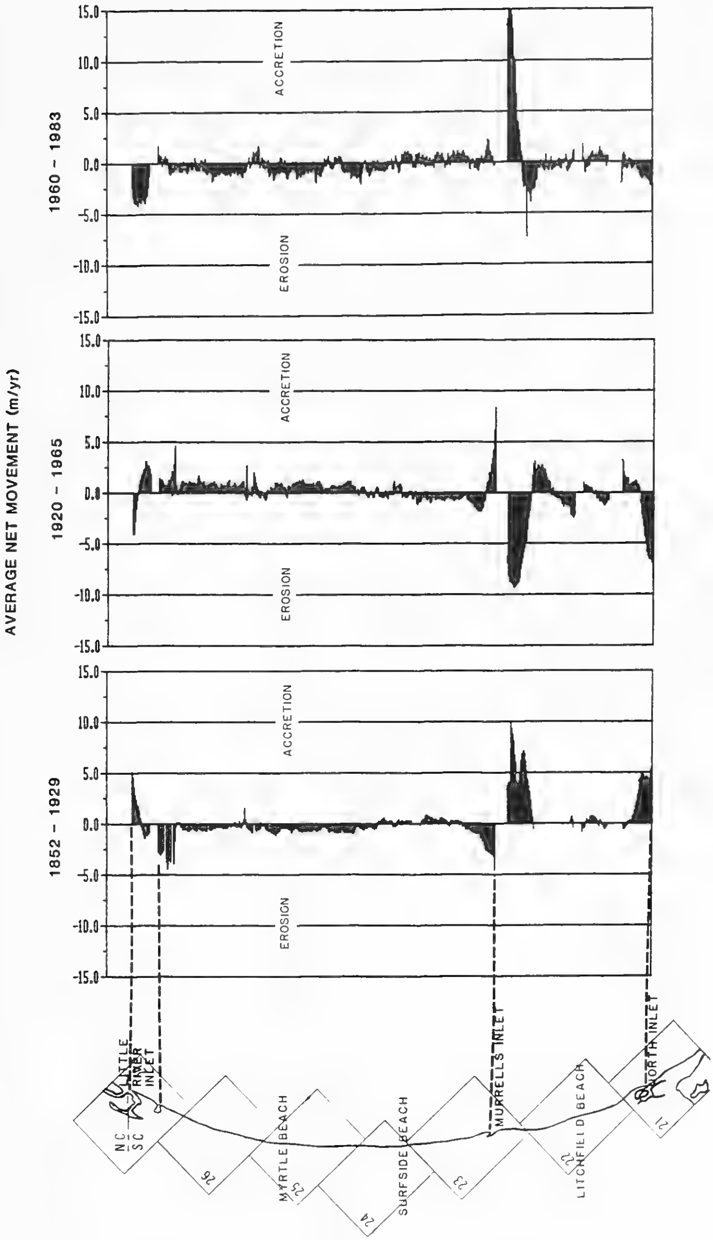


Figure 45. Temporal division of average net shoreline movement data for coastal reach 6

Table 9

Average Shoreline Movement (metres/year), North Inlet to South Carolina/North Carolina State Line

Location	Survey Dates 1872-1926	1872-1934	1874-1926	1874-1934	1874-1962	1926-1934	1934-1962	1934-1964	1962-1970	1962-1983	1964-1970	1970-1983
Debidue Beach [21/ 3 - 22/ 2]	1.3 (94)					-1.3 (99)	-0.6 (99)			-0.3 (100)		
Magnolia Beach [22/ 3 - 23/ 5]	4.2 (43)	-0.5 (55)				-1.8 (44)	0.0 (60)	-6.1 (39)		-0.3 (60)	-2.1 (40)	6.6 (39)
Garden City Beach [23/ 6 - 23/ 9]	-0.9 (99)	-2.9 (1)				-0.4 (99)		0.1 (99)			1.4 (99)	-0.2 (99)
Surfside Beach [23/ 10 - 24/ 4]	0.4 (37)		0.1 (50)	0.2 (12)		0.1 (86)	-0.3 (63)	-0.2 (37)	0.7 (63)		-0.1 (37)	0.0 (100)
Myrtle Beach [24/ 5 - 25/ 1]			-0.4 (100)			2.9 (100)	-0.4 (100)		0.4 (100)			-1.1 (97)
Ocean Forest [25/ 2 - 25/ 6]			-0.5 (96)	-0.9 (4)		2.9 (94)	-0.1 (98)		0.1 (100)			-0.7 (100)
Crescent Beach [26/ 1 - 26/ 4]			-0.3 (98)	-1.2 (1)		3.3 (98)	-0.2 (99)		-1.5 (99)			0.1 (100)
Cherry Grove Beach [26/ 5 - 26/ 6]			-0.3 (98)	0.0 (2)		3.4 (98)	-0.1 (100)		-2.0 (100)			0.5 (100)
Futch Beach [26/ 7 - 27/ 1]			-2.8 (66)	-2.0 (9)	-0.6 (5)	3.6 (86)	0.3 (95)		-1.0 (100)			0.6 (100)
Waiter Island [27/ 2 - 27/ 3]			0.7 (100)			8.3 (100)	-1.2 (100)		-4.2 (100)			-2.8 (100)

Note: Numbers in parentheses indicate percent shoreline surveyed during the given time interval. Numbers in brackets indicate the maps and segments contained in the data block; e.g., Waiter Island [27/ 2 - 27 3] extends from map 27 segment 2 to map 27 segment 3.

REACH 6

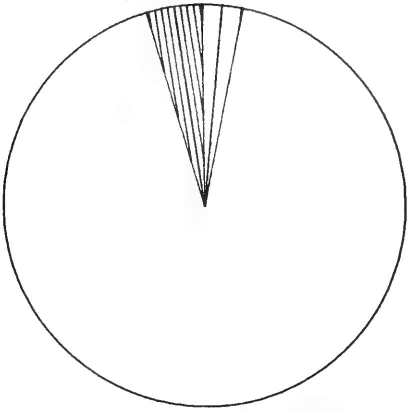


Figure 46. Summary of shoreline movements for reach 6, 1872-1983

Coastal reach 7

105. Northernmost, reach 7 lies within the State of North Carolina. Geomorphologically, it appears to be an extension of Brown's (1977) arcuate strand zone. However, it differs in that it has more frequent inlets and some true barrier islands, and it includes Cape Fear. The data set extends around Cape Fear to New Inlet on the north side of the Cape.

106. A visible change occurs in average movement of the shoreline in the vicinity of Cape Fear (Figure 47). West of Cape Fear River, shoreline movement is similar to reach 6, the arcuate strand. Erosion or accretion never exceeds 2.5 m/year except near Cape Fear River Inlet. Spatial distribution of standard deviation west of Cape Fear River is not as consistent as the arcuate strand or barrier island reaches; peaks occur along central portions of islands/beaches as well as in the vicinity of inlets. Two peaks of accretion in average movement and higher standard deviation between Shallotte Sound and Lockwoods Folly Inlet coincide with positions of two ephemeral inlets that opened sometime before 1924 and closed between 1933 and 1962. In

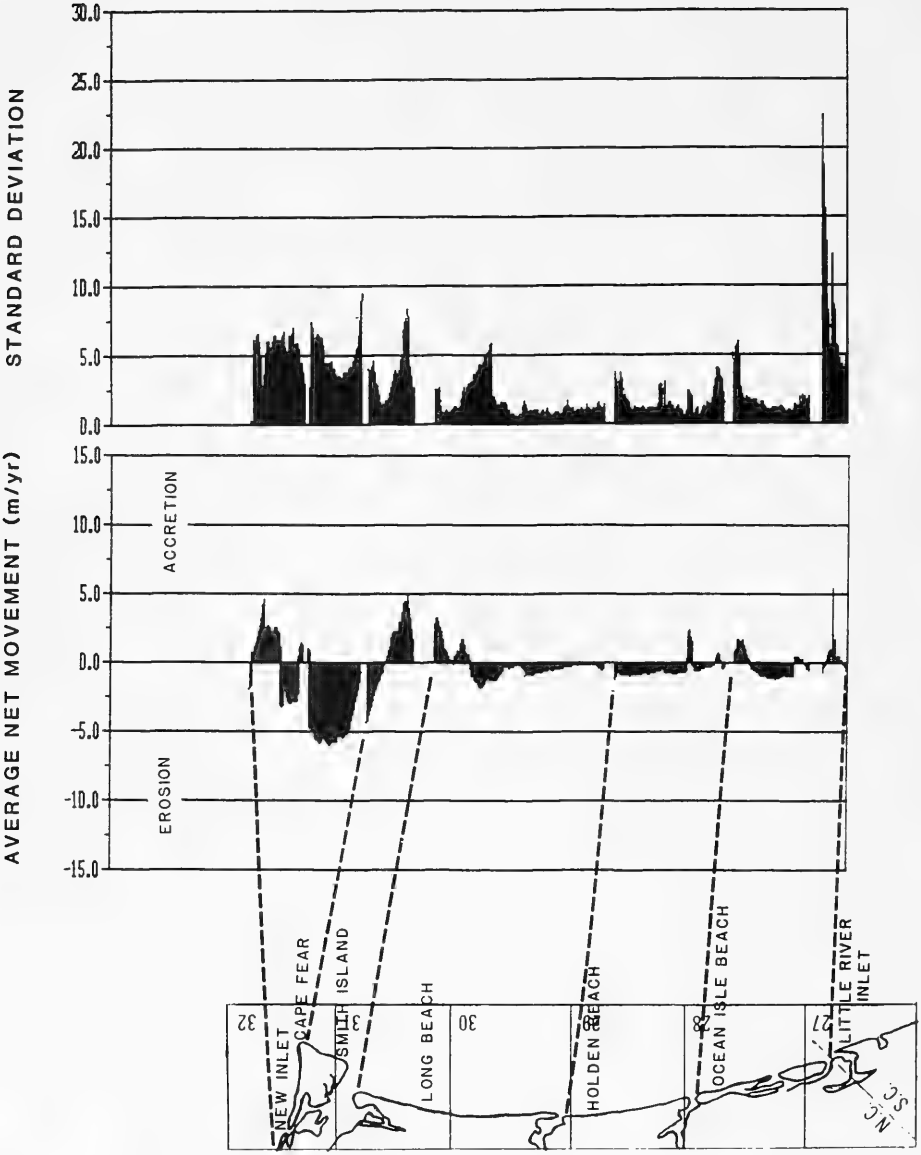


Figure 47. Average net shoreline movement and standard deviation of movement for coastal reach 7, 1857-1983

general, west of Cape Fear River, standard deviations are less than 2.5 m/year and exceed 5-m/year only in the vicinity of inlets. At Tubbs Inlet, standard deviation reaches a maximum of 22 m/year.

107. East of Cape Fear River and north of Cape Fear (Map 32), patterns of average movement and standard deviation change. Average movement increases in magnitude, ranging from 5-m/year accretion to 6-m/year erosion. Bald Head Island is strongly accretional on its western end, but becomes erosional as Cape Fear is approached. North of Cape Fear, erosion predominates to New Inlet. The updrift side of New Inlet is accretional. Standard deviation around and north of Cape Fear is similar to the barrier island zone, reaches 1, 2, and 3. Maximum deviations (greater than ±5 m/year) occur near inlets, and central portions of islands tend to be more stable. This trend is not clear at New Inlet, which has migrated since 1852. For the entire reach, erosion clearly predominates over accretion during the 1852 to 1982 span.

108. Maximum net movement is highest north of Cape Fear, exceeding 600 m in the 1852 to 1982 span (Figure 48). West of Cape Fear River, maximum movements do not exceed 200 m except in the vicinity of inlets. Magnitude of maximum movement is greater than the arcuate strand zone, but less than the barrier island zone. Peaks of maximum movement correlate with inlets.

109. West of Cape Fear River, division of the average net movement data into three periods reveals a behavior similar to reach 6 (Figure 49). Erosion and accretion appear to alternate from one period to the next. East of Cape Fear River, erosion seems to predominate during all three time intervals. The magnitude of erosion appears greatest prior to 1965. Accretion is generally limited to the immediate vicinity of inlets. Average net shoreline change for each survey interval for every beach and island in reach 7 is presented in Table 10.

110. Summarizing shoreline movement over reach 7 demonstrates just how similar it is to reach 6 (Figure 50). If the transects around and north of Cape Fear (Map 32) are separated out of the summary, the remainder of the shoreline is even more similar to reach 6 (Figure 51). Most of the shoreline west of Cape Fear is stable (78.5 percent) with only small percentages showing long-term accretion (11.9) or erosion (9.6 percent). The shoreline east of

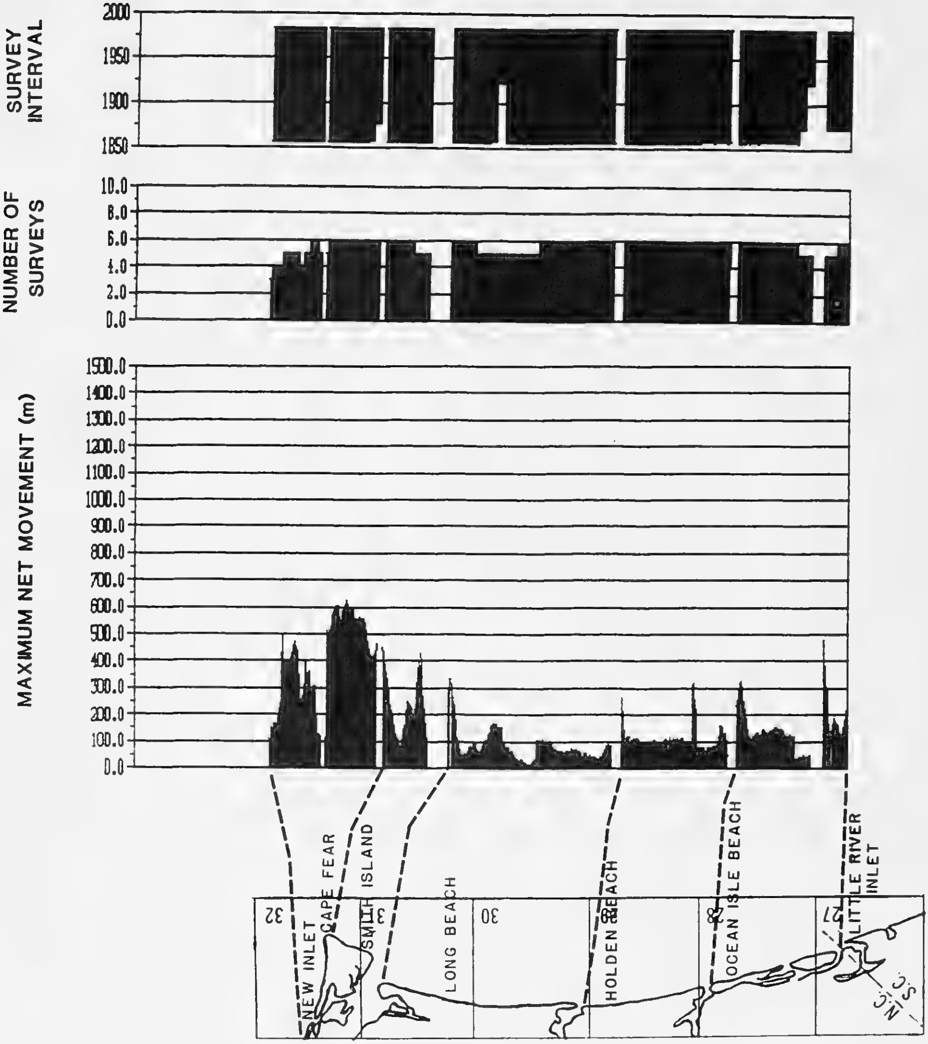


Figure 48. Maximum net shoreline movement, number of surveys used, and time interval of the surveys, for coastal reach 7

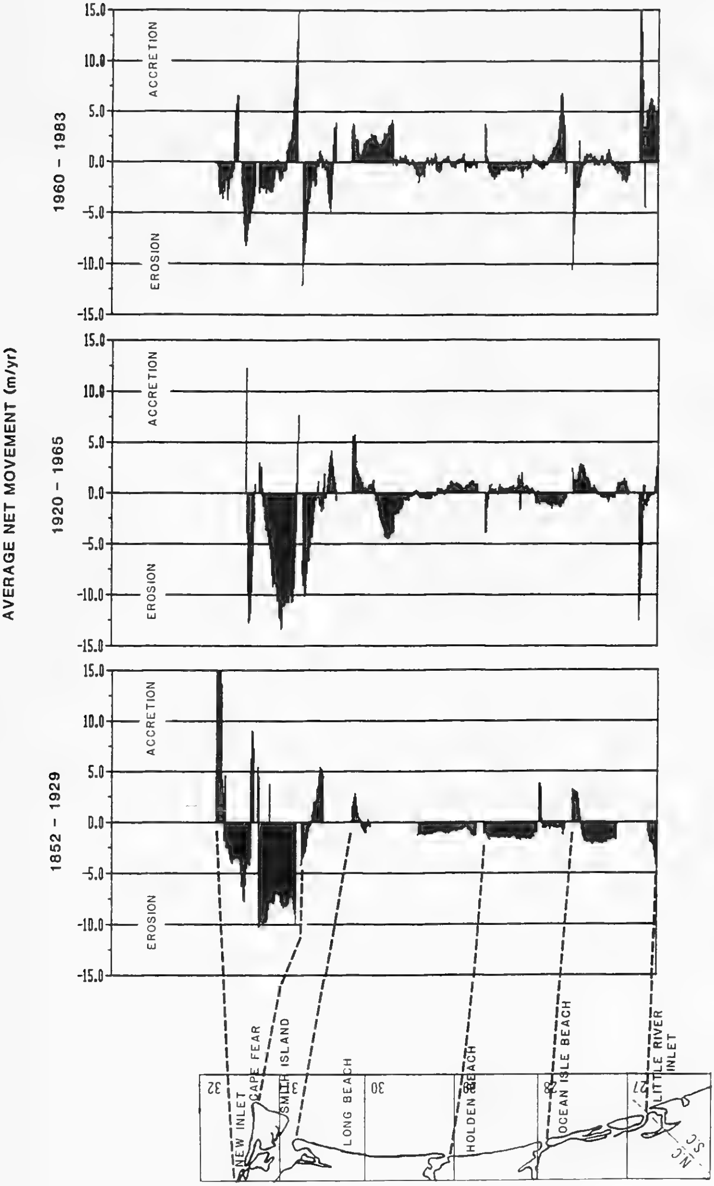


Figure 49. Temporal division of average net shoreline movement data for coastal reach 7

Table 10

Average Shoreline Movement (metres/year), South Carolina/North Carolina

State Line to Cape Fear, North Carolina

Location	1857-1924	1857-1934	1874-1926	1878-1914	1878-1924	1878-1934	1914-1924	1914-1934	1924-1934	1924-1970	1926-1934	1934-1962	1934-1964	1934-1970	1962-1970	1964-1972	1970-1983	1972-1983
	Survey Dates																	
Bald Beach [27/4 - 28/1]			-2.4 (47)						2.2 (33)		-1.2 (64)	-2.1 (97)		2.9 (2)	20.0 (98)		-1.9 (98)	
Hales Beach [28/2 - 28/7]	-0.9 (79)								2.0 (100)			0.2 (100)			0.7 (100)		-1.5 (99)	
Big Beach [29/1 - 29/5]	-0.6 (93)	2.0 (7)							0.1 (92)			-0.6 (99)			-1.4 (99)		2.1 (99)	
Holden Beach [29/6 - 30/2]	-1.3 (100)								3.3 (100)			-0.4 (83)	-3.0 (17)		-1.5 (83)	-2.6 (16)	-0.2 (83)	2.8 (16)
Long Beach [30/3 - 31/6]	-0.8 (46)				0.4 (17)				1.1 (100)			-0.9 (54)	0.1 (46)		2.9 (54)	0.3 (46)	0.5 (54)	-0.5 (46)
Bald Head [31/7 - 32/1]				2.7 (34)			9.2 (34)	6.8 (66)	-0.3 (34)			0.5 (66)		-0.7 (32)	-0.9 (66)		-0.5 (99)	
East Beach [32/2 - 32/3]				-6.5 (99)			-3.6 (100)		-6.5 (100)					-1.8 (99)			-0.8 (99)	
Bay Beach [32/4 - 32/7]				-6.1 (60)	-7.1 (2)	-5.1 (4)	5.2 (86)		-2.7 (33)	4.3 (55)				1.3 (38)			-2.3 (92)	

Note: Numbers in parentheses indicate percent shoreline surveyed during the given time interval. Numbers in brackets indicate the maps and segments contained in the data block; e.g., Bay Beach [32/4 - 32/7] extends from map 32 segment 4 to map 32 segment 7.

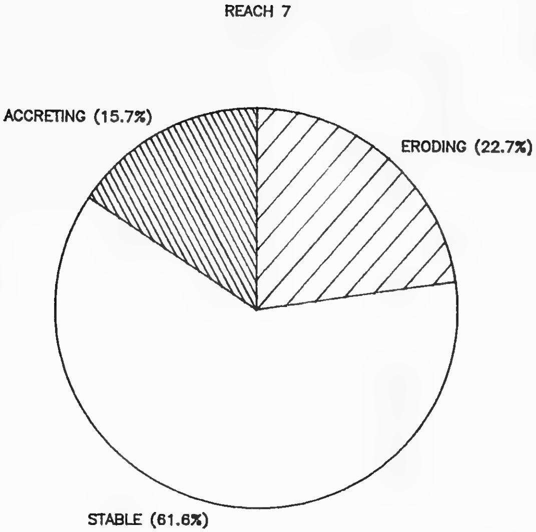


Figure 50. Summary of shoreline movement for coastal reach 7, 1857-1983

the Cape Fear River and north of Cape Fear to New Inlet is strongly erosional (61.0 percent). This small segment of coastline equals reaches 1 and 5 in spatial distribution of erosion. Very little of the coast around Cape Fear can be considered stable (12.3 percent) or accretional (26.7 percent) over the long term.

111. In general, the segment of North Carolina coast west of Cape Fear is very similar to the arcuate strand geomorphic zone in terms of its shoreline change. More numerous inlets in comparison to the arcuate strand introduce greater variability in spatial distribution of peaks in average movement, maximum net movement, and standard deviation. Likewise, greater temporal variation is evident by larger magnitude changes, especially at inlets. The segment east and north of the Cape Fear River (Map 32) is highly erosive spatially, similar to reaches 1 and 5.

Entire study area

112. The barrier island geomorphic zone is composed of reaches 1, 2, and 3. Within this zone, spatial distribution of erosion appears to increase southward (reach 3 = 30.1-percent erosion, reach 1 = 54.9-percent erosion)

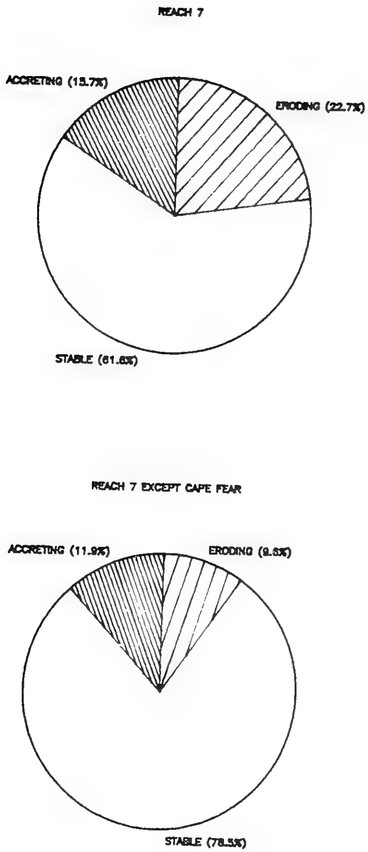


Figure 51. Summary of shoreline movements for coastal reach 7 west of the Cape Fear River and from the Cape Fear River to New Inlet

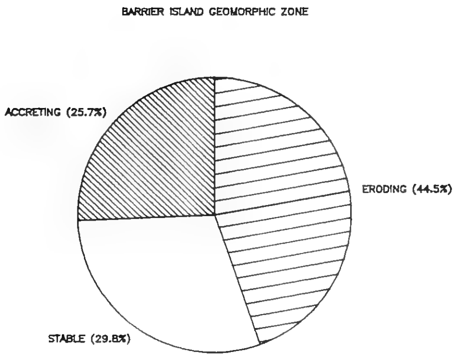
while accretion increases to the north (reach 1 = 14.6-percent accretion, reach 3 = 44.4-percent accretion). Overall, the barrier island geomorphic zone is spatially dominated by erosion (44.5 percent) over the long-term (Figure 52). Approximately 25.7 percent of the barrier island coastline is accreting, and 29.8 percent can be considered stable. Magnitude of average and maximum shoreline changes and variability in shoreline changes are large in this geomorphic zone.

113. The cuspate delta geomorphic zone is composed entirely of reach 5. Within this zone, erosion predominated (54.5 percent) at most locations (Figure 42). Approximately one quarter of the shoreline in reach 5 was stable (21.4 percent) and one quarter was accreting (24.1 percent). This zone is very similar in overall behavior to the barrier island zone.

114. Reaches 6 and 7 west of Cape Fear River compose the arcuate strand geomorphic zone, which is very different from the barrier island or cuspate delta zones (Figure 52). Long-term analysis of shoreline changes reveals most of the arcuate strand is stable (86.9 percent of shoreline has less than ±1 m/yr change). Accretion (7.3 percent) slightly outweighs erosion (5.8 percent) in the remainder of shoreline. Clearly, the factors controlling long-term shoreline changes are different between the arcuate strand and geomorphic zones to the south. The arcuate strand is most similar in shoreline response to reach 4; Bull Bay, which had 82.2 percent of its shoreline in the stable classification (Figure 38).

115. Summarizing transect data over the entire study area for the entire range of surveys available, approximately half the coastline is stable, 31.3 percent is eroding in excess of 1 m/yr, while 18 percent is accreting seaward (Figure 53). Variability in erosion and accretion is greatest at inlets. Most shoreline has changed less than 400 m over the 130-year span of data. Changes in excess of 1,000 m are relatively unusual.

116. In summary, this analysis indicates two primary types of historical shoreline changes: those associated with barrier islands and tidal inlets and those associated with continuous mainland beach. The former is dynamic and closely dependent on local changes at inlets. The latter, being freed from inlet disturbances, is mildly dynamic, but with little long-term net change.



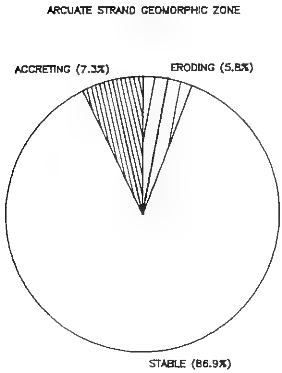


Figure 52. Summary of shoreline movement in the barrier island and arcuate strand geomorphic zones

Inlet Changes

117. From previous discussions in Parts II and IV, it should be apparent that inlets are extremely important in affecting changes along adjacent shorelines. However, many changes produced by inlets are not in an onshore/offshore direction. Alongshore changes have been quite radical at many inlets; yet at others, alongshore changes are small. To examine alongshore

ALL REACHES COMBINED

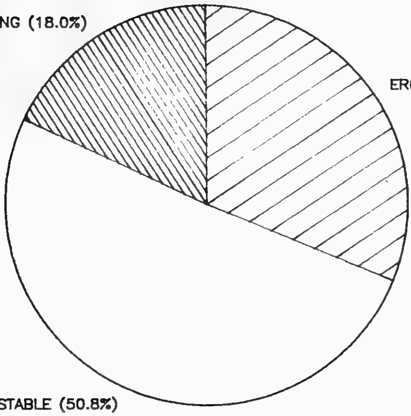


Figure 53. Summary of shoreline movement for the entire study area, 1851-1983

changes, the authors made simple measurements of updrift and downdrift spit lengths at each time interval on each map. It was assumed that littoral drift along this coast is from north to south. Inlet throat width was also measured. This information is presented in summary form in Table 11. In some instances, subaerial area measurements were made to observe changes in island or spit growth/erosion through time. Aerial change data are presented along with a brief descriptive narrative of each inlet. No attempt was made to estimate volume changes. Inlets that showed little alongshore change have been omitted, their across-shore changes having been reported in the previous discussion. The reader is reminded that the following discussion is based on inlet position as mapped at distinct points in time and should not be used to assume other than equally distributed changes during intervening periods. Examination of shoreline changes around inlets on the accompanying shoreline change maps is essential to understanding the descriptive narratives. Discussion proceeds from south (Map 1) to north (Map 32).

118. Savannah River, New River, Calibogue Sound, and Port Royal Sound are inlets located on maps 1 through 4 that have primarily onshore/offshore changes and are adequately characterized by the shoreline change technique.

Table 11

Summary of Inlet Changes

Inlet Name	No.	Seg. No.	Inlet Width, m: Net Change dates	Max. Width date	Min. Width date	Northern (East) Side of Inlet: Net Change m Net Rate of Change m/yr, dates	Max. Rate of Accretion m/year dates	Max. Rate Erosion m/year dates	Southern (West) Side of Inlet: Net Change m Net Rate of Change m/yr, dates	Max. Rate Accretion m/year dates	Max. Rate Erosion m/year dates
Trenchards	5	6,7,8	-60 (1859-1982)	850 (1859)	790 (1865)	-240 -2 (1859-1865)	40 (1859-1865)	-30 (1920-1955)	-365 -3 (1859-1982)	15 (1859-1865)	-10 (1955-1964)
Pritchards	5	9,10,11	550 (1859-1982)	1,000 (1955)	430 (1859)	-305 -2 (1859-1982)	22 (1964-1971)	7 (1955-1964)	-245 -2 (1859-1982)	9 (1964-1971)	-11 (1971-1982)
Skull	6	3,4	-850 (1856-1982)	1,030 (1856)	180 (1982)	790 6 (1856-1982)	14 (1856-1920)	-3 (1920-1955)	-60 -0.5 (1856-1982)	6 (1871-1982)	-3 (1956-1920)
Fripp	6	5,6,7	60 (1856-1982)	790 (1964)	610 (1856)	61 5 (1856-1982)	7 (1955-1982)	-2 (1856-1920)	-60 -0.5 (1856-1982)	4 (1856-1920)	-6 (1955-1983)
St. Helena Sound	6	8							-2,400 -19 (1856-1983)	none	-33 (1856-1920)
Frampton	9	2,3	975 (1851-1983)	1,160 (1983)	120 (1920)	-1,190 -9 (1851-1983)	10 (1933-1964)	-100 (1964-1970)	-550 -4 (1851-1983)	4 (1851-1920)	-20 (1933-1970)
N. Edisto River	9	4,5,6,7, 8,9	915 (1851-1983)	1,890 (1983)	975 (1851)						
Captain Sams	10	1	-610 (1921-1983)	915 (1921)	120 (1964)	2,190 35 (1921-1983)	97 (1921-1933)	none	-1,830 -30 (1921-1983)	4 (1933-1964)	-120 (1964-1970)
Stono	11	1,2,3,4	490 (1854-1983)	2,560 (1921)	1,520 (1854)	-1,220 -9 (1854-1983)	none	-18 (1862-1921)	800 6 (1854-1983)	26 (1862-1921)	-15 (1921-1933)
Lighthouse	13	1,2,3,4	-120 (1856-1983)	670 (1921)	244 (1933)	-60 -0.5 (1857-1983)	20 (1921-1933)	-3 (1857-1921)	-275 -2 (1857-1983)	9 (1955-1962)	-20 (1921-1933)
Charleston Harbor, Cummings Pt.	13	4,5,6				*			60 0.5 (1857-1983)	14 (1900-1921)	-14 (1857-1900)
Breach	13	13,14,15	90 (1875-1983)	305 (1875)	180 (1962)	180 2 (1875-1983)	5 (1921-1933)	none	-120 -1 (1875-1983)	2 (1933-1962)	-3 (1962-1983)
Dewees	14	5,6,7,8, 9,10	120 (1875-1983)	610 (1921)	430 (1875)	*			* 0 0 (1875-1983)	4 (1962-1983)	-9 (1934-1962)
Capers	14	5,6,7,8, 9,10	-305 (1856-1983)	670 (1875)	305 (1983)	-550 -4 (1856-1983)	-6 (1934-1962)	-13 (1856-1875)	*		
Price	14/15	11/1	-60 (1875-1983)	305 (1875)	245 (1934)	*			*		
Bull Bay	15/16	1/27				-245 -2 (1875-1983)	15 (1921-1934)	-24 (1934-1962)	945 9 (1875-1983)	17 (1875-1921)	-1 (1962-1983)

(Continued)

* Changes occurring at inlet are not adequately represented by alongshore measurements. See descriptive narrative and appropriate map and section number in Appendix A for further information. Those inlets not listed here were adequately examined by shoreline analysis procedures.

Table 11 (Concluded)

Inlet Name	No.	Seg. No.	Inlet Width, m: Net Change dates	Max. Width date	Min. width date	Northern (East) Side of Inlet: Net Change m Net Rate of Change m/yr, dates	Max. Rate of Accretion m/year dates	Max. Rate Erosion m/year dates	Southern (West) Side of Inlet: Net Change m Net Rate of Change m/yr, dates	Max. Rate Accretion m/year dates	Max. Rate Erosion m/year dates
Key	17/18	2/1	490 (1874-1983)	550 (1983)	60 (1874)	*			-60 -0.5 (1874-1983)	5 (1934-1962)	7 (1925-1934)
Cape Romain	17/18	2/1				180 -2 (1873-1983)	9 (1873-1925)	-20 (1925-1934)			
Romain River	17/18	2/1	-1,650 (1874-1983)	1,830 (1874)	180 (1983)	*			215 4 (1925-1983)	96 (1934-1962)	-120 (1962-1983)
Cape Romain Harbor	18	2,3,4,5	-1,770 (1873-1983)	2,745 (1873)	975 (1983)				3,600 33 (1873-1983)	34 (1873-1925)	none
South Santee R.	18	8,9,10	-60 (1873-1983)	610 (1962)	305 (1934)	-915 -8 (1873-1983)	20 (1962-1983)	-83 (1934-1962)	*		
North Santee Bay	20	1,2,3	-365 (1872-1983)	790 (1872)	370 (1934)	855 8 (1872-1983)	54 (1925-1934)	-20 (1934-1962)	*		
Winyah Bay	20	3,4	Jetty			1,280 10 (1857-1983)	34 (1925-1934)	-3 (1962-1983)	*		
North	21	2,2	-305 (1872-1983)	1,280 (1934)	550 (1962)	1,700 15 (1872-1983)	67 (1934-1962)	-34 (1925-1934)	-1,340 -12 (1872-1983)	13 (1925-1934)	28 (1852-1925)
Unnamed inlet	22	1,2	-120 (1872-1983)	180 (1872)	60 (1983)	1,525 14 (1872-1983)	46 (1926-1934)	-23 (1962-1983)	*		
Midway	22	2,3	-215 (1872-1983)	275 (1872)	60 (1983)	670 6 (1872-1983)	30 (1926-1934)	-3 (1872-1926)	-455 -4 (1872-1983)	6 (1872-1926)	-76 (1926-1934)
Murrells	23	4,5,6	275 (1872-1983)	855 (1926)	305 (1872)	-1,005 -9 (1872-1983)	30 (1963-1969)	-36 (1872-1926)	1,615 15 (1872-1983)	42 (1872-1926)	-29 (1934-1963)
Futch Beach	26/27	7/1	-60 (1873-1962)	305 (1924)	0 (1962)	1,100 18 (1873-1933)	27 (1924-1933)	none	-1,160 -19 (1873-1933)	none	-22 (1873-1924)
Hog	27	1,2	30 (1873-1983)	305 (1969)	60 (1924)	120 1 (1873-1983)	61 (1924-1933)	-17 (1962-1969)	-245 -2 (1873-1983)	13 (1933-1962)	-68 (1924-1933)
Little River	27	3,4	120 (1873-1983)	1,465 (1969)	305 (1924)	*			855 8 (1873-1983)	35 (1969-1983)	-61 (1962-1969)
Mad	27	3,4	-150 (1873-1983)	400 (1933)	120 (1969)	-1,435 -13 (1873-1983)	61 (1962-1969)	-37 (1873-1924)	*		
Tubbs	28	1,2	-185 (1924-1983)	550 (1924)	245 (1969)	120 2 (1924-1983)	68 (1924-1933)	-74 (1962-1969)	305 5 (1924-1983)	157 (1962-1969)	-81 (1924-1933)
Shallotte Sound	28/29	6,7/1	0 (1857-1983)	580 (1924)	395 (1969)	490 4 (1857-1983)	8 (1933-1962)	none	-550 -4 (1857-1983)	10 (1924-1933)	-9 (1969-1983)
Lockwood Folly	30	1,2,3	-215 (1856-1983)	370 (1856)	150 (1983)	855 7 (1856-1983)	13 (1969-1983)	-3 (1924-1933)	-610 -5 (1856-1983)	13 (1962-1969)	-8 (1856-1924)
Cape Fear	32	2,3				-1,160 -11 (1878-1983)	30 (1923-1933)	-39 (1878-1914)	*		
New	32	4,5,6 7	120 (1914-1983)	490 (1983)	245 (1972)	-580 -8 (1914-1983)	12 (1923-1972)	-129 (1914-1923)	610 9 (1914-1983)	27 (1923-1933)	-17 (1972-1983)

The reader is referred to previous shoreline change sections for information on shorelines adjacent to these inlets.

Trenchards Inlet (Map 5)

119. From 1859/60 to 1920/21, the updrift side of Trenchards Inlet grew southwest about 730 m, at an average rate of 13 m/year. The downdrift side eroded in response as the inlet throat decreased in width only slightly (60 m). By 1955, the updrift shoreline had receded northeast over 1,030 m, putting it landward of the 1859/60 position. Throat width remained constant, and only minor changes occurred on the downdrift side. Shoreline recession was evident along Capers Island throughout the time span. Erosion of the updrift spit continued until the 1982/83 survey, having moved northeast an additional 7 m/year since 1955. Surface area of the updrift spit on Capers Island had increased 3.3×10^6 m^2 between 1859/60 and 1920/21 (54,000 m^2/year), but lost 7.0×10^6 m^2 by 1982/83 (111,000 m^2/year).

Pritchards Inlet (Map 5)

120. Two tidal creeks intersected at the shoreline in 1859/60 forming a "V" shape with the point of the "V" seaward. The single inlet formed from these two creeks is Pritchards Inlet. Constant landward erosion until 1955 resulted in removal of the base of the "V" and intersection of two separate inlets within the shoreline. In 1859, distance between opposite sides of the inlet was about 425 m. By 1955, it had grown to 1,000 m. In 1859, distance from the land inside the "V" to the shoreline trend was about 240 m. With the pattern of erosion described, this center section was cut back approximately 180 m so that by 1983, the gap between inlets had a receded shoreline of only 60 m. The largest change came between 1859/60 and 1920/21, when the updrift side of the inlet retreated northeast about 270 m and the downdrift side retreated westward 120 m. Since 1920, updrift and downdrift spits have been small, both showing a maximum alongshore extension in 1971.

Skull Inlet (Map 6)

121. In 1859/60, Skull Inlet had a east-west orientation at its point of juncture with the shoreline. Updrift accretion and erosion downdrift have resulted in a nearly north-south orientation on the 1982/83 survey. Much erosion and accretion was accomplished between 1856/59 and 1920. The downdrift side was eroded approximately 185 m alongshore during this interval while the updrift side accreted approximately 890 m. The inlet throat narrowed considerably, from 1,030 m wide to about 245 m. Since 1920, throat width decreased

slightly to 180 m in 1982/83. Updrift and downdrift sides of the inlet have been relatively stable since 1920 with only minor erosion updrift between 1920 and 1955 and accretion (60 m) of a small spit on the downdrift side between 1971 and 1982/83.

Fripp Inlet (Map 6)

122. Fripp Inlet has become progressively offset seaward downdrift through shoreward erosion on the updrift side and accretion downdrift. Downdrift accretion reached its maximum in 1955, having accreted approximately 1.8×10^6 m^2 since 1856/59 (18,000 m^2/year). This accretion reversed between 1955 and 1962. Little change occurred since 1962 on the downdrift side. Net change between 1955 and 1983 is erosion of 1.4×10^6 m^2 (50,000 m^2/year). Most change in area is due to onshore/offshore changes; however, there was a net 60-m alongshore erosion on the southwest side of the inlet. Alongshore changes updrift had a comparable 60-m accretion. However, between 1856/59 and 1955, shoreline erosion resulted in a 2.3×10^6 m^2 loss, followed by slight accretion (0.2×10^6 m^2) by 1982/83. Most of this was due to onshore/offshore sedimentation. Inlet throat width varied only slightly during this period, from 610 m wide in 1856/59 to 790 m in 1964 to 670 m wide in 1982/83.

St. Helena Sound (Map 6)

123. In 1856/59, a large spit extended northeast from Hunting Island into St. Helena Sound. Landward shoreline erosion and alongshore erosion on the order of 2,000 m by 1920 resulted in a 6.0×10^6 m^2 (99,000 m^2/year) loss to the spit. Spit erosion continued to 1964 (1.1×10^6 m^2 lost, 26,000 m^2/year), but alongshore accretion to the northeast dominated between 1964 and 1983 (12,000 m^2, 640 m^2/year). With spit losses, the north end of Harbor Island, which lies north of Hunting Island, began accreting. From 1856/59 to 1955, it grew about 850 m north into St. Helena Sound. This 0.6×10^6 m^2 increase in area (10,000 m^2/year) was followed by an increase between 1920 and 1964 (50,000 m^2) and a small amount of erosion (200,000 m^2) between 1964 and 1982/83. Net change to the spit was 7.2×10^6 m^2 erosion, with a coincident 2.9×10^6 m^2 growth of Harbor Island. The absence of data between the dates presented here makes it impossible to investigate causal relationships of spit loss and growth of Harbor Island, but it is reasonable to speculate that sediment composing the 1859 spit may have migrated landward to build out Harbor Island.

124. Changes on the northeast side of St. Helena Sound, Fish Creek Inlet, and South Edisto River Inlet have been adequately represented by the shoreline change mapping. Likewise, shoreline changes surrounding a small, unnamed inlet just south of Frampton Inlet on map 9 are also represented by the shoreline change mapping technique; however, it had some small alongshore changes as well. From 1851/54 to 1920/21, it moved slightly northeast; and from 1920/21 to 1933, it moved southwest. Since 1933, it has remained stationary in its alongshore position.

Frampton Inlet (Map 9)

125. At Frampton Inlet, from 1851/54 to 1933, there were two tidal creeks that merged to form one inlet, similar to previously discussed Pritchards Inlet. Inlet throat width was approximately 180 m in 1851/54 and 120 m in 1933. During this interval, the throat migrated northeast. Between 1933 and 1964, throat width increased to 420 m, by alongshore retreat (610 m) on the southwest side of the inlet relative to 300 m of elongation on the northeast side. By 1970/74, additional alongshore losses on the southwest side (120 m) had combined with movement of the northeast side of the inlet 610 m to the northeast and separation into two inlets. On the 1983 survey, two distinct inlets, each about 300 m wide, are separated by approximately 900 m of shoreline. The southwest spit moved southwest an additional 120 m, and the northeast spit retreated 240 m as the inlets migrated apart.

North Edisto River Inlet (Map 9)

126. Over the time range of data used in this study, there has been little alongshore migration of North Edisto River Inlet. Most change has been in the onshore/offshore direction. The southwest side of the inlet has retreated landward steadily since 1851/54. The northeast side advanced seaward from 1851/54 to 1933, was stable to 1964, and advanced slightly from 1964 to 1970/74. From 1970/74 to 1983, it eroded back to about the 1964 position. Onshore/offshore changes resulted in widening of the inlet throat southwestward from approximately 975 m in 1851/54 to 1,830 m in 1964, to approximately 1,890 m in 1983. The magnitude of the onshore/offshore changes are given in Appendix A, Map 9, sections 4 through 9.

127. Deveaux Bank, which sits at the inlet mouth has undergone dramatic changes since it was first mapped in 1920/21. At that time, it was approximately 150 m long, extending in a north-northwest, south-southeast direction, and had approximately 24,000 m^2 of subaerial surface area. By 1933, it

migrated approximately 670 m northwest and was composed of two small islands totaling about 61,000 m^2 in surface area. No evidence of the island appears on the 1964 survey, but in 1970/74, it was at its maximum mapped extent. It trended northwest-southeast, starting at the same point as the island in the 1920's. Its long axis was about 2,070 m, and it was about 2.2×10^6 m^2 in area. By 1983, it was back to two small, thin, islands, the longest being approximately 600 m with a north-south orientation. Combined surface area was about 43,000 m^2. The net change from 1920/21 to 1983 has been an increase in surface area of 18,000 m^2. The banks are probably an exposed portion of the North Edisto River Inlet ebb-tidal delta. Changes outlined here illustrate the dynamic nature of ebb deltas in response to changing environmental conditions.

<u>Captain Sams Inlet (Map 10)</u>

128. The 1854 survey does not indicate any inlet in the shoreline, but by 1921, Captain Sams Inlet was approximately 1,340 m wide, with two small islands between. Since 1921, the northeast side of the inlet has been advancing in alongshore direction southwestward. The northeast side (spit) grew 1,150 m between 1921 and 1933 (97 m/year). Between 1933 and 1964, it grew at only 6 m/year, but this rate increased to approximately 44 m/year between 1964 and 1983. Net elongation from 1921 to 1983 was approximately 2,200 m. During this same time, southwest erosion occurred alongshore as the inlet migrated southwest. From 1921 to 1933, erosion on the southwest side was approximately 305 m, which was a slower pace than updrift side accretion. As a result, the inlet narrowed. Downdrift erosion and inlet narrowing continued to 1983, when the net result was approximately 1,800 m of southwest erosion and 400 m of narrowing. The inlet was at its narrowest in 1964 and 1970, when it was only about 120 m wide.

<u>Stono Inlet (Map 11)</u>

129. Stono Inlet is large with several islands in it, including Bird Key. Kiawah Island, southwest of the Inlet, accreted seaward rapidly between 1862/64 and 1921 (1,500 m) adding about 90,000 m^2/year. From 1921 to 1955, it eroded back slightly (60 m) and broadened. Since 1955, it remained fairly stable, having had a net increase in area of 5.7×10^6 m^2 since 1862/64. Subaerial shoals seaward of the inlet, present in 1862/64, were not evident on the 1921 survey, having perhaps migrated onto Kiawah Island and contributed to its seaward growth.

130. Folly Island, northeast of the inlet, has eroded landward and alongshore to the northeast over the duration of these data. From 1854/58 to 1921, it retreated over 1,080 m in alongshore direction (16 m/year). Alongshore retreat continued to 1983, although at a reduced rate (2.5 to 3.4 m/year). Net change between 1854/58 and 1983 was alongshore erosion of approximately 1,200 m. Coincident with rapid erosion of Folly Island between 1854/58 and 1921 was the development of Bird Key between Folly and Kiawah Islands. It was first mapped on the 1921 survey, where it had an area of 0.2×10^6 m^2. Its surficial area has waxed and waned dramatically between 1921 and 1983. Between 1921 and 1933, it lost 183,000 m^2 and then gained 1.1×10^6 m^2 by 1955. The 1964 survey shows a tiny island only 7,000 m^2 in size, representing a 1.2×10^6 m^2 loss since 1955. In 1983, the key was 244,000 m^2 in area, representing a net increase of 48,700 m^2 since 1921. Small changes in position, orientation, and shape accompanied these area changes.

131. As a result of changes in Kiawah and Folly Islands and Bird Key, throat width changed from 1,525 m in 1854/58, to a maximum of 2,560 m in 1921, down to 1,700 m in 1955, and back up to 2,010 m in 1983. A net width increase of roughly 500 m from 1854/58 to 1983 was due mainly to erosion of Folly Island.

Lighthouse Inlet (Map 13)

132. Most changes that have occurred at Lighthouse Inlet are the result of rapid shoreline erosion along Morris Island since completion of the Charleston Harbor jetties. Net erosion rate between 1857/58 and 1983 is over 10 m/year for the southern end of Morris Island. Folly Island, south of the inlet has also eroded landward since 1857/58, but the magnitude of change is small compared with Morris Island. A prominent seaward offset of Folly Island has resulted. The southern terminus of Morris Island has moved alongshore only slightly during this period. Net change from 1857/58 to 1983 has been about 60 m of southwest extension. Folly Island eroded southwest about 275 m during this same interval; however, because of landward retreat of Morris Island, the inlet throat retreated upstream and decreased in width by 120 m over the study duration.

Charleston Harbor (Map 13)

133. The northwest side of Charleston Harbor entrance is formed by Sullivans Island. Accretion in the vicinity of Fort Moultrie has been adequately measured by the shoreline mapping technique. Southwest of Charleston

Harbor is Cummings Point, on Morris Island. From 1857/58 to 1900, Cummings Point retreated alongshore approximately 600 m. This coincided with landward erosion of the entire northern portion of Morris Island, prior to jetty completion in 1895. From 1900 to 1955, Cummings Point grew northward into the harbor approximately 600 m. From 1955 to 1983, there was no net change. Net change from 1857/58 to 1983 was a slight increase in length of approximately 60 m.

Breach Inlet (Map 13)

134. The northeastern side of Breach Inlet has been accreting both seaward and alongshore to the southwest since first surveyed in 1875. Net change between 1875 and 1983 was approximately 180 m (1.7 m/year) with maximum advance (5 m/year) occurring between 1921 and 1933/34. Southwest of the inlet, alongshore erosion occurred during the data interval. Net change on the southwest side has been approximately 120 m (1.1 m/year) of erosion between 1875 and 1983. This erosion trend was punctuated by a period of no net change between 1921 and 1933/34 and 60 m of accretion between 1933/34 and 1962/64. Inlet throat width decreased from 300 m in 1875 to 180 m in 1962/64 and increased to 210 m by 1983.

Dewees Inlet (Map 14)

135. The southwest side of Dewees Inlet had numerous, but small, changes between 1856/57 and 1983. Its maximum mapped seaward extent was in 1921, but as of 1983, it was 150 m landward of that position. The northeast side of the inlet is bounded by Dewees Island. Dewees Island has experienced rapid onshore erosion along its southern end and accretion along its northern shoreline, resulting in reorientation of the shoreline from north-south in 1856/57 to northeast-southwest in 1983. A net loss in surface area of 2.0×10^6 m^2 over the 1856/57 to 1983 period resulted. Rate of loss varied from 30,000 to 60,000 m^2/year, except during 1921 to 1934, when there was a net accretion of 157,000 m^2. The new shoreline of Dewees Island is roughly parallel to Isle of Palms and Capers Island but landward of the former and seaward of the latter. Erosion on the south end of Dewees Island and small changes noted to Isle of Palms have resulted in a net widening of Dewees Inlet from approximately 430 to 550 m between 1856/57 and 1983.

Capers Inlet (Map 14)

136. Previously discussed changes on Dewees Island, particularly accretion on the north end, have influenced Capers Inlet. Northeast of the inlet,

alongshore erosion with seaward advance occurred between 1856/57 and 1875. However, net change between 1856/57 and 1983 has been alongshore (550 m) and landward erosion. A prominent spit extended southwestward in the late 1800's forcing Capers Inlet southwest. However, over 700 m (12 m/year) of alongshore erosion removed the spit by the 1921 survey. Between 1934 and 1983, the patterns reversed, and accretion occurred (240 m) to the southwest again, although landward of its former position. This coincided with accretion on Dewees Island resulting in a switch from a updrift offset inlet to a downdrift offset inlet. The inlet throat, approximately 600 m wide in 1856/57, increased to approximately 670 m in 1875 and then decreased steadily to approximately 300 m wide by 1983.

Price Inlet (Maps 14 and 15)

137. The 1856/57 survey for the southwest side of Price Inlet is incomplete, but it suggests approximately 1,400 m of northwestward spit accretion by 1875. The 1875 survey shows a well-formed spit with a small bay behind. Between 1875 and 1983, spit length remained constant, as did position of the inlet. Inlet width decreased from 1875 (300 m) to 1934 (240 m), but remained constant between 1934 and 1983. However, despite alongshore consistency, the seaward shoreline of Capers Island advanced and retreated considerably in the inlet vicinity. The southwest shoreline eroded from 1875 to 1921, accreted from 1921 to 1934, eroded from 1934 to 1962/63, and finally, accreted between 1962/63 and 1983. Northeast of the inlet, fairly stable alongshore shorelines had a similar, although inverted, history of cross-shore shoreline change. The shoreline accreted from 1875 to 1921, eroded from 1921 to 1934, accreted to its maximum seaward position by 1962/63, and eroded slightly between 1962/63 and 1983. Observed 180-deg out-of-phase relationship of onshore/offshore erosion/accretion has been discussed by FitzGerald (1984), who attributes it to ebb channel migration and associated welding of ebb delta features onto adjacent shorelines.

Bull Bay (Maps 15, 16 and 17)

138. Northeast Point forms the southwestern boundary of Bull Bay. Bull Island has been undergoing rapid erosion on its eastern end, driving it in a landward direction since 1875. Losses resulting from erosion have ranged from 20,000 to 35,000 m^2/year over the interval of data. Despite overall losses by erosion, Northeast Point accreted alongshore approximately 790 m between 1875

and 1921 and another 180 m from 1921 to 1962. Between 1962 and 1983, the Point broadened westward, but did not accrete farther into Bull Bay.

139. Bird Island, which lies within Bull Bay, is included in this analysis since it could not be adequately measured by the shoreline mapping technique. Bird Island first appears on the 1921 survey. Its subaerial surface area was approximately 244,000 m^2, and it was oriented in a northeast-southwest direction with a length of approximately 1,460 m. It is not evident on the 1934 survey, but by 1962, the island increased 1,150 m over its 1921 length, and area increased 232,000 m^2. The 1983 survey shows an additional increase in length of 180 m, but a decrease in surface area of 24,000 m^2. Net change from 1921 to 1983 was a 207,000-m^2 increase of surface area. Accompanying island length and area changes were position changes. The island as a whole moved approximately 600 m northeast from 1921 to 1964 and 550 m southwest by 1983. In 1983, it was approximately 250 m landward of its 1921 position.

140. Sandy Point Beach forms the northeast side of Bull Bay. It has experienced continuous onshore erosion since the 1875 survey. However, from 1875 to 1934, the spit tip accreted southwest approximately 610 m. Between 1934 and 1962, there was a dramatic reversal when the spit eroded 670 m alongshore. Erosion continued from 1962 to 1983 (180 m). Net change over the range of data was 240 m of erosion.

Key Inlet (Map 17)

141. Key Inlet was a small, narrow (60 m wide) inlet during the 1875 survey. Landward shoreline erosion combined with eastward inlet migration and westside erosion between 1875 and 1934. Net alongshore change west of the inlet was a loss of approximately 50 m. Inlet width doubled by the 1925 survey, doubled again by 1934, and again by 1962. By 1983, inlet width had increased to approximately 550 m. Also, by 1983, a long, narrow spit extended from the east end of Lighthouse Island, which protected Key Inlet from direct wave attack. The east side of the inlet rapidly eroded into Lighthouse Island from 1875 to 1925, but only eroded a small additional amount by 1983.

Lighthouse Island/Cape Romain (Maps 17 and 18)

142. Shoreline position changes at Cape Romain are responsible for changes in surficial area and shoreline orientation on adjacent Lighthouse Island. In 1874, Cape Romain was at its most seaward (easterly) extent, with a small hook extending roughly 600 m southwest. The 1925 survey shows about

900 m of westward cape erosion with approximately 500 m of southerly accretion since 1874. The cape tip was broad and blunt. From 1925 to 1934, westward erosion continued at a reduced rate, and the cape retreated northward approximately 180 m. Both bay and oceanside erosion resulted in narrowing of Cape Island in the vicinity of Cape Romain. A narrow east-west oriented spit about 600 m long formed the cape terminus. By the 1962/63 survey, Cape Romain had retreated an additional 480 m northward. Westward erosion resulted in the 1934 bay shoreline and 1962/63 ocean shoreline being in similar positions. The terminal spit elongated westward so that it was approximately 3,500 m long in 1962/63. This resulted in a longer Romain River outlet and protection of most of Lighthouse Island from direct wave attack. Additional landward retreat of both sides of the cape continued to 1983 (roughly 500 m north and 500 m west). The long east-west spit attached to the Cape Romain in 1962/63 was apparently breached by the Romain River. Sediment downdrift of the breach appears to have moved landward and welded onto Lighthouse Island, which in 1983 shows a long spit extending 4,250 m westward, past Key Inlet. That spit portion remaining on Cape Romain (800 m long) migrated landward about 500 m.

143. Between 1874 and 1962/63, Lighthouse Island accreted rapidly at its southeast end. From 1874 to 1925, island surface area dropped from 10.7×10^6 m^2 to 8.9×10^6 m^2; but by 1934, it had increased to 11.2×10^6 m^2. Accretion continued through 1983 when island area was 16.9×10^6 m^2. Island growth appears to correlate with spit growth on the tip of Cape Romain. A large increase in area (197,000 m^2/year) came between 1962/63 and 1983 when the spit was breached and part of it appears to have welded onto Lighthouse Island. Net change between 1874 and 1983 was an increase in area of 6.2×106 m^2. Southeasterly island growth and spit movements on Cape Romain have resulted in long-term narrowing of the Romain River Inlet from approximately 1,800 m wide in 1874 down to 180 m wide in 1983.

Cape Romain Harbor (Map 18)

144. Cape Island extends north to form the southern side of Cape Romain Harbor. The island's north end has accreted alongshore north-northeast since 1873/74. Rate of accretion was approximately 34 m/year between 1873/74 and 1934. From 1934 to 1983, accretion rate decreased to approximately 29 m/year. Net elongation of the island tip over survey duration is approximately 3,600 m. Alongshore growth to the north has been accompanied by landward shoreline erosion. Shoreward erosion was particularly severe toward Cape

Romain; however, between 1873/74 and 1983 overall surface area of Cape Island increased from 12.2×10^6 m^2 to 15.3×10^6 m^2, a net increase of 28,000 m^2/year. Erosion on the south and accretion north have resulted in a net northerly migration of Cape Island over the period of record.

145. Murphy Island, north of Cape Romain Harbor, has accreted since 1873/74. The largest increase came between 1962/63 and 1983. These changes are represented by the shoreline mapping procedure (Figure 39). Accretion on both sides of Cape Romain Harbor entrance has resulted in its narrowing from approximately 2,700 m wide in 1873/74, to 2,050 m in 1934, to approximately 975 m wide in 1983.

South Santee River Inlet (Map 18)

146. Cedar Island forms the northeast side of South Santee River Inlet. The island terminal spit accreted 850 m alongshore to the southwest at an approximate rate of 14 m/year between 1873/74 and 1934. Jetties at Winyah Bay to the north were completed about 1900. From the 1934 to 1962/63 survey, rapid spit erosion occurred (2,300 m, 83 m/yr) alongshore. Then from 1962/63 to 1983, the spit accreted 420 m again. Net change was a loss in length from 1873/74 to 1983 of roughly 900 m. A reversal of alongshore drift between 1934 and 1962/63 is evidenced by a rapid rate of erosion during that time, plus development of a small spit extending east and north from the eroded tip of Cedar Island. This spit was not present on 1934 or 1983 surveys.

147. Murphy Island on the west side of the inlet eroded alongshore from 1873/74 to 1934 as the inlet migrated to the southwest. The width of the inlet throat decreased from 550 to 300 m during this interval. Reversal of the drift between 1934 and 1962/63 caused only mild accretion on Murphy Island and widening of the inlet to over 600 m. Return of the drift to its normal southerly direction by 1983 resulted in accretion on both sides of the inlet and a decrease of over 100 m in inlet width.

North Santee Bay Inlet (Map 20)

148. Santee Point, on the northeast side of North Santee Bay Inlet, grew southward from 1872/73 to 1925 a distance of approximately 900 m. The 1925 survey shows several large islands seaward of South Island, which appeared to have formed a platform for seaward and alongshore (500 m) accretion of Santee Point by 1934. As with South Santee Inlet between 1934 and 1962/63, alongshore erosion removed 550 m from the length of Santee Point. Net shoreline change by 1983 was minimal. The inlet's southwest side accreted

from 1872/73 to 1934, eroded from 1934 to 1962/63, and accreted slightly to 1983. As a consequence of changes on both sides of the inlet, inlet width decreased from 800 to 360 m between 1872/73 and 1934, increased to 550 m wide in 1962/63, and decreased to 420 m wide in 1983.

Winyah Bay Entrance (Map 20)

149. Jetties at Winyah Bay Entrance were completed around 1900. North Island, north of the inlet, built alongshore to the south to 1962/63. Net change in subaerial surface area of North Island was an increase of 2.2×106 m^2 from 1857/58 to 1962/63. Between 1962 and 1983, erosion resulted in area losses of roughly 439,000 m^2. Net change in length of North Island was an increase of 1,280 m between 1857/58 and 1983. South of the jetties, South Island has undergone major changes in shoreline position, probably related to jetty construction. Between 1872/73 and 1925, South Island did not change drastically except that a long (4,500 m), thin, arcuate-shaped island formed from the jetty southward, roughly paralleling South Island's coastline. This thin island was up to 3,100 m offshore of South Island. The 1934 shoreline on South Island was similar to previous dates, except near Santee Point. The offshore island, however, changed to a "V" shape, with one leg anchored around the jetty. Maximum southwest elongation is approximately 1,100 m, and it moved about 300 m landward since 1925. The 1962/63 survey shows formation of a large island positioned inland of the 1934 island and 2,000 m of accretion on South Island's shoreline. This new island was primarily south of the jetty, but a small spit extended north (700 m). By 1983, area behind the 1962/63 island had filled in, leaving only a small tidal channel. The 1983 shoreline of South Island immediately south of the jetty was about 180 m landward of the 1962/63 small island shoreline. Farther south, shorelines show no offset. The 1983 south jetty survey shows a large spit (over 2,000 m long) extending into Winyah Bay. By 1983, a small 1962/63 spit extending north of the south jetty increased in area by 2.1×10^6 m^2. South Island area changes south of the jetty are presented in Table 12.

North Inlet (Map 21)

150. South of North Inlet, a long spit projected north in 1872. This spit eroded alongshore south approximately 1,600 m by 1925/26. Between 1925/26 and 1983, net alongshore change south of the inlet was approximately 200 m of northward accretion. Alongshore drift reversal prior to 1962 is evident by extension of a small northward trending spit from the 1962 shoreline.

Table 12

Area Changes South of the Winyah Bay Jetties

Dates	Area Difference m^3	Rate of Change m^2/year
1872/73-1925	+232,000	+4,700
1925-1934	-585,000	-49,000
1934-1962/63	+9,500,000	+327,000
1962/63-1983	+4,800,000	+227,000
1872/73-1983	+13,800,000	+124,000

Reversal at this inlet, South Santee River Inlet, and others may be due to local reversal in littoral drift around ebb-tidal deltas as described by Fitz-Gerald, Hubbard, and Nummedal (1978). However, this mechanism does not explain why drift reversals occur in the 1934 to 1962 time frame. In this case, it appears ebb delta landward migration by 1983 extended the shoreline seaward 300 m from its 1872 position.

151. The north side of North Inlet extended approximately 120 m alongshore from 1872 to 1925/26 to form a small spit. Also, a small island formed, effectively creating two adjacent inlets. From 1925/26 to 1934 the spit showed a net erosion of 300 m (232,000 m^2) followed by rapid southward accretion of 1,900 m (1.3×10^6 m^2) by 1962. Spit growth protected the island from direct wave attack and returned morphology to a single inlet. Spit length in 1983 was equal to its length in 1962; however, landward shoreline erosion and island incorporation resulted in a 1.4×10^6 m^2 increase in area. Net change between 1872 and 1983 north of the inlet was approximately 1,700 m of alongshore growth and a 2.7×10^6 m^2 growth in area.

152. Inlet width was over 1,000 m in 1872 decreasing to 850 m total for two inlets that formed in 1925/26 through spit growth and island formation. Island erosion and spit retreat widened the inlet to 1,250 m by 1934. The 1962 survey shows one inlet again approximately 975 m wide, narrowing to 730 m wide in 1983 by spit accretion on the south side.

Unnamed inlet (Map 22)

153. A small, unnamed inlet lies between Debidue Beach and Pawleys Island. The inlet's north side grew consistently southwest from 1872 to

1962/63. Rate of accretion varied from 15 m/year up to 46 m/year during the 1926 to 1934 period. This resulted in a southerly inlet migration with corresponding downdrift erosion. Inlet throat width decreased from approximately 180 m in 1872 to 90 m in 1962/63. Between 1962/63 and 1983 surveys, the inlet's northeast side eroded, reducing spit length approximately 490 m. South side accretion kept the inlet throat around 100 m wide.

Midway Inlet (Map 22)

154. The northern side of Midway Inlet eroded 180 m alongshore between 1872 and 1926. This northeastward erosion was followed by rapid southwestward accretion (240 m) between 1926 and 1934. A more modest rate of accretion (11 to 15 m/year) continued to 1983 for a net (1872-1983) southwest growth of 670 m. Inlet changes on the south side are inversed, with accretion of over 300 m between 1872 and 1926 and steady erosion (690 m) between 1926 and 1983. Inlet throat width narrowed from 275 m in 1872 to 150 m in 1926 and then increased to over 1,000 m in 1934. From 1934 to 1983, throat width decreased steadily to only 60 m. Net change from 1872 to 1983 was a narrowing of the inlet by just over 200 m.

Murrells Inlet (Map 23)

155. Murrells Inlet 1872 survey shows a long northeast trending spit extending southwest. The inlet throat, about 300 m wide in 1872, is in its most southerly position. Between 1872 and 1926, the long spit severely eroded northeasterly (1,950 m) while a new spit grew (2,280 m) toward the northeast from a southerly point along Magnolia Beach. This resulted in shoal accretion south of the inlet. Inlet throat width increased to 850 m as Murrells Inlet migrated to a northerly position. From 1926 to 1934, this south side spit continued to advance northeastward approximately 300 m. North side accretion (180 m) resulted in narrowing of the inlet to 300 m by 1934. From 1934 to 1963, erosion/accretion patterns reversed, with over 850 m of alongshore erosion south of the inlet and 580-m growth of a new spit on the north side. Inlet width increased to 670 m as it migrated south. South side erosion and north side accretion continued to the 1969/70 survey. Jetty construction occurred in 1977-1980. The 1983 survey shows no change in north side spit length since 1969/70, with mild accretion to the south (30 m). Throat width decreased slightly from 640 m in 1969/70 to 580 m in 1983.

Futch Beach Inlet (Maps 26 and 27)

156. Futch Beach Inlet was closed between 1934 and 1962/63. Tidal creek flow was diverted to nearby Hog Inlet. From 1873 to 1934, the inlet's northeast side accreted approximately 1,100 m southwest. The south side eroded approximately 1,150 m as inlet width increased roughly 50 m.

Hog Inlet (Map 27)

157. The northeast side of Hog Inlet accreted alongshore roughly 600 m from 1873 to 1933/34. Inlet throat width remained constant (90 m) as erosion on the southwest side kept pace with northeast side accretion. Between 1933/34 and 1962/63, the pattern reversed. Northeast of the inlet, there was 420 m of spit erosion, and there was 360 m of accretion on the southwest side. Throat width increased to 180 m and up to 300 m by 1969/70. From 1962/63 to 1969/70, northeast side erosion continued while the southwest side remained fairly stable. Both sides accreted 60 m between 1969/70 and 1983, reducing inlet throat size to approximately 120 m. Between 1873 and 1983, net change northeast of Hog Inlet was approximately 120 m of accretion, and the southwest side had 240 m of erosion. Throat width was just over 200 m in 1983.

Little River Inlet (Map 27)

158. Little River Inlet and adjacent Mad Inlet are separated by Bird Island to form two inlets. Jetty construction on Little River Inlet was completed in 1983. The west side of Little River Inlet advanced alongshore 1,200 m from 1873 to 1924/26, while Bird Island moved eastward. During this time interval of eastward migration of the inlet, Bird Island increased from 1,830 m long to 2,930 m long. No measurable alongshore changes occurred between 1924/26 and 1933/34, but from 1933/34 to 1969/70, alongshore erosion of the westside spit occurred (850 m). Bird Island also decreased in length from 2,930 m in 1924/26 to 1,525 m in 1969/70 as inlet width increased from 300 m in 1924/26 to 1,460 m in 1969/70. The 1969/70 to 1983 period saw a decrease in inlet width to approximately 600 m as the southwest side accreted 490 m and Bird Island grew in length to 2,250 m.

159. By 1969/70, Bird Island was no longer a true island, having welded to the mainland on its northeast corner. From 1873 to 1969/70, island area increased steadily from a surface area of 1.0×10^6 m^2 to 2.9×10^6 m^2. This represents a net yearly increase in area of approximately 19,000 m^2/year.

Mad Inlet (Map 27)

160. Position of the west side of Mad Inlet is controlled by changes in position and aerial extent of Bird Island described above. The inlet's east side eroded rapidly (1,890 m, 37 m/year) from 1873 to 1924/26 and then accreted slightly (120 m, 14 m/year) from 1924/26 to 1933/34. Another period of erosion (240 m, 8 m/year) followed from 1933/34 to 1962/63. From 1962/63 to 1969/70, rapid accretion (420 m, 60 m/year) followed. Accretion patterns continued (150 m, 11 m/year) to 1983. Inlet throat width increased from 275 m in 1873 to a maximum of almost 400 m in 1933/34 and then narrowed to 120 m in 1969/70 and 1983.

Tubbs Inlet (Map 28)

161. The earliest survey date available for Tubbs Inlet is 1924. From 1924 to 1962/63, the inlet's east side accreted (1,300 m) west quite rapidly, up to 68 m/year. Land west of the inlet lost 975 m of length during this time interval. Inlet throat width narrowed from 550 m in 1924 to approximately 300 m in 1962/63. From 1962/63 to 1983, patterns reversed with east of the inlet eroding approximately 1,200 m (up to 157 m/year). Inlet width increased to 360 m by 1983. In 1983, Tubbs Inlet appeared as two inlets separated by an island approximately 300 m long.

Shallotte Sound (Maps 28 and 29)

162. East of Shallotte Sound inlet, alongshore accretion added 480 m (up to 8.4 m/year) between 1857/59 and 1962/63. No substantial changes in length occurred between 1962/63 and 1983. The inlet's west side eroded 300 m from 1857/59 to 1924, accreted 90 m from 1924 to 1933, and eroded 210 m (7.4 m/year) from 1933 to 1962/63. From 1962/63 to 1969/70, it maintained its length, but eroded an additional 120 m by 1983. Net changes (1857/59 to 1983) include an east side length increase of 480 m, a west side length decrease of 550 m, and an increase of inlet width from approximately 400 m in 1857/59 to approximately 480 m in 1983. Maximum inlet width (580 m) occurred in 1924.

Lockwood Folly Inlet (Map 30)

163. Since the earliest survey date (1856/57), Lockwood Folly Inlet has migrated west. Between 1856/57 and 1924, east side accretion added 730 m while west side erosion removed 550 m in length. Between 1924 and 1969/70, the east side eroded slightly (up to 3 m/year) or remained stable. The west side eroded slightly (up to 3 m/year) from 1924 to 1962, but accreted (13 m/year) from 1962 to 1969/70. From 1969 to 1983, east side accretion

(180 m) coincided with west side erosion (90 m). Net change (1856/57 to 1983) was 850 m of east side accretion and 610 m of west side erosion. Inlet throat width decreased from 360 m in 1856/57 to 150 m in 1983.

Cape Fear (Map 32)

164. Shoreline position changes near Fort Caswell and Bald Head on Cape Fear River (Map 31) have been measured by the shoreline mapping procedure (Figure 47). Likewise, onshore-offshore changes on both sides of Cape Fear have been presented.

165. Cape Fear was most seaward on the 1878 field survey, but retreated north-northwest 1,400 m by 1914. No substantial changes occurred at the cape tip between 1914 and 1923, but by 1933/34, it had accreted 300 m to the southeast. It retreated due north 240 m by the 1972/75 survey and moved east an additional 180 m by 1983. Net change between 1878 and 1983 of the tip of Cape Fear has been approximately 1,100 m of north-northwest erosion. Cape area has been steadily decreasing, as evidenced in Table 13; however, rate of loss has steadily decreased since 1878.

Table 13

Subaerial Surface Area Changes at Cape Fear

Dates	Difference in Area m^2	Rate of Area Change m^2/year
1878-1914	-3.2×10^6	-88,000
1914-1923	-0.5×10^6	-50,000
1923-1933/34	-0.2×10^6	-16,000
1933/34-1972/75	-0.2×10^6	-6,000
1972/75-1983	-85,000	-8,000

New Inlet (Map 32)

166. New Inlet is north of Cape Fear, along a north-south trending coastline. In 1878, there were two long, thin islands (1,750 and 4,050 m) composing the shoreline just north of a 360-m-long spit extending northerly from East Beach on Smith Island. As a result, there were two inlets (60 and 670 m wide), both south of the 1983 position of New Inlet. By 1914, either these two inlets had closed and a new inlet opened farther north, or a new inlet had formed from northward migration of the larger inlet and small inlet

closure. New Inlet in 1914 continued to move north as its south side accreted 790 m alongshore. The north side eroded 1,150 m between 1914 and 1923 and then accreted 600 m from 1923 to 1972/75. From 1972/75 to 1983, 180 m of south side erosion accompanied 30 m of north side erosion. Inlet width reached its maximum in 1983 at 480 m. Minimum width was measured on the 1972/75 survey at 240 m.

PART V: PRESENT AND FUTURE SHORELINE CHANGES

Analysis of Present Shoreline Positions

167. The shoreline is defined by the zone of intersection of land, sea, and air. Shoreline position at any point in time is a function of complex interaction of five principal factors: sea level, sea energy, sediment supply, geology, and human involvement. These factors operate over very short to very long time scales. Sea level includes daily tides, surges, annual tide variations, climate and geologically controlled water-level changes, and other naturally produced changes to ocean water levels. Little opportunity was available to evaluate sea level effects within the study area beyond what has already been discussed in previous sections. Sea energy is manifested in waves and currents that reach the shoreline. The WIS data were used to examine waves as a factor in controlling shoreline position. Previous research described in Part II indicates most sediment for South Carolina's beaches comes from exhumed pre-Holocene coastal sediments. No quantifiable data exist on sediment supply reaching beaches to allow evaluation of this factor as a control on shoreline position. Nearshore shelf bathymetry, depth to pre-Holocene semiconsolidated sediments, and antecedent topography are geological influences on shoreline position. A brief evaluation of bathymetry and depth to pre-Holocene sediment was conducted in the study area. Human intervention has affected shoreline position in several locations within the study area. At most locations of human intervention, time frames for intervention have been short. However, at Charleston Harbor and Winyah Bay, humans have had an impact for roughly two-thirds of the time embraced by this study. Effects of this intervention on the coastline at Morris Island, South Island, and other locations have been described previously in the shoreline change data analysis.

168. To compare large amounts of shoreline data generated in this analysis to shoreline orientation, bathymetry, and depth to pre-Holocene material, data were summarized for 282 coastal segments defined in the original mapping procedure (Figures 22a and b). A summary of shoreline change for each section of each map is included in Appendix A. Since original selection of segments was based solely on the straightness of shoreline and not directly on its erosion/accretion history, the following results can be considered only

preliminary. A more rigorous approach, which will define shoreline segments based on records of erosion and/or accretion, is planned for future reports by the authors. Comparison of wave and erosion/accretion data for each segment was additionally complicated since WIS data are summarized only in 16-km-long blocks. Therefore, erosion/accretion data had to be further grouped to match 16-km WIS spacing.

Waves

169. Using power spectrum analysis and principal component analysis, May (1983) compared WIS data for the North Carolina coast to eight shore zone attributes, including shoreline change. For most of North Carolina, there was no correlation between wave climate and shore zone rate of change. In a few areas, however, low-period, high-amplitude waves correlated with high erosion.

Wave height

170. Average net shoreline change was calculated for every 16-km segment of coastline defined by WIS. Average shoreline change was compared with average wave height, maximum significant wave height, and occurrence of significant wave height greater than 1 and 2 m. Each of these wave height parameters was further compared with maximum shoreline change (the envelope of change between the two most divergent shorelines irrespective of their dates) for each 16-km section of shoreline.

171. Average wave height, which ranged between 0.48 and 0.74 m along the coast, showed no apparent trends when compared with average shoreline change. Likewise, average shoreline change versus maximum significant wave height (2.6 - 5.3 m) and occurrence of significant wave heights greater than 1 m, showed no apparent relationship. Average shoreline change versus occurrence of significant wave heights (Hs) greater than 2 m does show some trends (Figure 54). Data suggest less erosion and more accretion as occurrence of waves greater than 2 m decreases. Generally, in those areas where large waves (Hs > 2 m) hit the shoreline relatively often, average rates of erosion are expected to be larger.

172. Maximum shoreline change versus significant wave heights in excess of 1 and 2 m showed no apparent organization. Maximum shoreline change versus average significant wave height (Figure 55) showed a very weak suggestion of increasing shoreline movement with increasing average height; however, there

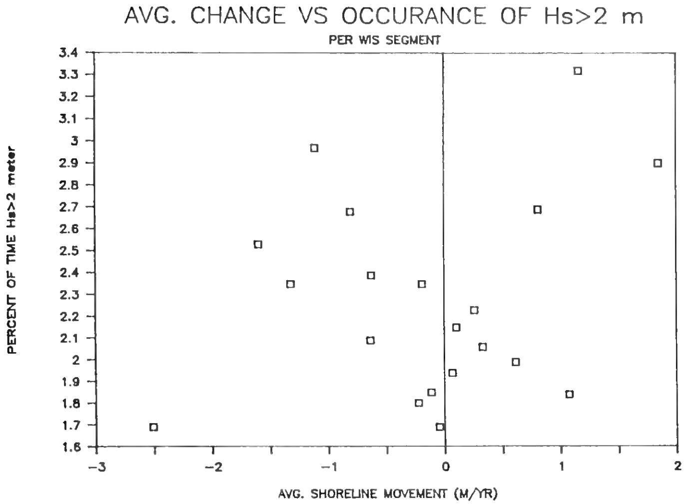


Figure 54. Average net shoreline change versus occurrence of significant wave heights greater than 2 m

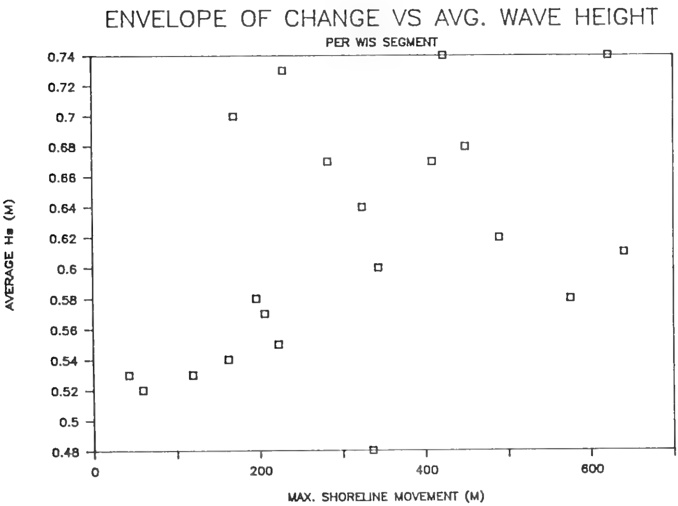


Figure 55. Maximum net shoreline change versus average significant wave height

was considerable data scatter at higher average significant wave heights and larger shoreline movements. The trend between maximum shoreline change and maximum significant wave height is clear (Figure 56). Shoreline movement increases with increasing maximum height. Figure 4 shows that maximum significant wave height is greatest along the barrier island and cuspate delta geomorphic zones and least along the arcuate strand. Likewise, spatial distribution of erosion is greater in the barrier island and cuspate delta zones than in the arcuate strand (Figure 52).

173. Figures 54 through 56 suggest that shoreline change along South Carolina's coast is dependent on incidence of large waves at the shoreline. This in turn suggests that long-term erosional history of the coast may depend heavily on storm frequency and magnitude. Data presented by Simpson and Miles (1971) suggest a decreasing probability of tropical storm occurrence from south to north in the study area. It is difficult to attribute shoreline erosion or accretion at every segment to presence or absence of large waves since other factors influence effectiveness of waves in changing the shoreline. Orientation of the coast relative to direction of wave approach, nearshore slope, and sediment composition of beach and nearshore are factors that can greatly modify effects of waves on shoreline change.

174. In addition to wave height, wave period (T) was examined relative to average and maximum shoreline movements. Occurrence of waves with periods greater than 4, 7, 8, and 11 sec were compared with shoreline change data. No relationship was apparent between average shoreline change and any wave period data. Data points were widely scattered (e.g. Figure 57). Comparisons of maximum shoreline movement and wave period do not show any trends except at periods greater than 11 sec (Figure 58). Three distinct groups are evident related to percentage of time that waves of $T > 11$ sec occur. Within each group, there appears to be no correlation between maximum movement and $T > 11$ sec. Examination of the three groups shows a division based on shoreline orientation. The four east-west trending WIS segments west of Cape Fear receive fewest $T > 11$ sec waves. These four WIS segments roughly coincided with reaches 6 and 7, which have the most stable shorelines (Figure 52). Northeast-southwest trending barriers form the middle grouping. The segment of coast receiving most $T > 11$ sec waves is north-south trending zones north of Cape Romain and near Tybee Island. This corresponds with reaches 5 and 1 respectively, which have the largest amount of erosion of all reaches

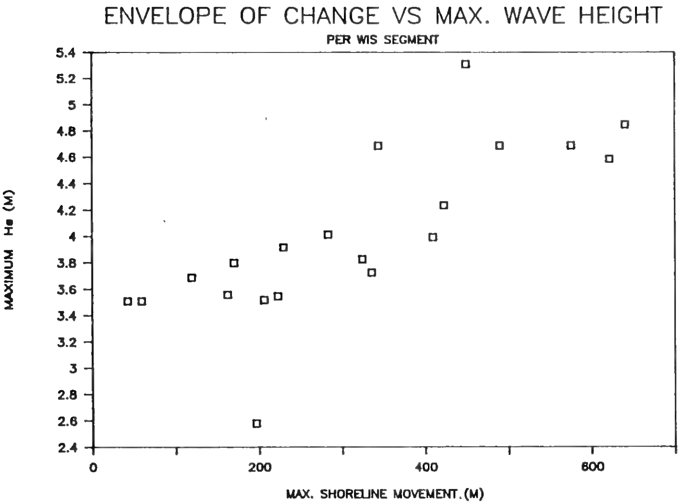


Figure 56. Maximum net shoreline change versus maximum significant wave height

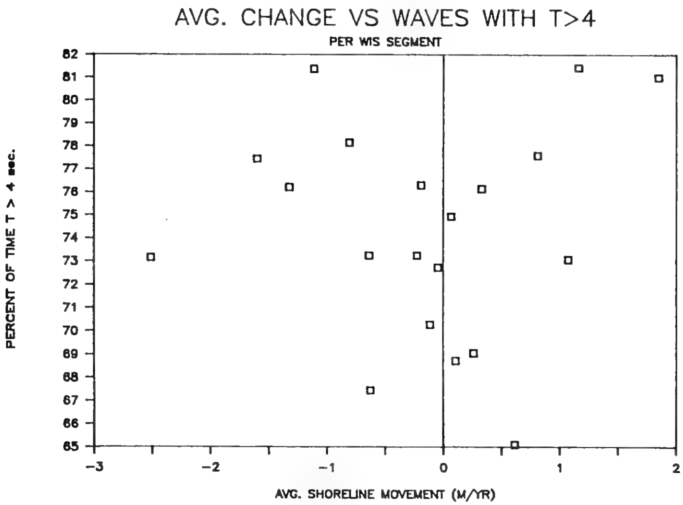


Figure 57. Typical example of data scatter for average shoreline change versus wave period

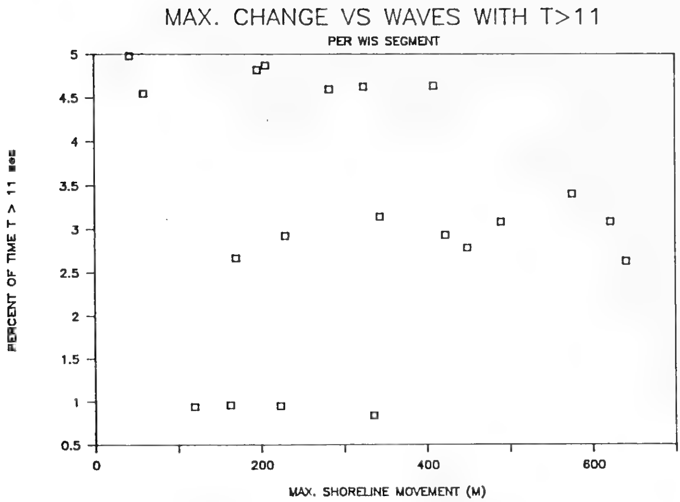


Figure 58. Maximum net shoreline movement versus occurrence of waves with a period greater than 11 sec

(Figures 26 and 42). May (1983) noted that 55 to 60 percent of the energy supplied to the coast of North Carolina was from swell waves. The data point in each group that shows largest shoreline movement is the WIS segment immediately south of a Cape. Where T > 11 sec occurrence is low, the WIS segment south of Cape Fear has largest shoreline changes. Of the northeast-southwest trending shoreline group, the WIS segment just south of Cape Romain has largest shoreline changes. In the group of high percent occurrence of T > 11 sec , Tybee Island (which is capelike in morphology) has most shoreline movement. These data do not demonstrate any relationship between wave period and maximum shoreline movements, but they do hint that shoreline orientation plays an interactive role with waves in affecting erosion/accretion of the shoreline.

Shoreline orientation

175. Shoreline orientation with respect to predominant average and storm wave approach affects wave and current conditions in the littoral zone and, thus, may contribute to shoreline changes. To examine this factor, orientation of each coastal segment (Figures 22a and b) in the study area was determined, and scatter plots of orientation versus average annual and maximum shoreline change were prepared.

176. Figure 59 shows percentage of segments with orientations in specified degree categories. Shorelines in 64 percent of the segments are aligned in a general northeast-southwest direction between 30 and 90 deg.

177. Scatter plots showing shoreline orientation versus average annual and maximum shoreline change for all segments were completed (Figure 60). These did not show a significant trend that might indicate a direct relationship between shoreline orientation and shoreline movement. Separate plots were made for each of the seven coastal reaches to see if trends occurred in certain geomorphic areas. None of the reach plots indicated the existence of significant correlation. Figure 61 showing data spread for reach 2 is typical.

178. Absence of trends indicating a relationship between shoreline movement and shoreline orientation suggests that orientation to approaching waves by itself does not have a substantial effect on shoreline changes. The previous section indicated that orientation was a significant factor in reception of large period waves; however, no correlation was evident between wave period and shoreline change. None the less, the east-west arcuate strand, which has fewest $T > 11$ sec waves, has the most stable coastline, and north-south oriented reaches 1, 2, and the segment of reach 7 north of Cape Fear have widespread erosion.

<u>Bathymetry</u>

179. Nearshore bottom slopes and historical shoreline changes were compared to determine if there was any correlation. For this purpose, distance from the shoreline midpoint of each coastal segment to the 1.8-m, 5.5-m, and 9.1-m depth contours was measured on 1:80,000 scale NOS hydrographic charts. Corresponding slopes were calculated. Average yearly shoreline change and maximum shoreline change were compared with slope for each coastal segment.

180. Scatter plots of nearshore slope angles versus average and maximum shoreline changes in each segment were constructed (e.g. Figure 62). In general, the scatter plots show that there is little apparent correlation between nearshore slopes and either maximum or average annual shoreline change. To further examine the data, scatter plots were made for each of the seven reaches. However, there appeared to be little correlation between nearshore slopes and shoreline change in any individual reaches.

181. Figure 63 showing data for reach 6 indicates increasing shoreline movement with gentler slopes; however, there are too few data points at

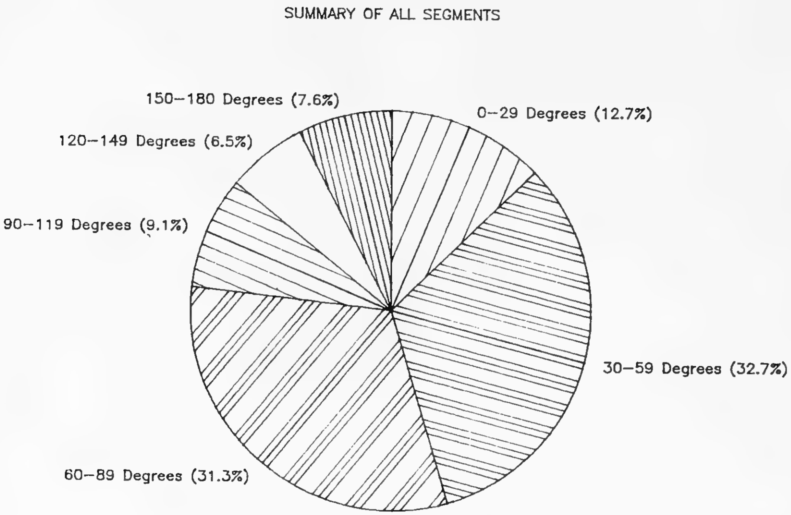
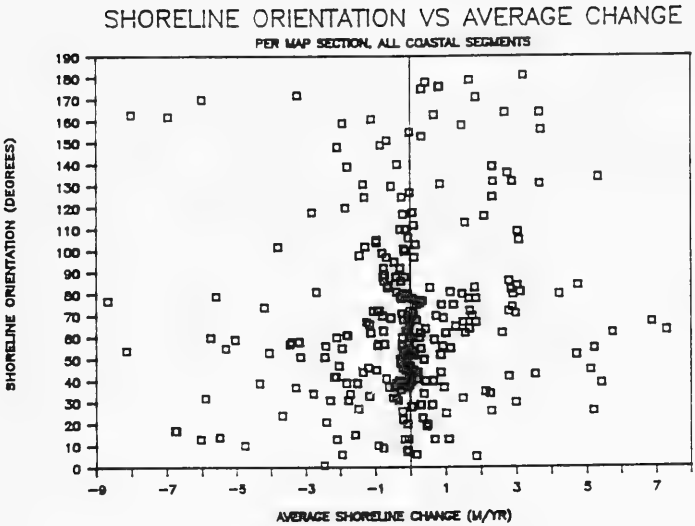


Figure 59. Division of shoreline segments into specified orientation categories

gentler slopes for confirmation. Gentle slopes have greater horizontal displacement of shoreline per unit vertical change in sea level.

182. On Figures 62 and 63, it can be noted that although there is no apparent linear correlation, a large number of data points are clustered where comparatively steep slopes correspond to low values for shoreline change. Inspection of shoreline change maps and data for individual reaches indicates that the largest number of data points are derived from reaches 6 and 7, which extend from Winyah Bay to Cape Fear. Comparing data from reaches 6 and 7 with data from reaches to the south shows significant differences in nearshore slopes and shoreline movement between these two areas.

183. Table 14 shows percentage of coastal segments in each area that have nearshore slopes steeper than specified values. This figure shows nearshore slopes on-the-whole are steeper in reaches 6 and 7 than in southern reaches. Figures 64 and 65 compare cumulative percentage of segments with maximum and average annual shoreline movement greater than specified values. Both figures indicate in reaches 6 and 7 shoreline movement has, overall, been substantially less than in reaches 1 through 5. Figures 66 and 67 compare maximum and average annual shoreline movements of segments that have nearshore



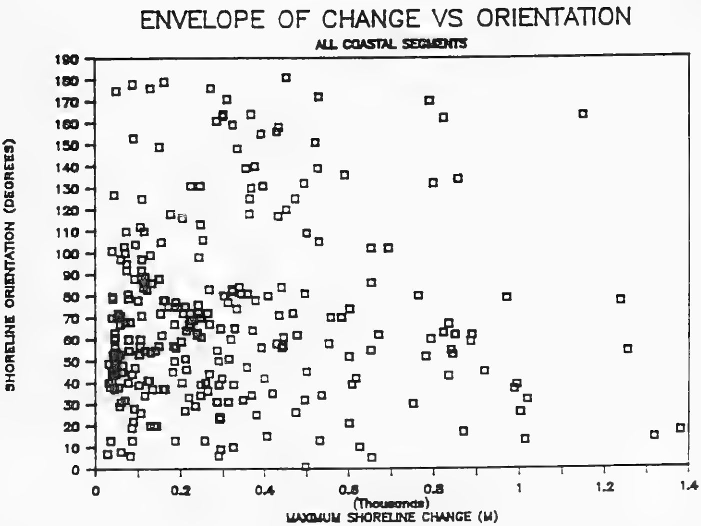
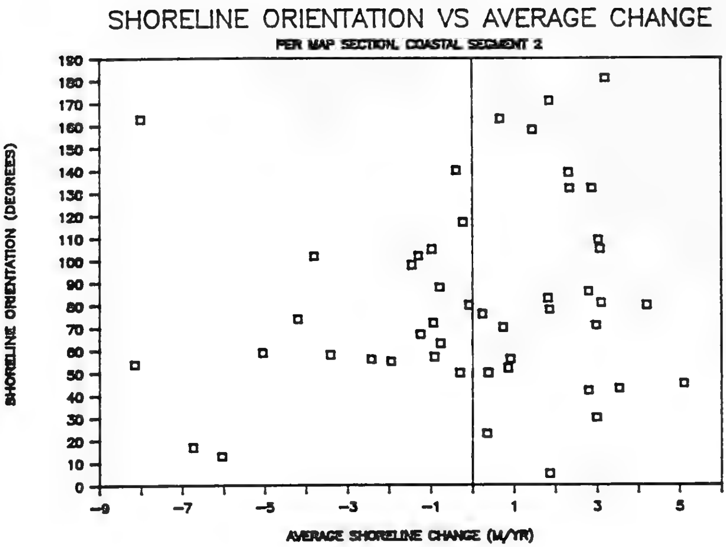


Figure 60. Shoreline orientation versus average and maximum net shoreline movement



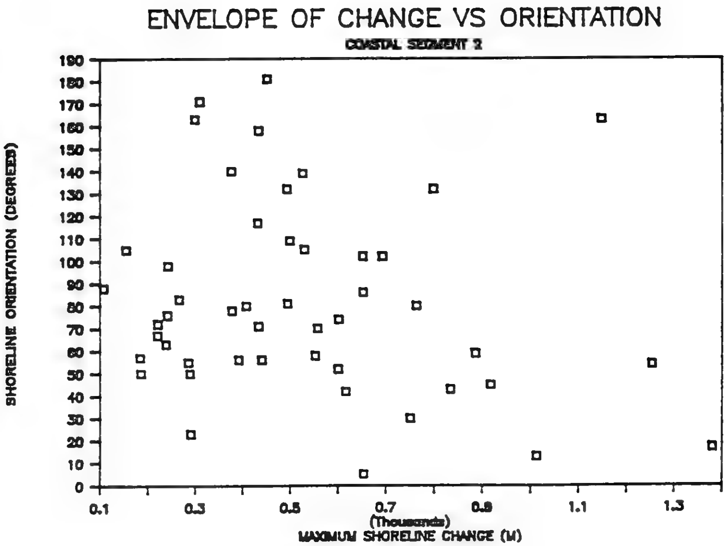
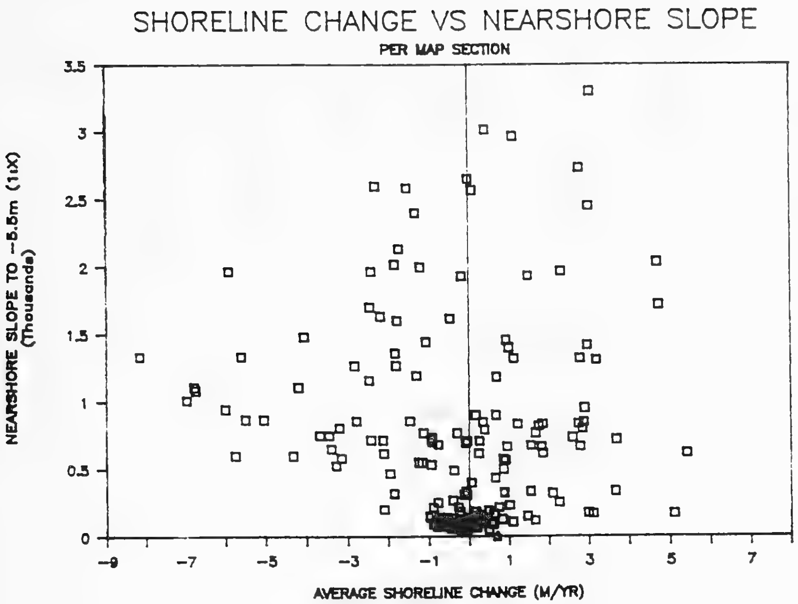


Figure 61. Shoreline orientation versus average and maximum net shoreline movement in reach 2



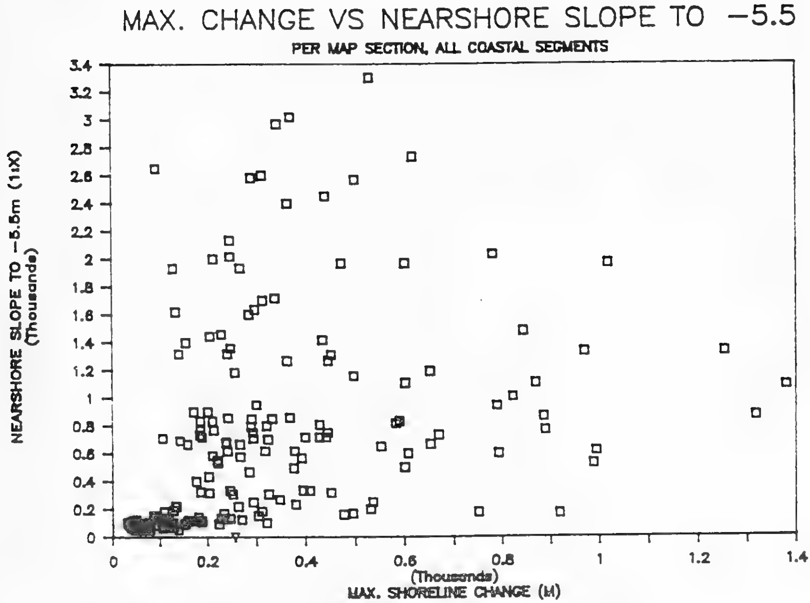


Figure 62. Average and maximum net shoreline change versus nearshore slope out to -5.5 m mean low water (MLW)

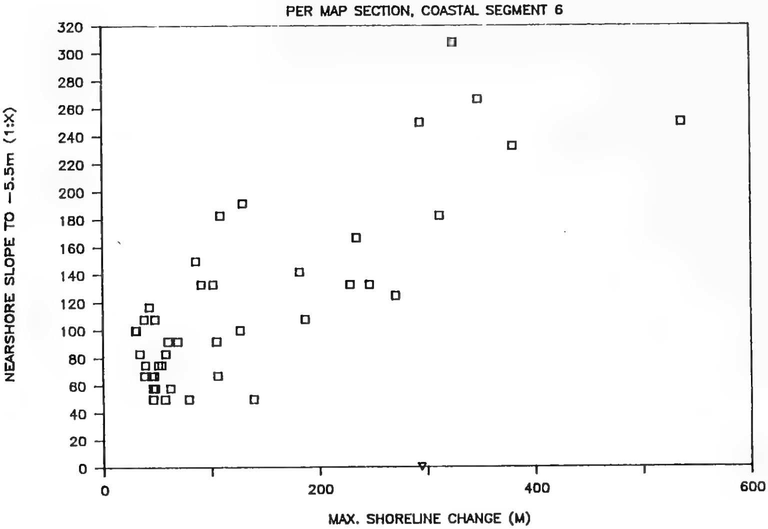


Figure 63. Maximum net shoreline change versus nearshore slope out to -5.5 m MLW for reach 6

Table 14

Cumulative Percentage of Total Shoreline Distance with Nearshore Slopes to -1.8, -5.5, and -9.1 m MLW Steeper than Designated Values

Reaches	Slope ≤1:100	≤1:200	≤1:300	≤1:400	≤1:500	≤1:600	≤1:900
				to -1.8 m MLW			
1 through 5	9.3	58.0	65.7	74.8	76.6	80.7	
6 and 7	72.7	97.3	98.9	100.0	100.0	100.0	100.0
				to -5.5 m MLW			
1 through 5	0.0	1.3	1.3	2.4	5.9	17.0	60.6
6 and 7	53.7	89.3	93.9	100.0	100.0	100.0	100.0
				to -9.1 m MLW			
1 through 5	0.0	0.0	0.0	0.0	0.0	5.8	33.2
6 and 7	0.0	11.9	26.6	31.6	48.1	64.6	98.2

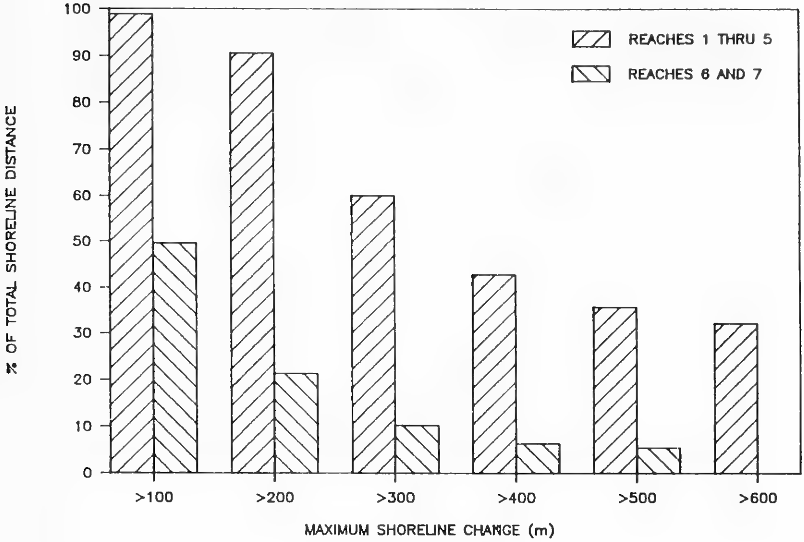


Figure 64. Cumulative percentage of total shoreline distance versus maximum shoreline change greater than specified values

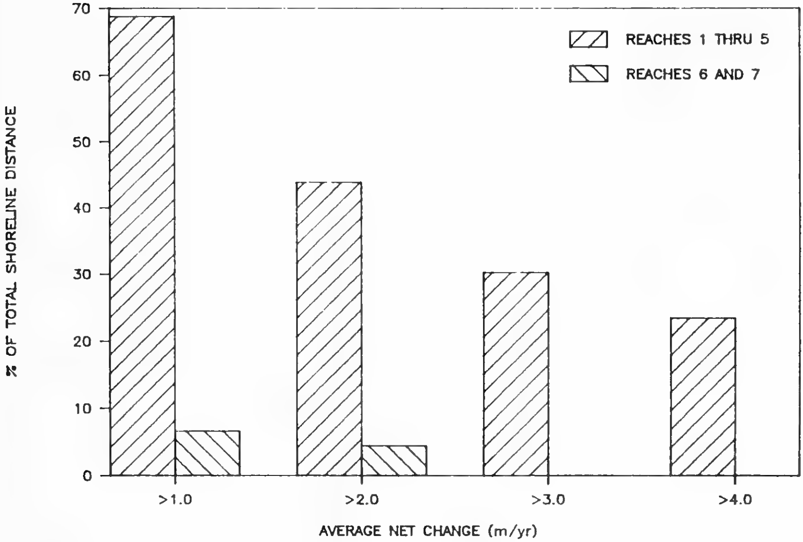
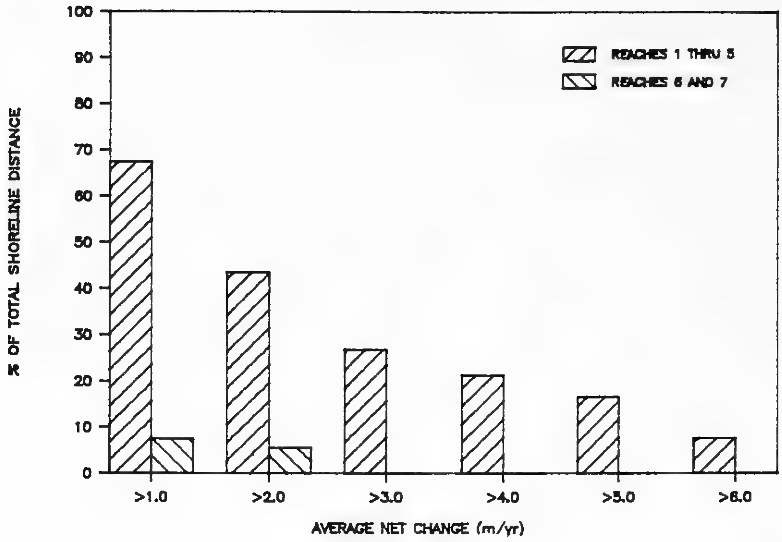


Figure 65. Cumulative percentage of total shoreline distance versus average net shoreline changes greater than specified value



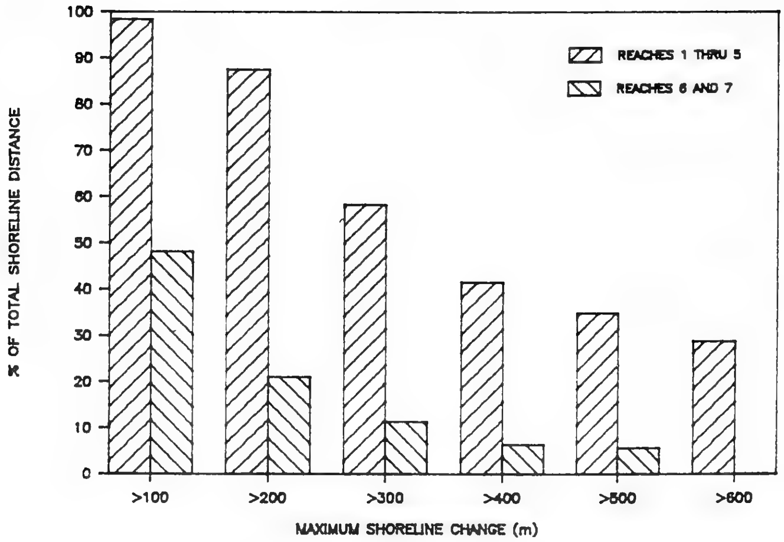
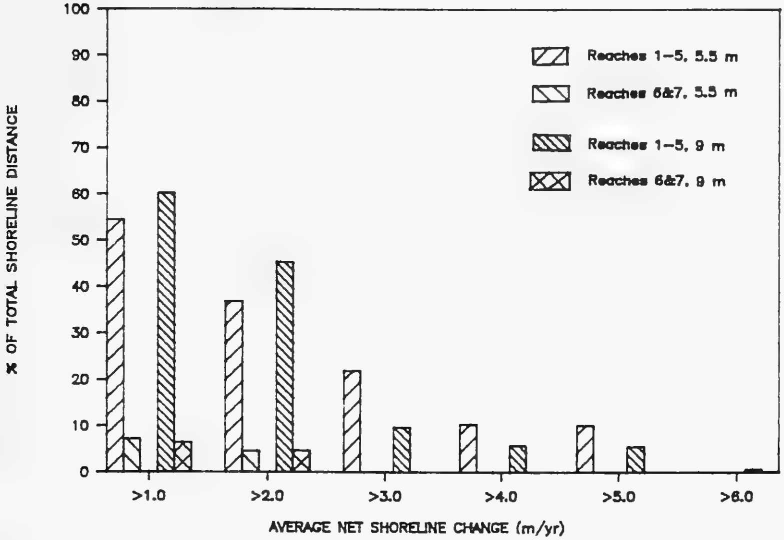


Figure 66. Cumulative percentage of shoreline distance of segments having slopes steeper than 1:300 to -1.8 m MLW versus average and maximum net shoreline changes greater than specified values



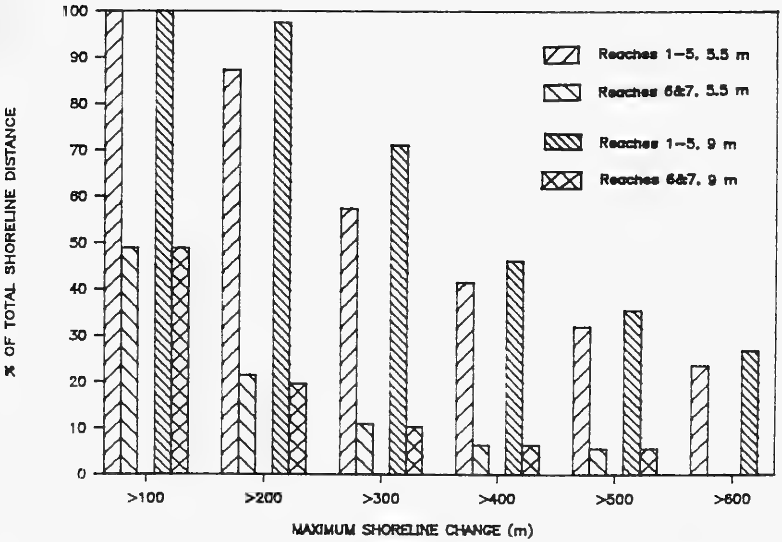


Figure 67. Cumulative percentage of shoreline distance of segments having slopes steeper than 1:900 to -5.5 and -9 m MLW versus average and maximum net changes greater than specified values

bottom slopes of specified values. Figure 66 compares data for segments with nearshore slopes to the 1.8-m depth contour of 1 on 300 or steeper. This figure shows that even with comparable steepness values there is substantially less shoreline movement in reaches 6 and 7 than in coastal segments farther south. Figure 67 compares shoreline movement for segments having nearshore slopes to 5.5- and 9.1-m depth contours of 1 on 900 or steeper. A considerable difference is evident in shoreline movement between the two areas comparable to data in Figure 66.

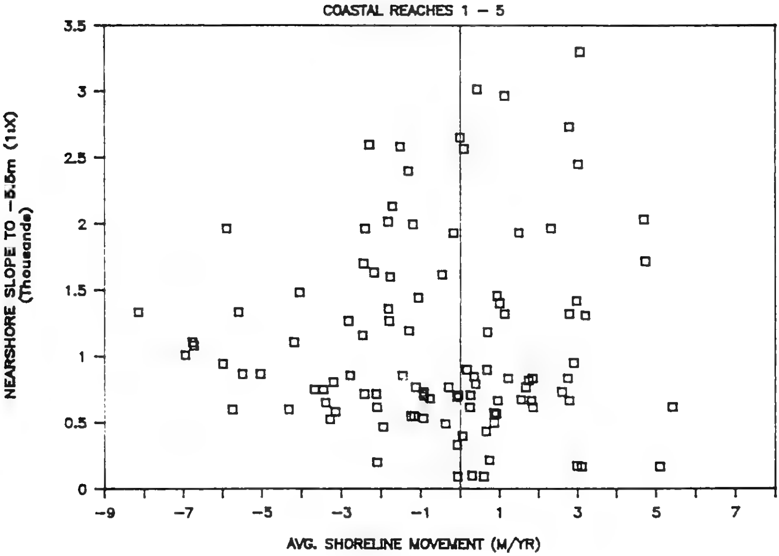
184. Figures 68 and 69 demonstrate graphically the contrast between reaches 6 and 7 and other reaches by means of scatter diagrams having a common scale. These diagrams clearly show consistent grouping of data points in reaches 6 and 7 contrasted to wide scatter of data points for reaches 1 through 5. Reasons for these differences are not apparent. Differences in wave climate, geology, sediment supply, orientation, coastal morphology, and the fewer number of inlets in reaches 6 and 7 may have a combined influence with nearshore slopes on shoreline stability.

Geology

185. The study area is located along the seaward margin of the Atlantic Coastal Plain Province. Both emerged and submerged portions of the coastal plain are topographically subdued and have a gentle seaward slope. Surficial lower coastal plain deposits consist of a fringe of Holocene beach and back-barrier sediments backed by a broad zone of Pleistocene sediments. These give way inland to outcrops of Cretaceous and Tertiary formations. A complete geologic description of the area is presented in Part II.

186. Core data from the inner continental shelf between Cape Fear and Cape Romain show that in many places older deposits either outcrop or lie close beneath the shelf surface (Meisburger 1979, Frankenburg 1987, unpublished CERC data). Figure 70 shows positions of cores containing ancient deposits and downhole depth to pre-Holocene deposits. Except for Eocene age biogenic carbonate sediments near Cape Fear, these deposits are of Cretaceous and Paleocene age.

187. Shallow depth of these formations on the shelf suggests they may lie close beneath the shoreface and beach in some areas, particularly along the predominantly mainland arcuate strand shoreline between New River Inlet and Cape Fear. Shoreface cores from the immediate vicinity of Myrtle Beach, South Carolina, encountered hard substrate at shallow depth (Frankenburg



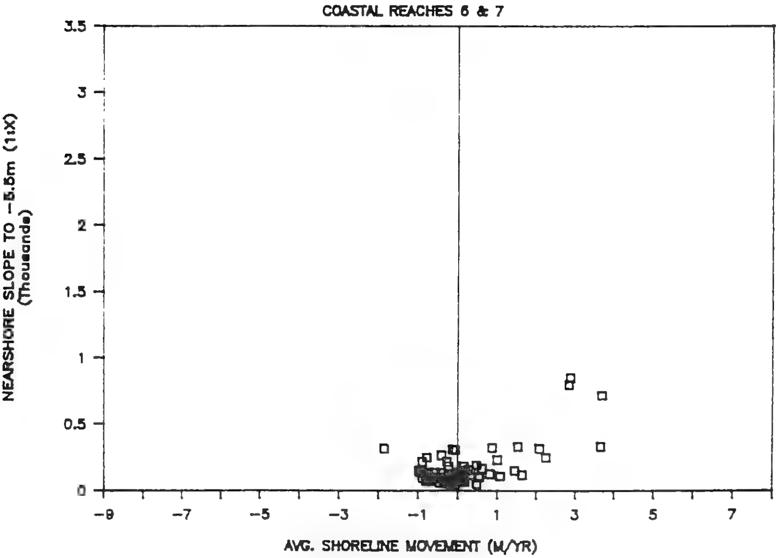
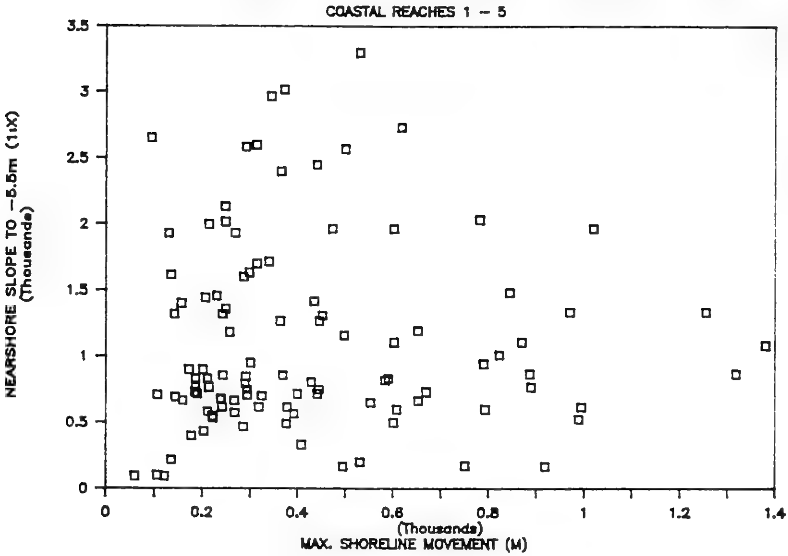


Figure 68. Average net shoreline change versus nearshore slope to -5.5 m MLW for reaches 1 through 5 and 6 and 7

MAX. CHANGE VS NEARSHORE SLOPE −5.5



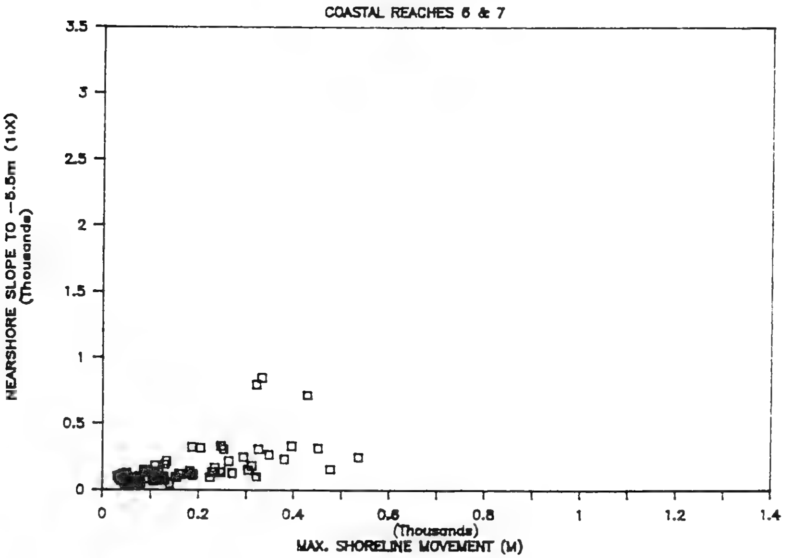


Figure 69. Maximum net shoreline change versus nearshore slope to -5.5 m MLW for reaches 1 through 5 and 6 and 7

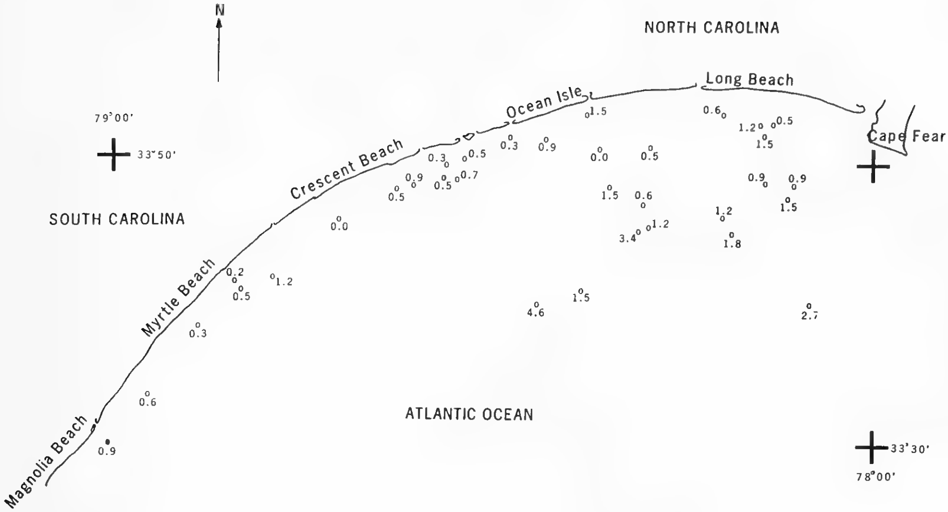


Figure 70. Map showing locations of inner continental shelf cores containing pre-Holocene sediment. Numbers indicate downhole depth in metres to the pre-Holocene contact

1987); rock fragments up to cobble size were observed on Myrtle Beach and other arcuate strand beaches during visits by one of the authors in 1981 and 1985.

188. Presence of pre-Holocene material near the surface of the arcuate strand geomorphic zone may be partially responsible for its relative stability over the long term. Semiconsolidated sands and clays would be more resistant to erosion than loosely consolidated sands. FitzGerald, Hubbard, and Nummedal (1978) noted that many South Carolina inlets that were not migrating rapidly through time were apparently anchored in pre-Holocene sediments. Inner shelf cores are not available for South Carolina south of Cape Romain. Depth to pre-Holocene sediments along the cuspate delta or barrier island geomorphic zones is unknown, but based on coring data in the literature (e.g. Barwis 1976, Hubbard and Barwis 1976), it appears deeper than in the arcuate strand zone.

<u>Inlets</u>

189. Previous sections of this report have discussed the role of inlets in affecting shoreline change. This fact was noted by numerous authors (e.g.

Hubbard et al. 1977, Fitzgerald and Hayes 1980) for various subreaches of the South Carolina coast. This data set, which includes the entire coast, emphasizes the role of inlets in controlling shoreline change history. Average shoreline change is consistently most variable, and maximum shoreline change is greatest in the vicinity of inlets. It is not implied that every inlet-adjacent shoreline is highly variable, but a majority do influence shoreline position for several kilometres up and down drift.

Future Shoreline Changes

190. If an old geologic axiom is reworded slightly to "the present is the key to the future," results of this study can be carefully applied to predict future shoreline changes between Tybee Island, Georgia, and Cape Fear, North Carolina. This assumes that factors which have controlled past shoreline erosion/accretion will operate in the same way with the same magnitude in the future. Rates of change given in Appendix A and within various figures and tables throughout this report can be applied to near future estimation of shoreline change. However, accuracy of predictions decreases with increasing projection into the future and/or projection into shoreline areas that have been historically variable. Sea level, sea energy, geology, sediment supply, and human intervention are the variables that control present and future shoreline positions. This report indicates storm waves are important in affecting the shoreline; however, prediction of number and frequency of future storms is impossible. Bathymetry and shoreline orientation have some effect on erosion/accretion also, but through time, these are constantly being modified by waves and currents. Sea level is another important factor determining future shoreline change rates. Over the last 20 million years, sea level has been episodically dropping along South Carolina. Over the last 15,000 years, sea level has risen. Rate of rise has decreased perceptibly over the last 4,000 years, although modern tide gages still detect an overall trend of rising sea level. Predictions for the future (Gorman, in preparation) include rapid increases in sea level as the result of climatic warming from human intervention.

191. Unpredictability of these and other long-term factors coupled with variability of short-term factors such as inlets means prediction of future shoreline change cannot be very accurate with increasing temporal spacing from

present. Some observations of present characteristics of the study area, however, can be made to allow estimates of future shoreline position.

192. The arcuate strand, which has slowest erosion/accretion rates, will probably remain the least variable geomorphic zone in the near future. Its sheltered orientation to storm waves, the presence of pre-Holocene semi-consolidated sediments near the surface, and general lack of inlets will all combine to keep this coastline relatively stable. Sea level rise, if accelerated in the future, could have a dramatic effect since elevation of this shoreline is low.

193. The cuspate delta shoreline can be expected to continue as an erosional area into the future. Erosion results from loss of sediment from damming and diversion plus its nearly north-south orientation, which makes it susceptible to storm waves. An additional factor is the considerable amounts of fine sediments that compose the marshes behind cuspate delta barrier beaches. As beaches transgress over marshes, the finer sediments will be easily removed, thus accelerating rates of erosion.

194. Bull Bay and other large bays will continue to show only mild erosion/accretion. Their natural protection from storm and wave attack means the most influential factors are sediment supply and sea level changes. Changes in these two factors are generally slow, so the immediate future of Bull Bay and other large bays is not likely to be different from its recent history.

195. Shoreline movement in the barrier island geomorphic zone is variable spatially and temporally. Frequent inlets, human interference, open orientation to wave attack, and variable nearshore bathymetry all contribute to shoreline position variability in this reach. Bathymetry and orientation are not likely to change significantly in the near future. Disequilibrium created by human intervention will slowly readjust to a new equilibrium if no further harmful intervention occurs. Therefore, areas of high erosion south of Charleston and accretion to the north will gradually abate. Areas immediately adjacent to most South Carolina inlets, however, may be subject to rapid changes at any time. Radical changes at inlets and adjacent shorelines can occur over very short periods, making change prediction difficult. The remaining barrier island geomorphic zone will continue into the near future as it is presently, stable to slightly eroding near midsections of barriers with increasing variability toward inlets.

196. If the South Carolina coastline is examined through time specifying that any landward movement, no matter how small, is erosion and any seaward movement is accretion, then shoreline trends are toward erosion. However, temporal division of data shows no one shoreline segment has eroded significantly faster than adjacent segments given a sufficient length of time. Erosion and accretion appear to dynamically alternate spatially and temporally with the present net effect of shoreline erosion. Specific locations, such as northern Kiawah Island, have been accreting steadily, and other areas have been eroding steadily over the 130 years of survey data; but overall there appears to be a dynamic balance favoring erosion. In the distant future, as sea level rise changes or climatic changes affect storm properties, the dynamic balance may swing toward more erosion or accretion.

PART VI: SUMMARY AND CONCLUSIONS

198. This is the third and final report in a series of shoreline change studies undertaken cooperatively between NOS and CERC. Additional funding for map production was provided by the Division of Research and Statistical Services of the State of South Carolina. All survey data reduction, quality control, and publication of shoreline change maps were performed by NOS; data analysis and preparation of this report were completed by CERC. The study area comprises the northern coast of Tybee Island, Georgia, the entire coastline of South Carolina, and the contiguous coastline of North Carolina to Cape Fear (Figure 1). Changes in ocean shoreline position were evaluated from 1851 to 1983 using survey data from NOS.

199. Shoreline change maps, Tybee Island, Georgia, to Cape Fear, North Carolina, are included as a separate enclosure to this report. Thirty-two 1:24,000-scale USGS quadrangles were selected as base maps for this project. They were revised with 1:24,000-scale color aerial photography taken in 1982/83. Historical data obtained from NOS topographic surveys were compiled, rectified, and transferred to the base maps. The final composite shoreline position maps were used by CERC to evaluate shoreline changes within the study area.

200. Using a digitizing procedure, average and maximum net shoreline change was quantified every 50 m along the open coast. Shoreline change rates are presented in graphical form at 50-m intervals and have been summarized in tabular and graphical format for various along-the-coast intervals. Shoreline change data were compared with various environmental factors to evaluate causes for observed changes and to predict shoreline change rates for future years. The following characteristics of shoreline change within the study area can be concluded from this study:

- a. During every time interval examined, spatial distribution of shoreline change varied greatly. Mainland beaches of the arcuate strand geomorphic zone were least variable and had lowest shoreline change rates. Barrier island beaches were most variable spatially and had highest change rates.
- b. Spatial variability in shoreline change rates was influenced most by proximity to inlets. Shoreline change rates were largest and most variable immediately adjacent to inlets and decreased with distance from any inlet. Coastline centrally located between inlets had least variability and lowest

shoreline change rates. The arcuate strand has relatively few inlets.

c. Dramatic alongshore changes in the shoreline occurred in the vicinity of inlets. Inlet formation and migration and changes in inlet ebb-tidal delta morphology not only affect cross-shore position of the shoreline, but also control growth and decay of spits and barriers in an alongshore direction. Changes in inlet width of over 1,000 m and aerial changes on the order of 110,000 m^2/year to adjacent spits were observed. Temporal examination of alongshore changes at inlets suggests they result from continuous changes in inlet and ebb delta morphology driven by changes in environmental factors such as reversals in drift direction.

d. Shoreline change rates have varied greatly from one period to another. Some segments of shoreline are temporally consistent in change direction, but most alternate between periods of erosion and accretion. Through 130 years of survey data, net change has been in favor of erosion. Temporal variations and difficulties encountered in trying to account for them prevent accurate quantitative forecasts of shoreline change decades into the future.

e. The east-west oriented arcuate strand geomorphic zone, extending from North Inlet to Cape Fear River, is the most stable shoreline examined. Approximately 87 percent of this shoreline has changed ±1 m/year or less over the duration of survey data. The remaining shoreline is divided equally between erosion and accretion in excess of ±1 m/year.

f. Bull Bay, which is protected in several ways from a full range of wave conditions experienced by the rest of the coast, has a stable shoreline. Approximately 82 percent of Bull Bay has changed ±1 m/year or less over the duration of survey data. The most sheltered segments of shoreline (4 percent) have accreted more than 1 m/year, and shoreline open to waves from the northeast (14 percent) has been eroding in excess of 1 m/year.

g. Segments of shoreline predominantly showing erosion (more than 50 percent of shoreline is eroding greater than 1 m/year) were the barrier island shoreline between Tybee Island and St. Helena Sound, the cuspate delta geomorphic zone centered around the Santee River delta, and north of Cape Fear. Although no correlation was evident between shoreline orientation and shoreline change, these three reaches are the most north-south oriented reaches in the study area. Examination of wave data suggested north-south shoreline segments received highest percentages of swell waves.

h. The only segment of shoreline in which accretion (greater than 1 m/year) dominated was between Charleston Harbor and Bull Bay. Approximately 45 percent of this shoreline was accreting, while 30 percent was eroding and 25 percent changed ±1 m/year or less. The dominance of accretion in this area is due in large measure to trapping of alongshore drift north of the Charleston Harbor jetties.

i. Human impact has resulted in rapid erosion along Morris Island, south of the Charleston Harbor jetties, and contributed to wide distribution of erosion in the cuspate delta region. The Santee River had the fourth largest discharge of east coast rivers prior to damming and diversion in 1942. Loss of sediment supply to the coast has contributed to high erosion rates in this area.

j. Summarizing shoreline change for the entire study area coastline shows approximately 51 percent has been stable with ±1 m/year or less change, approximately 31 percent has eroded faster than 1 m/year, and 18 percent has accreted faster than 1 m/year over the 130-year span of survey data.

k. Maximum significant wave height correlates well with maximum net shoreline change. Maximum change occurs where maximum significant wave heights are greatest. Maximum significant wave heights are lowest along the arcuate strand and highest near Tybee Island, Charleston, and Cape Romain.

l. Nearshore slopes were compared with shoreline changes, but no direct correlations were evident. However, even where nearshore slopes had similar steepness, shoreline changes in the arcuate strand were consistently lowest, suggesting factors other than bathymetry were controlling shoreline movements.

m. Coastal stability in the arcuate strand geomorphic zone appears related in part to geology. Throughout this area, pre-Holocene semiconsolidated materials lie at or close to beach and nearshore surfaces. The proximity of these sediments to the surface and their increased resistance to erosion may contribute to the reduced potential for erosion. Stable inlets along this coast have been found by others to be anchored in pre-Holocene sediments.

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APPENDIX A: SUMMARY OF SHORELINE CHANGE DATA PER SEGMENT

Column Legend

MAP = number identifying one map within the enclosed set of National Ocean Service (NOS) maps. Refer to Figure 18.

SEGMENT = number identifying a small stretch of coastline within a particular map. Segment numbers are listed on Figure 22.

A T MOVE = average total (net) movement; within each segment of each map, data were collected along shore-perpendicular transects located 50 m apart along the coastline. Total net shoreline movement for each transect was used to calculate the average total (net) movement for the segment. Units = metres, "-" = erosion.

M T MOVE = maximum total (net) movement; within each segment of each map, data were collected along shore-perpendicular transects located 50 m apart along the coastline. Net shoreline change at the transect with maximum movement within the segment is listed in this column. Units = metres, "-" = erosion.

A SH CHG = average shoreline change; the average total (net) movement for all transects within a segment, divided by the number of years between the first and last shoreline data set. Units = metres/year, "-" = erosion.

M STD DEV = maximum standard deviation; standard deviation of shoreline change for the transect within a segment showing maximum variability in shoreline position over the measured interval of time. Units are in ± metres around the average shoreline change of that transect. These data are intended to give the reader a rough indication of just how variable the long-term shoreline change can be within a given segment of coastline.

NUMBER OF TRANSECTS ERODING, STABLE, AND ACCRETING = within each segment of each map, shoreline change data were collected along shore-perpendicular transects located 50 m apart along the coastline. Within a segment, the number of transects eroding (>1 m/year landward movement), accreting (>1 m/year seaward movement), and/or stable (<1 m/year movement) were totaled. These data can be used to calculate the percentage of each segment within each of the three shoreline change categories.

REACH = the entire study coastline was divided into seven zones (reaches) of similar geomorphic characteristics. Refer to Figure 21.

						NUMBER OF TRANSECTS		
MAP	SEGMENT	A T MOVE	M T MOVE	A SH CHG	M STD DEV	ERODE	STABLE	ACCRETE
REACH 1								
1	1	76.8	129.	0.69	4.21	0	16	5
1	2	-274.5	-497.	-2.47	3.57	17	6	0
1	3	-277.6	-363.	-2.83	2.76	10	0	0
1	4	-70.6	-139.	-0.68	9.47	6	6	0
1	5	373.1	991.	5.18	11.67	3	0	22
1	6	-67.8	-85.	-1.35	2.49	5	0	0
1	7	85.7	472.	2.32	2.59	2	3	11
1	8	209.1	420.	1.68	4.29	0	4	8
1	9	-160.1	-364.	-1.32	3.00	41	26	0
1	10	-332.6	-359.	-2.70	1.73	5	0	0
1	11	-211.8	-247.	-1.72	1.98	39	0	0
1	12	-260.4	-298.	-2.18	1.74	17	0	0
1	13	-301.8	-314.	-2.45	2.43	13	0	0
1	14	-211.7	-286.	-1.77	1.18	22	0	0
1	15	-58.3	-134.	-0.47	1.38	2	14	0
1	16	627.6	856.	5.32	32.80	0	0	16
1	17	371.9	432.	3.02	19.24	0	0	16
1	18	183.2	262.	1.49	8.53	0	3	11
1	19	-115.8	-180.	-0.94	4.30	24	23	0
2	1	32.1	67.	0.26	2.12	0	22	0
3	1	122.6	148.	1.00	5.07	0	32	38
3	2	-21.9	-111.	-0.18	1.68	0	29	0
3	3	-147.6	-214.	-1.20	1.53	18	3	0
3	4	-224.9	-248.	-1.83	1.58	21	0	0
3	5	-282.7	-313.	-2.30	1.69	60	0	0
3	6	-184.5	-290.	-1.52	4.03	32	6	0
3	7	-1.3	-78.	-0.01	1.68	0	32	0
3	8	36.8	55.	0.30	1.71	0	8	0
3	9	46.8	56.	0.38	1.91	0	6	0
3	10	57.0	73.	0.46	1.07	0	5	0
3	11	21.2	45.	0.17	1.72	0	5	0
3	12	-36.7	-91.	-0.30	2.89	0	33	0
3	13	-166.7	-246.	-1.35	3.66	25	8	0
3	14	-256.4	-337.	-2.09	3.03	24	1	0
4	1	-222.9	-396.	-1.80	2.31	64	0	0
4	2	-136.8	-282.	-1.11	2.20	5	4	0
4	3	2.7	29.	0.02	1.50	0	12	0
5	1	-67.2	-151.	-0.55	7.05	3	7	0
5	2	-11.7	206.	-0.02	6.89	5	6	4
5	3	136.0	200.	1.13	6.88	0	7	12
5	4	52.0	70.	0.42	7.89	0	11	0
5	5	11.3	-172.	0.09	14.48	4	37	0
5	6	-221.9	-374.	-1.80	11.86	26	8	0
5	7	-672.4	-970.	-5.60	8.19	14	2	0
5	8	-697.3	-792.	-5.76	5.32	36	0	0
5	9	-532.5	-606.	-4.33	4.58	6	0	0
5	10	-261.9	-339.	-2.13	2.73	7	1	0
5	11	-423.1	-444.	-3.46	2.46	15	0	0

MAP	SEGMENT	A T MOVE	M T MOVE	A SH CHG	M STD DEV	NUMBER OF TRANSECTS ERODE	STABLE	ACCRETE
6	1	-396.7	-428.	-3.20	2.44	39	0	0
6	2	-258.9	-318.	-2.11	1.83	16	1	0
6	3	-248.5	-320.	-2.04	3.40	11	0	0
6	4	-6.7	274.	-0.05	4.17	10	24	9
6	5	216.9	345.	1.75	9.73	0	9	31
6	6	322.5	566.	2.60	11.13	0	0	10
6	7	-298.3	-501.	-2.41	6.32	95	0	0
6	8	-731.6	-1018.	-5.91	3.19	31	0	0
6	9	851.2	1343.	6.90	11.58	0	0	13
6	10	-23.0	-30.	-0.36	1.70	0	4	0
7	1	-11.8	-34.	-0.53	2.60	2	6	0
REACH 2								
7	2	137.8	232.	0.67	2.73	1	0	5
7	3	256.0	442.	2.32	4.17	0	1	6
7	4	384.7	423.	3.03	3.54	0	0	6
7	5	393.7	419.	3.10	3.30	0	0	10
8	1	-10.8	408.	-0.08	3.84	12	6	9
8	2	112.3	403.	0.86	6.65	2	4	5
8	3	365.3	389.	2.79	6.93	0	0	3
8	4	381.4	481.	2.99	8.98	0	0	7
8	5	243.9	316.	1.86	8.31	0	0	8
8	6	-128.3	-145.	-0.98	3.17	3	4	0
8	7	-103.0	-108.	-0.79	2.89	0	3	0
8	8	95.5	448.	0.73	6.11	0	11	6
8	9	461.8	655.	3.53	9.93	0	0	31
8	10	203.8	309.	1.85	1.83	0	0	6
8	11	189.7	433.	1.45	2.79	0	7	21
8	12	377.5	415.	2.88	4.83	0	0	4
8	13	402.3	486.	3.07	5.28	0	0	7
8	14	419.3	431.	3.20	4.87	0	0	3
8	15	388.7	409.	2.97	4.46	0	0	6
8	16	-49.3	376.	-0.38	2.98	29	73	13
9	1	-248.9	-286.	-1.95	2.41	14	0	0
9	2	-446.6	-553.	-3.41	3.17	49	0	0
9	3	-661.5	-886.	-5.05	7.82	66	0	0
9	4	-1023.5	-1254.	-8.15	10.10	22	0	0
9	5	-791.1	-925.	-6.04	8.78	10	0	0
9	6	-498.5	-693.	-3.81	6.34	6	0	0
9	7	306.4	750.	2.34	4.82	0	5	10
9	8	549.6	704.	4.20	5.69	0	0	17
9	9	667.7	918.	5.10	6.82	0	0	26
10	1	117.1	392.	0.91	6.03	0	34	31
10	2	-161.2	-203.	-1.25	2.78	39	10	0
10	3	-122.0	-187.	-0.94	2.69	23	29	0
10	4	31.1	120.	0.24	3.31	0	36	0
10	5	239.0	315.	1.85	3.99	0	1	42
10	6	234.4	257.	1.82	3.20	0	0	12
11	1	360.8	615.	2.79	9.24	0	4	34

MAP	SEGMENT	A T MOVE	M T MOVE	A SH CHG	M STD DEV	NUMBER OF TRANSECTS ERODE	STABLE	ACCRETE
11	2	-1014.3	-1148.	-8.01	7.96	7	0	0
11	3	-545.7	-598.	-4.20	4.80	6	0	0
11	4	-314.4	-441.	-2.42	3.74	50	0	0
11	5	-99.5	-229.	-0.77	1.73	11	60	0
11	6	-119.4	-136.	-0.92	2.57	6	12	0
11	7	-38.1	-99.	-0.30	4.25	0	15	0
13	1	47.1	84.	0.38	9.21	0	32	0
13	2	44.3	69.	0.35	9.43	0	4	0
13	3	-182.5	-243.	-1.46	4.39	3	1	0
13	4	-835.1	-1231.	-6.74	15.06	91	0	0
13	5	-161.2	-216.	-1.30	14.38	10	3	0
13	6	-27.1	-82.	-0.22	9.15	0	7	0

REACH 3

13	6	-27.1	-82.	-0.22	9.15	0	7	0
13	7	226.6	367.	3.65	5.07	0	2	15
13	8	293.3	339.	4.73	1.52	0	0	6
13	9	172.6	242.	2.79	1.95	0	1	12
13	10	70.1	90.	1.13	3.34	0	4	16
13	11	114.9	186.	1.85	3.20	0	4	25
13	12	90.0	159.	0.95	1.92	0	4	2
13	13	-9.7	-141.	-0.09	1.79	2	11	0
13	14	288.7	301.	2.67	1.53	0	0	3
13	15	267.3	301.	2.90	3.52	0	0	7
13	16	144.9	238.	1.55	1.33	0	1	65
14	1	178.2	214.	1.67	2.31	0	0	27
14	2	130.6	159.	1.21	2.31	0	4	25
14	3	17.6	-65.	0.16	3.91	0	27	0
14	4	73.9	140.	0.68	4.33	0	5	3
14	5	92.8	132.	0.86	6.94	0	26	3
14	6	69.8	95.	0.65	5.44	0	4	0
14	7	5.5	29.	0.05	3.77	0	4	0
14	8	-27.4	-80.	-0.25	2.16	0	8	0
14	9	-417.2	-932.	-3.29	8.95	34	3	10
14	10	-675.4	-709.	-5.32	8.01	5	0	0
14	11	-506.1	-843.	-4.06	15.53	79	3	5
15	1	297.3	416.	2.75	12.07	0	0	48
15	2	100.9	192.	0.93	3.36	0	25	20
15	3	-114.7	-206.	-1.06	2.85	24	23	0
15	4	-188.3	-249.	-1.82	2.62	6	1	0
15	5	-273.4	-369.	-2.78	2.13	7	0	0
15	6	-730.8	-869.	-6.77	3.14	41	0	0

REACH 4

15	7	-44.9	-113.	-0.41	2.03	1	6	0
15	8	18.0	28.	0.17	2.27	0	4	0
15	9	32.7	56.	0.30	0.62	0	3	0
15	10	-28.5	-62.	-0.26	1.43	0	15	0

MAP	SEGMENT	A T MOVE	M T MOVE	A SH CHG	M STD DEV	NUMBER OF TRANSECTS ERODE	STABLE	ACCRETE
15	11	15.9	49.	0.15	1.06	0	8	0
15	12	-13.8	-33.	-0.13	0.77	0	4	0
15	13	-31.7	-44.	-0.29	1.21	0	10	0
15	14	-18.7	-34.	-0.17	0.90	0	3	0
15	15	-93.1	-151.	-0.86	1.18	9	19	0
15	16	-196.1	-323.	-1.94	1.99	7	0	0
15	17	-202.7	-289.	-1.96	1.59	24	0	0
15	18	-126.5	-210.	-1.49	1.76	3	1	0
15	19	-76.8	-122.	-0.75	2.15	2	3	0
15	20	-126.7	-219.	-1.17	1.87	15	7	0
15	21	-55.2	-112.	-0.52	2.58	3	7	0
15	22	-9.0	-54.	-0.08	0.83	0	15	0
15	23	-62.0	-84.	-0.62	0.81	0	9	0
16	1	-5.0	68.	-0.04	3.08	0	27	0
16	2	-6.1	50.	-0.06	1.52	0	21	0
16	3	-2.4	-15.	-0.02	0.99	0	7	0
16	4	3.5	15.	0.04	0.95	0	4	0
16	5	-30.2	-60.	-0.28	1.15	0	20	0
16	6	-20.3	-70.	-0.19	1.34	0	12	0
16	7	-22.6	-29.	-0.21	2.33	0	5	0
16	8	-24.6	-62.	-0.23	1.77	0	18	0
16	9	-15.8	-55.	-0.15	1.43	0	5	0
16	10	2.9	-67.	0.03	2.16	0	16	0
16	11	-32.7	-47.	-0.30	1.67	0	12	0
16	12	-17.3	-36.	-0.16	1.22	0	6	0
16	13	-5.8	-32.	-0.05	1.20	0	15	0
16	14	-8.0	-15.	-0.11	0.66	0	3	0
16	15	-0.5	54.	-0.06	1.59	0	6	0
16	16	-34.5	-77.	-0.32	1.97	0	10	0
16	17	-13.6	-24.	-0.13	1.04	0	7	0
16	18	-2.1	29.	-0.02	1.34	0	9	0
16	19	9.4	35.	0.10	1.38	0	11	0
16	20	-8.5	-28.	-0.08	0.92	0	4	0
16	21	35.0	46.	0.32	0.66	0	3	0
16	22	34.4	66.	0.32	1.04	0	8	0
16	23	46.2	72.	0.43	1.03	0	6	0
16	24	9.6	38.	0.09	2.08	0	7	0
16	25	91.7	224.	0.84	3.12	0	19	16
16	26	88.2	130.	0.81	0.75	0	4	2
REACH 5								
16	27	-944.8	-1237.	-8.67	8.00	9	0	0
17	1	-748.0	-822.	-6.96	2.79	96	0	0
17	2	-644.4	-789.	-5.99	5.32	56	0	0
18	1	-597.1	-1318.	-5.50	6.20	82	4	0
18	2	-213.0	-293.	-3.68	2.99	20	1	0
18	3	511.0	685.	4.69	5.93	0	0	21
18	4	566.8	652.	5.20	6.70	0	0	11
18	5	625.6	849.	5.74	8.45	0	0	19

MAP	SEGMENT	A T MOVE	M T MOVE	A SH CHG	M STD DEV	NUMBER OF TRANSECTS ERODE	STABLE	ACCRETE
18	6	794.3	822.	7.29	10.56	0	0	16
18	7	747.2	834.	6.86	8.99	0	0	23
18	8	-122.7	-764.	-1.13	10.90	31	10	18
18	9	-29.6	-188.	-0.28	4.02	8	10	3
18	10	-126.1	-170.	-1.17	5.07	20	9	0
20	1	-93.6	-155.	-3.16	7.69	4	3	0
20	2	-102.6	-186.	-0.92	7.21	10	16	0
20	3	580.1	864.	5.41	35.43	0	0	73
20	4	92.5	135.	0.74	2.06	0	30	2
20	5	74.0	87.	0.59	1.87	0	17	0
20	6	38.0	75.	0.30	1.40	0	21	0
21	1	-9.2	-24.	-0.07	1.32	0	12	0
21	2	-254.5	-526.	-2.11	3.76	84	32	0
REACH 6								
21	3	-65.8	-294.	-0.78	6.44	1	12	0
21	4	91.3	172.	0.82	5.02	0	14	13
21	5	121.1	156.	1.09	1.86	0	5	9
22	1	41.5	77.	0.49	3.75	0	34	9
22	2	2.6	54.	0.02	1.46	0	80	0
22	3	-25.6	-43.	-0.23	2.80	0	23	0
22	4	-38.8	-60.	-0.35	0.63	0	22	0
22	5	-55.1	-69.	-0.50	0.62	0	29	0
22	6	-45.8	-60.	-0.41	1.62	0	30	0
22	7	22.3	48.	0.20	1.65	0	23	0
23	1	54.9	62.	0.49	3.35	0	10	0
23	2	69.5	92.	0.62	4.00	0	11	0
23	3	111.2	134.	1.01	6.29	0	10	13
23	4	-45.7	-188.	-0.41	8.15	5	10	1
23	5	251.7	512.	2.25	13.92	0	4	21
23	6	-14.6	-75.	-0.13	7.69	0	24	0
23	7	-106.9	-134.	-0.97	2.89	13	11	0
23	8	-76.9	-127.	-0.69	1.58	8	37	0
23	9	-4.1	-26.	-0.04	0.92	0	65	0
23	10	10.8	27.	0.10	1.20	0	77	0
24	1	3.1	16.	0.02	1.16	0	26	0
24	2	19.5	38.	0.18	1.09	0	31	0
24	3	14.7	33.	0.14	1.27	0	43	0
24	4	-7.7	-28.	-0.07	1.32	0	31	0
24	5	-23.6	-43.	-0.22	0.88	0	37	0
24	6	-14.7	-28.	-0.13	0.88	0	15	0
24	7	-36.1	-53.	-0.33	2.10	0	33	0
25	1	-14.4	-35.	-0.13	2.38	0	46	0
25	2	-11.0	-38.	-0.10	1.82	0	88	0
25	3	-14.7	-40.	-0.13	1.68	0	67	0
25	4	-24.4	-54.	-0.22	2.10	0	45	0
25	5	-25.9	-46.	-0.24	1.07	0	25	0
25	6	-7.9	-23.	-0.07	1.28	0	32	0
26	1	-4.6	50.	-0.04	2.97	0	54	0

MAP	SEGMENT	A T MOVE	M T MOVE	A SH CHG	M STD DEV	NUMBER OF TRANSECTS ERODE	STABLE	ACCRETE
26	2	1.5	21.	0.01	1.64	0	42	0
26	3	-14.4	-27.	-0.13	1.81	0	46	0
26	4	-1.3	-31.	-0.01	2.09	0	46	0
26	5	-6.0	-21.	-0.06	1.42	0	26	0
26	6	9.3	24.	0.08	1.83	0	23	0
26	7	-86.9	-159.	-0.80	5.61	10	13	0
27	1	-69.6	-188.	-0.56	3.47	12	21	0
27	2	-24.9	-41.	-0.23	3.88	0	28	0
27	3	17.8	67.	0.16	5.41	0	27	0
	REACH 7							
27	4	-7.9	-55.	-0.07	5.41	0	20	0
27	5	61.1	99.	0.88	8.68	0	7	6
27	6	55.2	113.	1.65	12.22	0	4	1
28	1	16.5	57.	0.29	22.40	0	20	0
28	2	1.9	-29.	0.03	2.08	0	39	0
28	3	-112.6	-148.	-0.90	1.74	29	66	0
28	4	42.2	149.	0.34	1.88	0	17	3
28	5	180.2	197.	1.46	4.90	0	0	10
28	6	160.1	211.	1.28	5.97	0	3	6
28	7	53.3	97.	0.43	5.12	0	4	0
29	1	-33.9	-60.	-0.27	3.28	0	9	0
29	2	6.5	82.	0.05	4.10	0	32	0
29	3	-49.8	-74.	-0.40	1.23	0	32	0
29	4	69.5	290.	0.55	2.41	0	15	10
29	5	-85.1	-104.	-0.67	3.12	0	47	0
29	6	-79.9	-101.	-0.64	2.97	0	39	0
29	7	-94.5	-113.	-0.76	1.53	0	38	0
29	8	-96.7	-108.	-0.77	2.14	0	12	0
30	1	-94.1	-104.	-0.74	3.68	0	10	0
30	2	-112.9	-157.	-0.89	3.77	2	6	0
30	3	-23.5	-67.	-0.18	1.58	0	80	0
30	4	-38.1	-64.	-0.30	1.68	0	38	0
30	5	-60.0	-73.	-0.47	1.10	0	22	0
30	6	-87.9	-110.	-0.69	1.03	0	27	0
30	7	-102.5	-130.	-0.81	1.05	1	16	0
31	1	-11.0	-34.	-0.19	1.68	0	50	0
31	2	-58.0	-76.	-0.98	2.29	18	12	0
31	3	9.7	253.	-0.06	5.83	35	62	20
31	4	298.8	322.	2.85	2.65	0	0	6
31	5	302.5	333.	2.88	2.48	0	0	6
31	6	223.5	419.	2.13	2.76	0	2	6
31	7	-42.1	-147.	-0.61	2.68	6	5	1
31	8	115.4	162.	1.67	2.60	0	0	5
31	9	254.7	346.	3.69	8.34	0	0	12
31	10	252.1	303.	3.66	7.64	0	0	14
31	11	144.3	200.	2.09	4.71	0	0	6
32	1	162.1	235.	1.54	3.87	0	7	18
32	2	-195.0	-451.	-1.86	4.52	32	14	0

MAP	SEGMENT	A T MOVE	M T MOVE	A SH CHG	M STD DEV	NUMBER OF TRANSECTS ERODE	STABLE	ACCRETE
32	3	-500.2	-623.	-4.77	9.43	107	2	0
32	4	-348.1	-529.	-3.23	7.33	11	3	1
32	5	-157.3	-311.	-1.58	6.94	39	7	7
32	6	240.1	272.	2.29	6.40	0	0	34
32	7	118.3	475.	1.48	6.48	5	6	25